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Direct Shear Testing of Tire Bales for Soil Reinforcement Applications

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Abstract

Perhaps it is time to bring recycled tires into the family of geosynthetics. In particular, recycled tire bales are being proposed for applications that are traditionally accomplished using various soil reinforcement applications (e.g. MSE walls and steep slopes). There are growing environmental interests in the utilization of recycled tire bales for civil engineering applications, triggered partly by the significant volumes of tires that could be disposed of in transportation projects. In particular, tire bales have been used to stabilize steep slopes due to a combination of their lightweight and reinforcement mechanisms. Tire bales are manufactured by compressing approximately 100 waste auto and light truck tires into a 2 cubic yard, 1-ton bales. Each bale is fastened with galvanized or stainless steel baling wire. However, only limited quantification of the mechanical properties of tire bales has been conducted so far. Accordingly, an experimental testing program was initiated by the Texas Department of Transportation at the University of Texas at Austin to quantify the interface shear strength between tire bales stacked in a brick fashion. This paper presents preliminary results of large-scale direct shear tests, undertaken to evaluate the interface shear strength between 1-ton tire bales.

Introduction

Every year, the United States produces 281 million scrap tires (RMA, 2002). Recent success in civil engineering applications involving use of tire bales for soil reinforcement has peaked environmental interests because of the significant number of tires that can be disposed even in small projects. Specifically, tire bales are being proposed for soil reinforcement applications, namely transportation projects involving stabilization of steep embankment slopes (Zornberg et al. 2004). Figure 1 shows an example of tire bales being used for slope stabilization. The lightweight property of the bales along with the expected high interface shear strength between bales helps stabilize the fill by mechanisms similar to those developed by conventional reinforcement inclusions.

Direct shear tests are currently being conducted at the University of Texas at Austin to define the interface shear strength properties between the tire bales. Quantification of the mechanical properties of tire bales is expected to further encourage their use in civil engineering applications. The irregular shape and unusually large size of the bales pose significant challenges in the development of consistent testing procedures. Nonetheless, the design of the testing setup has been completed, and preliminary test results are presented herein.

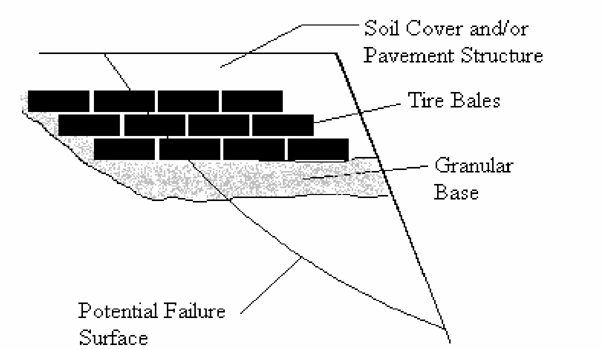

Figure 1. Tire bales being used in slope stabilization.

Materials and Methods

Figure 2 shows a tire bale similar to those being used in the testing program. No standards are available to guide the design of a test for obtaining the interface shear strength properties of materials with such large dimensions. Consequently, a new testing layout was designed by the University specifically as part of this project. The direct shear tests conducted in this study use three conventional tire bales stacked in brick-like fashion. The bales are oriented along the same axis and are tested at in-situ moisture content.

Figure 3 shows a schematic view of the direct shear-testing equipment. The bottom two bales are restrained from lateral movement while the top bale slides across them. The top bale is loaded horizontally using a high capacity actuator, which is statically mounted on a reaction column. The normal (vertical) load is applied using a second actuator mounted directly to a steel bearing plate attached to the top of the bale. A roller assembly reacting against a load bearing I-beam allows displacement of the vertical actuator along with the top tire bale during testing. A steel bearing plate is placed on the two loaded faces of the sliding bale to distribute the load applied by the respective actuators. A load cell is used to measure the load applied by the horizontal actuator. The linear potentiometers placed at the front and back of the top bale measure the horizontal displacement. Preliminary tests have shown that the top bale may experience a "rocking" motion due to the irregularities in the bales and the high interface shear strength in concentrated areas. This was resolved by placing the horizontal actuator towards the lower portion of the top bale.

Figure 2. Typical tire bale.

