Jurnal Kejuruteraan 34(2) 2022: 263-267
https://doi.org/10.17576/jkukm-2022-34(2)-10

Structural Displacement of Prestressed Concrete Sleepers Subjected to Six Coaches Commuter Load at Pinang Tunggal and Kobah

Mashita Harun[a], Mohd Ikmal Fazlan Rozli[a*], Kay Dora Abd Ghani[a] & Norliyati Md.Amin[b]

[a]*College of Civil Engineering, Universiti Teknologi MARA Cawangan Pulau Pinang, 13500 Permatang Pauh, Penang, Malaysia*
[b]*College of Civil Engineering, Universiti Teknologi MARA, 40000 Shah Alam, Selangor, Malaysia.*

**Corresponding Author: ikmalcivil@gmail.com*

Received 17 January 2021, Received in revised form 9 July 2021
Accepted 11 August 2021, Available online 30 March 2022

ABSTRACT

Nowadays, train is one of an effective transportation in Malaysia. Commuter started the operation at Central Region had extended the operation at Northern Region in 2015.Since the volume of passengers were increasing every year, it caused railway track need to be maintenance frequently due to the displacement of concrete sleeper on railway track. According KTMB representative, the displacement happened depend on the soil condition. However, this study figured out the structural displacement concrete sleeper under different of soil condition. A site investigation had been carried out along railway track from Butterworth to Alor Setar. In this study had selected Pinang Tunggal the subsoil condition silty sand in category which displacement 7.40mm and Kobah the subsoil condition under soft clay, the displacement 0.15mm accordingly. The tools that had been used in this site investigation such as vibrator machine and piezometer. The captured records transferred to software called as Dewesoft to measure the displacement of concrete sleeper. From the result had been plotted on the graph showed sandy silt had shown the highest displacement compared with the soil condition soft clay. Therefore, the roof cause of displacement of concrete sleeper at railway track may cause the water table in the subsoil. This study would assist the authority to plan the maintenance on railway track.

Keywords: Dynamics; prestressed concrete; railway; sleeper; dewesoft

INTRODUCTION

The construction of electrified double track railway project at Northern Peninsular of Malaysia had been finished their construction on 2015. Keretapi Tanah Melayu Berhad (KTMB) had been begun their service on September 2015 which was Electric Trains System (ETS) started its service carrying passenger from northern region to south region. The increasing passengers were growth every year made KTMB imported commuter from Klang Valley to northern region for covered up daily basis consuming.

Began by three coaches KTMB brought up to six coaches for every day used. The frequently services of passenger trains such as ETS, commuter and additional freight trains leaded displacement of soil indirectly prestressed concrete sleepers were having cracks and deflection due to unstable soil condition. KTMB always have maintenance on railway track which has deflection at known area has displacement.

Prestressed concrete sleepers (PCS) as shown at Figure 1 are the most used on the railroad. They played some roles to support and absorb the variety of trains loading transferring to the ground (Javad et al. 2015). The railways track (explained railways structure can subdivided into two groups; Superstructure and substructure. Superstructure is consisting of the rails, rail pad, and concrete sleepers and fastening system.

Meanwhile, substructure is associated with a geotechnical system consisting of ballast, sub ballast and sub grade (formation). Railways track sleeper is main part of railways structures (Kaewunruen and Remennikov 2009). Its major roles are to distribute loads from the rail foot to the underlying ballast bed. PCSs are the most popular railway sleepers around the world generally, and Malaysia especially. This is because the PCSs get easily from the manufacturer who supplied the sleepers. Other than hand, it is more sustainable until more than many years.

FIGURE 1. Railway Track

Dong et al. (2018) has conducted a study on site investigation regarding subsoil condition railway track from Bukit Mertajam to Alor Setar has been conducted. During electrified double track raiway project, the researcher made some testing to clarify type of subsoil. Table 1 showed the differential soil along the route from Bukit Mertajam to Alor Setar.

TABLE 1. Summary on subsoil condition [4]

Location	Subsoil Condition
Bukit Mertajam to Tasik Gelugor	Sand and sandy Silt (Residual soil). Very Soft to Soft clay was encountered near to Tasek Gelugor.
Tasek Gelugor to Pinang Tunggal	Very Soft to Soft clay
Pinang Tunggal to Sungai Petani	Sandy Silt (Residual soils). Very Soft to Soft clay was encountered near Pinang Tunggal.
Sungai Petani to Terusan Dulang Kechil	Sandy Silt (Residual soils) with localized soft clay at Gurun area
Terusan Dulang Kechil to Junun to Alor Setar	Very Soft to Soft clay

Yean-Chin (2012) studied stiffening soft soil which supporting railway track.The analysis is about designing dynamic of track-ground vibration on high speed trains.Well documented track- ground vibration analysis had shown in these paper.

