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International Conference on Earth Science, Mineral, and Energy With the theme, "Harmonizing on Exploration, Extraction, and Conservation"

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Preface

It has been twelve years Faculty of Mineral Technology Universitas Pembangunan Veteran Yogyakarta held an annual national or international conference on energy, mineral, and earth science. This year the conference was called International Conference on Earth Science, Mineral and Energy (ICEMINE) 2018 with the theme "Harmonizing on Exploration, Extraction and Conservation". This conference was held on 11th October 2018 and hosted by the Faculty of Mineral Technology, Universitas Pembangunan Nasional Veteran Yogyakarta.

Geological conditions of Indonesia contribute a lot of mineral and energy resources. On the other hand, Indonesia also has high risks of geological disasters. We all have the right to explore and extract the mineral and energy resources in the earth through technology, but also have to maintain the environmental impacts and carry out conservation. Therefore, in this conference, we invite all geologists, geophysicists, petroleum engineers, mining engineers, metallurgist, environment and geo-tourism geoscientist as well as earth science students from all parts of society and institution of the world to share their knowledge, experience and concepts, in order an explore, extract and conserve. We wish those three activities could develop in harmony.

Yogyakarta, 11 October 2018

Editor in Chief

Dr. Ir. Sutarto

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Analysis of temporary support effectiveness in very softrock tunneling at Cisumdawu's Tunnel

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Analysis of temporary support effectiveness in very softrock tunneling at Cisumdawu's Tunnel

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Abstract. Temporary support aims to minimize deformation, it is installed immediately after excavation, especially in the case of softrock tunnels. In this study, Numerical modeling is used to analyze the optimization of the support system design, and then compared with the monitoring results. Based on numerical analysis, it is found that installation of pre-support before excavation is recommended, it can reduces deformation on the tunnel roof. This is advantageous, because pre-support decrease installation of other support. The use temporary support such as shotcrete and steel set, is enough to produce a more stable tunnel condition, especially for tunnel sections not affected by pre-support such as the tunnel floor.

1. Introduction

A large increase in the use of shallow tunnels in softrock has been observed, mainly in urban regions, during the last few years. These tunnels have been built for a variety of purposes, such as transportation, water supply and as part of sewerage systems [15]. The cisumdawu Road is categorized as a national strategic project located in West Java. During the development of this project, the tunnel construction for Road tunnel became the first implemented in Indonesia. The type of material in the Cisumdawu is classified in softrock type, NATM (New Austrian Tunneling Method) is selected as a tunnel excavation method

Many definitions and/or concepts regarding soft rocks have been proposed [3,5,10]. Soft rocks, i.e. sandstone [13] and mudstone [26] have the main characteristics such as large deformability, strong dependence of resistance on degree of saturation or temperature, and susceptibility to alteration. For simplicity, soft rocks have been classified into two sets [16] geological soft rock and engineering soft rock. The set of the geological soft rock has the intrinsic properties of weakness, looseness and expansibility, while the engineering soft rock generates significant plastic strain and creep strain subjected to engineered effect [27]. At present, there are numerous researches on softrock tunnel design and construction problems. For example, the stud y on construction characteristic and dynamic

behavior of soft rock tunnel [24], the study of reasonable support scheme for soft rock tunnel in high gestures zone [21] the analysis of failure properties and formatting mechanism of soft rock tunnel [23] However, there are less researches on the systematic classification of soft rock tunnel and the pointed construction methods in accordance with their classes in the systemic classification of soft rock tunnel. It is still difficult to find an advanced, effective and universal design and construction method in soft rock tunnel projects [12]. Support optimization for soft rock tunnel is always the hot issue in engineering field. As soft rock has significant expansibility and time-variant characteristics due to its low strength, easily weathered, large void ratio, small bulk density and large water permeability,it always results in a serious impact on the engineering safety and construction period[4].

2. Method

2.1 Project Overview

The cisumdawu tunnel is called to be the longest road tunnel in Indonesia, it is located about 19KM away from Cileunyi Bandung City of West Java (figure 1). Position location of the tunnel is in STA. 12+628 – STA. 13+100 Cisumdawu Toll Road. The total length of tunnel is 1,1 km, with a height of 8,5 m and width of 11,7 m. tunnel depth is shallow, with the overburden of up to 52,8 m. The type of material around the tunnel is generally in the form of silty clay and fully weathered mudstone.

