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Investigation on Prestressed Concrete Sleeper (PCS) Subjected to Dynamic Loading on Site and Experimental Works.

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ABSTRACT

The purpose of the research was to study the condition of prestressed monoblock concrete sleeper (PMCS) under dynamic loading experimentally and through site investigation. From this research, the value of deflection base on acceleration of concrete sleepers have been obtained. This study showed the possible correlation and relation of the PCS deflection located under a railway track. This research includes experimentation process which includes experimental investigations for dynamic loading of prestressed concrete sleepers (PCS) were examined in terms of its capability to accommodate their own design capacity and the relationships between load and displacement happened within the concrete sleeper. This study will help the railway authorities to understand and take any maintenance action to their rail infrastructure. From experimental test, the highest deflection on KTMB and EPMI rail seat section is 1.35 mm and 1.04 mm respectively. From site investigation at KM20.75, the highest deflection occured is 5.993 mm which is lower compared to the highest deflection at KM26.25 with the value of 7.06 mm.

Keywords: PCS; KTMB; EPMI; Rainflow Cyclic; AS 1085.12; KM20.75; KM26.25

INTRODUCTION

Railway tracks consist of components grouped into two categories, superstructure and substructure. Superstructure consists of rails, rail pads, fastening system, and sleepers. Ballast, sub-ballast, and subgrade are classified as a substructure [1]. Among those components, the roles of sleepers are noticeable which is used to support the rail and maintain the track gauge, to withstand vertical and longitudinal movement of rails, and to transfer and distribute loads from rail to ballast [2]. Prestressed concrete sleeper with longer life cycles and lower maintenance costs brought many technical and economic advantages to the railway engineering [3]. With their great weight, prestressed concrete sleepers assure the stability for the train [4]. A previous study of constant amplitude of prestressed concrete sleeper (PCS) subjected to three coaches train [5] has determine the pattern of load applied to the PCS as the load pattern is important in designing and lifetime of PCS.

PCS if not maintained properly will cause a lot of problem be it to authorities and civilian. The failure of PCS fabricated in Brazil has been studied by [8]. It is found that the sleeper will have shear failure at mid-span and flexural failure at rail seat. The displacement of the PCS also can be due to void underneath sleeper [10]. The researcher manages to obtained the data on-site. It is found that the voided ballast will caused the PCS to have at least 60% more deflection compared to a well compact ballast. Thus, it is important for the rail authorities to do regular maintenance at a problematic rail track.

Method used in this study was collecting a raw data from site measurement at Kajang-UKM railway station and using strain ratio method in determining the constant amplitude. Besides, rainflow cyclic counting method was used to determine the number of cycles of load applied by the moving three car set train on the PCS. The data that gained were analysed using Microsoft Excel software. From the study, amplitude values from the raw data of load by the moving trains were produced as in figure 1. The study had concluded that the maximum strain value under three car set train due to several data was 55.4762 5mm/m.

The study of loading capacity of prestressed concrete sleeper under harmonic function [6] has determined the ability to withstand the fatigue loading during services and the flexural behaviour of PCS under low velocity impact. The study also has produced harmonic functions that express the amplitude waveform through numerical modelling constant amplitude.

