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Large-scale triaxial tests of dense gravel material at low confining pressures

Stanislav Lenart[a,b,*], Junichi Koseki[b], Yukika Miyashita[b], Takeshi Sato[c]

[a]*Slovenian National Building and Civil Engineering Institute (ZAG), Slovenia*
[b]*Institute of Industrial Science (IIS), The University of Tokyo, Japan*
[c]*Integrated Geotechnology Institute Ltd., Japan*

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Abstract

The results of a series of large-scale triaxial tests performed on dense, prismatic gravel specimens, with a height of 50 cm and a cross-section of 23 cm × 23 cm, are described. The specimens were prepared at a density equal to approximately 95% of the maximum density at the optimum moisture content. Deformations were measured locally using vertical and horizontal local deformation transducers. Stress conditions with selected levels of very low confining pressure were used to simulate specific conditions in the case of road and railway embankments. Particular attention was paid to the bedding error at the top and the bottom ends of the specimens, and to fixing transducers onto the membrane to be used under low confining pressure. The confining pressure was applied by vacuum and varied from 10 kPa to 75 kPa. Unsaturated specimens were tested under drained triaxial compression using monotonic and cyclic loading with frequencies in the range of 0.5–5 Hz. The effects of a large number of load cycles and of specimen preloading were investigated.

Keywords: Gravel; Large-scale triaxial test; Low confining pressure; Cyclic loading

1. Introduction

Gravel materials in flexible pavements play an essential role in the overall deformation behaviour of such pavements. The goal during the construction process is to compact the gravel material into a layer at the densest and stiffest possible state, which can be achieved by using the optimum moisture content defined by the Proctor compaction test. During the operation, the unbound gravel material layer is exposed to specific in situ stress conditions and traffic loads. These are simulated in laboratory tests to better understand the deformation behaviour of the gravel material.

Repeated load triaxial tests, with variable or constant confining pressure, have been used for more than one decade to evaluate the mechanical properties of unbound granular materials (Gomes-Correia et al., 1999). A standardized procedure (EN 13286-7) defines a test specimen with a diameter larger than 5 times the maximum particle size of the material, resulting usually in a diameter of 150 mm and a height of 300 mm (Erlingsson and Magnusdottir, 2002). In these tests the response is measured by displacement transducers attached directly to the central part of the specimen. The attachment is enabled by anchors which penetrate into the specimen. For this reason some local disturbance may be present in the specimen. No effort is made to reduce the bedding error due to friction between the specimen and the top cap or between the specimen and the pedestal.

*Corresponding author at: Slovenian National Building and Civil Engineering Institute (ZAG), Slovenia.
E-mail address: stanislav.lenart@zag.si (S. Lenart).
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2. Stress conditions in railway roadbeds

The large-scale triaxial tests presented in this paper were conducted giving consideration to the results of practical applications in railway track design. Thus, tests were needed for which the in situ stress conditions and railway traffic loads could be adequately simulated.

Momoya et al. (2005) presented the load distribution under sleepers for moving-wheel loading and fixed-point loading. Following their procedure, Fig. 1 shows the results for a typical prototype railway track, with a distance between adjacent sleepers of 60 cm. A maximum axle load equal to 225 kN, as defined in the Slovenian regulations for railway design, was used in the analysis.

A noticeable difference between the peak vertical pressure levels under the sleepers, for moving-wheel loading and fixed-point loading, can be observed (Fig. 1). The stress conditions in the sub-ballast layer, approximately 50 cm under the sleepers, were calculated using the theory of elasticity (Poulos and Davis, 1974). As can be seen in Fig. 2, the maximum vertical stress does not exceed 150 kPa, whereas the horizontal stress lies in the range of 10–55 kPa. It should be noted that the possible effects of the principal stress axis rotation, induced by the non-zero values of shear stress τ_{zx} and investigated by Momoya et al. (2005) and Inam et al. (2012), among others, were out of the scope of the present study.

It is obvious that rather low confining pressure should be used in triaxial tests simulating in situ stress conditions. Large-scale triaxial tests on dense gravel material under cyclic loading were conducted in the past by other researchers (AnhDan and Koseki, 2004; Maqbool and Koseki, 2010, among others), but the confining pressure exceeded 50 kPa in most of the studies, except for a limited number of studies, such as Ezaoui et al. (2010), Taheri et al. (2012) and Taheri and Tatsuoka (2012).

