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VERIFICATION OF THE VALIDITY OF THE IMPACT FACTOR USED IN THE DESIGN OF PC SLEEPERS

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Abstract. *The purpose of this study is to identify the actual load environment of train loads acting on PC sleepers in order to perform effective maintenance and optimize design of PC sleepers. In Japan, the design load for PC sleepers is calculated by multiplying the static wheel load by impact factor, which is a factor for considering the impact load (generally 2.0) and this value has been conventionally used since the beginning of the use of PC sleepers in Japan. However, considering the improvement of current track and vehicle maintenance technology, it is considered that wheel flats and track irregularities that cause impact loads have been reduced. Therefore, it is necessary to identify the impact factor based on the field tests. In this study, the wheel load was measured in the long rail section of the conventional line, and the actual condition of the impact factor was investigated. As a result, the current impact factor 2.0 is in a safer side to freight trains. Furthermore, for commuter trains, we confirmed that the impact factor for the static design wheel load in Japan (generally 80kN) can be lower than the current value.*

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1 INTRODUCTION

PC sleepers are an essential component that contributes to the safety, stability and high-speed transportation of modern railways. PC sleeper is a component made of prestressed concrete which is laid under the rails of railway track. Its main role is to keep the distance between the two rails constant and to properly distribute the load of the passing train transmitted through the rails to the gravel called ballast. In addition to PC sleepers, there are wooden sleepers and iron sleepers. PC sleepers have advantages such as mass production and high durability.

Figure 1 shows an example of a PC sleeper laid on a railway track in Japan. Although there are differences in the distance between rails (track gauge) and the size of PC sleepers, the structure of railway track is generally the same throughout the world. Mass introduction of PC sleepers in Japan began around the 1960s and the cumulative number the cumulative number of installations has exceeded 39.5 million only for Japanese National Railways (JNR) and JR companies which took over most of the assets of the JNR after privatization. The life expectancy of PC sleepers is usually 50 years. However, in recent years, PC sleepers which exceeded this life expectancy have also increased and studies for appropriate maintenance and replacement guidelines have been promoted [1][2].

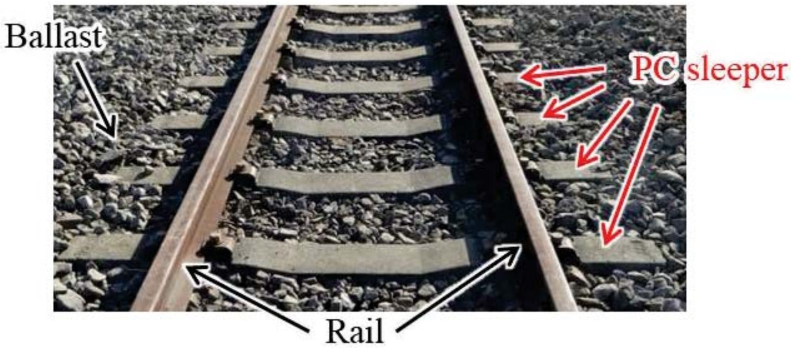

Figure 1: Example of a PC sleeper laid on a railway track

Figure 2 shows the method of design of PC sleepers in Japan. The PC sleeper is designed so that the PC sleeper does not crack under a predetermined design load. In Japan, the design load for PC sleepers is calculated by multiplying the train load transmitted via wheels (static wheel load) by impact factor, which is a factor for considering the impact load (generally 2.0) [3]. However, this value has been conventionally used since the beginning of the use of PC sleepers in Japan. The impact load is generated by unevenness of the wheel (wheel flat) and irregularities [4]. Since the track and vehicle maintenance technology advance in recent years, it seems that wheel flats and track irregularities causing impact loads have been reduced compared to the past time. Therefore, the value of this impact factor may not be in accordance with the actual situation. In order to evaluate the remaining life and to make an optimal design of track members such as PC sleepers, it is required to properly understand the load condition.

In this study, the wheel load was measured in the long rail section of the conventional line, and the actual condition of the impact factor was investigated.

