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Research Paper

Performance of geosynthetic reinforced soil bridge abutments with modular block facing under fire scenarios

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ABSTRACT

This paper investigates the effect of fire on the performance of geosynthetic reinforced soil bridge abutments using experimental tests and finite element analyses. Experimental programs were comprised of a series of tensile strength tests at elevated temperatures and fire resistance tests, which were performed on a physical model. Findings revealed the adverse effect of fire on geosynthetic reinforced soil bridge abutments when fire duration exceeded 60 min. Results show that the depth within the backfill affected by the fire is approximately 50 cm.

1. Introduction

In recent years, the use of the geosynthetic reinforced soil (GRS) technology for bridge abutments has been recommended because it has advantages over conventional methods. The GRS bridge abutment system includes a segmental geosynthetic reinforced soil wall with a bridge seat (sill) placed on the top of it. The stability of these structures depends on the mechanical properties of the reinforcing elements as well as their interactions with the soil. Fig. 1 shows a typical GRS bridge abutment system with modular concrete block facing.

Geosynthetic reinforcements such as geotextiles and geogrids are made from synthetic polymers and mechanical properties of the polymers change with increased temperatures. Nonlinear increases in creep, a significant reduction in tensile strength, increased failure strain, increased degradation, a reduction in the modulus of elasticity, and a reduction in surface hardness are some of the consequences of increased temperatures on the properties of these types of material [1–8]. Few attempts have been made to study the effect of temperature distribution on reinforced soil structures (due to ambient temperature variations). Segrestin and Jailloux [9] investigated the effect of temperature variation on the geosynthetic aging and discovered that in a reinforced soil structure, the temperature within the backfill varies to a depth of 10 m. A seven-year observation of a reinforced earth structure on the M25 motorway at Waltham Cross, UK, carried out by Murray and Farrar [10]. Their observation showed that 0.3 m behind the facing, soil temperature was relatively close to ambient temperature and after a distance of almost 4 m from the nearest external boundary, the soil temperature was constant. Kasozi et al. [8] studied numerically the temperature distribution in a mechanically stabilized earth wall structure in Las Vegas, NV using field data from the Tanque-Verde MSE wall in Tucson, AZ. Based on their study, the overall average temperature within the backfill was much higher than the highlighted test in ASTM D6637 [11]. They recommended that a reduction in reinforcement strength from rising temperatures should be considered when designing reinforced soil structures. Apart from ambient temperature, one of the factors that may cause temperature to rise in reinforced soil structures is fire. Studies on the behavior of geotechnical structures when subjected to fire are not very common, possibly because the thermal conductivity of soil is low and the likelihood of mechanical properties changes of soil due to fire is low. In the case of GRS, owing to the nature of geosynthetics (as mentioned earlier), more investigation on the effect of fire on GRS performance was required. As reported in NCHRP Project 12-85 [12] (Highway Bridge Fire Hazard Assessment), structures beneath bridges that are close to the

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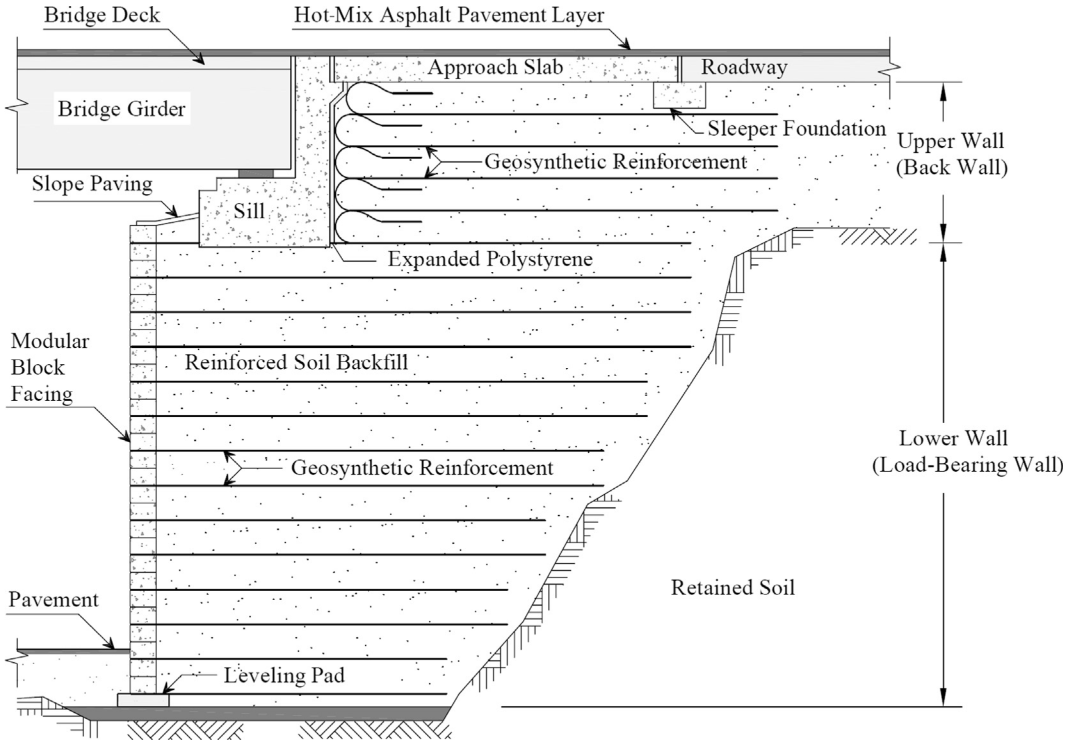

