Circular Lining Behaviour due to Earthquake Load in MRT Jakarta Underground Tunnel Area CP-106

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Abstract. *One solution to congestion in Jakarta is to build a Mass Rapid Transit (MRT), a special application for subway structures. This study calculates circular tunnel behavior in static and dynamic conditions due to earthquake effects. Static condition analysis using Muir Wood's theory and dynamic conditions using the theories of Wang (1993) and Panzien (2000). The depth of the MRT tunnel in the CP-106 area is at a depth of 11 meters by diverting by clay with NSPT 3-20. The results show that in static condition has tunnel deformation that works at 8.06 mm. In the dynamic analysis with earthquake acceleration in 0.359 g produces oval deformation at 15.95 mm. The maximum deformation limit given is 20 mm with a maximum earthquake acceleration value of 0.4 g. In conclusion, MRT Jakarta area CP-106 in static condition has a lower deformation than dynamic conditions, but both conditions fulfill the deformation tunnel requirements.*

Keywords: Mass Rapid Transit, static, dynamic, earthquake, oval deformation.

Introduction

Large cities in developing countries are often faced with problems transportation. One problem that is faced by big cities is the congestion. Jakarta, the capital city of Indonesia, is an example of a large city in a developing country that has problems in the field of transportation. The Jakarta Government certainly has several solutions to overcome existing transportation problems, one of which is the construction of a mass transportation system in the form of MRT (Mass Rapid Transit). The Jakarta Mass Rapid Transit (MRT) project will be built along 110.8 kilometers and has two transportation corridor corridors, namely the 23.8 kilometer air-south corridor and 87 kilometer east-west corridor. In the first phase, construction will start from Lebak Bulus towards the 15.7 kilometer Bunderan HI, including the construction of 13 stations. Then in the second phase, construction will start from the Bunderan HI towards 8.1 kilometers of Kampung Bandan including the construction of 8 underground stations.

In first phase of Jakarta MRT projects especially build in the subway tunnel structure. Tunnel construction which is done on soft land especially in Jakarta has the advantage in the excavation process. The soil base in Jakarta is dominated by soft clay deposition that is approximately 2500 years old. In the event of a strong earthquake, the area of tunnel Jakarta is most vulnerable to a process of land subsidence. In addition, large-scale earthquakes will also propagate earthquake vibrations so that they experience amplification or magnification of the shock of the structure above or below. According to the earthquake map of Indonesia published by USGS (2009), the city of Jakarta is in the Peak Ground Acceleration zone between 0.245 g – 0.4 g. The data is used for reference seismic design for MRT tunnel construction in Jakarta (Marlihat and Mangape, 2009).

Materials and Methods

The Jakarta MRT tunnel with a diameter of 7.3 m which was dug below the surface of the ground by means of the Tunnel Boring Mechine (TBM) using the shield tunneling method. The tunnel construction on the ground is carried out by excavating and removing the soil in front of the tunnel by installing a lining behind it to hold the tunnel walls and floor. In planning tunnel lining, there are things to consider, namely the behavior of circular tunnel lining. Muir Wood's (2002) theory provides a method for analyzing static conditions of tunnels by considering Axial Force, bending moment, and lining deformation. Static analysis of circular tunnel behavior can be described in the equation:

$$N = \frac{r_o(S_n+2S_t)\cos 2\theta}{3} + p_w . r_e + N_o \tag{1}$$

$$M = \frac{r_o . r_e(2S_n + S_t)\cos 2\theta}{6} \tag{2}$$

$$U = \frac{r_e . r_o{}^3(2S_n+S_t)\cos 2\theta}{18E_{lin}.I} \tag{3}$$

The circular layer analysis method analyzes dynamic loads by considering earthquake loads. Dynamic load analysis with calculations:

$$\gamma_{max} = \frac{\tau_{max}}{G_m} = \frac{\left(\frac{PGA_M}{g}\right)\sigma_v . R_d}{\frac{E_m}{2(1+\upsilon_m)}} \tag{4}$$

dengan,

PGA_M = the acceleration of the peak land adjustments influences the site class
σ_v = earth vertical stress (kN/m^2)
τ_{max} = earth shear stress (kN/m^2)
R_d = stress reduction factor
E_m = modulus of soil elasticity (kN/m^2)
G_m = earth shear modulus (kN/m^2)
υ_m = soil poisson ratio