Figure 1. Location of Cisumdawu's Tunnel

Pre-support system with steel pipe grouting is also called "canopy tube system", "umbrella arch method", or "long forepoling method"), is installed over the tunnel crown (figure 2 on the left). Pipe umbrella is constructed using 114 mm of diameter steel pipe, 6 mm of thick and 12 m of length and 7° of installation angle. The steel pipe is installed 1 layer, 600 mm on crown top heading after tunnel face sealing with GRP bolt and shotcrete was installed, in order to provide stable conditions on the tunnel face during drilling for pipe installation. The excavation stage is divided into 7 stages with 3 bench (see figure 2 on the right), excavation starting from the upper section and then lower section. shotcrete and steel set are used as temporary support. Stage 6.1, 6.2 and 6.3 in Fig. 2 is the core, which acts as a weight and as a load balancer to handle the pressure at tunnel floor.

2.2 Numerical Analysis

The Finite Element Method has been the most widely applied numerical method for analysing engineering geotechnical problems, because of its flexibility in handling complex materials and boundary conditions [7]. The numerical modelling of Cisumdawu Tunnel is carried out with Phase2 version 8.0. Phase2 is a two-dimensional elasto-plastic finite element program provided by RocSience Inc. *Phase2* 8.0 offers a wide range of support modeling options. Bolt types include end anchored, fully bonded, cable bolts, split sets and grouted tiebacks. Liner elements can be applied in the modeling of shotcrete, concrete, steel set systems, retaining walls, piles, multi-layer composite liners, geotextiles and more. But the program is limited for analyze the tunnel on the longitudinal axis. The most correct way of modelling pipe umbrella systems is with three-dimensional (3D), more details around the supporting effect of the pipes can be analysed. This can be used to evaluate the design. Phase2 has an axi-symmetric option to investigate simple three-dimensional problems. However, this option cannot be used for gravity loaded near-surface tunnels [2].
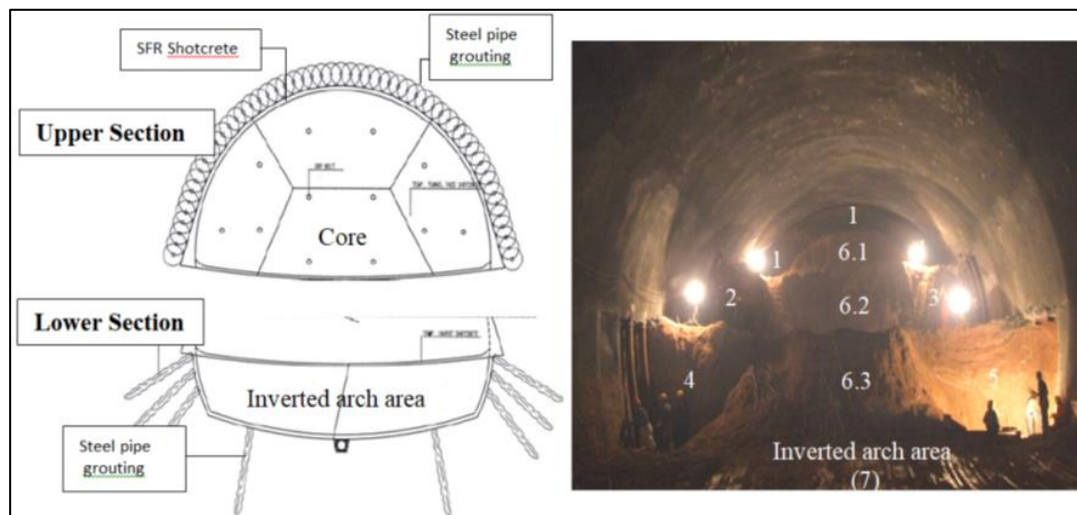
Figure 2. Excavation stage and support system design of Cisumdawu's Tunnel