Fig. 1. Typical GRS bridge abutment system with modular concrete block facing.

roadway, like piers and abutments, were involved in many crash events that occurred underneath the bridge. Based on statistical data, half of fire events related to bridges occurred under the bridges. According to this report, two complete bridge-collapses in the United States (the MacArthur Maze freeway interchange in Oakland and the Nine Mile Road Bridge in Detroit) were caused by fuel tanker accidents (which results in huge fire). Such accidents are inevitable, making the study of GRS bridge abutments behavior when subjected to fire of importance.

Austin [13] carried out one of the few studies to investigate the effects of fire exposure on geosynthetic reinforced soil structures. In his research, two different wall configurations were tested in front of a gas furnace. The blocks used in his study were (a) a standard block and (b) a standard block with a 35 mm cavity and half brick masonry facing. As reported in his study, the fire used was in accordance with BS 476 Part 20 (British Standards Institution, 1987a). Fire testing time was 30 min. At the end of the test, when the maximum temperature of the furnace was 871 °C, the recorded temperature in the cavity (at the connector locations) was 66 °C and the temperature recorded behind the brick faced half of the test panel was 17 °C. Ambient temperature was 14 °C. Austin concluded that exposure to short-period fires does not have a significant effect on GRS structures with segmental blocks.

In recent years, GRS bridge abutment construction in Iran has gained considerable attention. Owing to a high number of road accidents, which can lead to fire near structures under bridges, the Road, Housing and Urban Development Research Center of Iran (BHRC) investigated the performance of GRS bridge abutments under possible fire scenarios. This study is part of a more comprehensive study supported by Tehran University and BHRC to evaluate the performance of GRS bridge abutments under fire conditions.

The results presented in this paper are derived from laboratory tests and numerical models. Laboratory tests included a series of tensile tests under elevated temperatures up to 140 °C for two types of geogrids as well as four fire resistance tests on a physical model of reinforced soil structure with the modular block facing exposed to a hydrocarbon fire curve with a maximum temperature of 1100 °C. For numerical modeling, a parametric study was performed using finite elements method. Numerous researchers have identified the advantages of finite elements method (FEM) for modeling and predicting the behavior of GRS bridge abutments [14–19]. The finite element model was calibrated using measured temperature data from fire resistance tests. This calibrated model was used to predict the behavior of a 4.8 m high GRS bridge abutment under various sill pressures and different fire durations. The results of this study improve our understanding of the performance of these structures under fire loading conditions.

2. Experimental program

2.1. Materials

The sand used in physical models was a siliceous, medium to coarse, clean washed sand. The coefficient of curvature (Cc) and coefficient of uniformity (Cu) were 1.42 and 7.89, respectively. Sand grains were formed from rounded and sub-rounded particles. Using the standard index density test recommended by ASTM D4254 [20] and ASTM D4253 [21], the minimum and maximum dry unit weights of the sand were found to be 16.43 and 18.78 kN/m^3, respectively. Results of direct shear tests suggest that the internal friction angle of the sand was 34°. Direct shear tests were conducted in accordance with ASTM D3080 [22]. Two types of geogrid were used, a PVC coated polyester (PET) geogrid and a uniaxial high-density polyethylene (HDPE) geogrid with ultimate tensile strengths of 40 kN/m and 45 KN/m, respectively. The physical and mechanical properties of the geogrids are presented in Table 1. Solid cast concrete blocks with dimensions of 150 mm × 150 mm × 150 mm was used as the facing element in the physical model. The 28-day compressive strength of normal concrete was almost equal to 28 MPa (according to FHWA design