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Constant Amplitude Spectrum Of Three Coaches Train And Cyclic Counting On Prestressed Concrete Sleepers (PCS)

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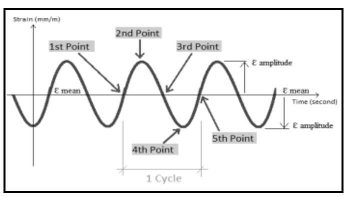
Graphical abstract



Abstract

The raw strain data collected from Keretapi Tanah Melayu Berhad (KTMB) railway are in variable amplitude. This paper discovers how the variable amplitude data can be changed to the constant amplitude data. It is found that the raw strain data is not suitable for fatigue and strength testing on Prestressed Concrete Sleepers (PCS). Apart from that, the most suitable method in determining the numbers of cycles is Rainflow Cycle Counting Method. Through rainflow cycle counting method, the number of cycles is determined. The numbers of cycles are used to simplify the laboratory test such as fatigue and strength test for the PCS. The frequencies of dynamic loading test on the PCS are set based the numbers of cycles. The constant strain data are also converted into constant loading data using the relationship of stress-strain and loading-stress. Constant amplitude loading will again simplify the laboratory testing. The goal is to show that the designs used in PCS are appropriate based on current loading demand. Then, a comparison of constant amplitude data is made between different numbers of coaches and freight train. The maximum data from the comparison shows that the higher loadings are obtained from freight train.

Keywords: Prestressed Concrete Sleeper (PCS), constant amplitude, rainflow counting method

1.0 INTRODUCTION

A PCS is a support for the rails in railway tracks [1]. PCS in used to hold the rail gauges at its required distance and transferred the loading to ground. Compared with wooden sleepers, PCS are now widely used in railway system. Besides PCS having a longer service life, it also requires less maintenance than wooden sleepers. Rail fastenings are used to fasten rails to the PCS. Based on history, the first concrete sleeper was made in Germany in 1906 that used for the railway track between Nuremberg and Bamberg [2]. Current practice shows that PCS is designed based on an international code (AS1085.14). Apart from that, PCS can also be designed based on EN 13230 and local railway authority specification (Keretapi Tanah Melayu Berhad, KTMB). KTMB is a company that manages railway system in Malaysia. Quantity and position of the prestressed wires must follow all the specification. Usually the weight of one PCS is approximately 219 kg excluding rail fastenings [3]. There are various types of counting method used to calculate fatigue lives. Although various methods may still be used, Rainflow Counting is the preferred method [4]. Older methods which often utilized are level crossing, peak crossing and simple range. Level crossing usually specified to eliminate small amplitude variations while peak crossing use small amplitude of a loading eliminated. Only the largest peak or valley between the successive mean crossing is counted rather than counting all peaks and valleys [5]. This paper gives a better understanding of the fatigue performance of the PSC. This is done to assist in the laboratory simulation via substitution of variable amplitude to a constant amplitude using a few parameters.

2.0 METHODOLOGY

There is a collection of raw data at the site measurement. Then, the data was first analysed from primary data to secondary data i.e. the constant amplitude [6]. The variable amplitude was breakdown into small spectrum by classification of "N" parameter [6]. This specified "N" is determined based on the coach and wheel of the train as shown in Figure 1. The number of cycle and their frequency is then determined using the most preferred method, i.e. the rainflow counting method. To apply the rainflow cycle counting method, the data is plotted into different N parts [4]. Thus, twelve graphs were plotted differently.