According to **Hoek**, **2001**, a zone of improved material above the tunnel crown can be used to simulate the pipe umbrella support. The layer is defined as an arch above the excavated tunnel face. The height of a general cross section is estimated from the longitudinal section (figure 3). Since the pipes are overlapping and installed with an angle, the distribution of the improved layer will vary with length of the pipe umbrella section.
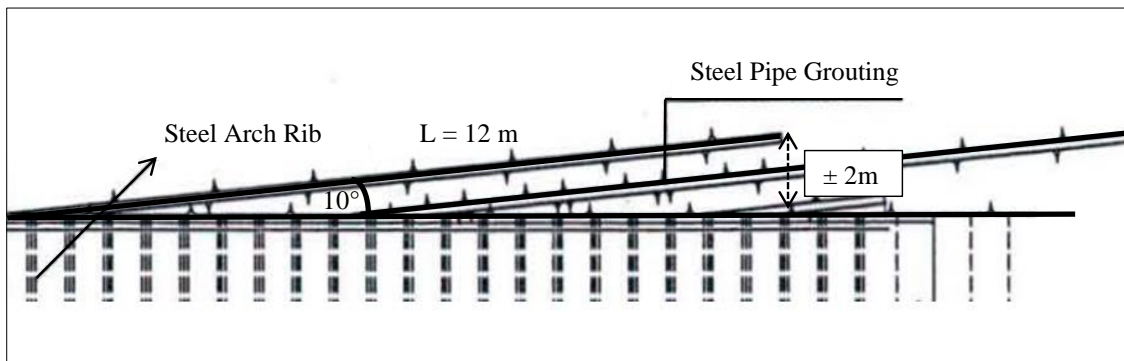
Figure 3. Height of a pipe umbrella general cross section for estimated longitudinal section

The improved material representing the pipe umbrella support layer consist of steel pipes, grout filling and the original soil. The material properties of the improved layer are estimated by a weighted average of the strength and the deformation properties of the components, based on a cross sectional area. A formula of the assumed weighting of the three components is developed and presented in Equation (Margrete,2014) :

improved layer = (softrock material x 0,8) + (steelpipe x 0,01) + (concrete x 0.19)

2.3 Monitoring
The main purpose of field monitoring is to comparatively analyze the monitoring data and to determine the actual effect in different kinds of support schemes by real-time monitoring the horizontal convergence, crown settlement, rock pressure of initial lining and secondary lining (Xian-min et al. 2011). In this study, monitoring was performed only to find out the deformation of the tunnel especially point STA.12+890. Monitoring data obtained from the results of measuring using Total Station and prism-targets, monitoring frequency can be seen in table 1. while the target position can be seen in figure 4

Figure 4. Prism-target position

Table 1. Tunnel Monitoring Spacing and Frequency

| Item	Spacing	Target Number	Frekuensi		
			0-15 days	15-30 days	Over 30 days
Horizontal Displacement	10-50 m	2 prisms	1-2 times/day	2 times/week	1 time/week
Roof Settlement	10-50 m	1 prism	1-2 times/day	2 times/week	1 time/week

3. Result and Discussion

3.1 Support System Design

the cisumdawu tunnel has two Pattern Design (PD), namely PD 1 and PD 2, PD 1 is applied to tunnels that have weak geological conditions., and PD 2 is applied to good geological conditions. Difference PD 1 and PD2 can be seen in figure 5 and table 2. Invert closure has not been performed while analyzing the effectiveness of the temporary support.

3.2 Numerical Modelling Analysis
3.2.1 Pre-Support (Pipe Umbrella)

The calculated values of the material properties of the improved layer for pipe umbrella analysis are presented in Table 3. including the material properties estimated for each of the three components (material, steel pipes and grout filling). Approximations of the values of the improved material layer are performed to fit the other parameters (Margrete,2014). Based on the function, the installation of pipe umbrella aims to protect the crown tunnel during the excavation. So, it is necessary to analyze the displacement, before the installation of the umbrella pipe and after it is installed. the results can be seen in figure 6 and figure 7.
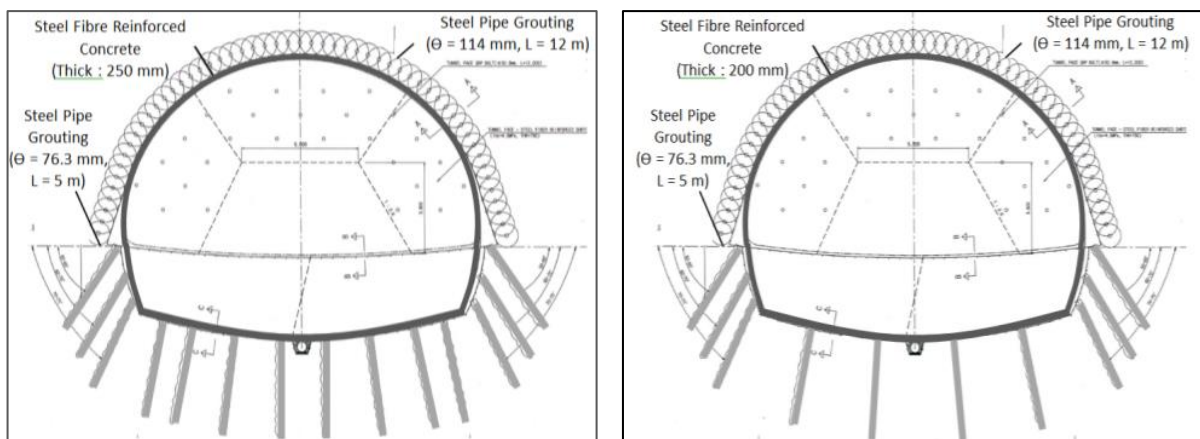
**Figure 5** Temporary support system design PD1 (Left) and PD2 (right)