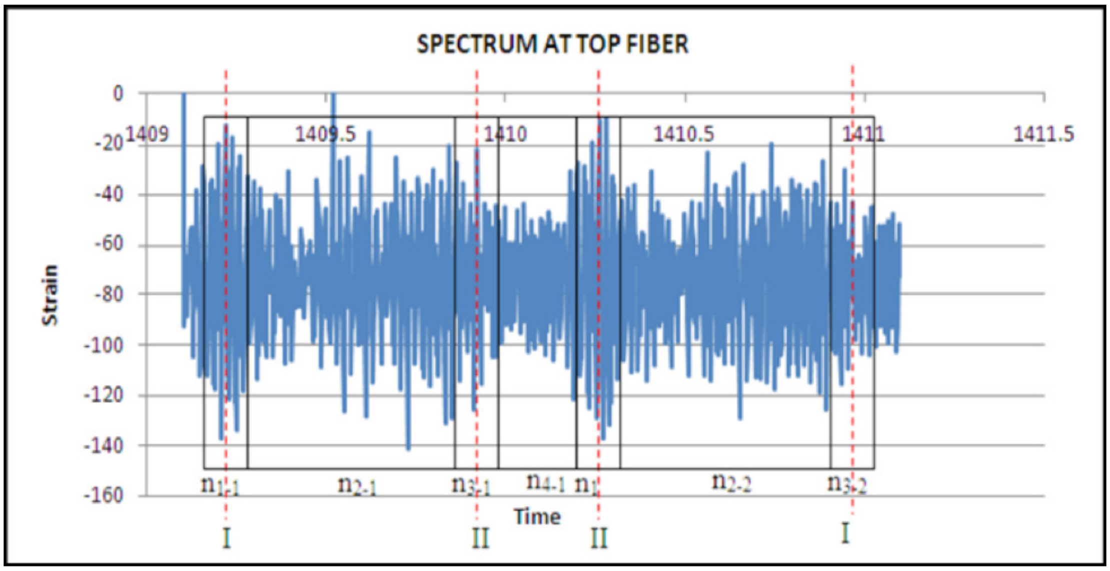

FIGURE 1. Constant Amplitude Graph Stains versus Time
Souce: Rozli et al. (2015)

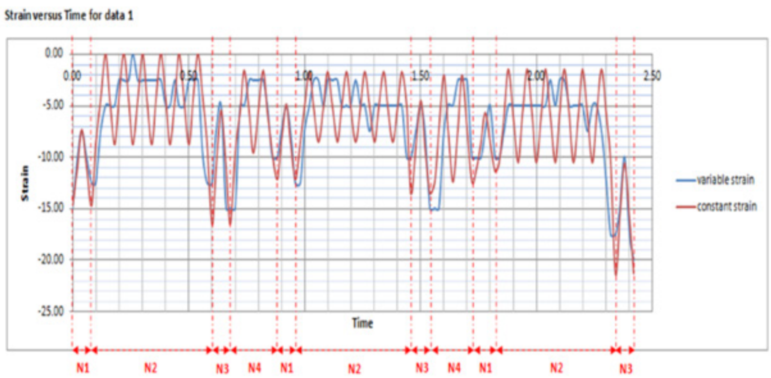

FIGURE 2. Constant Amplitude Block Sequence Graph Strain versus Time
Souce: Ilias et al. (2014)

The site measurement was made at KTM Kajang and the pattern of strain versus time history of PSC under cyclic loading was determined as in figure 2. The highest and lowest load subjected on PCS were indicated by relating the past investigation of the consistent amplitude of PCS exposed to three coaches train [5] that appeared in table 1 as the information was determined by utilizing rainflow cyclic checking technique. The information depended on commuter passenger train that gathered at Kajang-UKM railroad station, Selangor, Malaysia.

Following the Australian standard (AS 1085.12) [7], a repeated load for 3 million cycles are applied varying uniformly with each cycle. After that, the repeated loading cannot exceed 600 cycles per minute which means less than 10 Hz per cycles. In other words, 3 million cycles of repeated loading will be applied on each of the rail seat of PMCS (KTMB and EPMI) followed by the no. of cycles as stated in table 2. Furthermore, by using equation below, no. of cycles can be identified to imitate actual freight train.