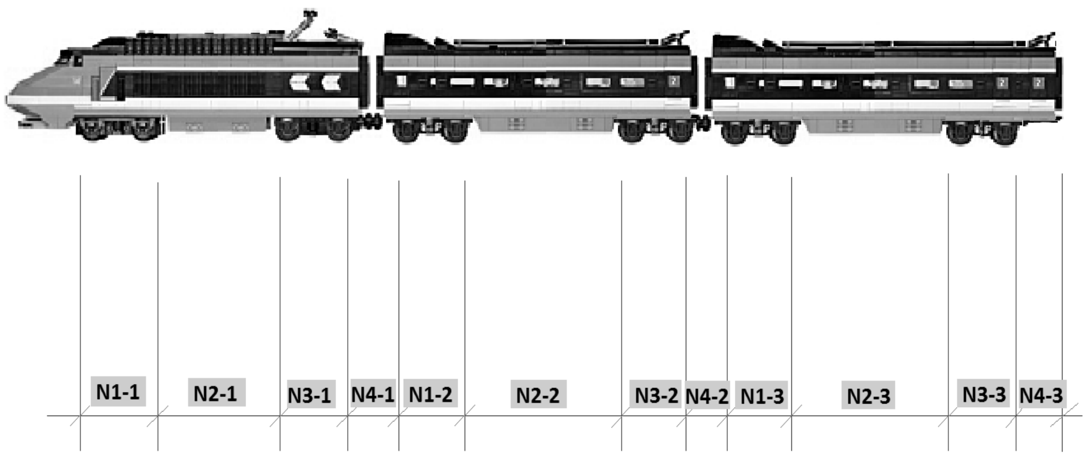


Figure 1 The division of N parts for three coaches.

3.0 RESULTS

From the data collected on-site (KTMB), the analyses were done using Microsoft Excel and assisted by manual calculation. The strain data was recorded in the Microsoft Excel from the strain gauge (on-site). After that the data was selected based on the N criteria of three coaches' trains. From the site, seven data for three coaches' trains was collected. The result from the data analysis was summarized in tables and graphs to make it clearer.

The variable graph of strain against time is shown in Figure **2**, where the division of N was identify as labeled. The data of strain is in mm/m while the time is in second.

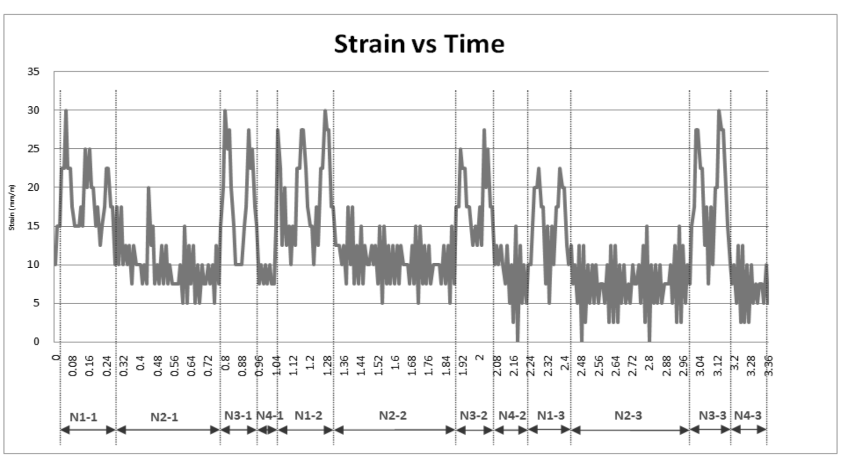


Figure 2 Graph of variable amplitude strain against time

4.0 DATA ANALYSIS

4.1 Rainflow Cycle Counting Method

The data was plotted differently to make it easier to apply the rainflow cycle counting method [7]. The graph was labeled with alphabet "P" and "V" for the peak and valley point respectively (
Figure **3**). Then the total peak and valley was counted. From this graph, the value for the peak is six and same as the value for the valley. The bold black line represents the peak flow while the soft black line represents the valley flow. The circled value of P6 and V6 are largest value for peak and valley respectively. These data was count to determine the number of cycle using equation 1.

$$\text{Number of cycle} = \frac{\text{Total peak} + \text{Total valley}}{2} \qquad (1)$$

