

Substructure reinforcement study of Cisomang bridge at Purwakarta-Bandung-Cileunyi toll road, West Java Province, Indonesia

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Abstract. At the end of 2016, significant displacement occurred at P2 pier of Cisomang Bridge at Purwakarta-Bandung-Cileunyi toll road KM 100+700, West Java. The shift of pier is caused by the movement of soil under the substructure that has been indicated since 2012. P2 pier is constructed over clay shale. Clay shale has characteristics when in dry condition, the soil has high shear strength, but when the soil absorbs water or expose in open air, the soil loses its strength. P2 pier displacement results in extreme structural damage, so immediate handling is needed to stop the shifting of the pier. Analysis and reinforcement study are carried out using finite element method. Based on analysis, it is discovered that the existing slope stability safety factor of P2 pier is 1.09, indicating that the soil movement can occur if the clay shale is disrupted. Reinforcement is designed to mitigate the shift of the P2 pier by adding 38 pile foundations to the existing foundation configuration. Each pile has diameter of 1.2 meter with a depth of ± 30 meter across the existing slip circle. Reinforcement increases the slope stability safety factor to 1.25, indicating that the P2 pier after reinforcing is in safe condition.

1. Introduction

Infrastructure is a driver of economic growth. From the allocation of public and private financing, infrastructure is considered as a locomotive of national and regional development [1,2]. Infrastructure is also important to improve the quality of life and human well-being, among others in increasing the value of consumption, increasing labor productivity and access to employment, and increasing real prosperity. Infrastructure also has important importance in increasing the value of consumption, increasing labor productivity and access to employment [1-3].

Bandung-Jakarta connected with two toll roads, which are: Purwakarta-Bandung-Cileunyi (Purbaleunyi) and Jakarta-Cikampek. Jakarta-Cikampek toll road was built in 1988, connecting Jakarta to the Cikampek (Karawang District). Purbaleunyi toll road, consists of two sections. The first section, Padaleunyi toll road was built in 1991, connects two sub-districts under jurisdiction of West Bandung District and Bandung District; Padalarang and Cileunyi. Padaleunyi toll road is by-passing the Bandung City with several interchanges. The second section is the toll road that connects Cikampek to Purwakarta until Padalarang, named Cipularang (Cikampek-Purwakarta-Padalarang) toll road, which was built in 2005. Before 2005, people would have to exit at Padalarang and then continue their journey through arterial roads before entering the Jakarta-Cikampek toll road [4]. Figure 1 shows the road alignment of Purbaleunyi toll road and the location of Cisomang Bridge.



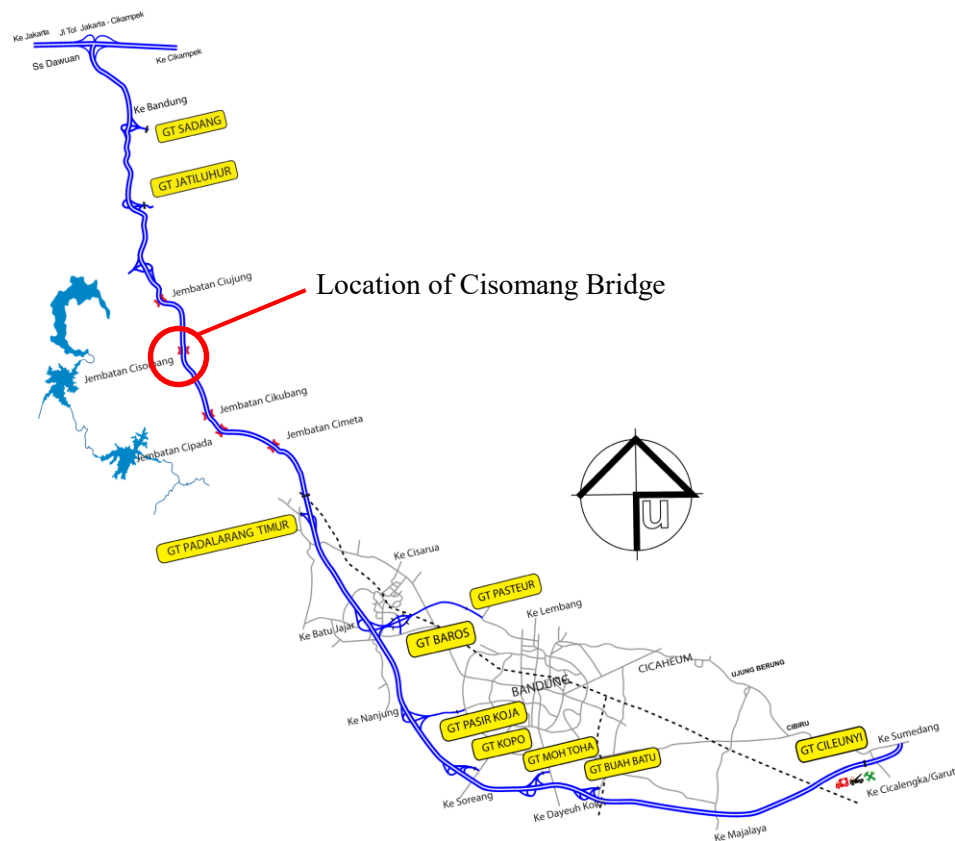


Figure 1. Purbaleunyi toll road [5].