TABLE 1. Minimum and Maximum of Load Applied on PCS

Load,P (kN)		
Maximum	Minimum	Ratio of Cycles
87	41	1.38
61	26	7.30
81	43	1.32
70	30	2.33

Souce: Rozli et al. (2015)

TABLE 2. Minimum and Maximum of Load, Hertz and No. of Cylcles

Load,P (kN)		Hertz (s^{-1})	No. of Cycles
Maximum	Minimum		
87	41	1.0	1.38/ 335766
61	26	1.0	7.3/ 1776156
81	43	1.0	1.32/ 321168
70	30	1.0	2.33/ 566910

$$1.38/\sum 12.33 \text{ x } 3 \text{ million cycles} = 335766 \text{ cycles} \quad (1)$$
$$7.30/\sum 12.33 \text{ x } 3 \text{ million cycles} = 1776156 \text{ cycles} \quad (2)$$
$$1.32/\sum 12.33 \text{ x } 3 \text{ million cycles} = 321168 \text{ cycles} \quad (3)$$
$$2.33/\sum 12.33 \text{ x } 3 \text{ million cycles} = 566910 \text{ cycles} \quad (4)$$

SITE INVESTIGATION

In this investigation, two sites were chosen to be investigated. The site was picked by KTMB because it is known as a non-problematic and also a problematic site condition (in terms of PCS movement). The sites chosen were Pinang Tunggal (KM23) and Pinang Tunggal (KM26.25). This research was carried out to determine the deflection behaviour of PCS located at a different site location. Most of the site is located far away from the nearest electrical source thus limiting the capability to continuously collect data. Site investigation only can collect data from 8.00am until 12.00pm because the battery of laptop can only hold for about 4 hours. During the 4-days site investigation, almost 20 data on all types of train were able to be gathered and upon further analysis, only 17 data were extracted to be analysed. KM20.75 locations consist of soil settlement due to settlement of culvert beneath the subgrade of the rail track. The location was surround by paddy field which consist of soft alluvial soil. The culvert is functioned to provide route to deliver the water stream into and out of paddy field. The second location are located at KM26.25 of route in Pinang Tunggal. This route consists of railway bridge infrastructure. These locations are selected due to its suitability to compare with data at problematic soil as the rail track was builds on a well-structured facility. The data collection will be among two types of train which is freight train and Electric Train Services (ETS). The data for KTM commuter also will be taken as additional data. Figure 3 and 4 shows the images of the site location at KM26.25 and KM 23 respectively taken from Google Earth in plans view geographically.

FIGURE 3. The Site Location at KM26.25 Which Consist of Bridge at Pinang Tunggal

In this study, an instrument called Vibration Analyzer was used to record the required data on site. Vibration analyzer instrument consist of few important parts such as cable and piezometer sensor. Piezometer is an important equipment as it will detect the even the smallest movement of PCS. The piezometer sensor is attached at the edge of PCS by binding it with a special glue. This glue will not have an effect on the value of vibration collected. Then, all the device were connected to a computer that were equipped with a software that can read the data collected. The software can show the real time data of the deflection of PCS. The location position of piezometer sensor must be observed and recorded. It is because the piezometer can read 3-axis of accelereation position. The acceleration obtained were caused from the moving train.. The units of acceleration recorded were mm/s^2. After that, the data will be converted to deflcetion by using a double ingtegration method. In theoretical view of mathematical integration, the relationship between acceleration and deflection can be tied by using double integration method. If an object's acceleration is known, a double integration can be used to acquire the objects position.. Thus, in this research the concept of double integration were used to get the value of deflection. Figure 5 and 6 shows the image taken from both actual site investigation.

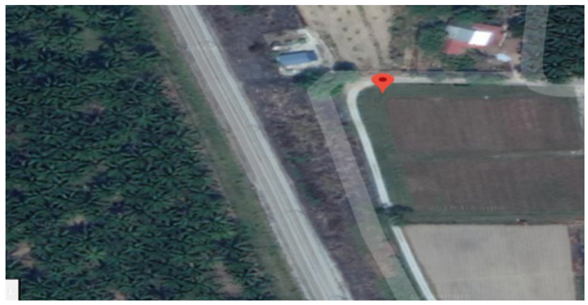

FIGURE 4. The Site Location at KM23 Which Consist of Paddy Field Area at Pinang Tunggal

FIGURE 5. Site location (KM23)

FIGURE 6. Site location (KM26.25)