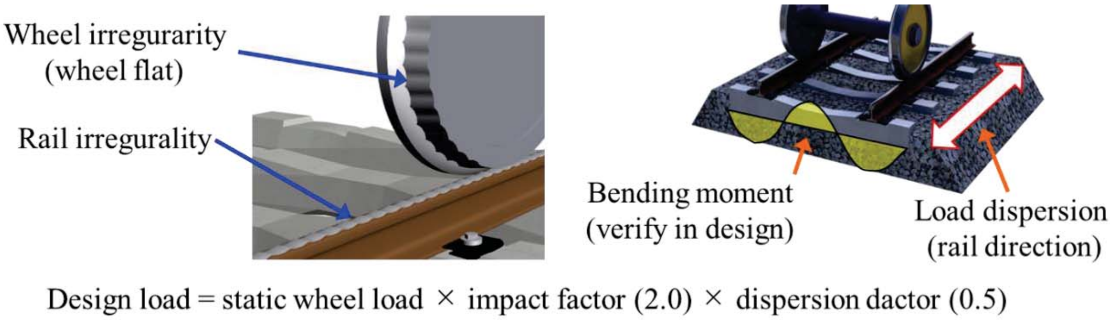

Figure 2: Method of design of PC sleepers in Japan

2 ON-SITE MEASUREMENT

2.1 Target site and PC sleeper

Figure 3 shows the track conditions of measurement site and Figure 4 shows the type 3 PC sleeper which is installed the site. The measurement site is a straight continuous welded rail section. The rail used in the site is a “60kg N-rail”, which is specified in Japan industrial standards (JIS). The target PC sleeper is a “Type 3 PC sleeper” specified in JIS. This type of PC sleeper is for a straight section and a curved section with a radius of 800m or more, and is one of the most popular PC sleepers Japan. The No. 3 PC sleeper is designed under the condition of a design wheel load of 160kN with the impact factor of 2.0. The default interval of PC sleepers in the target section is 41 sleepers per 25m, but the each interval between sleepers varies by several tens of mm.

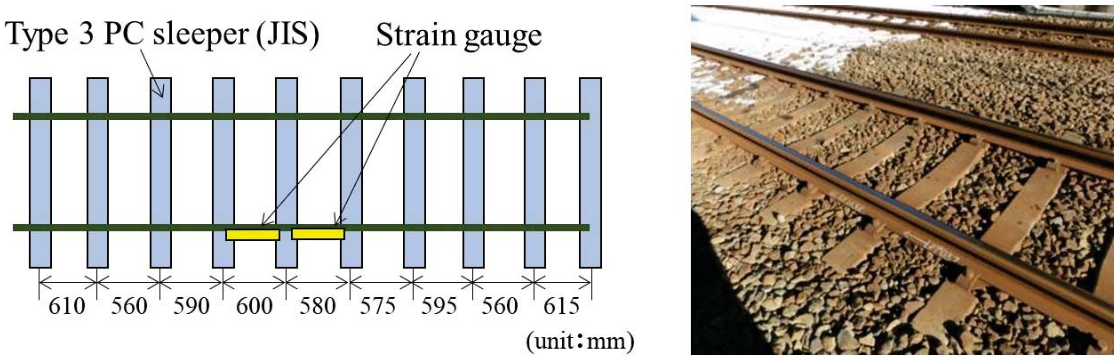

Figure 3: conditions of measurement site

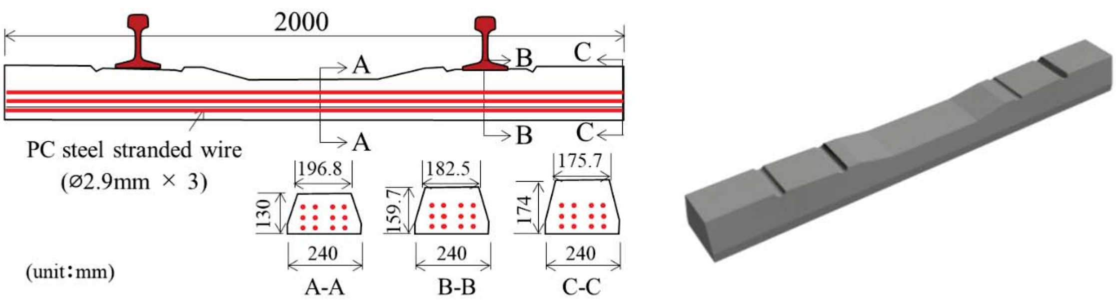

Figure 4: Type 3 PC sleeper

2.2 Measurement method

Figure 5 shows the method of measuring wheel load. In this measurement, a strain gauge for measuring the wheel load was attached to the side surface of the rail. The wheel load was measured by converting the measured strain. A piezoelectric accelerometer was installed on a PC sleeper about 30m away from the measurement point in the direction of train arrival, and used it as a trigger to start measurement. The strain gauge was connected to the National Instruments modules and stored in a PC via a LAN cable. The sampling rate was 10kHz. The recording program was constructed by LabVIEW. In this measurement, wheel load of both commuter trains and freight trains were measured. The measurement period is 50 days in total, and the number of measurement cases is 6042 for commuter trains and 2107 for freight trains.