Cisomang Bridge is a long span bridge with simple beam at span A1-P0, P0-P1, P4-P5, P5-A2 and continuous integral at span P1-P2-P3-P4-P5. Cisomang Bridge is located on the second section of Purwakarta-Bandung-Cileunyi (Purbaleunyi) toll road, which is Cipularang (Cikampek-Purwakarta-Padalarang) toll road at KM 100+700 [6]. The length of the Cisomang Bridge span is 253.127 meters with a width of 24.1 meters consisting of 2 lanes [7]. Cisomang Bridge consists of 7 spans with 6 pillars using a foundation of 1200 mm and 1500 mm bored pile types. Long section of Cisomang Bridge can be seen in figure 2.

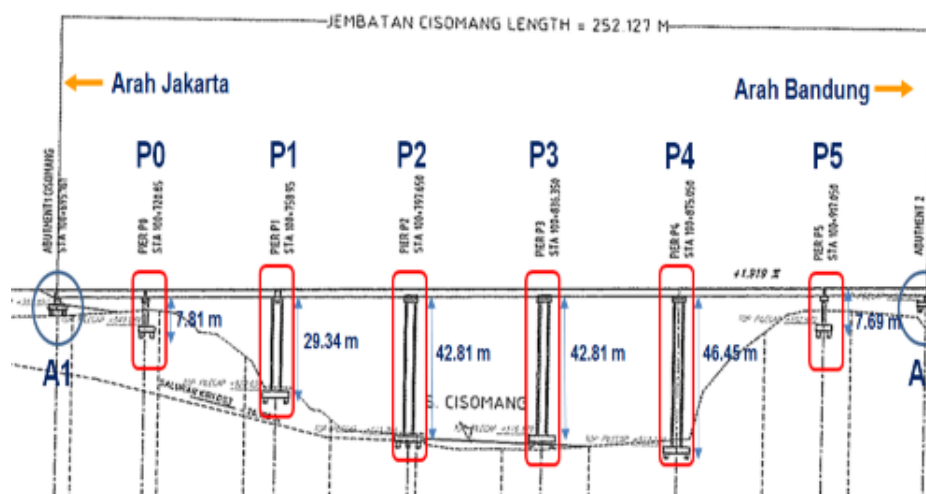


Figure 2. Long section of Cisomang bridge [6].

At the end of 2016, significant displacement occurred at P2 pier of Cisomang Bridge at Purwakarta-Bandung-Cileunyi toll road KM 100+700, West Java. The shift of pier is caused by the movement of soil under the substructure that has been indicated since 2012. P2 pier is constructed over clay shale. Clay shale has characteristics when in dry condition, the soil has high shear strength, but when the soil absorbs water or expose in open air, the soil loses its strength [6]. The stratigraphy of soil below P2 pier can be seen in Figure 3. P2 pier displacement results in extreme structural damage, so immediate handling is needed to stop the shifting of the pier. The structural damage caused by the shifting of pier can be seen in Figure 4.

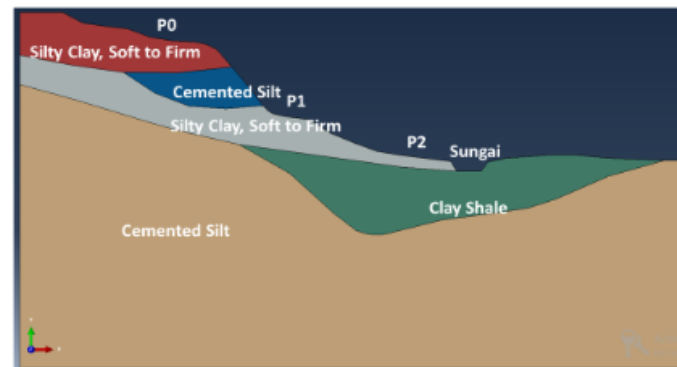


Figure 3. Stratigraphy of soil below Cisomang bridge P2 pier [8].



Figure 4. Structural damage on Cisomang bridge's piers [6].

