Engineering Properties of Environmentally Friendly Sand and Crumb Rubber Mixtures

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Purpose and Objective

In 1990, over 240 million scrap tires were discarded in the United States and approximately 3 billion waste tires had accumulated in stockpiles and that number has grown every year since. Scrap tires can be used in a variety of civil engineering applications and have most notably been used as a civil engineering fill substitute. This offers an environmental friendly solution to seemingly useless "waste tires." The primary benefits include the reuse of an otherwise useless waste, lighter unit material weight, and lower cost. Tire chips can be used as either a separate substitution entirely or as a mixture with types of soil, such as sand. When a sand and tire chip mixture is used, the result is higher shear strength, larger unit weight, smaller compressibility, and reduction flammability.

This project's goal is to characterize the engineering properties of such sand and waste tire mixtures. Specifically, this project uses clean silica sand mixed with crumb rubber, much like those found at school playgrounds. These engineering properties will show that such fill substitutes are not just environmentally friendly, but can offer sound engineering solutions to problems where heavier normal type fill may be adverse and is generally more cost effective.

Material Tested

Most Civil Engineering applications use large tire shreds about 2 inches in nominal size. This research looks at the effects of crumb rubber on sand and waste tire mixtures, which is significantly smaller. CRM Rubber (Crumb Rubber Manufacturers) graciously donated finer crumb rubber for testing. The objective was to obtain crumb rubber that is similar in size to silica sand passing the #10 and #20 sieves which are between 1/10" and 1/20" nominally. Figure 1 shows a grain size distribution of both the silica sand and CRM crumb rubber used for experimentation.

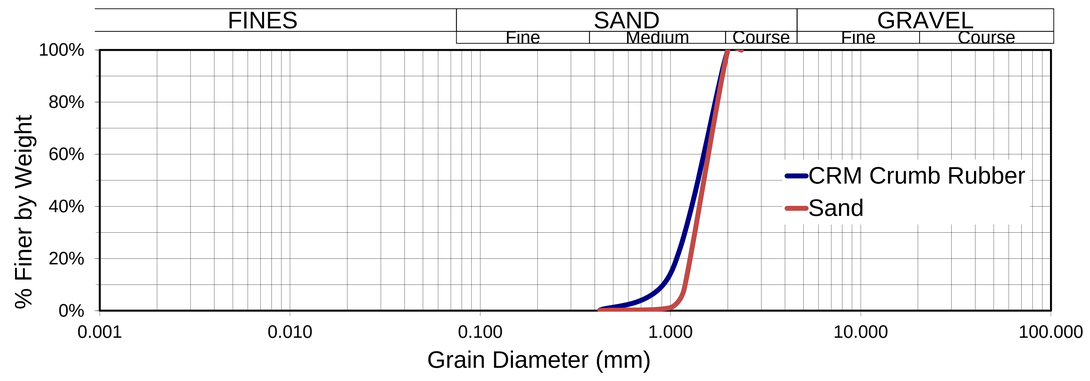
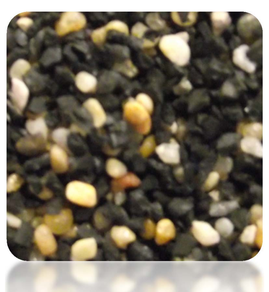


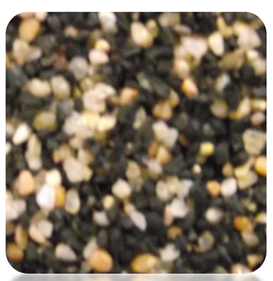
Figure 1. Grain Size Distribution of sand and rubber.

Different mixtures of sand and crumb rubber were tested. The below figures show the different mixtures tested with their ratios by weight shown. (S=Sand, R=Rubber).

50S:50R



65S:35R



80S:20R

0S:100R

100S:0R

Testing Procedures (Cont)

This research aimed to look at the effect that different sand and crumb rubber mixtures have on soil unit weight and soil strength. These parameters are important for civil engineers for the design of various ground structures such as embankments, slopes, and roadways. American Society for Testing and Materials (ASTM) standards were used to perform maximum, minimum, and strength testing on various sand and crumb rubber mixtures. Table 1 summarizes the different tests performed on the different sand and crumb rubber mixtures. Figures 2 and 3 show the equipment used for testing the unit weight and soil strengths respectively.

References

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Testing Procedures (Cont)

Table 1: Summary of Testing Program

Parameter Tested	ASTM Standard
Minimum Soil Unit Weight	ASTM D 4254
Maximum Soil Unit Weight	ASTM D 4253
Bulk Soil Unit Weight	ASTM C 29
Shear Strength	ASTM D 3080

Figure 2. ASTM mold used to test unit weights.

