Abstract

Currently there are many solutions to improve soil properties. Geosynthetic materials (geogrids and geotextiles) are particularly useful in reinforced soil systems. Geosynthetic-reinforced structures have been widely used in road engineering and in the construction of railways due to their economy and effectiveness compared to the traditional soil improvement methods. A considerable number of retaining structures have been successfully constructed using geosynthetic reinforcement layers. In many of these retaining structures, footings are located on the backfill and over the soil (e.g. footings on bridge abutments or roads located on top of the retaining structure). Despite the increasing use of geosynthetic-reinforced soil systems for retaining structures, still uncertainty exists concerning the real interaction of these materials with the soil and consequently, the current design methods need validation for different conditions and interactions. The soil-geosynthetic interaction can be very complex because it is affected by structural, geometrical, and mechanical characteristics of the geosynthetic, by the mechanical properties of the soil and by boundaries and loading conditions. This thesis starts with exploring the existing literatures on the soil-geosynthetic interactions in MSE walls. The review of the literatures underpins further development in the soil-geosynthetic interaction by experimental, analytical and numerical modelling for the mechanically stabilized earth wall systems and under the strip footing load. In mechanically stabilized earth walls and especially under the strip footing load, the necessary reinforcement length and consequently the size of the reinforced block depend on the reinforcement layers stiffness and strength, soil properties and interface apparent coefficient of friction. Next, model test results obtained from full-scale tests on the geogrid reinforced stabilized earth walls were analysed with analytical methods. The model MSE walls were prepared and tested at Brandenburg University of Technology Cottbus-Senftenberg (Pachomov et al., 2007) and the data were provided by the Naue Company. Two models were constructed, one with a full-height plywood panel (flexible) and another one with a full-height concrete face (rigid). There were two different steps considered in the full-scale models; the backfill construction step with a preloading effect caused by vibratory plate compactors for each layer of sand between the geogrid layers and the static strip footing load after the preloading effect from a localized roller compactor load. The instrumentation used in these tests provided valuable measurements of strains on the reinforcements, lateral wall deflection, vertical and lateral earth pressures before and after applying the strip footing load. These measurements have been used as a database for the evaluation of analytical and numerical methods commonly used in design of mechanically stabilized earth walls with different facing panels (rigid and flexible) and considering the preloading effect. Comparison between the measured maximum reinforcement tensile forces calculated from the strain gauges results after the backfill construction step with the AASHTO (2012) and K-stiffness methods showed that, the AASHTO (2012) method overestimated the maximum tensile force specially for the deeper layers and the K-stiffness and simplified stiffness methods underestimated the maximum tensile forces for the full-scale tests specially in upper layers. By increasing the overall flexural rigidity of the facing panel, the lateral wall deflection and reinforcement strains decrease in both the analytical models as in the measurements. A new modified analytical method has been developed based on the existing methods by considering the facing panel rigidity and compaction load (preloading) effects for calculating the maximum tensile forces in reinforcement layers and maximum wall deflections. This new model leads to a better agreement with the measurements. A scaled experimental setup (compared to the full-scale tests) was made to investigate the real interaction of the soil-reinforcement layers more in detail. Different types of geosynthetic materials were tested under different loading conditions. These scaled experimental tests had the scale factor of 1/5 compared to full-scale tests for both the size of model and the reinforcement stiffness. There were two loading steps in small-scale models similar to full-scale models, the first loading step (to consider

the effect of preloading from a roller compactor in full-scale models) and the second loading step (to consider the effect of strip footing load in full-scale models). From the PIV (Particle Image Velocimetry) analysis it was found that two failure lines with the angle of ($\pi/4+\varphi/2$) formed under the strip footing load: one from inner edge of the strip footing to the wall face (shallow position) and another from the outer edge of the strip footing (deep position). The facing panel rigidity and preloading influences the lateral wall deflection and vertical earth pressure and consequently, the maximum tensile load in the reinforcement. PIV analysis showed that the stiffness of the nonwoven geotextile in-soil is different from the in-air condition After that, the full-scale measurements are compared with the results of the 2D numerical analysis for the vertical and horizontal earth pressures, maximum tensile forces in reinforcement layers after backfill construction step and after considering different methods for compaction load. The numerical results illustrate that for the rigid face compared to the flexible face, the upper layers have more influence on the stability and the wall deflection under the strip footing load. By considering two equal distributed loads (as the compaction load) in top and bottom of each soil layer, there is good agreement between the full-scale tests and numerical modelling in the backfill construction step. The numerical models showed the equivalent static load can be used for the preloading effect of the roller compactor to have the same tensile loads and maximum wall deflection under the static strip footing load. 2D numerical calculations were used to investigate the influence of a horizontal restriction of the strip footing load. When only vertical movement is allowed, the maximum wall deflection is lower than when horizontal movement is allowed. Finally, 2D numerical analysis was performed to simulate the small-scale tests by considering the facing panel rigidity and preloading effects. There is good agreement between the 2D numerical analysis and small-scale test results except for the non-woven geotextile. Considering the higher stiffness for the non-woven geotextile under confining pressure, there is still difference between the numerical and test results.