LARGE SCALE DIRECT SHEAR TESTING WITH TIRE BALES

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Abstract: There are growing environmental interests in the utilization of recycled tire bales for civil engineering applications. Due to their lightweight and free-draining properties, tire bales have been used to stabilize failing embankments as well as provide a cost efficient subgrade for newly constructed roads. Tire bales are manufactured by compressing approximately 100 waste auto and light truck tires into a 2 cubic yard, 1-ton bale. Each bale is fastened with galvanized or stainless steel baling wire. 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 the results of the large-scale direct shear tests, undertaken to evaluate the interface shear strength between 1-ton tire bales.

INTRODUCTION

Every year, the United States produces approximately 281 million scrap tires (RMA, 2002). Due to recent success with tire bales in civil engineering applications, environmental interests have been peeked with the realization of such significant waste tire disposal. Tire bales are currently being proposed for soil reinforcement applications, namely transportation projects involving stabilization of steep embankment slopes (Zornberg et al. 2004). Figure 1 shows 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. The high hydraulic conductivity of tire bale composites allow for easy dissipation of pore water pressures.

Direct shear tests have been conducted at the University of Texas at Austin to define the interface shear strength properties between the tire bales. Quantification of such mechanical properties of tire bales is expected to further encourage their use in civil engineering applications. While no direct shear test results with tire bales have previously been published, the results presented herein have good repeatability and are confidently provided.

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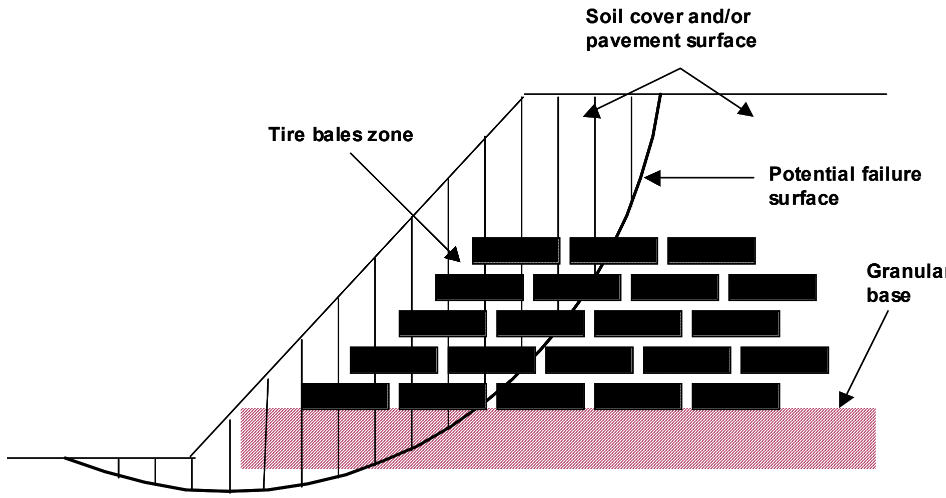

Figure 1: *Tire bales being used in slope stabilization*

Materials and Methods: Figure 2 shows a tire bale similar to those being used in the testing program. No standards are currently available for such large scale direct shear testing. Consequently, a new testing device was designed by the authors to facilitate the necessary testing for obtaining the interface friction angle of the bales. The direct shear tests conducted in this study use three conventional tire bales stacked in brick-like fashion, oriented along the same axis.

Figure 3 shows a schematic view of the direct shear-testing equipment. The bottom two bales are restrained from lateral movement with anchors and tie chains, 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 sliding bale measure the horizontal displacement.