Meanwhile, Zhai et al. (2011) induced track-ground vibration high speed trains by showing that vertical ground vibration is much larger than lateral and longitudinal components.The analysis and modelling was well documented in this paper.However, in this study site investigation had been held at two different area with two different soil conditions sandy silt and soft clay.

In review, Rozli et al. (2018) explained about soil-structure interaction of railway track.The constantly vibration on railway track with weak soil caused soil settlement. In Malaysia,prior to maintenance on railway track KTMB staffs would be visual inspection on the site. Some area had effected with the ‘pumping’ works caused PCS was surrounding by mud.This maintenance works would take some for recovering.

In review paper Kouroussis et al. (2014), the atuhors showed that the characteristic of vehicles effects on ground vibrations.There are two conditions of vehicles for testing at quasi-static anda dynamic which were given impact on ground vibration.

Askarinejad et al. (2018) has studied the deflection of sleeper at different soil at Australian railway track.The soil condition for Site A in category soft clay which is softer (lower resilient modulus).Meanwhile, Site B soil condition known to be medium to high strength silt stone.The studied had proven that the deflection shown at Site A is 3.2mm compared Site B is 1.7mm. This was meant that, type of soil condition contributed the delfection of sleeper.

OBJECTIVES

The objective of this study is to make comparison between two type of soil condition of railway track from Bukit Mertajam to Padang Besar. Two known area have different soil condition would be tested.First at Pinang Tunggal have sandy silty and Kobah have soft soil. Both will compare the displacement versus time that taken from site investigation by using vibration machine as equipment of reading data while Dewesoft is a software for transferable raw data to graph.

METHODOLOGY

SITE INVESTIGATION

Keretapi Tanah Melayu Berhad (KTMB) representative given the permission for the area concerned with concrete sleeper displacement during the first site investigation. Following discussion, a decision to investigate Pinang Tunggal and Kobah, as shown in Figure 2, due to the soil conditions, with the Pinang Tunggal area covered by sandy silty ground and the Kobah soil condition being soft clay soil.

FIGURE 2. Map Pinang Tunggal and Kobah

(a)

(b)

FIGURE 3. a) Site location from Google Maps. b) On-Site Pinang Tunggal

(a)

(b)

FIGURE 4. a) Site location from Google Maps. b) On-Site Kobah Station, Pendang

Figure 3 and Figure 4 showed the site location at Pinang Tunggal and Kobah testing had been carried out. During the testing was being carried out we had monitored by KTMB respectective for safety issue. The classified of soil condition at Pinang Tunggal and Kobah based on the previous research had summarized soil condition as shown at Table 1. Since within Pinang Tunggal the soil condition under sand clay. However, at Kobah within Terusan Dulang Kechil to Alor Setar the soil condition under soft clay.

During the site investigation, tools such as a vibrator machine and a piezometer were used. A vibrator machine, as shown in Figure 5, is a piece of equipment used to record data from an object that has a piezometer installed at the edge of a concrete sleeper, as shown in Figure 6. Special glue was used to adhere the piezometer. The glued had no effect on the piezometer reading capture.

FIGURE 5. Vibrator machine

FIGURE 6. Piezometer

The piezometer reading will be interpreted by a software called Dewesoft, as shown in Figure 7. The data accelaration was captured in three directions on the piezometer: the X-axis was lateral, the Y-axis was vertical, and the Z-axis was longitudinal.

In this study, the vertical direction was given higher priority than the others because it provided the greatest displacement. The raw data transferred at Dewesoft in terms of acceleration m/s^2 would be double intergrated to obtain displacement at the vertical direction, i.e. the Y-axis.

As shown in Fig. 8, the displacement was extracted into Excel. The acceleration from the X-axis and Z-axis, on the other hand, is also exported to Excel. Prior to comparing different site locations, a graph would be plotted from the data display.

