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Investigation of mechanical/dynamic properties of carbon fiber reinforced polymer concrete for low noise railway slab

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ABSTRACT

In this paper, the mechanical/dynamic property of the carbon fiber reinforced polymer concrete (CFRPC) was investigated to reduce the vibration/noise problems on rail slab. The CFRPC was fabricated with the different weight fraction of carbon fiber and different fiber length. The oxygen plasma treatment was performed to enhance the adhesion between the carbon fiber and epoxy resin. The surface of the carbon fiber with the oxygen plasma treatment was characterized using X-ray photoelectron spectroscopy (XPS) analysis and scanning electron microscope (SEM). The flexural strength of the CFRPC was measured using 3-point bending test. Also, the frequency dependent variation of the stiffness and damping of the CFRPC were measured by impact test to characterize their ability to reduce the vibration. In this study, the CFRPC with 12 mm of optimal fiber length and 2 wt% of the optimal fiber content showed 25.12 MPa flexural strength and 0.01954 damping value. Finally, it was found that the noise level of the railway using CFRPC sleeper was decreased by 4 dB compared to that using the polymer concrete sleeper, from the impact test of the scaled model of the railway structure.

1. Introduction

Cement concrete is widely used in construction structure and civil engineering, because it is cheap and has a high durability. However, as the high speed train has been developed, a significant noise problem was occurred due to low vibration/noise absorption characteristics of cement concrete sleeper (Fig. 1) [1–3]. To solve the noise problem of a concrete sleeper, many research have been studied, for example, changing the railway structure and attaching the absorption material such as web damper on the rail [4–8]. However, the decreased noise level using these methods was not significant. Therefore, new material has been needed for reduction of noise and vibration of the railway structure.

Nowadays, the polymer concrete (PC) has been widely used to enhance the noise/vibration absorption characteristic. PC is composed of the various polymer [9,10] and aggregates, having the excellent vibration/noise absorption, corrosion resistance and fast curing time. Therefore, they are used for various applications such as the drain channel and machine tool bed and repairing the damaged air-strip or road [11–13]. Also, the fiber reinforced polymer concrete (FRPC) has been widely applied to civil construction to strengthen the concrete structures in recent years. Especially, the recycled plastic fibers using the plastic waste has been studied such as a polyethylene terephthalate (PET), polypropylene (PP), carbon fiber and glass fiber [14–16]. Advantages of using waste/recycled plastics are (1) reduction of municipal solid wastes being landfilled; and (2) an alternative to pressure-treated lumber that leaches toxic chemicals into water; and (3) saving the energy source in manufacturing process.

In this work, we used the recycled chopped carbon fiber because of the high specific strength and specific stiffness, ease of handling and application, a faster construction rate and the corrosion-free characteristic [17]. The previous application of FRPC was focused only on the improvement for durability of construction structure for substitution of the conventional cement concretes. However, the vibration reduction capability of FRPC especially for railway applications has not been studied yet to the authors' best knowledge. In this study, the frequency dependent variation of the CFRPC stiffness and its loss factor were obtained using impact vibration test. Based on the basic properties from the impact test, the noise and vibration performance of CFRPC

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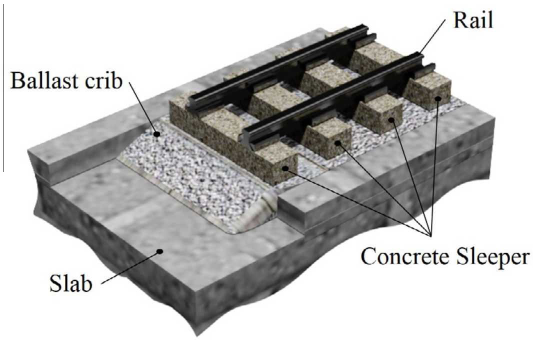

Fig. 1. Schematic of the concrete sleeper in railway structure.

were evaluated. Also, the mechanical properties of CFRPC was measured by flexural test with respect to the fiber contents and fiber length. The oxygen plasma treatment was performed to enhance the adhesion between the carbon fiber and epoxy resin. The surface of the carbon fiber with the oxygen plasma treatment was characterized using X-ray photoelectron spectroscopy (XPS) analysis and scanning electron microscope (SEM). Also, the 1/6 scale model of railway structure using CFRPC sleeper was fabricated to evaluate the noise performance and compared PC sleeper.

