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Dynamic response evaluation of tall noise barrier on high speed railway structures

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ABSTRACT

The aim of this paper is to obtain a fundamental understanding of the dynamic response of tall noise barriers during the passage of high speed train and to develop a practical method for evaluating this in anticipation of planned increases in running speed in the future. Tall noise barriers recently installed on Japanese high speed railway structures have a low natural frequency; therefore, they may resonate with the train draft pressure that up until now has not been a crucial condition for practical design. As a result of field measurements and numerical simulations, it was found that the dynamic response of noise barriers excited by passing trains can be explained by the resonance effect between pulse excitation of the train draft and the natural frequency of the noise barriers and by the tail-pulses overlap effect. Methods to generalize the resonance effect with the multi-body system and the tail-pulses overlap effect with the free vibration theory of the single-degree-of-freedom system were shown. Finally, two design methods were proposed: a precise method based on simulation and a simple method based on static design load. The simple method uses a design train draft pressure which is a function of noise barrier natural frequency when train speed is 260 m/h or 360 m/h.

1. Introduction

Railway structures such as bridges or viaducts generally have noise barriers or bridge railings at the edge of overhanging slabs. They are effective for noise reduction, snow prevention, wind shielding, offering security for workers and preventing trespassing on the lines. In Japan, barriers are installed along high-speed infrastructure to reduce noise in particular, depending on the use of land adjacent railway lines. Barriers made with H-shaped steel struts and precast PC plates are now most common, to save cost and labor, compared to the previously used conventional simple RC walls with high rigidity. The design of H-shaped steel struts, which determine the structural performance of the noise barrier, must take various effects into account: train draft, fatigue, propulsive force on the bridge railing, flying snow due to the passage of trains, the effect of earthquakes, and wind load, which is often crucial for design [1]. In general, H-shaped steel struts of noise barriers are designed with adequate yield strength for a design wind load of 3.0 kN/m^2, assuming a wind velocity of about 50 m/s.

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The design load of the train draft pressure forming the main topic in this paper, however, is 1.0 kN/m^2. Since the value of the train draft pressure is usually lower than the wind load, it is not generally considered for failure assessment in practical design, and only considered for fatigue failure. The design value of 1.0 kN/m^2 is a conservative value based on previous investigations into conventional noise barriers comparatively low in height. Nevertheless, over recent years, there has been a growing need for tall noise barriers as new Shinkansen lines are built, to shelter the trackside environment. In practice, tall noise barriers have a lower natural frequency than conventional noise barriers, calling for investigation of the dynamic resonance amplification due to passing high speed trains.

Considerable research has been devoted to the sound insulation efficiency and resistance performance of noise barriers whereas their dynamic response has been largely ignored [2–4]. The design requirements for structures such as noise barriers or station buildings are contained in the Eurocode EN 1991-2:2003 'Traffic Loads on Bridges' [5]. The data on which this code is based were originally developed by the European Railway Research Institute (ERRI) D189 committee and also forms the basis for the railway-specific European Committee for Standardization standard [6]. The code outlines procedures for describing the form of the train-induced draft pressure with the peak value, although it implicitly assumes static loading throughout without considering the resonance amplification of structures. Backer et al. [7], of the UK, pointed out that the previous code, derived from experimental data relating to the continental G1 gauge, would lead to inappropriate calculations of the pressure coefficient for GB gauge conditions and developed two correction methods applicable to the calculations which could adapt results to cover UK-specific situations [8]. Additionally, the applicability of the code to lightweight or flexible structures was also referred to as an issue in terms of fatigue calculations. In Germany, the dynamic effect of noise barriers has been studied in part, although the investigations were limited and the results could not be applied to Japanese noise barriers [9]. Belloli et al., in Italy, investigated the situation where noise barrier structures are employed as part of the catenary support structure instead of standard poles, and the influence of this configuration on the quality of the current collection in high speed pantographs, in consideration of the dynamic response of the noise barriers [10]. Research is still underway in Japan, to evaluate observable train draft pressure and the noise barrier dynamic response to this, and to adapt design methods. The authors of this paper however have as yet on conducted limited investigations into this [11]. The dynamic response of noise barriers needs to be quantified to gain insight into noise problems which could arise from increased train running speeds in the future.

The aim of this paper is to obtain a fundamental understanding of the dynamic response of tall noise barriers during the passage of high speed trains and to develop a practical method to assess these phenomena, using insight already collected through previous studies about the train draft pressure [12–16]. Section 2 of this paper first describes the measurement and analysis methodologies used, and then Section 3 clarifies the essential mechanisms underlying the dynamic response of noise barriers during the passage of trains based on measurement and analysis, while Section 4 gives a general overview and quantifies the effects of the various factors on noise barrier response during the passage of trains. Finally Section 5 proposes new practical design methods for evaluating the dynamic response of noise barriers during the passage of trains.

2. Methodology

2.1. Target structure and noise barrier

Fig. 1 shows the dimensions of the target structures discussed in this paper. The target structures consist of a RC wall type pier, a RC girder with a bridge length of 10 m and a rigid frame viaduct with a bridge length of 40 m. These structures were chosen because they were designed using the standard design and their dimensions are representative of those found on the Japanese high speed railway network.

Fig. 1 also shows the cross-section of a semi-cover snow storing type noise barrier, also to be discussed in this paper, installed on high speed railway line viaducts. The bent H-shaped steel struts on this type of noise barriers reduces the amount of snow falling onto the bridge surface. The target for this paper are noise barriers with a height *H* equal to rail level

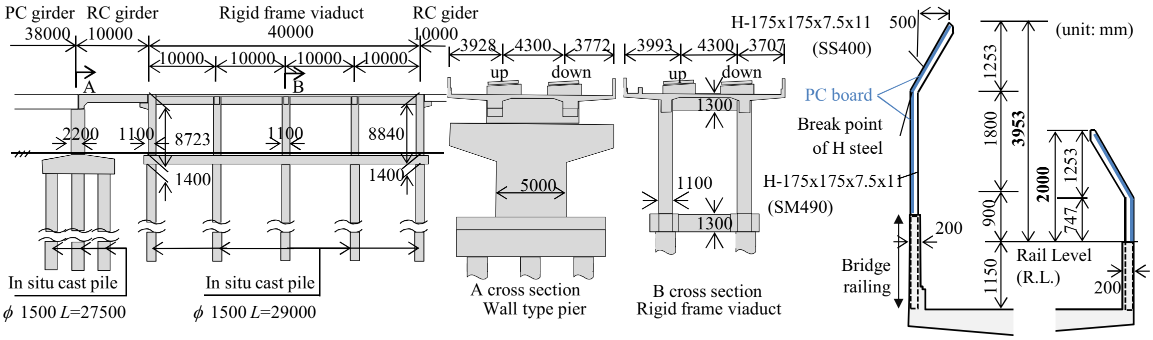

Fig. 1. Dimensions of target structures and noise barriers.