2. Literature study

2.1. Clay shale

Clay shale is a rock that is compacted from weathering layers of clay and silt over a long period of time. Clay shale has large montmorillonite content and has a high activity value, so they can be categorized as expansive soils [9]. Expansive soil has characteristics when in dry condition, the soil has high shear strength, but when the soil absorbs water or expose in open air, the soil loses its strength. These characteristics can cause structural damage to buildings and bridges [6,10].

Bored pile work on clay shale type of soil, it is known to be very sensitive to the weathering process and reduced lateral stress due to the drilling process which results in a decrease in soil strength. The decrease in soil strength in the clay shale can vary greatly depending on the duration of the soil drilling,

the length of time the clay shale is exposed to the weather, and the sensitivity of the clay shale itself [11].

2.2. Foundation reinforcement

Previous researchers conducted a study on reinforcing the foundations of the Kalanggeta Bridge in Serang District, Banten Province [12]. Reinforcement is done by increasing the number of pile foundations in the existing pile configuration to increase the permit load. Reinforcement is done by adding 4 additional piles, so that the foundation able to withstand the design load. Furthermore, the connection between the existing pile cap concrete and the new pile cap concrete is analyzed using the post-installed rebar connection method to produce a monolithic structure.

3. Methodology

Analysis and reinforcement study are carried out using PLAXIS 2D software. PLAXIS is two /three-dimensional finite element method-based software developed for geotechnical engineering displacement and stability analysis. PLAXIS is equipped with features to handle various aspects of complex geotechnical structures and construction processes [13].

4. Analysis and reinforcement study

4.1. Existing data on Cisomang bridge

The field parameter used in analysis obtained from test that has been conducted by Jasamarga (state-controlled *toll road* operator in Indonesia). Figure 5 shows the result of standard penetration test (SPT) of soil conducted around P2 pier of Cisomang Bridge. Existing data and sketch of P2 pier structure can be seen in table 1 and figure 6. The concrete strength of P2 pier is approximately 27,5 MPa.

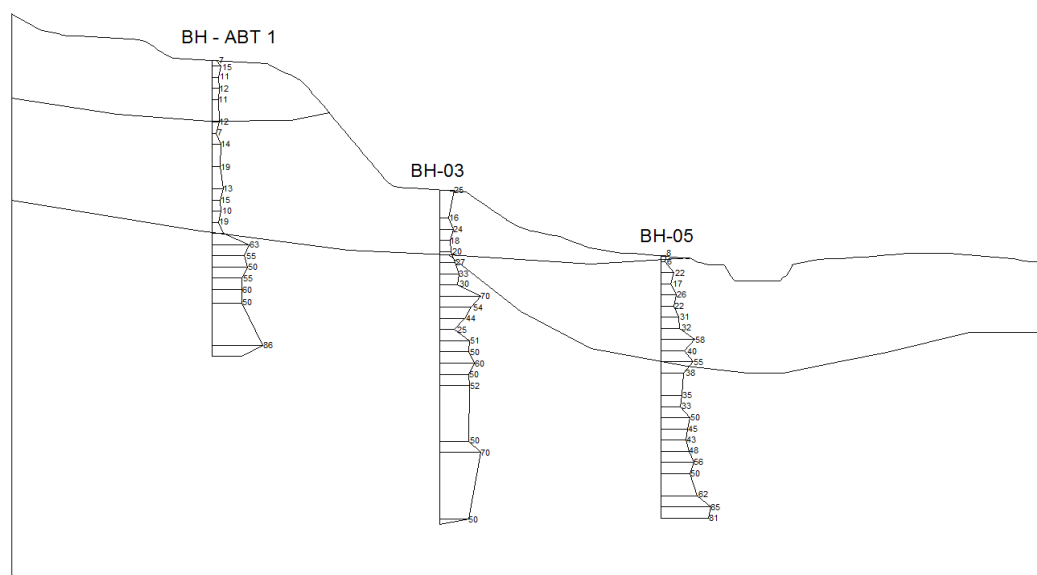


Figure 5. Standard penetration test result of Cisomang bridge [8].

Table 1. Existing data of P2 pier Cisomang bridge [8].

