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Converting Constant Amplitude Loading Of Prestressed Concrete Sleeper (PCS) From Variable Amplitude

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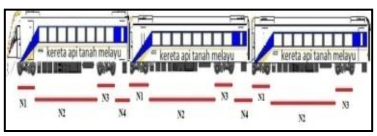
Graphical abstract



Abstract

Prestressed Concrete Sleepers are structures that support railway system and absorb variable loading from the train that pass along the rail. In this study, variable amplitude loading from PCS taken from site measurement was converted into constant amplitude loading. Therefore the number of cycles and frequency are also important to be determined. There are various method for counting the number of cycles and the best adoptive method was Rainflow Cycle Counting. Once the number of cycles is obtained as well as the constant amplitude stress in a series of stress block, the prediction of fatigue life of PCS can be analyzed by further research in the laboratory work. However the limitation of this study is only to obtain the constant amplitude loading of PCS and also counting the number of cycles in various series of stress blocks.

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

1.0 INTRODUCTION

PCS is the most important component in a railway system because it transmits the loads from the train to the ground. Typically, sleepers are the track components that positioned on the ballast formation transversely. They include receiving loading from the rail and transferring it to the ballast, to maintain track gauge and to keep the rail inclination at 1/20 or 1/40 depending on the railway network [1]. Researchers had determined that PCS has a longer service life span compared to traditional wood sleeper. The PCS has 40 to 50 years of service life [2]. Previous study had shown that PCS of 50/60 strentgh that have maximum modulus elasticity of 37 GPa will receive 80 million cycles load of 125 kN at both rail seats before crack or damage initiating [3]. To convert the raw data to constant amplitude, Rainflow Method was chosen amongst others because of its less error in converting the data.

2.0 METHODOLOGY

Based on the raw data obtained onsite, the train speed can be determined through the value of length of the Electric Multiple Unit (EMU) train. With the known time frame of each passing through of the train, the speed then can be analyzed. Besides that, every part in each coach was labelled and the variable loading can be separated into several parts which are the front wheel, center body, rear wheel and the last part; which is the length between rear wheel and front wheel of the coach. This separation part of each coach will have different variable loading of the train movement that was obtained through the onsite recording of load. Later, the constant amplitude load is determined by analyzing their minimum and maximum load characteristics. Figure 1 shows how the classification of loadcycles, "N" parameter. The application of the Rainflow cycle counting is then used to assess the number of cycle of the series loading in every part of the train. Fatigue data were collected during on-site measurement (preliminary work) [4].

Figure 1 Schematic diagram of train sections.

3.0 RESULTS

The data were obtained along rail track from Bangi to Kajang and the recording activity is possible with the help from commuter train operator (Keretapi Tanah Melayu Berhad). However in this study, only four samples of fatigue data are analyzed. Each data consist of mainly top and bottom type of loading as two strain gauges were located at the top and bottom PCS respectively. In this study only one type of variable data could be made constant because some of the data only have readable patterns that can be analyzed. Figure 2 shows the reading variable amplitudes captures in line with the train. This constant amplitude was then elaborated in the data analysis.

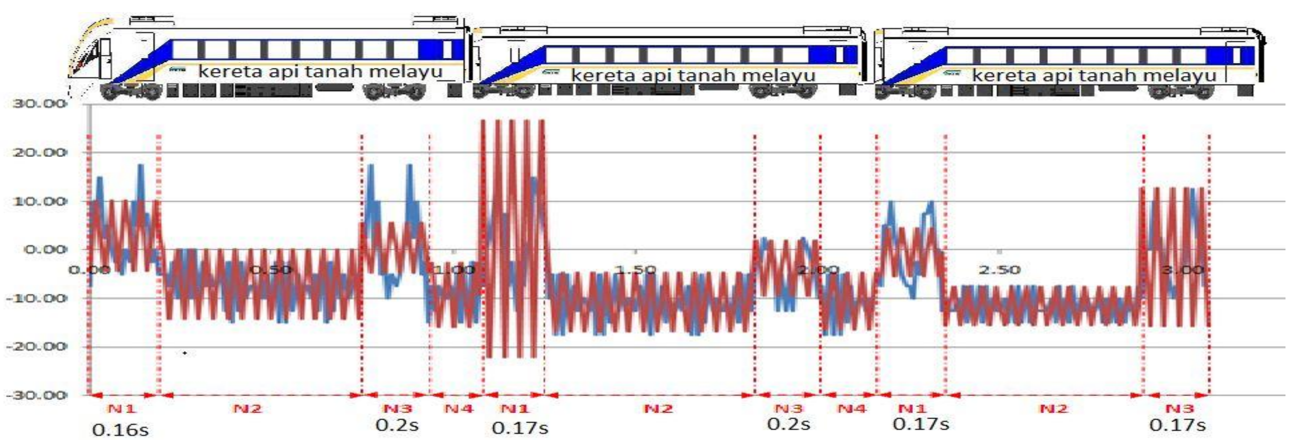


Figure 2 Bottom strain gauge reading

4.0 DATA ANALYSIS

4.1 Train Speed

The train speed can be determined from the whole length of the coaches and also the time frame of the passing train. In this study, the train speed is computed via simple calculations, i.e. by dividing the total length of the train with the total traveling time based on the measured fatigue data.