2. Experimental

2.1. Specimen preparation

The basic mixing ratio between the aggregates and epoxy resin (4:1 weight ratio) of standard polymer concrete was chosen following the manufacturer's recommendation. The epoxy resin (ERR200 (RM-2), JUNG DO E&P. LTD, Korea) and hardener (ERH200, JUNG DO E&P. LTD, Korea) were mixed by 5:1 weight ratio. The epoxy resin is formed by reacting epichlorohydrin with bisphenol A to form diglycidylethers of bisphenol A (DGEBA). Two types of the aggregate were mixed (coarse aggregate: 0.85–1.2 mm, fine aggregate: 0.25–0.6 mm), the mixing ratio of the coarse aggregate and fine aggregate was chosen as 2:1 [18]. The aggregate mixture and the epoxy resin/hardener were mixed by hand. After then, the carbon fiber (ACECA-NA1, ACE C&TECH, Korea) was added with respect to the fiber contents (0 wt%,

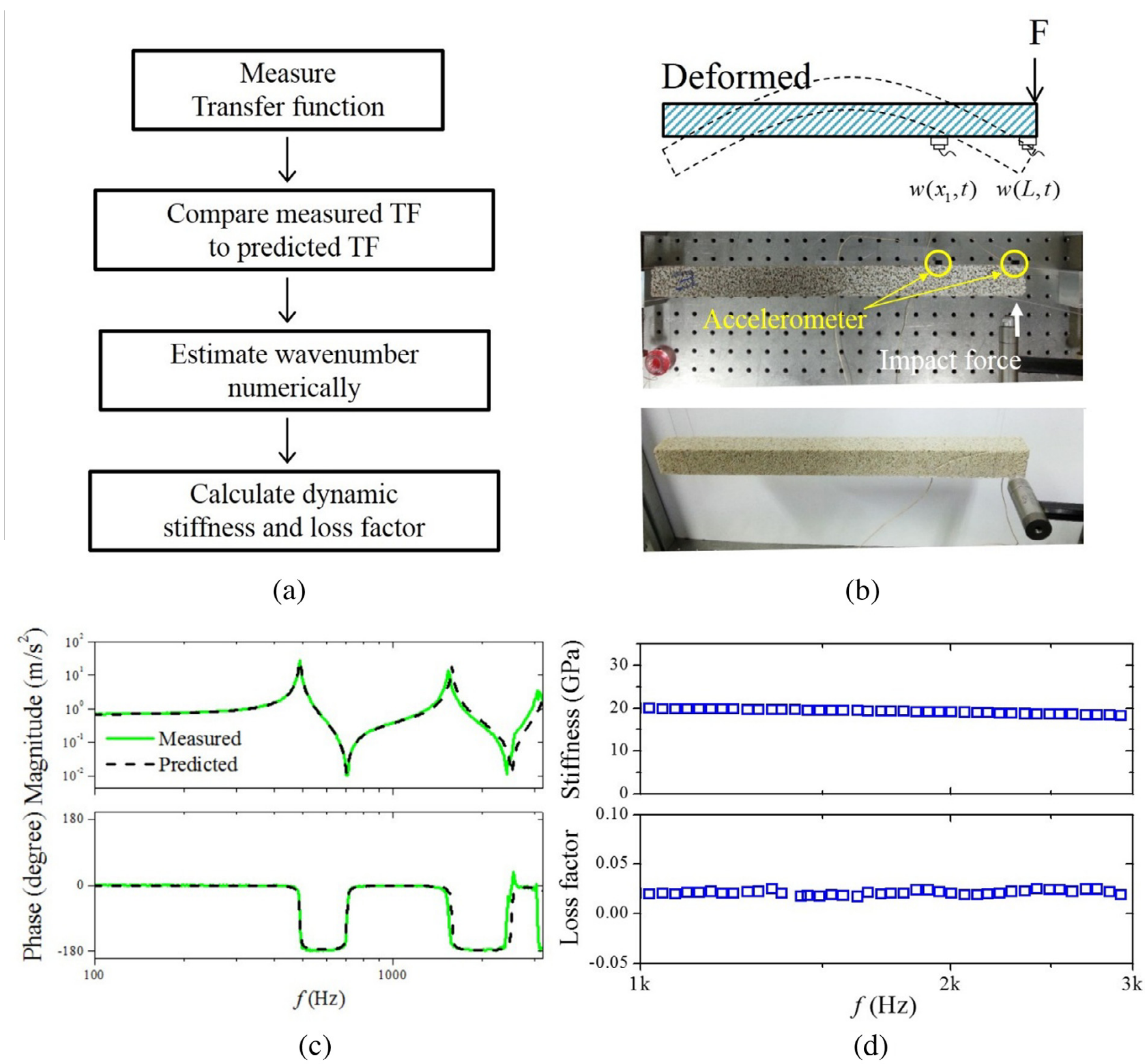

Fig. 2. Impact test based on the beam transfer function method. (a) Diagram, (b) experimental setup of impact test, (c) measured stiffness and loss factor in the frequency domain, and (d) stiffness and loss factors.