Figure 3. Direct Shear machine setup used to test mixture's strength.

Results

The unit weight represents the density of a given sample. Because soil can be remolded, compacted, and reconfigured, the unit weight is variable and dependent on the soil's level of compaction. The maximum and minimum represent the extremes of the densities, while the bulk represents a nominal or regular density. Figure 4 shows how the density increases as more sand is added to the mixture and less rubber.

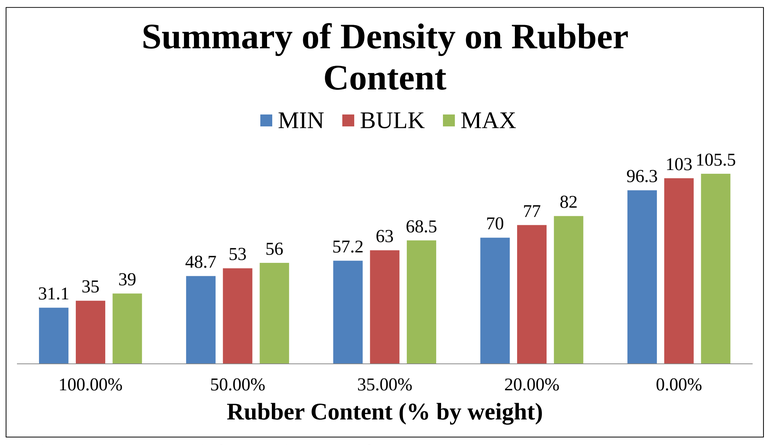

Figure 4. Unit Weight Testing Results.

The strength of soil can be measured by a single parameter called "the friction angle," which represents a soil's shear strength. In Figure 5, the friction angle is found by taking the slope of the line of the shear strength versus normal stress applied to the soil. The friction angle varies between 23° for pure rubber and 39° for pure sand. As expected, the sand-crumb rubber mixtures are in between these values and decrease as more rubber is added (Figure 6).

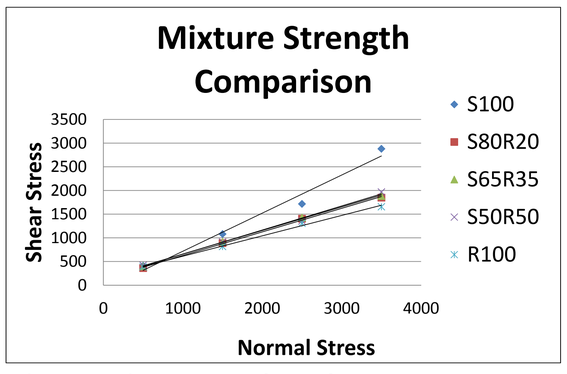

Figure 5. Mixture Strength Results.

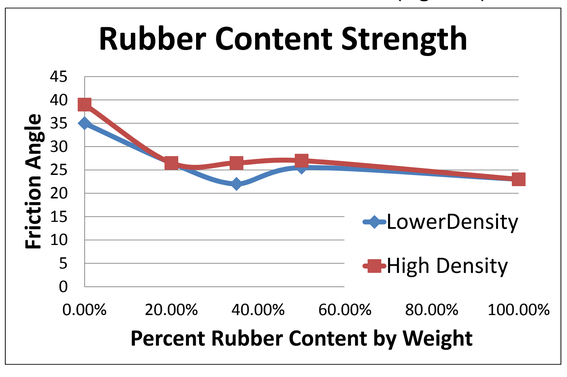

Figure 6. Rubber Content's Effect on Strength.

Conclusions

The results of this research show three important conclusions supporting that sand and recycled tire mixtures can be used in Civil Engineering applications. They are:

1. **Lighter Material:** The percent rubber content significantly decreases the unit weight of the fill, up to 65%. This means that the rubber and sand mixtures can support such projects as embankments without having significant weights themselves.

2. **Reduced Strength:** The shear strength of rubber and sand mixtures is smaller than the equivalent sand only mixtures with a reduction of about 30%. This reduction is significant, but when adequately characterized can be used as lightweight fill in projects such as embankments or roadbeds.

3. **Insensitive Strength Change in Mixtures:** The shear strength does drop when crumb rubber is added to sand, but the change in shear strength is relatively insignificant (less than 5%) between different mixtures of crumb rubber. Therefore, rubber and sand mixtures can be used in different mixtures with similar results leading to more economical and more recycled tires.

Acknowledgements

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