Table 2. Difference PD 1 and PD2

Types	PD 1	PD2
Steel pipe Grouting (Pipe Umbrella)	Ө114.3 mm , L = 12 m, CTC 500 mm(lateral), 3000 mm(longitudinal), installation angle 10°	Ө114.3 mm , L = 12 m, CTC 500 mm(lateral), 4000 mm(longitudinal), angle 10°
Shotcrete	250 mm (1ST steel fibre shotcrete+Steel rib = 125 mm and 2ND Steel fibre shotcrete =125 mm)	200 mm (1ST steel fibre shotcrete+Steel rib = 100 mm and 2ND Steel fibre shotcrete =100 mm)
Steel Rib (H beam)	150 x 150 x 7 x 10, spasi 600 mm	150 x 150 x 7 x 10, spasi 700 mm

Table 3. Improved Layer for Pipe Umbrella Analysis (PD1 dan PD2)

Parameter	Symbol	Material (Softrock)	Steel Pipe	Concrete (margrete,2014)	Improved Layer
Unit weight	γ (MN/m^3)	0.0175	0.081	0.023	0.0192
Young's Modulus	E(MPa)	26.5	210000	31000	8011.2
Poisson ratio	v	0.3	0.3	0.15	0.272
Tensile Strength	σ_t (MPa)	0	415	5	5.1
Friction Angle	ϕ (°)	10	High	35	20
Cohesion	c (MPa)	0.014	High	5	0.075