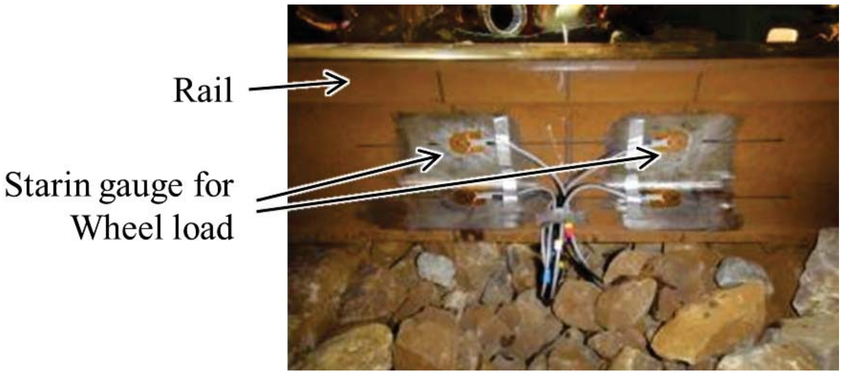

Figure 5: Sensor for measuring wheel load

3 MEASUREMENT RESULTS

Figure 6 shows the time-series data of the measured wheel load, and Figure 7-9 shows the wheel load of commuter train for each time. The data in Figure 9 is obtained by averaging wheel load for every 30 minutes. The average wheel load is 51.9kN for commuter trains and 87.2kN for freight trains, and the maximum wheel load is 105.9kN for commuter trains and 154.0kN for freight trains. The wheel load of commuter trains on weekdays tends to increase at commuter hours, from around 7:00 to 8:00 and from 18:00 to 20:00. On holidays, wheel load of commuter trains tends to increase around 16:30. According to Figure 9, the wheel load at around 18:00, which is the maximum on weekdays, was 1.15 times larger the wheel load at around 14:00 on weekdays, the wheel load at around 16:30, which is the maximum on holydays, was 1.13 times larger than that at 14:00.

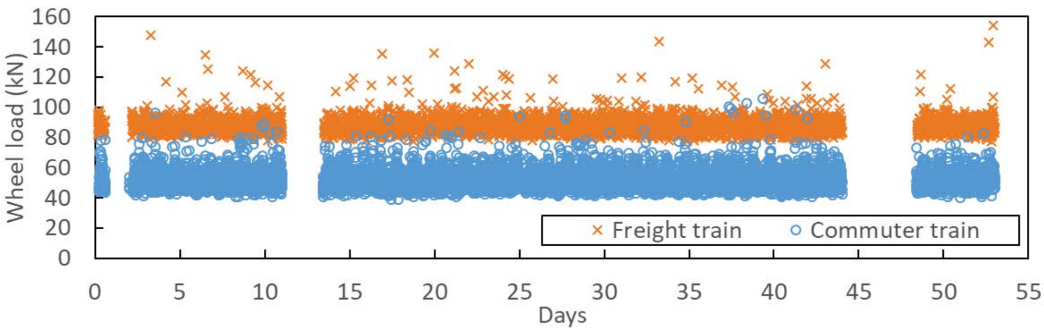

Figure 6: Time-series data of the measured wheel load

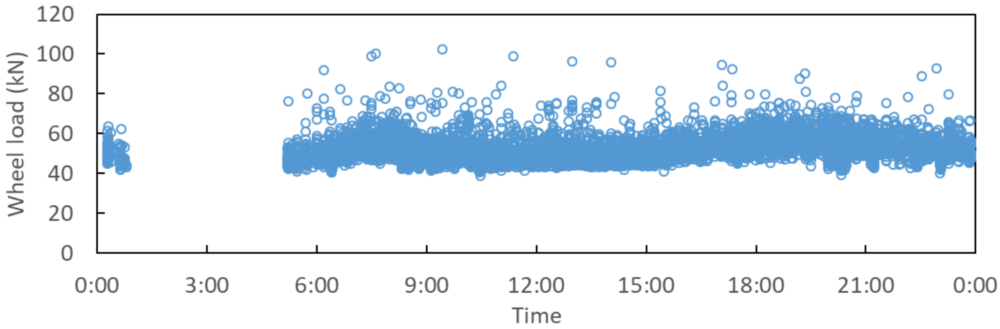

Figure 7: Wheel load for each time (Weekdays)