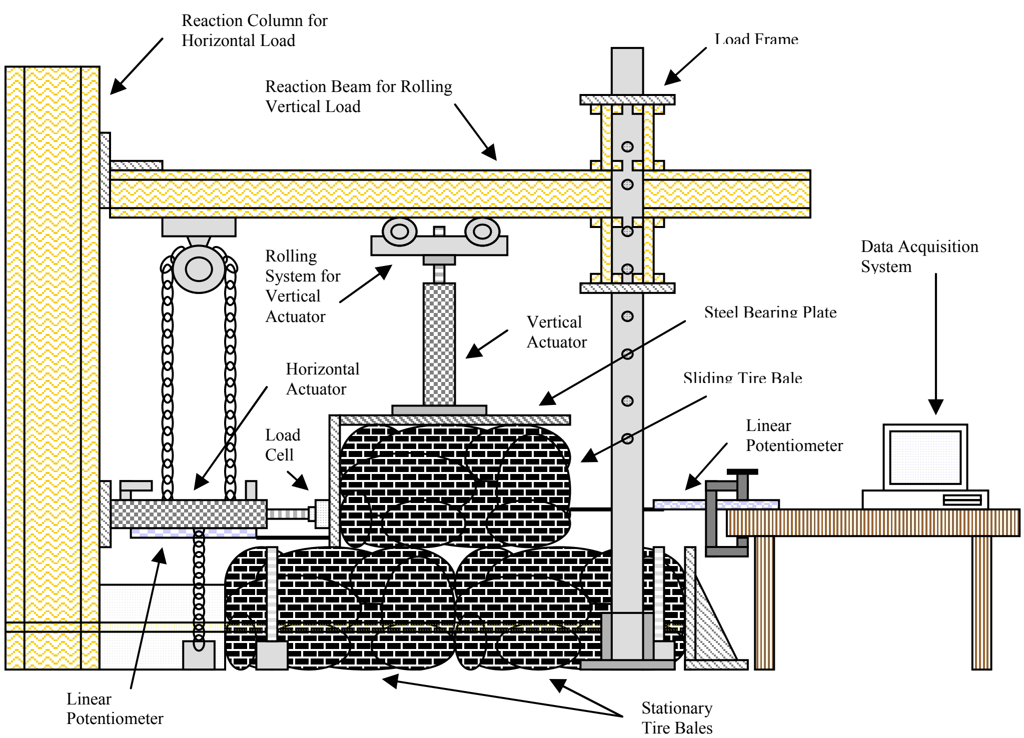

Figure 3. Direct shear testing equipment.

Preliminary Results

Figure 4 shows the horizontal shear force as a function of shear displacements for a test conducted using a normal (vertical) load of 4500 lbs. The test procedure involves unloading horizontally the tire bale after reaching a displacement of 14 inches. The results show a marked rebound in shear displacements, which illustrate the significant deformations that take place within the bale as it is horizontally loaded. Specifically, as indicated by the linear potentiometer readings at the point of application of the horizontal load, the horizontal displacement of 14 inches during loading is followed by a horizontal rebound of approximately 8 inches. A second linear potentiometer was installed in the back of the sliding bale to monitor simultaneously the movement of the front and back of the bale.

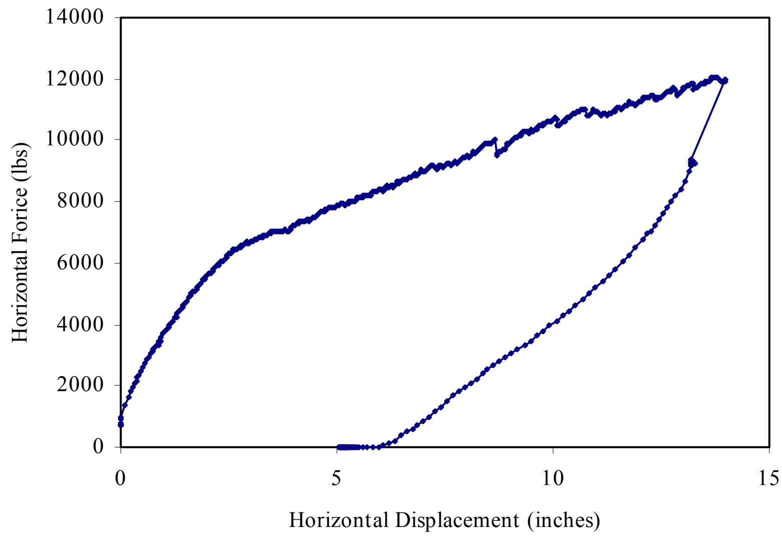

Figure 4. Typical horizontal force versus shear displacement values.

The results shown in Figure 4 also indicate that a significant shear resistance develops between the stacked tire bales. Specifically, a horizontal resistance between bales exceeding 12,000 lbs is obtained when the applied normal load is only 4,500 lbs (the load of approximately two bales). Consequently, tire bales are expected to provide a good alternative for stabilization of shallow slopes. The interface shear strength that develops between tire bales for typical field layouts will be quantified upon completion of this testing program. Specifically, this involves defining the interface shear strength envelope under various placement conditions of the tire bales. The current testing plan includes conducting direct shear tests conducted using representative values of normal load. Additional tests are planned to evaluate aspects such as the most effective orientation for the bales during placement and the presence of soil between tire bales.

References

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