4.2 Cycle Counting

Rainflow cycle counting is chosen to calculate the number of cycles in this study. This counting method eases the cycle determination of a set of spectrum loading or loading history that makes it a preferred method. It is also used widely due to its efficiency [4]. This method involves calculating the peak and valley for a set of spectrum or loading history. The number of cycles determined from the formula is shown in Eq.1.

$$\text{Number of cycles} = \frac{\sum \text{peak} + \sum \text{valley}}{2}$$

(

E1)

4.3 Constant Amplitude Loading

The process of analyzing the constant amplitude (CA) could use several formulas [5]. A set of spectrum loading normally appears variably. Thus, it is very important to determine CA. It is also important to find the constant loading as one equivalent constant amplitude cycle is able to cause the same fatigue damage as the whole complex or random cycles [6]. For every series of loading that are separated, continuous steps are required to apply to the other series of loading. Formation of CA loads involve three basic equations which are shown in Eq. 2, Eq. 3 and Eq. 4.

The arrangement of the constant amplitude cycle follows the principle of basic cycle (Figure 2 and Figure 3).

$$\text{Strain ratio,R} = \frac{\text{strain min}}{\text{strain max}} \qquad \text{(Eq. 2)}$$

$$\text{Mean value of strain, } \varepsilon_{mean} = \left(\frac{\text{total strain in a series}}{\text{total number of the data in a series}}\right) \qquad \text{(Eq. 3)}$$

$$\text{Train amplitude, } \varepsilon_{amplitude} = \left(\frac{1-R}{1+R}\right) * \varepsilon_{mean} \qquad \text{(Eq. 4)}$$