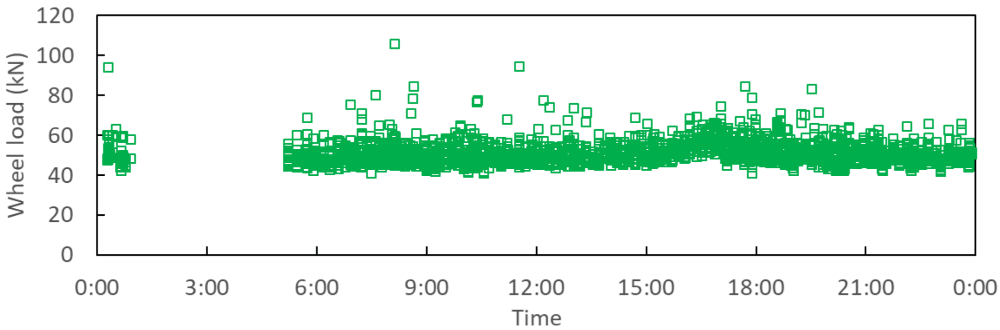

Figure 8: Wheel load for each time (Holydays)

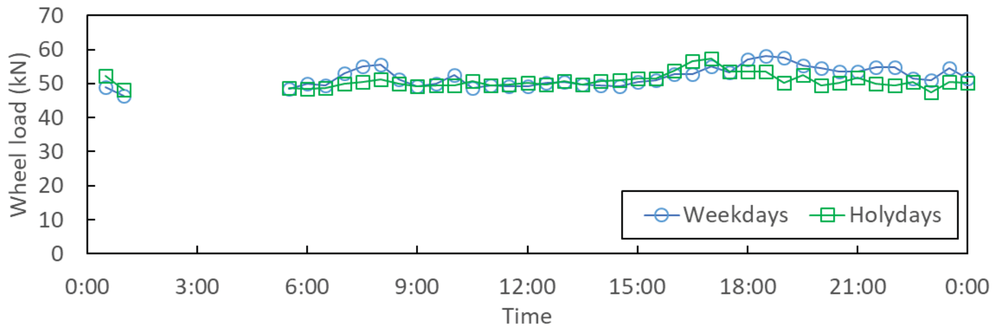

Figure 9: Wheel load for each time (averaging wheel load for every 30 minutes)

Figure 10 shows the minimum, average, and maximum values of wheel load measured by each trains in order to evaluate the variation of the wheel load in the same train. The minimum and average values of the wheel load of each train is similar value, but the maximum wheel load varies widely. From this, there is a possibility that a significant wheel load is caused by a wheel flat generated on a specific train.

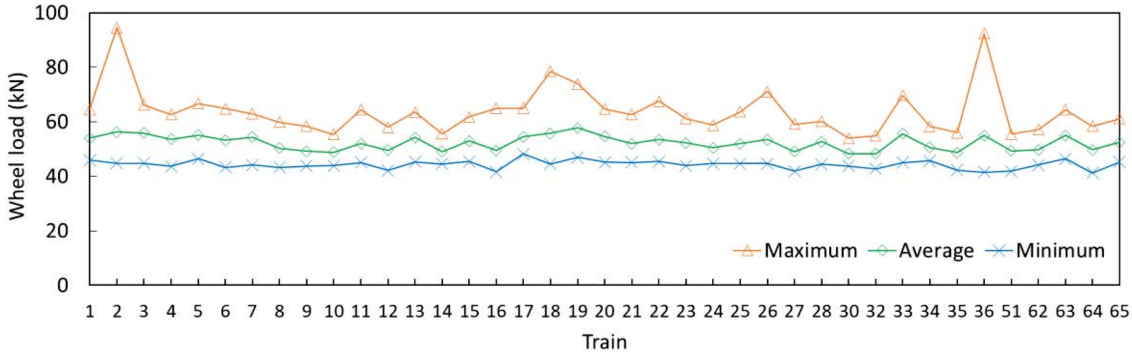

Figure 10: Wheel load measured by each trains

Figure 11-12 shows the probability distribution of wheel loads for commuter and freight trains. The same graph also shows a probability density function following a log-normal distribution. From this graph, the measured wheel load generally followed a log-normal distribution. The mode of wheel load for commuter trains was 48-49kN, and the mode of wheel load for freight trains was 88-89kN.