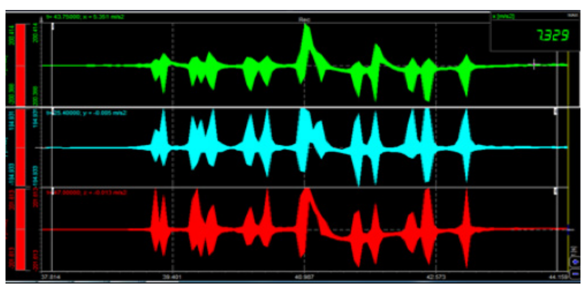

FIGURE 7. The output of analysis using Dewesoft

Time	x.AI 0	y.AI 1	z.AI 2	y/Double integral.Integral, derivative 1 (Integral, derivative)
s	m/s2	m/s2	m/s2	mm
0	-0.82116	2.18035	-0.26916	0.006198
0.0001	0.162485	0.977514	0.043233	0.006228
0.0002	1.354436	1.073633	-0.33131	0.00627
0.0003	0.978315	-0.42775	0.232861	0.006318
0.0004	-0.39874	-4.5195	1.051635	0.006356
0.0005	0.143206	-5.30838	1.286111	0.006355
0.0006	0.918658	-1.415	-0.0673	0.006314

FIGURE 8. Deflection data extracted from Dewesoft

Figure 9 showed a Commuter is daily operation trains. It rides passenger from Padang Besar to Bukit Mertajam. The operation of Commuter is every hour per train at upline and downline directions. However, the maximum speed of Commuter can achieve 120 KM/h. At the beginning operation KTMB started by three coaches. Since the demand of passenger ride of Commuter, KTMB supplied six coaches from Commuter Klang Valley.

The data was obtained from the Commuter passenger train. This is due to the fact that commuter trains frequently pass through the site location, both in the down9ine and upline directions. Within an hour, commuters passed through more than four times. However, during the recording, the data piezometer fell due to the impact of the Commuter's high speed. In addition, a few data points had been collected.

There were two directions: upline and downline. Upline was from southern to northern, while downline was from northern to southern.

TABLE 2. Record data at site investigation

Commuter 6 coaches		
Pinang Tunggal	28/3/2018 10.53am	Upline
Pinang Tunggal	9/4/2018 8.45am	Downline
Kobah	2/4/2018 10.21am	Upline
Kobah	3/4/2018 9.20am	Downline

FIGURE 9. The Commuter

RESULT

As a result of the site investigation, a graph in displacement versus time was plotted, as shown in Figure 9. On the graph below, four readings represent different directions at Pinang Tunggal and Kobah, where Commuter is referred to as a passenger train.

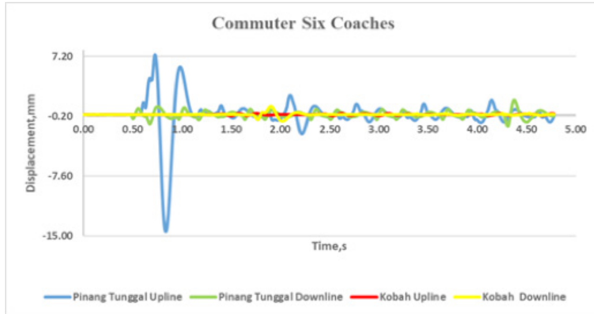

FIGURE 10. Displacement vs Time

TABLE 3. Maximum Displacement of prestressed concrete sleepers subjected to six coaches commuter load at Pinang Tunggal and Kobah

Commuter 6 Coaches	Pinang Tunggal Displacement (mm)	Kobah Displacement (mm)	Differentiate of Displacement (mm)
Upline	7.40	0.15	7.25
Downline	1.77	1.02	0.75
Differentiate Between upline and downline.	5.63	-0.87	
Type of soil	Sandy Silt	Soft Clay	

The highest displacement recorded at Pinang Tunggal upline direction with the soil condition sandy silt was 7.40 mm, while the lowest displacement recorded at Kobah upline direction with the soil condition soft clay was 0.15 mm, according to Table 3. The different between Pinang Tunggal and Kobah was 7.25 mm.

The displacement was also recorded in the downline direction, with the highest displacement occurring at Pinang Tunggal 1.77 mm and the lowest displacement occurring at Pinang Tunggal 1.02mm.The different between two locations Pinang Tunggal and Kobah was 0.7 mm.

Between of upline and dowline direction also were having different displacement even at same location testing.At Pinang Tunggal the different between upline and downline were 5.63 mm.Meanwhile, at Kobah the different between upline and downline direction displacement was – 0.87 mm.

The soil condition given the displacement of concrete sleeper when load wheel axle trains applied on concrete sleeper, according to the results shown in Table 3.

