Biaxial fatigue test for the utilization of stabilized soils in the subgrades of High Speed Rail infrastructures

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1 Introduction

In situ soils present in right-of-way of civil engineering projects generally have mechanical characteristics inconsistent with stress rates generated by civil engineering infrastructures. To enhance their engineering and mechanical properties for a use in subgrade layers, it is common to mix them with a few percent of hydraulic binders [Bell, 1996]. These materials are called stabilized soils or cement-treated soils. The design of these structures is based on the measurement of monotonic mechanical performances of materials.

However, for transport structures, the service life of infrastructures leads to a number of loadings superior to 10^7 cycles for pavements and 10^8 for high speed rail lines HSR. The result is that, for these infrastructures, fatigue is one of the main failure modes. For HSR capping layers, as for other transport infrastructure layers, the fatigue criterion is the maximum tensile strength under cyclic loadings located at the bottom of the layers.

Currently, in the French railway sector, the global lack of knowledge on the mechanical fatigue behavior of stabilized soils has purely and solely led to them not being used. Therefore, to rationalize the costs of these infrastructures, the definition of design rules for these materials in relation to their mechanical fatigue is a major technical, economic and environmental challenge.

Recent studies [Preteseille et al., 2013] have shown that the bottom of the stabilized capping layer is subjected to a biaxial tension stress in contrast to pavement where it is uniaxial [Preteseille and Lenoir, 2015]. Setting out from this observation an appropriate test to reproduce this stress state was found and proposed [Preteseille et al., 2014; Preteseille and Lenoir, 2016], it is the biaxial flexural test (BFT).

The aim of this paper is to give preliminary basis for the design of these layers. The BFT fatigue test is performed on two stabilized soils. Results are discussed and compared with stresses in HSR capping layer.

2 Results and discussion

The BFT consists in laying a circular plate with a thickness t of 50 mm and a diameter D of 300 mm on a support ring with a diameter D_S of 280 mm [Preteseille and Lenoir, 2016]. The load is applied on the upper face through a ring with a diameter D_L of 140 mm. The fatigue test is a two-step procedure. First, the monotonic flexural test consists in applying a steadily increasing load at a speed of 0.8 mm/min to measure the maximum bending stress $\sigma_{f\ BFT}$. Then, plates are submitted to a sinusoidal cyclic load $\sigma_{log10(Nfail.)}$ with a constant amplitude at 30 Hz up to the failure. The parameter $N_{fail.}$ corresponds to the number of cycles necessary to reach the failure.

Two fine-grained soils were studied in this paper, the first (AD) is a sandy clay material, the second (ASE) is a regolith of micaschiste. Both soils are stabilized with 5% of cement CEM II/B-M (LL-V) 42.5 R, due to the important clay fraction AD was also stabilized with lime. Stabilized soils are fully described in Preteseille and Lenoir [Preteseille and Lenoir, 2016].

Results are presented in figure 1. The biaxial flexural strength $\sigma_{f\ BFT}$ is 1.07 MPa for AD and 1.02 MPa for ASE. And σ_8 is 0.54 MPa and 0.64 MPa for AD and ASE respectively, σ_8 corresponds to the calculated flexural stress that leads to failure after 10^8 cycles.

Computed stresses in the capping layer are presented with a semi-logarithmic scale in figure 2. The x-axis is the moduli of the stabilized capping layer and y-axis is the maximum biaxial tensile stress σ_T located at the bottom of

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this layer. Each square represents the value σ_T from the modeling for a given couple of thickness and moduli. The fatigue performances of AD and ASE are added in order to determine the required thicknesses. The mechanical properties of AD and ASE are good enough, i.e. performances better than the ones for a thickness of 20 cm.

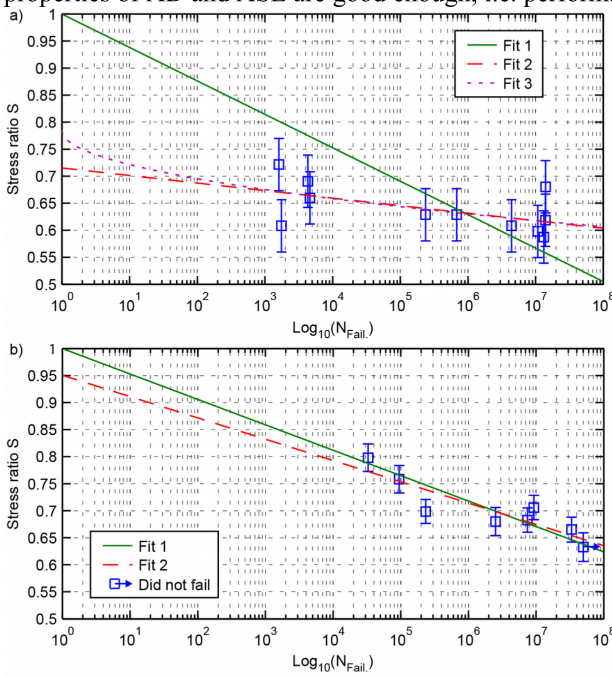

Figure 1: Fatigue curves of a) AD b) ASE

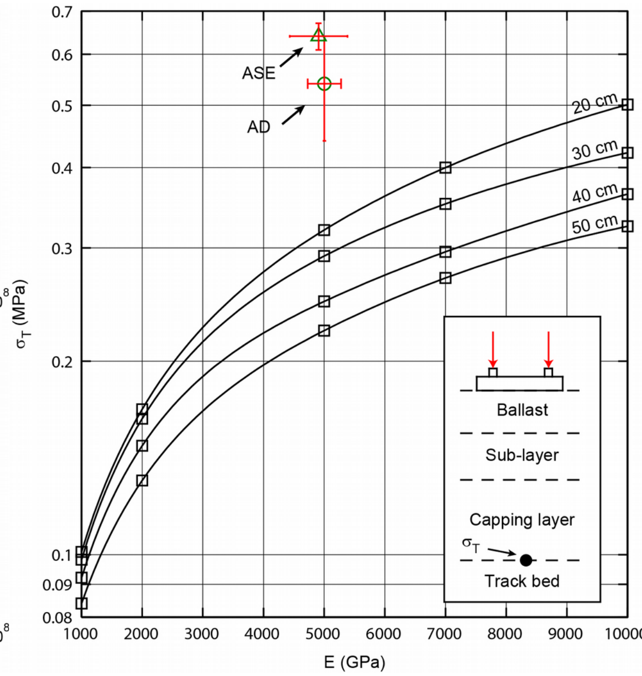

Figure 2: Computed stresses at the bottom of the capping layer

3 Conclusion

In conclusion, the BFT is a relevant procedure to study the mechanical fatigue of stabilized soils used in the capping layer of HSR infrastructures.

Results are very promising even if safety coefficients are used in design procedure. Nevertheless, results should be considered cautiously because they stay at the laboratory scale and real behavior in the field must be studied.

Several environmental friendly solutions are conceivable to rationalize the costs of the structures, rationalize the global thickness of the structure and the nature of the used materials, consider the use of stabilized soils in other layers of the HSR structure (e.g. sub-layer), optimize the use of hydraulic binders (amount, type,…) and enhance constructive applications (compaction rate, materials…).

References

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