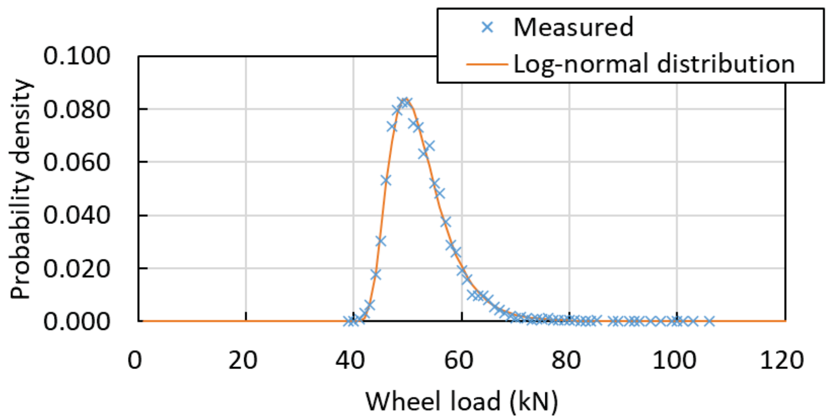

Figure 11: Probability distribution of wheel loads for commuter train

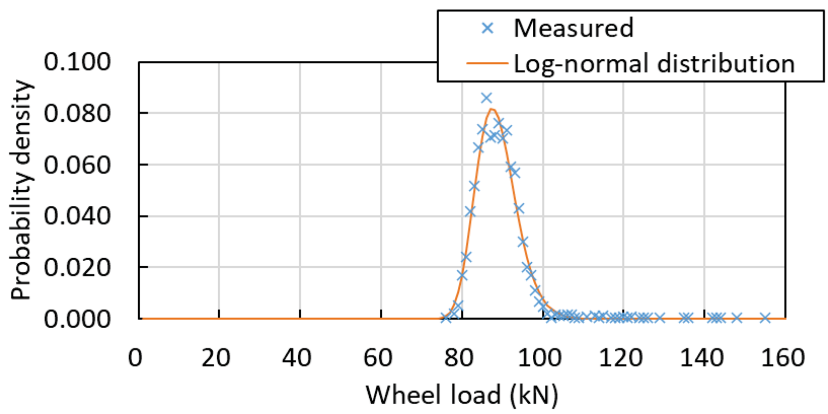

Figure 12: Probability distribution of wheel loads for freight train

Figure 13-16 shows the excess probabilities of measured wheel load and impact factor. The excess probability obtained from the probability density function following a lognormal distribution was also shown in the figure. From figure 13 and figure 14, it is confirmed that wheel load of commuter train measured in the field test exceeding 90kN are approximately 0.1% or less, which is significantly smaller than the design wheel load considering the impact load (160kN). Similarly, when converted wheel load to an impact factor for a static wheel load of 80kN, impact factor which exceeds 1.2 are 0.1% or less. The main reason for this is the weight of the vehicle of a recent commuter train is lighter than the designed wheel load. For freight trains, percentage of wheel load which exceeds 140kN is less than 0.1%, and also impact factor which exceeds 1.8 is less than 0.1%, which is close to the value used in the design (2.0). In addition, the excess probability distribution of commuter trains roughly matches the excess probability by the log-normal distribution. On the other hand, for freight trains, the log-normal distribution underestimated the excess probabilities especially in the region where the wheel load was more than 110kN. This means that commuting trains run only the same type of train and the variation of train speed passing the site is relatively small. Whereas, for of freight trains, there are many types of locomotives and freight wagons, and the variation in passing speed is larger than the commuter train.