For the bending moment equation, axial force and oval deformation due to earthquake loads on the cross section of the tunnel as a function of maximum flexural strain are described as follows :

$$M_{max} = \frac{1}{6}K_1 \frac{E_m . r^2 . \gamma_{max}}{1+\upsilon_m} \tag{5}$$

$$N_{max} = K_2 . \tau_{max} . r = K_2 \frac{E_m . r . \gamma_{max}}{2(1+\upsilon_m)} \tag{6}$$

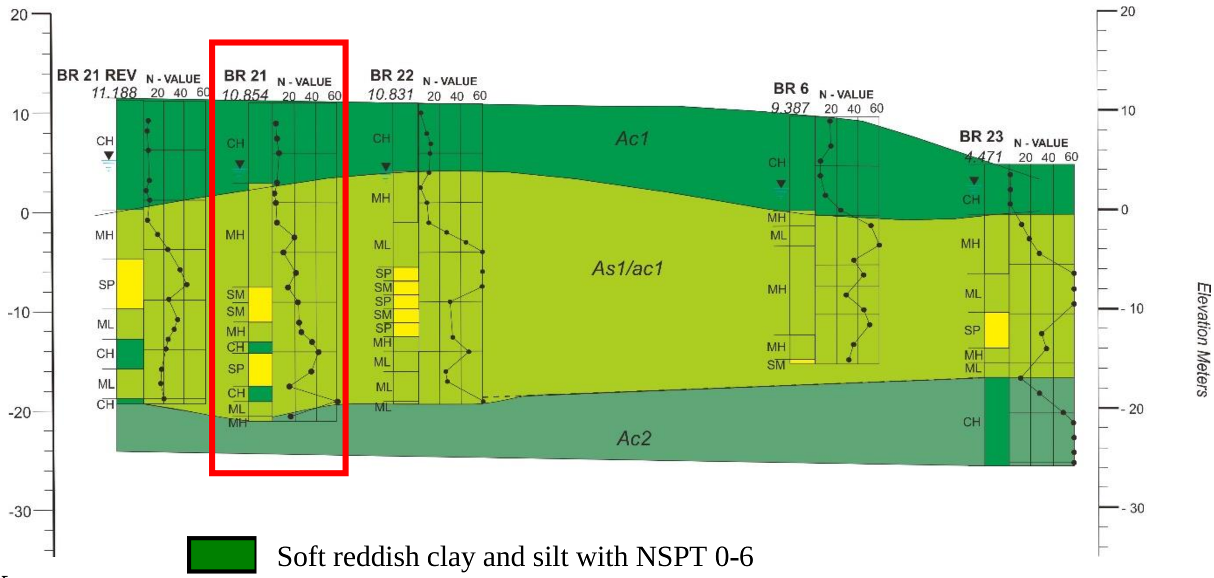
$$\Delta d = \frac{D . K_1 . F . \gamma_{max}}{3} \tag{7}$$

The underground construction research site is located on the CP 106 section which is viewed from the Upper Dukuh pedestrian bridge (STA 13k + 000) to the Upper Dukuh Station (STA 13k + 916). In this study primary and secondary data are used as input data in the modeling of circular lining tunnel behavior analysis in the Jakarta MRT tunnel construction project. Primary data in the form of results of land investigations that have been carried out previously as well as the results of surveys and documentation. Secondary data in the form of soil layers interpretation and tunnel design.

Results and Discussion

Soil Profile

In this study, the soil layer in the Jakarta MRT tunnel from Upper Dukuh Bridge to Upper Dukuh Station where taken in one section is BR 21. Soil conditions at the construction site are dominated by soft clay at a depth of less than 10 m from the ground surface and silt layer to sand with medium density at a depth of 15 to 20 m.



Keterangan :

Ac1 — Soft reddish clay and silt with NSPT 0-6

As1 — Silt to Sand with NSPT 2-40

Ac2 — Hard clays with NSPT 10-40

Figure 1. Interpretation of the Jakarta MRT tunnel layer CP 106 section

Static Load Analysis

The strength of the lining in the tunnel in this study can be divided into two, namely the axial force and the bending moment. For static analysis, the load applied is in the form of surcharge, soil pressure and water pressure. His empirical analysis refers to Muir Wood's theory in the Land Transport Authority (2002). Overall, the results of the analysis of empirical calculations under static conditions such as bending moments, axial forces, and lining deformation can be seen in Figure 2.