Therefore, train acceleration influenced the displacement of concrete sleepers because the higher the speed, the greater the displacement of concrete sleepers.

DISCUSSION

According to the findings of the site investigation, the Commuter's accelaration at the highest speed caused the impact of accelaration to cause the greatest dispalcement on concrete sleeper at Pinang Tunggal. Furthermore, the location of the site at Kobah near the railway station caused the Commuter to slow down when approaching the railway station.

Other than hand, the structure of the railway track played a role in the displacement of concrete caused by ballast movement. Frequent passenger and freight trains passing through on concrete sleepers left the area devoid of ballast. It has the potential to cause the impact of load trains directly compressed on concrete sleepers on the subsoil.

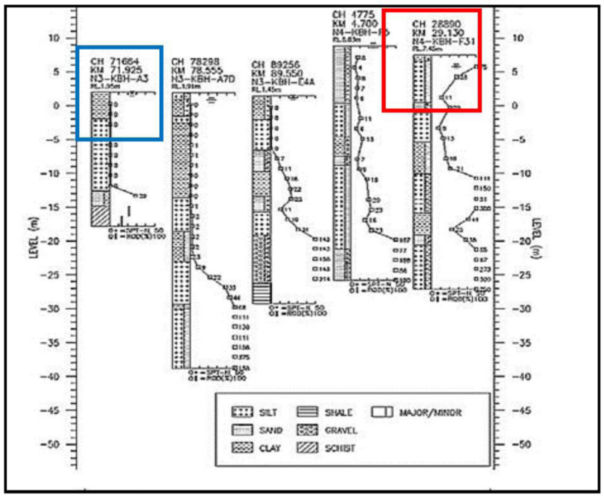

FIGURE 11. Typical Borelogs Profiles of the subsoil
Souce: Yean-Chin (2012)

As studied by Yean-Chin (2012) at Figure 11 showed that the major cause of concrete sleeper displacement was water table in the subsoil. During the construction of the railway track, typical borelogs profiles of the subsoil were tested in a laboratory. The red circle featuring the area at Pinang Tunggal indicates that there was water table at the subsoil . Meanwhile, no water table was found at the top subsoil at Kobah. As the conclusion, water level in the subsoil given the displacement of concrete sleeper at railway track.

ACKNOWLEDGEMENT

Many thanks to Keretapi Tanah Melayu Berhad (KTMB) Cawangan Utara En. Zailan who granted permission for this team to conduct an on-site investigation.

DECLARATION OF COMPETING INTEREST

None

REFERENCES

Askarinejad, H., P. Barati, M. Dhanasekar, and C. Gallage. 2018. Field studies on sleeper deflection and ballast pressure in heavy haul track. *Australian Journal of Structural Engineering* 19 (2): 96-104. doi: 10.1080/13287982.2018.1444335.

Dong, K., David Connolly, Omar Laghrouche, P. Woodward, and Pedro Alves Costa. 2018. The Stiffening of Soft Soils on Railway Lines. *Transportation Geotechnics* 17. doi: 10.1016/j.trgeo.2018.09.004.

Javad, T., P. Mendis, T. Ngo, and M. Sofi. 2015. Behaviour of pre-stressed high strength concrete sleepers subjected to dynamic loads.

Kaewunruen, S., and A. Remennikov. 2009. Impact capacity of railway prestressed concrete sleepers. *Engineering Failure Analysis* 16(5): 1520-1532.

Kouroussis, G., D. P. Connolly, and O. Verlinden. 2014. Railway-induced ground vibrations – a review of vehicle effects. *International Journal of Rail Transportation* 2 (2): 69-110. doi: 10.1080/23248378.2014.897791.

Rozli, M. I. F., Z. R. M. Nor, J. Ahmad, S. F. Senin, A. S. Rahman, A. A. P. Muhaimin, K. D. A. Ghani, and N. M. Amin. 2018. A review: Soil structure interaction of railway structure in Malaysia permanent way. *AIP Conference Proceedings* 2020.

Yean-Chin, Tan. 2012. Ground Treatment Design for 200 km Electrified Double Tracks Railway Project at Northern Peninsular Malaysia.

Zhai, Wanming, Zhenxing He, and X. L. Song. 2011. Prediction of high-speed train induced ground vibration based on train-track-ground system model. *Earthquake Engineering and Engineering Vibration* 9: 545-554. doi: 10.1007/s11803-010-0036-y.