Numerical simulation results (figure 6) for the maximum displacement value at the first excavation stage without pre-support is 65 mm on tunnel roof, while displacement value on the roof after the installation of pipe umbrella reduced to 40 mm. Figure 7 shows total displacements after the tunnel excavation is complete, the maximum displacement value are 60 mm (without pre-support) and 40 mm (with pre-support). This result states that the installation of pipe umbrella is recommended for *pre-support* in softrock tunnelling, but pre-support does not reduce the deformation that occurs on tunnel floor.
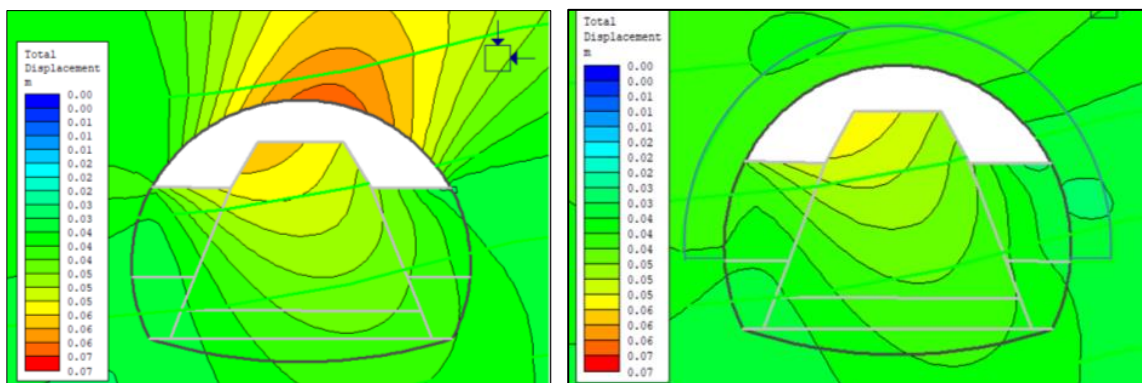
Figure 6. Simulation results of total displacements on stage 1 excavation with pre-support (right) and no pre-support (left)
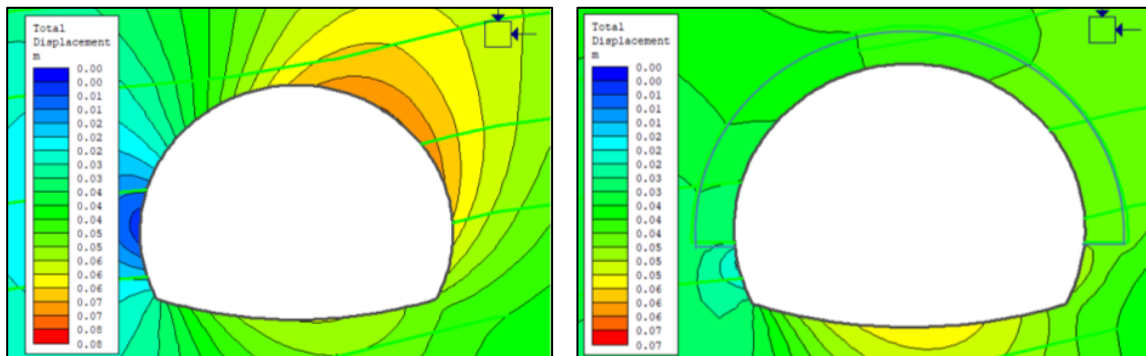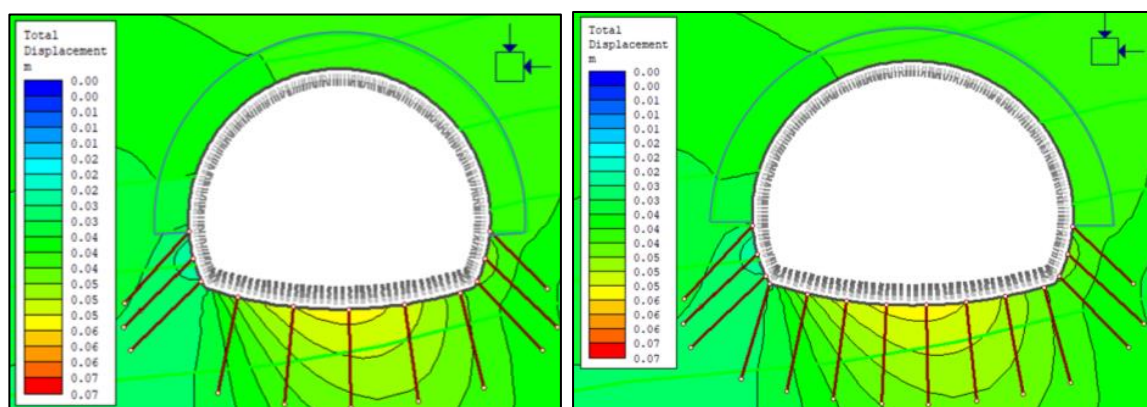
Figure 7 Simulation results of total displacements after excavation is complete with pre-support (right) and no pre-support (left)

3.2.2 Temporary Support

Temporary support types installed are steel rib and shotcrete. in this study not only analyze the temporary support of PD1 and PD2,but also analyze the effect of pre-support on temporary support. Figure 8 shows total displacements occurring in the tunnel with pre-support and temporary support of PD 1 and PD2 .

Based on the numeric simulation result (figure 8), the average tunnel displacement is 38 mm, the maximum displacement value in PD1 and PD2 is almost 55 mm on the tunnel floor. there is not too much difference between PD 1 and PD2.what needs to be discussed here is that there is no major difference between tunnels that are pre-support installed only (right side figure 7), with pre-support and temporary support tunnel (figure 8), there's just a little difference. ie a temporary support reduces the displacement ±5 mm on tunnel wall and ±10 mm on the the floor . based on these results, it is estimated that the installation of a temporary support while pre-support is also installed, does not contribute greatly to minimizing displacement in the tunnel. just by installing pre-support, sufficient to provide stable conditions on the tunnel roof even without installing temporary support. it means that pre-support can be a support for the tunnel. But this statement could be wrong, because there is no numerical method that can simulate the pre-support (pipe umbrella) in tunnel, i.e about the influence of spacing steel pipe on the pipe umbrella design. Table 4 shows numerical simulation results of tunnel analyzes at each stage of excavation, with various models of support design systems.