Structure	Dimension (m)
Pile cap width	7,6
Pile cap length	21,86
Pile cap height	2
Foundation diameter	1
Foundation length	30

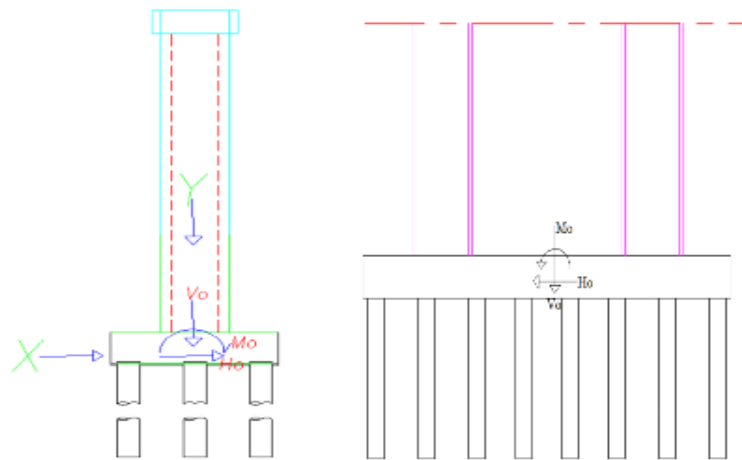


Figure 6. The sketch of P2 pier Cisomang bridge [8].

4.2. Safety analysis of Cisomang bridge

Based on analysis, it is discovered that the existing slope stability safety factor of P2 pier is 1.09 less than recommended value of safety factor (1.25) by Indonesian Standard [14], so reinforcement is needed to increase safety factor value of slope stability. Figure 7 shows the existing slip circle of Cisomang Bridge near P2 pier.

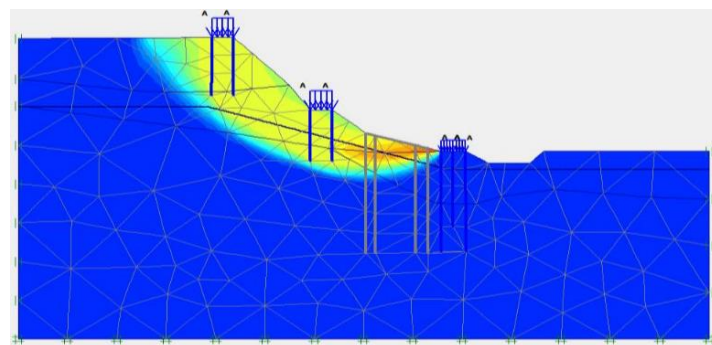


Figure 7. Existing slip circle of Cisomang Bridge's slope.

Reinforcement is designed to mitigate the shift of the P2 pier by adding 38 pile foundations to the existing foundation configuration. Each pile has diameter of 1.2 meter with a depth of ± 30 meter across the existing slip circle and clay shale layer. Reinforcement increases the slope stability safety factor to 1.25 same with recommended safety factor value (1.25) by Indonesian Standard, indicating that the P2 pier after reinforcing is in safe condition. Figure 8 shows slip circle of Cisomang Bridge near P2 pier after reinforcement.

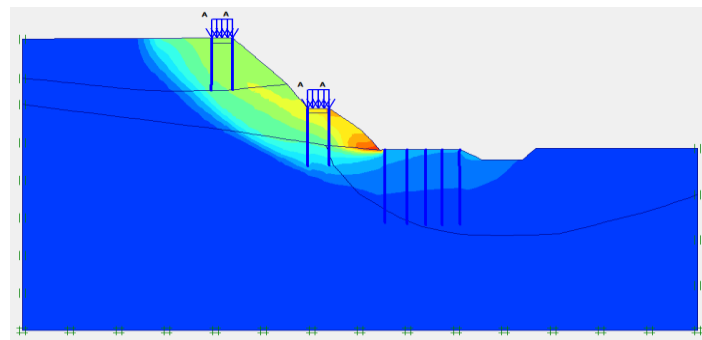


Figure 8. Slip circle of Cisomang Bridge's slope after reinforcement.

In order to monitor remotely the shifting of pier and soil underneath substructure, the installation of bridge health monitoring system is recommended, such as inclinometer and linear variable differential transformer (LVDT) to prevent bridge failure and fatalities.

5. Conclusion

A significant displacement occurred at P2 pier of Cisomang Bridge at Purbaleunyi toll road KM 100+700, West Java. The shift of pier is caused by the movement of soil under the substructure that has been indicated since 2012. Based on analysis, it is discovered that the existing slope stability safety factor of P2 pier is 1.09, indicating that the soil movement can occur if the clay shale is disrupted. Reinforcement is designed to mitigate the shift of the P2 pier by adding 38 pile foundations to the existing foundation configuration. Each pile has diameter of 1.2 meter with a depth of ± 30 meter across the existing slip circle. Reinforcement increases the slope stability safety factor to 1.25, indicating that the P2 pier after reinforcing is in safe condition. The installation of bridge health monitoring system is recommended to prevent bridge failure and fatalities.

Acknowledgment

The funding support from Unit Penelitian dan Pengabdian Masyarakat (UPPM) Politeknik Negeri Bandung is gratefully acknowledged. All supports and facilities from Department of Civil Engineering and Geotechnical Area of Expertise Group Politeknik Negeri Bandung are also much appreciated.

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