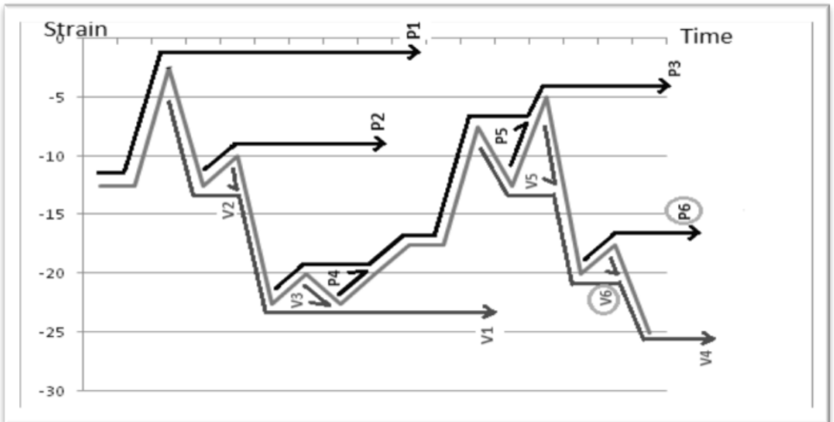


Figure 3 Rainflow counting method

4.2 Constant Amplitude Data

The raw data recorded was not constant in amplitude. Thus, using strain amplitude and strain mean the constant amplitude graph is sketched [6]. Equation 2 and equation 3 were used to indicate all the point needed for one cycle. Firstly, the curve starts at strain mean as the first point. Then, strain mean is added with strain amplitude to construct as the second point.

The third point was again referring to the value of strain mean. After that, the fourth point was identified by strain mean minus the strain amplitude. Finally, the curve (sketch) ends again at strain mean as the fifth point. The curve starting at first point and ending at fifth point is considered as one cycle. The procedures were repeated continuously to sketch another cycle for every coach.

Figure 4 shows that the formation of one cycle of strain data against time.

$$\text{Mean} = \frac{\text{Total strain}}{\text{Number of data}} \qquad (2)$$

$$\text{Amplitude} = \left(\frac{1-R}{1+R}\right) \times (2) \qquad (3)$$

Figure **5** shows the complete constant amplitude graph for three coaches commuter train. The curve in

Figure 5 is the results after analyzing the raw data variable amplitude shown in

Figure **2** to portray the different pattern from both graphs. Table 1 shows the complete constant amplitude only for part N1-1.

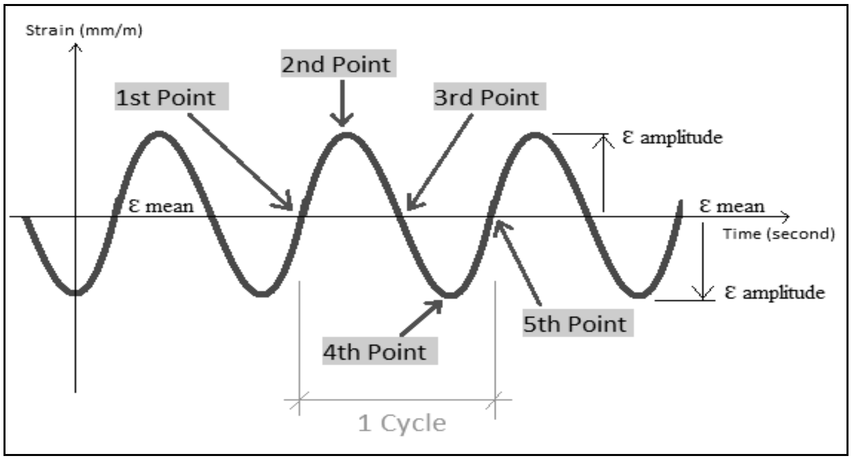


Figure 4 The formation of cycle in graph strain against time

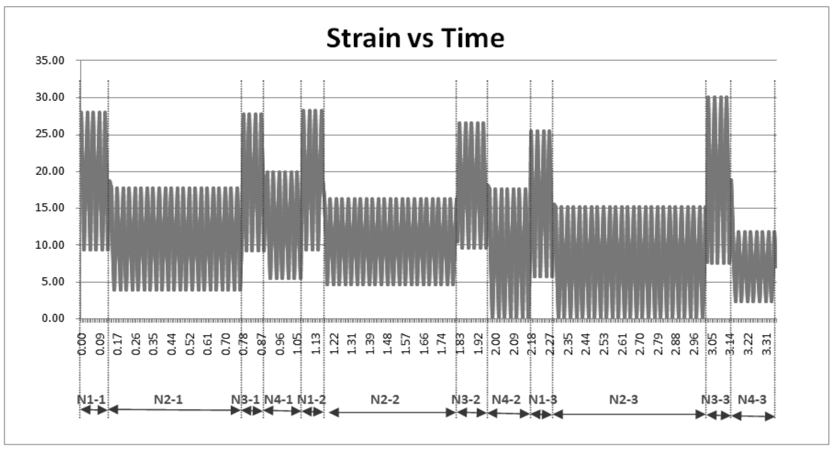


Figure 5 Graph of constant amplitude strain against time (data from Figure 2)