Figure 8. Simulation results of total displacements after excavation is complete with pre-support and Temporary support (PD 1 on the left, PD2 on the right)

Table 4. Numerical simulation results of tunnel at each stage of excavation

| Excavation Stage	Total Displacement (mm)											
	No Support		Pre-Support Only (1)		Temporary Support Only (2)				(1) and (2)			
					PD1		PD2		PD1		PD2	
	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg
1	63(R)	43	42(W)	38	60(R)	44.8	53(R)	41	42(R)	39.5	42(R)	39.5
2	60(R)	43	46(F)	37	56(R)	42.3	49(R)	40	46(F)	40.5	46(F)	40.5
3	68(R)	48	46(F)	40.5	60(R)	46	53(R)	43	46(F)	41.3	46(F)	42.5
4	64(R)	48	49(F)	38.8	56(R)	44.8	53(F)	43	49(F)	42	49(F)	41.3
5	68(R)	50	49(F)	42.3	56(R)	47.3	53(W)	44	49(F)	44.8	49(F)	43
6	64(R)	50	53(F)	42.5	56(R)	47.5	53(F)	44	49(F)	44	53(F)	44
7	64(R)	50	57(F)	44	56(R)	47.5	56(F)	44.8	53(F)	44	53(F)	44

*Note :R: Roof, F:Floor, W:Wall

3.3 Monitoring Result
In order to verify the adequacy of the original design and assess the stability of the rock structures during construction, observational methods are extremely useful. Figure 9 shows displacement for 15 days at STA 12+890, the average displacement is 1.4 cm or 14 mm per day and maximum diplacement is 24 mm. In monitoring of the stability of structures, displacement measurements are usually performed, because of the easy and reliable data being obtained The field measurement results are only numbers, unless they are properly interpreted. For interpreting the measurement results properly, the hazard warning levels for the measurement quantities are needed for assessing the stability of the structures.

Theoretical approaches based on critical strain of geomaterials can be used to determine hazard warning levels [18]

$$\varepsilon_c = \frac{U_c}{R}$$

Where, ε_c is critical strain, U_c is allowable displacement of tunnel and R is radius of the tunnel. Critical strain value based on test results is 1,05%, the radius value is considered equal to the tunnel height which is 8.5 m. Thus, the allowable displacement is obtained ± 9 cm or 90 mm. The results of tunnel stability analysis at STA 12 + 890 based on measurement data and numerical simulation can be seen in Table 5.
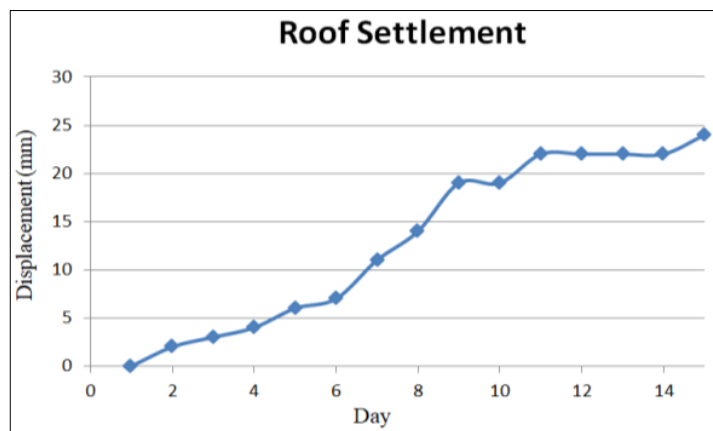
Figure 9. Roof settlement measurement at STA 12+890

Table 5. The result of tunnel stability analysis

Pattern Design	Calculated Displacement (mm)	Measured Displacement (mm)	Allowable Displacement(mm)	Tunnel State
PD 1	44	24	90	Stable
PD 2	44	24	90	Stable

Conclusion

Softrock material is easily deformed if disturbed, one of the causes is due to excavation. The most effective actions that can be done is the installation of pre-support (pipe umbrella) before excavation. in some cases, many researchers say pipe umbrella is not a support, since there is no method that can explain in detail the effect of pipe umbrella on tunnel.

In this study, pre-support analysis was made in simple form, and the result is that the pre-support is recommended for very softrock tunneling, because it could reduce displacement by around 30-40%. however, that only happens on the tunnel roof. So, another support is required to provide stable conditions throughout the tunnel. Based on the results of numerical analysis for tunnel support is found that the temporary support does not contribute greatly to reducing displacement on tunnel roof, But it is useful to reduce displacement that occurs on the wall, and especially on the tunnel floor. Analysis results also show that if only using temporary support is not recommended, it will causes large displacement. Actual displacement can only be known by monitoring, but the results are only numbers unless they are properly interpreted. The hazard warning levels are needed for assessing the stability of the structures. The determination of the warning level with the critical strain approach produces the allowable displacement of 90 mm, the number is greater than the actual deformation that occurs in the tunnel. it shows that the support system in cisumdawu tunnel is effective in controlling deformation.

Acknowledgement

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