METHODOLOGY

For this research, a strain gauge length of 60 mm and a LVDT type of 30 mm were chosen. The rail seat repeated load test was done by referring fourth edition of Australian Standard, Part 14 Prestressed concrete sleepers (AS 1085.14 - 2012) that was prepared by Committee CE-002, Railway Track Material and was approved on behalf of the Council of Standards Australia. Australian Standard was used as reference for laboratory testing for this study because of this standard has been used widely by railway transport system in Malaysia especially KTMB. The load cell was positioned above the PMCS at area where PMCS will receive dynamic load that transferred from a moving train through a rail. Neoprene supports pad of two 25 x 165mm plywood and loading plate were placed directly under load cell to help in distribution of loading as requirement from Australian Standard.

The vertical dynamic load was applied on precast PMCS at the positive moment of PMCS. The support of PCS and its loading configuration were based on Australian Standard (AS 1085.14 – 2012). Instead of using neoprene, plywood was used as the replacement for fatigue load test. By using marker pen, marking was made to made sure the location of the support and the plywood are at the accurate location. From the center of the load subjected to the PMCS, a length of 330 mm to the left support and 330 mm to the right support, making the full length of support to support to be 660 mm in total are to be marked by marker pen. Also, 45 mm of length from the center of the load to the left and 45 mm to the right at the top of PMCS in normal condition are marked too as the place to put the plywood below the load plate.

For a clear illustration, Figure 7 depicts the location of the support. Figure 8 shows the side of the PCS with its tendons (16 numbers) and the location of the LVDT and its callsign number. 3 LVDT's was used, one at the bottom, directly under the location were the load applied, assigned as LVDT 1 to check the deflection of the concrete sleeper and 2 other LVDT were located at the side and on the last tendon of the concrete sleeper, assigned as LVDT number 2 and 3 respectively to record any movement from the 16 number of tendons as shown in figure 9. Furthermore, figure 10 shows the plywood positioned below the plate directly under the hammer before dynamic cycling testing. Meanwhile, figure 11 shows the isometric sketch of the PMCS for fatigue test.

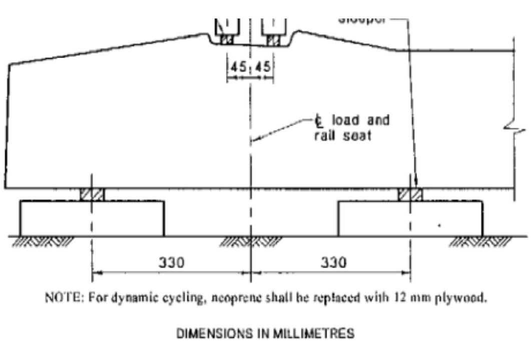

FIGURE 7. Location of the Support and its Loading with Accurate Dimensions (Fatigue) (AS1085.14-2012)

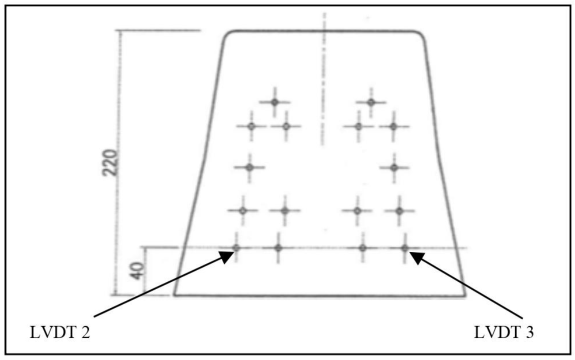

FIGURE 8. Concrete Sleeper with its Tendons and Dimensions (Fatigue) (AS1085.14-2012)

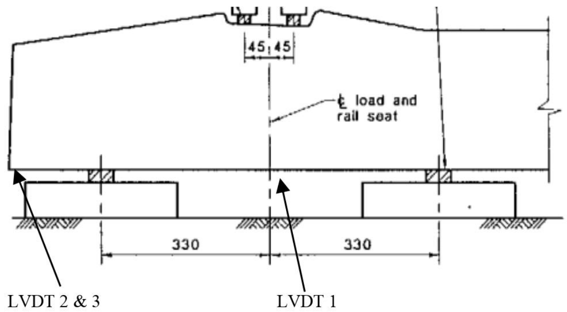

FIGURE 9. LVDT Location (Fatigue) (AS1085.14-2012)