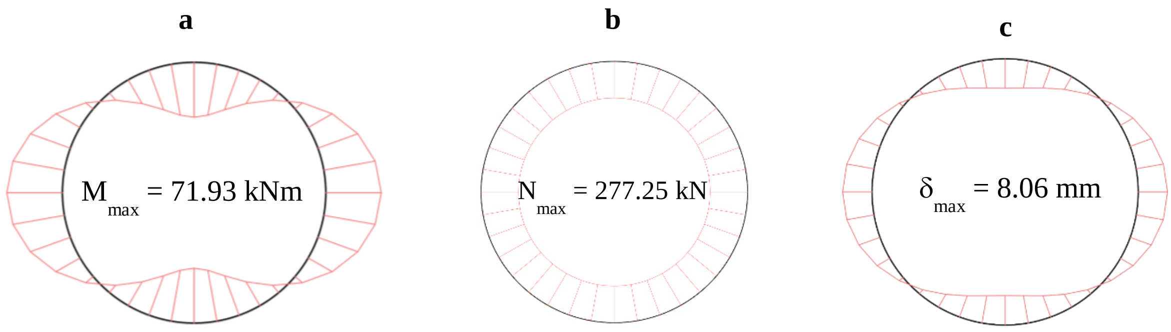


Figure 2. Behavior of circular tunneling static load analysis tunnel. (a) Bending Moment, (b) Axial Force, (c) Deformation.

The strength of the lining in the picture above can be stated that the lining is still able to withstand the axial force and bending moment received. The results of axial force analysis and maximum bending moment based on the empirical method were 277.25 kN and 71.93 kNm. Static condition analysis conducted in section BR 21 is still within safe limits to be applied.

Dynamic Load Analysis

For dynamic load analysis, the calculation of the empirical method uses the methods of Wang (1993) and Panzien (2000). This method is validation and has a high level of accuracy if the results are the same. Circular tunnel behavior in overall dynamic load analysis can be seen in Figure 3.

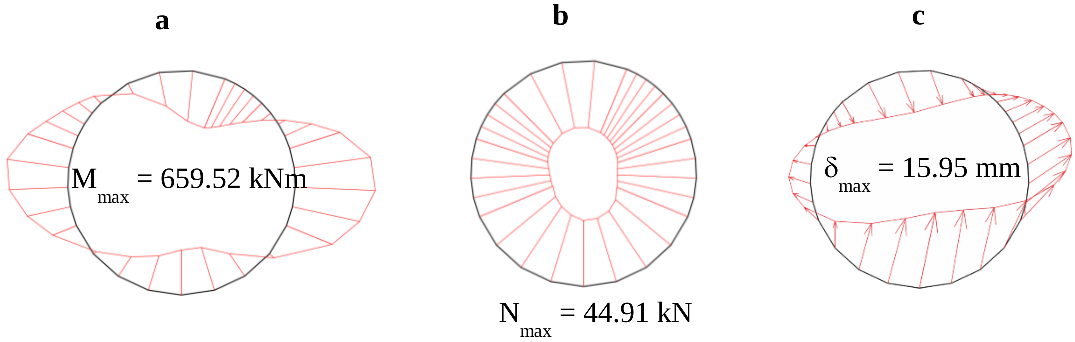


Figure 3. Behavior of circular tunneling dynamic load analysis. (a) Bending Moment, (b) Axial Force, (c) Deformation.

The results of axial force analysis and the maximum bending moment due to earthquake load based on the empirical method were 44.91 kN and 659.52 kNm. As for tunnel deformation of 15.95 mm, this shows that dynamic load conditions produce greater deformation than static conditions.

Conclusion

The lining ability which is assessed based on axial force, bending moment and oval deformation due to static and dynamic loads is carried out in section BR 21 in the CP-106 area. Deformation values in the analysis of static conditions have smaller results than dynamic conditions due to dynamic conditions considering the peak ground acceleration (PGA) value of 0.359 and do not consider friction between the lining and the ground. So this can make the tunnel deformation greater than the static condition which only considers overburden loads and surcharge loads. But from these two conditions, tunnel deformation is still within the safe limits because it has a deformation value below 20 mm.

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