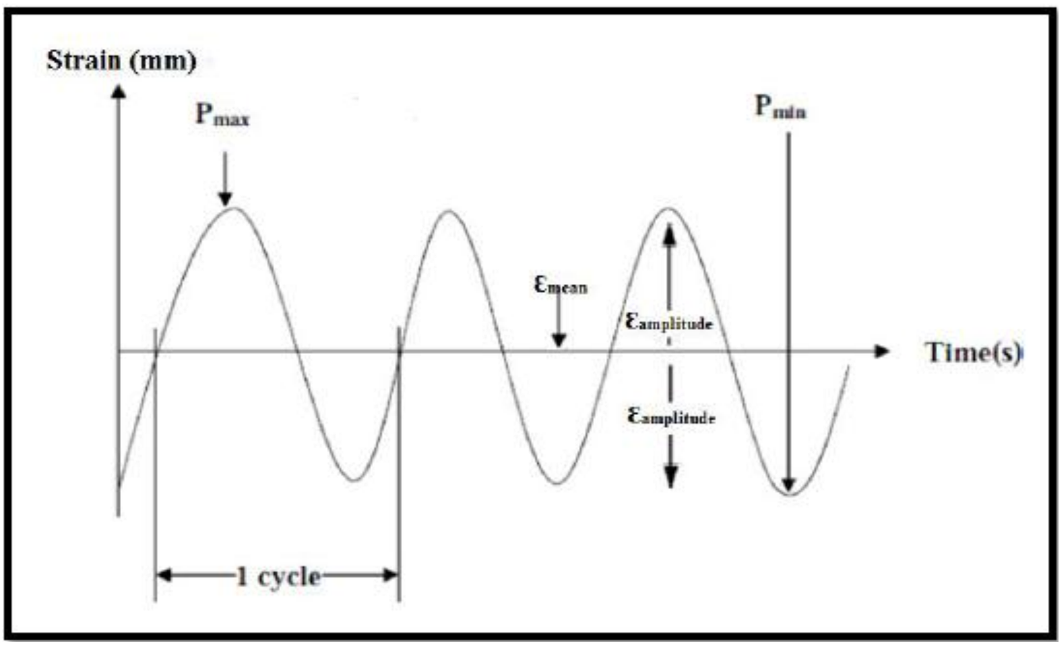
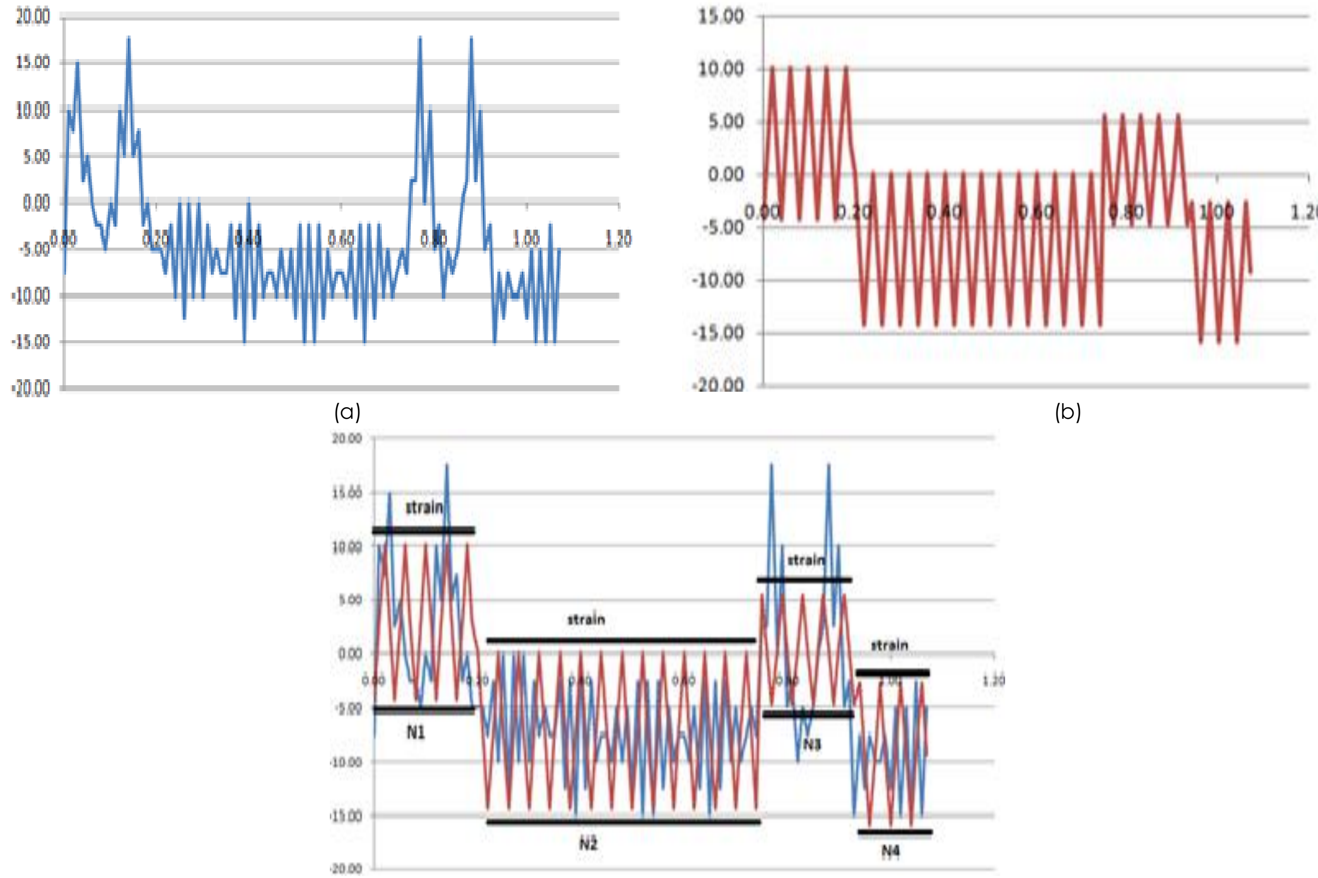


Figure 3 Constant amplitude cycle formation



(c)

Figure 4 Conversion of variable and constant amplitude

The different patterns of variable and constant amplitudes can be seen in Figure a) and b). Figure c) shows the ouput when these two variables and constant amplitudes graphs are combined. This proves that the main objective of the has been achieved.

5.0 DISCUSSION

The results (constant amplitude data) were generated from variable amplitude strain data that were earlier collected from onsite measurement. This converting process requires a few steps; and at the same time preserves the other parameters such as number of cycles and their frequencies using rainflow counting method. Variable amplitude was split down into smaller block sequence separately based on classification of the "N" parameter. Determining frequency and cycles are important during this process. The data will be used further to analyse the fatigue life of PCS (future research); especially when conducting fatigue test of a PCS in the laboratory. The maximum loading for train is found to occur during peak hour. The data chosen was collected at that time (during peak hour) rather than use of a random data.

6.0 CONCLUSION

In this paper, the pattern of strain versus time history of PSC under cyclic loading is determined. It seems to be similar with the cyclic loading during services. This paper discusses the investigation on the process of converting the variable amplitude load to become constant amplitude by analyzing the primary data from site measurement. The number of cycle in a series of stress blocks is determined using the rainflow cycle counting method.

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