FIGURE 10. Plywood Supports Positioned in Experimental Work

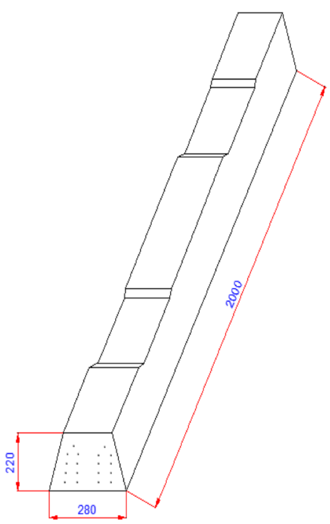

FIGURE 11. Isometric Sketch of Prestressed Monoblock Concrete Sleeper

RESULT AND DISCUSSION

From the studies, the value of deflection from site investigation and experimental were gathered and compared to show its relationships. Figure 12 and 13 shows the graph of load and displacement for KTMB and EPMI side respectively captured using LVDT and Vibration Analyzer. Table 3 shows the tabulated reading of dynamic load applied and deflection on EPMI and KTMB rail seat area in experimental test recorded by LVDT 1 and Vibration Analyzer in millimetre.

TABLE 3. Tabulated Data of Highest Deflection for Each Load Cases

Coaches	Load,P (kN)		LVDT 1 (EPMI) (mm)	LVDT 1 (KTMB) (mm)	Highest Deflection in Vibration Analyzer (mm)
	Max	Min			
N1	87	41	1.04	1.35	KTMB 1.52
N2	61	26	0.89	0.91	
N3	81	43	0.84	0.80	EPMI 1.44
N4	70	30	0.82	0.87	

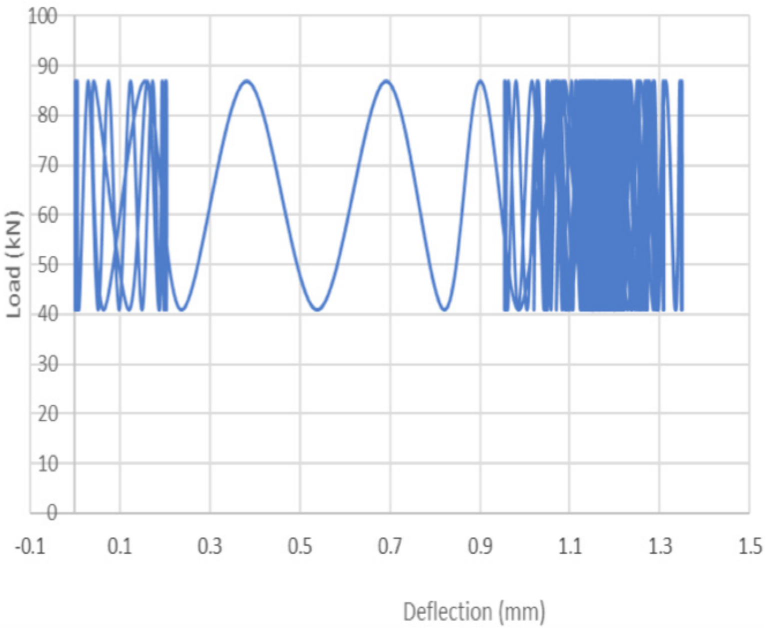

FIGURE 12. N1 Deflection on KTMB Rail Seat Section using LVDT (Experiment)