Table 1 Complete constant amplitude data N1-1

Coaches	Variable amplitude		Constant Amplitude		No of cycle
	Time	Strain, ε	Time	Strain, ε	Cycle
N1-1	0.00	-7.50	0.00	10.06	8
N1-1	0.01	10.00	0.01	2.88	8
N1-1	0.02	7.50	0.01	-4.31	8
N1-1	0.03	15.00	0.02	2.88	8
N1-1	0.04	2.50	0.03	10.06	8
N1-1	0.05	5.00	0.03	2.88	8
N1-1	0.06	0.00	0.04	-4.31	8
N1-1	0.07	-2.50	0.04	2.88	8
N1-1	0.08	-2.50	0.05	10.06	8
N1-1	0.09	-5.00	0.06	2.88	8
N1-1	0.10	0.00	0.06	-4.31	8
N1-1	0.11	-2.50	0.07	2.88	8
N1-1	0.12	10.00	0.08	10.06	8
N1-1	0.13	5.00	0.08	2.88	8
N1-1	0.14	17.50	0.09	-4.31	8
N1-1	0.15	5.00	0.09	2.88	8
N1-1	0.16	7.50	0.10	10.06	8
N1-1	0.17	-2.5	0.11	2.88	8
N1-1	0.18	0.00	0.11	-4.31	8
N1-1	0.19	-5.00	0.12	2.88	8

5.0 DISCUSSION

Based on the results and data analysed, the maximum loading for train occurs during peak hour. This can be seen based on the data set for three coaches' train. The data for three coaches' train was recorded during the peak hour. The different can be seen when the loading was compared with the other set of data three coaches commuter train, which exhibits their own data for cycle and pattern in the constant amplitude graph. These differences were caused by the speed of the train. When the train travels faster, this will make the loading also become higher. The cycle also affected and become longer in a short period of time. Apart from that, the loading was observed to be higher at the division of N3. This division was located at the second axle which is positioned at behind of the coach. Theoretically, when the axle hit the rail on the prestressed concrete sleeper, the strain would become higher. This is the same when the second axle hits the rail. The load will directly transfer to the prestressed concrete sleeper. The second axle where the division of N3 shows higher loading is probably due to passengers' habit and preference to sit at the back of the coach. Human's premonition doesn't like to sit in front. They will only sit in front when the seats at the back are full. This would increase the load at the second axle compared to first axle.

6.0 CONCLUSION

All the collected raw variable data was successfully converted to constant mode. By doing that, the number of cycles, frequency and loading for each individual coaches had been determined. Based on the data analysis, the design used for prestressed concrete sleeper by MASTRAK was appropriated with current impact loading caused by local trains. Apart from that, this study also simplifies the laboratory testing for fatigue and strength on the PCS.

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References

[1] Kaewunruen, S. and Remennikov, A. M. 2008. Impact Damage Classification Of Railway Prestressed Concrete Sleepers. *The Core of Integrated Transport*. 97.

[2] Kumaran, G., Menon, D. and Krishnan N. K. 2003. Dynamic Studies Of Railtrack Sleepers In A Track Structure System.

[3] Remennikov, A. and Kaewunruen, S. 2007. Experimental Determination Of Energy Absorption Capacity For Prestressed Concrete Sleepers Under Impact Loads. *Faculty of Engineering-Paper*. 373.

[4] Amzallag, C., Gerey, J. P., Robert, J. L. and Bahuaud, J. 1994. Standardization Of The Rainflow Counting Method For Fatigue Analysis. *International Journal of Fatigue*. 16: 287-29.

[5] Ariduru, S. 2004. *Fatigue Life Calculation By Rainflow Cycle Counting Method. MSME thesis,* Middle East Technical University, Ankara, Turkey.

[6] Sharul, N. I., Dozier, E., Afidah, A., Siti Hawa, H. and Mohd Ikmal Fazlan, R. 2014. Loading Capacity of Prestressed Concrete Sleeper Under Harmonic Function. *Applied Mechanics and Materials.* 118-122.

[7] Irvine, T. 2011. *Rainflow Cycle Counting In Fatigue Analysis.*