Figure 2: *Typical tire bale*

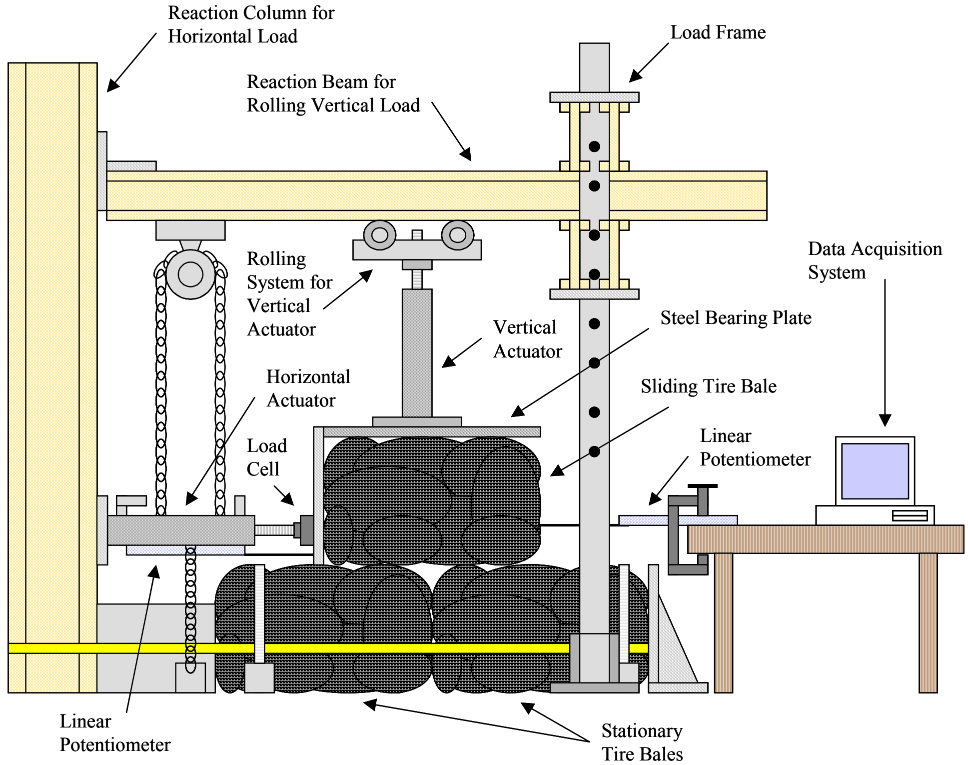

Figure 3: *Direct-shear testing device*

RESULTS AND ANALYSIS

The direct shear testing was performed for a range of normal stresses to determine a failure envelope for the tire bale composite. Dashed vertical lines on Figure 4 indicate

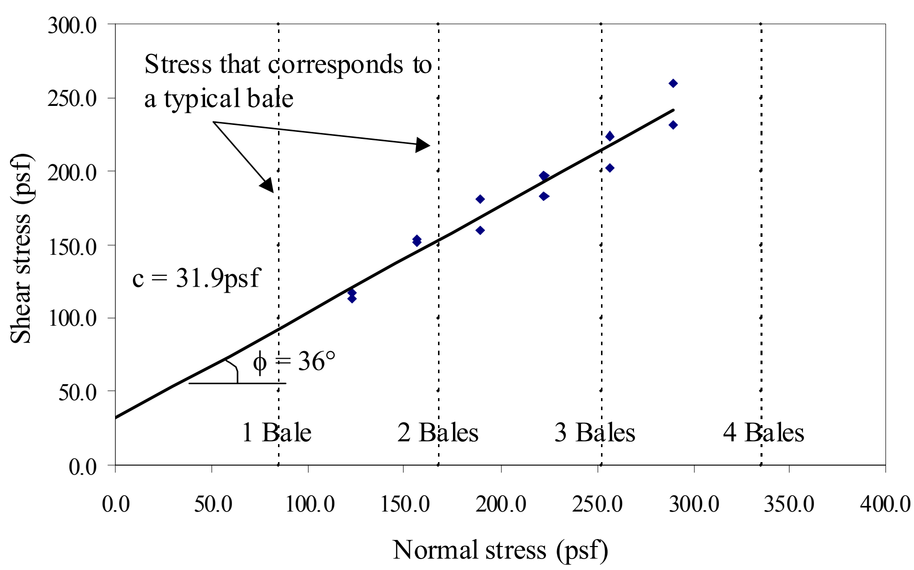

Figure 4: *Failure envelope for tire bale composite*

approximate normal stresses provided by tire bale self-weight. The resulting interface friction angle was found to be approximately 36°. As seen in Figure 4, there was small variability for each test at a given normal stress. Two tests were run at each normal stress for a total of 12 tests.

All tests were run at a displacement rate of approximately 0.01 inch/sec. The displacement rate was measured from the front of the bale. Differential (lateral) displacement of the front and back of the sliding bale allowed for quantification of the compressibility during lateral loading. Typically, the maximum horizontal compression of the sliding bale for all normal stresses was 1.5 to 2 inches (approximately 2.5% strain).

In a recent project involving the use of recycled tire bales for a slope failure repair along Interstate 30 east of Fort Worth, TX, the repaired slope has shown very good performance. The initial slope failure was due to above average rainfall. This project, carried out in 2002, required the use of 360 recycled tire bales, totaling about 36,000 scrap tires.

DISCUSSION AND CONCLUSIONS

The compressibility of tire bales must be considered when using them for subgrade in road construction. In addition, it is recommended to provide a granular base below the tire bale layers to allow for easy drainage.

Due to the high hydraulic conductivity (comparable to free-draining granular soils) and the confirmed high interface friction angle of tire bales, it is beneficial to consider tire bales as a leading alternative for lightweight material in civil engineering applications. While no cost analysis for the utilization of tire bales has been presented in this research, it is necessary to consider the environmental benefit of reusing waste tires for various applications.

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