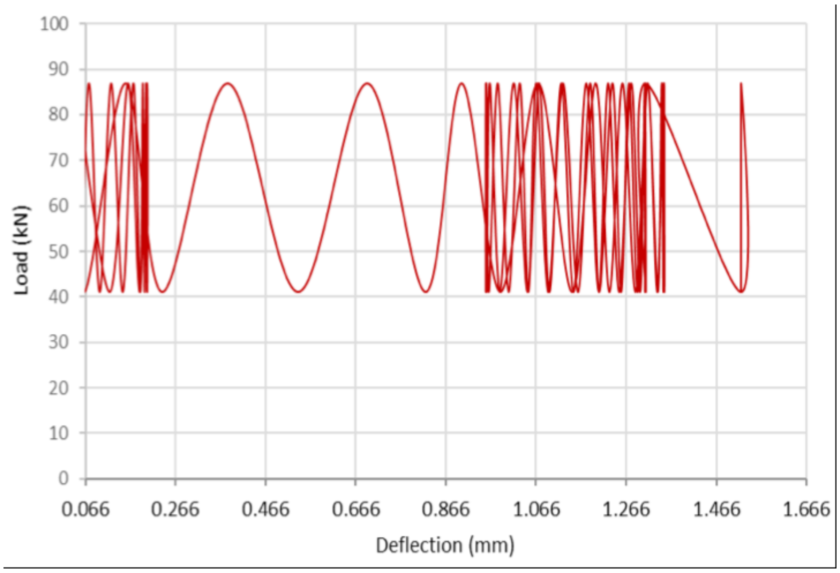

FIGURE 13. N1 Deflection on EPMI Rail Seat Section using Vibration Analyzer (Experiment)

