Deformation Behavior of Clays Under Railway Traffic Loading

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ABSTRACT: In this paper, dynamic-cyclic loading in subgrade and subsoil resulting from railway traffic is briefly described by using some typical in-situ measurements. These data are then used as input parameters for investigating the deformation behavior of a medium plasticity clay under cyclic triaxial condition. The tests are done under the condition that the surface of soil samples is constructed as drainage boundary during cyclic loading. In the experimental investigation, static consolidation pressure as well as the maximum and frequency of cyclic loads are varied in some relevant zones. Based on the test results, some empiric relationships, especially permanent strain depending on the ratio of maximum cyclic stress to static stress, are proposed. Besides, the comparison between numerical and experimental results is also given.

1 INTRODUCTION

In Germany, there are at present two large railway projects in construction, that is, new high speed line Köln-Rhein/Main as well as Nürnberg-Ingolstadt (design train speed 300 km/h), where slab superstructures are applied. Under this condition, higher requirement of railway foundation construction should be met by applying DS 804 and DS 836 of the German Railway. According to this document, for example, allowable soil types as well as required density and stiffness of subgrade and subsoil are prescribed. In design, the proof of dynamic stability and long-term settlement resulting from railway traffic are necessary.

In some cases, however, railway tracks have to be constructed on the soils such as MH- and CH-Clays, which are normally not permissble for railway foundations of high speed line. Hier, the essential aspects are in regard to the dynamic instability and the large long-term deformation of the soils under dynamic-cyclic loading. As a result, some measurements in subsoils such as soil replacement or treatment may be necessary. The important question in this aspect is therefore, how extensive (deep and wide) such measurements should be for a safe and economical design.

In this paper, some empiric relationships describing the long-term deformation of a medium plasticity clay are deduced by using the cyclic triaxial test results simulating the cyclic loads from railway traffic. In addition, corresponding theoretical indication is also given.

2 DYNAMIC LOADING FROM RAILWAY TRAFFIC

The important physical variables describing the response of subgrade and subsoil to the railway traffic are mainly dynamic stress and its predominant frequency, vibrating velocity and acceleration as well as deformation, see Figure 1.

A detailed description and assessment regarding the dynamic loading in subgrade and subsoils under railway traffic is given in *Kempfert & Hu (1997)* and *(1999)*. In the following, only the results regarding dynamic stress and its predominant frequency, which are directly the input parameters for stress-controlled cyclic triaxial tests, are illustrated.

Figure 1. Measuring site by passing of a high speed train in Waghäusel, Germany.

The in-situ measurements under high speed lines showed that the maximum of dynamic stress in subgrade and subsoil is dependent on wheel set loads, train speed, installation depth of measuring instrument as well as superstructure form, see Figure 2 and 3.

It can be clearly seen that the dynamic stress σ_c in subgrade and subsoil is largely affected by train speed and superstructure. Up to about 150 km/h, there is no significant increase of dynamic compressive stress for ballasted track and slab system. After this point, it increases nearly linear with train speed up to about 300 km/h. Then, dynamic stress becomes almost constant again. This is generally the same tendency as theoretical prediction. In terms of our experience, stress amplification factor of 1.3 may be applied to the subsoil under slab superstructure and 1.6 to that under conventional ballasted track.The stiffer the superstructure, the smaller the measured dynamic pressure.

Upon the measurements, it has been found out that the attenuation of dynamic stress in depth under slab superstructure is slower than that under ballast superstructure. But the dependence of dynamic stress on depth can be well assessed using static finite element calculation under consideration of stress amplification factor.