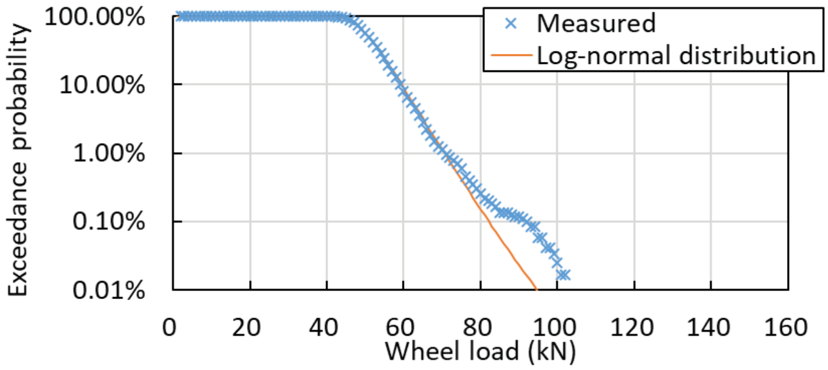

Figure 13: Excess probabilities of measured wheel load for commuter train

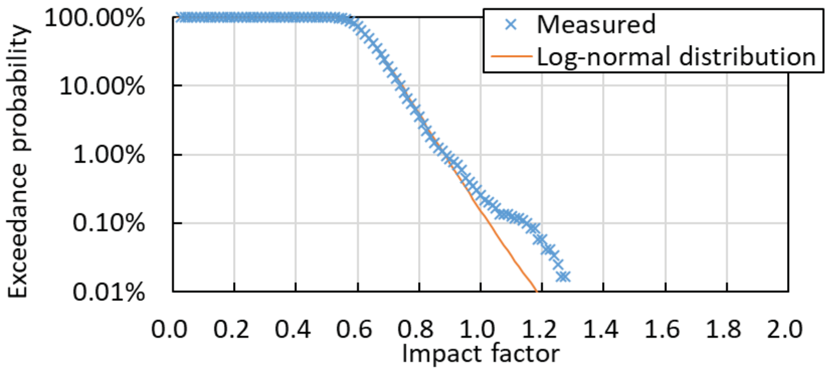

Figure 14: Excess probabilities of measured impact factor for commuter train

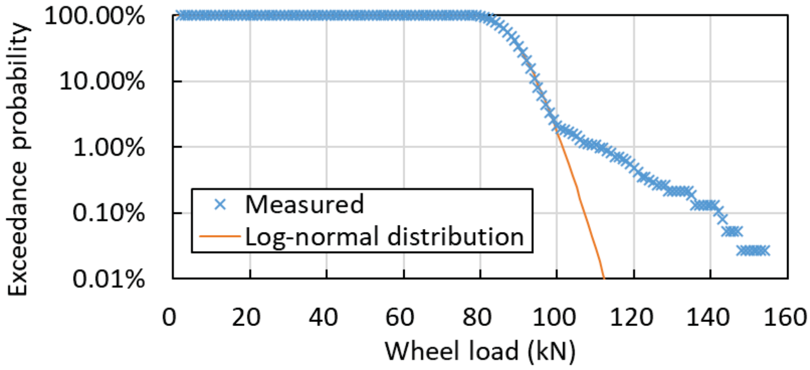

Figure 15: Excess probabilities of measured wheel load for freight train

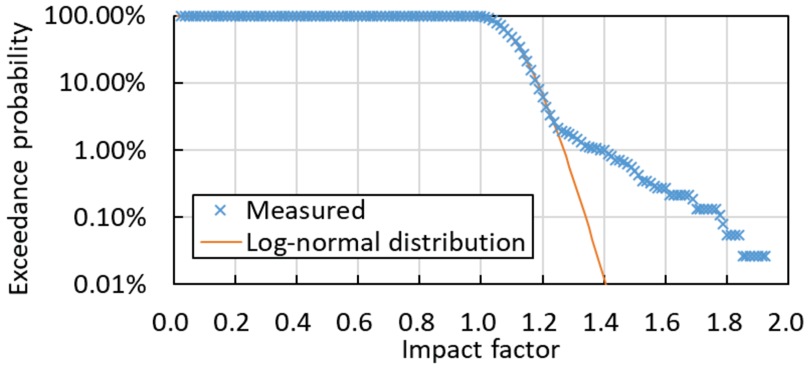

Figure 16: Excess probabilities of measured impact factor for freight train

4 CONCLUSION

The purpose of this study is to identify the actual load environment of train loads acting on PC sleepers in order to perform effective maintenance and optimize design of PC sleepers. In the study, the wheel load was measured in the continuous welded rail section of the conventional line, and the actual condition of the impact factor was investigated. The conclusions obtained are as follows.

- The maximum wheel load measured in the study is 105.9kN for commuter trains and 154.0kN for freight trains.
- On weekdays, the average wheel load during commuting hours was 1.18 times higher than the wheel load measured during the daytime.
- The impact factor of 2.0, which has been used in the design of the PC sleeper, is generally appropriate for freight trains. However, for commuter trains, the design wheel load was large compared to the measured wheel load.
- For commuter trains, the probability of occurrence of the wheel load considering the impact load could be roughly estimated by log-normal distribution. Based on this, it can be used for future design and prediction of fatigue life.

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