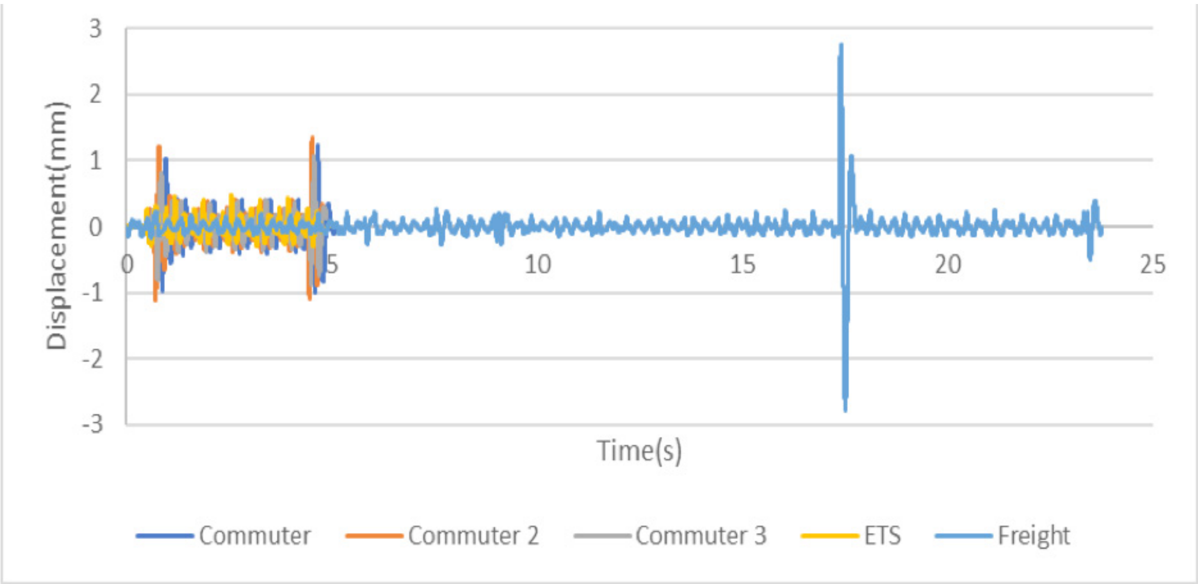

FIGURE 14. Load Against Deflection Produced from Site Investigation at KM23

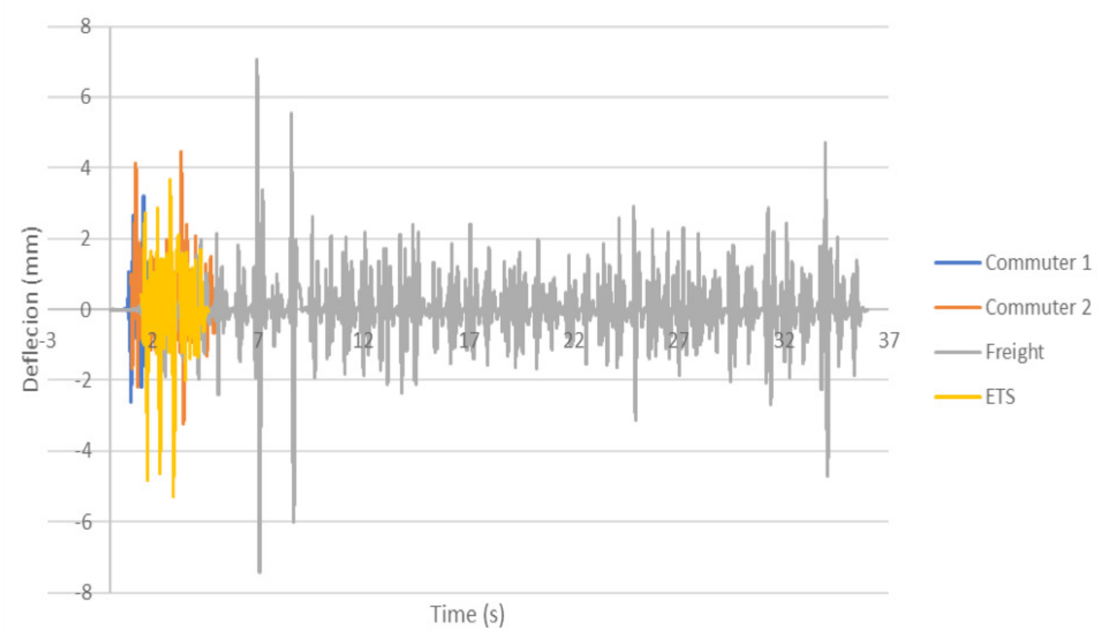

FIGURE 15. Load Against Deflection Produced from Site Investigation at KM26.25

Figure 14 and 15 depicts the deflection reading obtain by Vibration Analyzer from fatigue experiment testing on laboratory. Furthermore, figure 14 shows the graph of load against deflection produced from site investigation at KM23. The train consists of 15 set coaches and it was travelling at a recorded speed of 60km/h. The highest deflection was 2.88 mm. Figure 15 depicts load – deflection graph from railway site at KM26.25. The highest deflection was 7.06 mm. Finally, table 4 shows the comparison of acceleration and the deflection of PCS for freight train at KM26.25 and KM23.

TABLE 4. Comparison on the PCS Deflection Freight Train at KM23 and KM26.25

Train	Speed (km/h)	Maximum Deflection (mm)
Freight (KM26.25)	70	7.06
Freight (KM23)	60	2.88

CONCLUSION

Findings from the research, shows the deflections of PCS relates with the types of trains running on it. As shown in the results, the deflection for freight train at KM26.25 is higher than at KM23. This happens due to differences between the material that freight train carried during the test and the acceleration produced between both trains. At KM26.25, the freight train carried the domestic luggage which was heavier than fertilizer carriage. Furthermore, the acceleration produced by freight train on KM26.25 are higher than KM23. Last but not least, the maximum deflection on KTMB rail seat section turned out to be 1.35 mm and 1.04 mm for EPMI rail seat section. This research can be more details in future due to a lot of weather condition can be concern during investigation. In order to improve the reliable of the acceleration data, the investigation can be carried out in various season in a year. The consideration can be including rainy season and dry season due to changes of density in concrete sleepers. Also, reaction frame in the laboratory should be maintained regularly so that calibration of the equipment is always in accurate conditions.

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DECLARATION OF COMPETING INTEREST

None

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