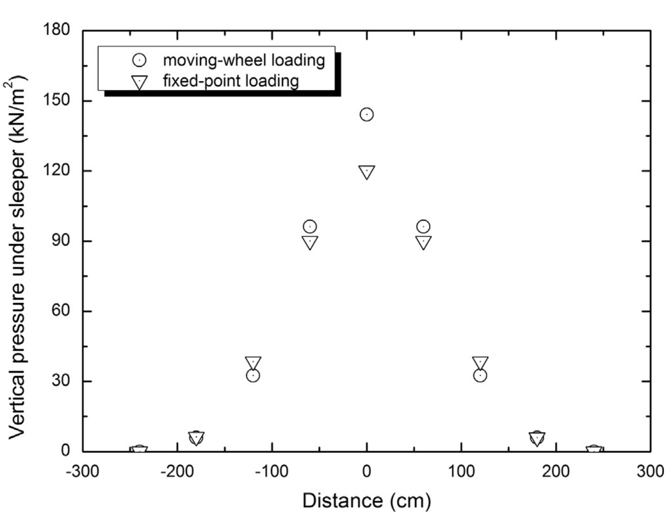

Fig. 1. Vertical pressure under sleepers at different distances from the loading point. The width of the sleepers is equal to 24 cm and the length is equal to 260 cm. (based on Momoya et al. (2005)).

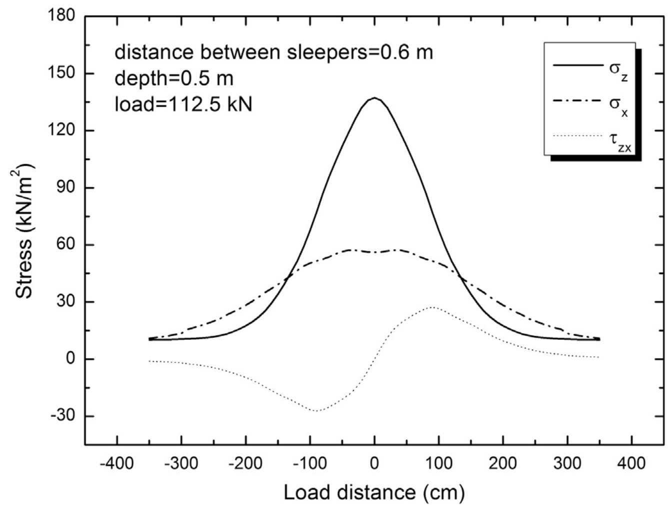

Fig. 2. Typical stress distribution under rail track.

3. Testing procedures

Considering the issues presented above, a different approach to dense gravel material deformation tests was used. The present research followed two main goals:

(1) to modify the existing testing apparatus in such a way that low confining pressure of the tested unbound gravel material could be used. Local disturbances (Erlingsson and Magnusdottir, 2002) due to the penetration of anchors at the side of the specimen and local confinement of the specimen caused by friction between the specimen and the top cap or the pedestal had to be avoided. The accuracy of the modified testing device needed to be assessed, and
(2) to investigate the effect of repeated loading on the unbound gravel material used for railway tracks.

Although the same large-scale triaxial apparatus had already been used in earlier research work (AnhDan et al., 2006a, 2006b), the tests presented in this paper differed from previous tests with respect to the low confining pressure applied (less than 50 kPa). They also differed in terms of the standardized procedure (EN 13286-7), namely, the elimination of local disturbances due to the penetration of the displacement transducer anchors into the specimen, as well as the bedding error.

3.1. Large-scale triaxial apparatus

The large-scale triaxial apparatus at the Institute of Industrial Science, University of Tokyo, was used. The device and its calibration have been described in detail in previous reports (e.g., Goto et al., 1991; Hoque et al., 1996; AnhDan and Koseki, 2004; AnhDan et al., 2006a, 2006b). The procedures described therein were used to calibrate the transducers. The test results were validated by test repetition. Although a major part of the testing device had been developed and verified earlier, two components still needed to be assessed. Firstly,