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Properties of chipped rubber roofing membrane and sand mixtures for civil engineering applications

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ABSTRACT

Waste rubber materials have been a popularly recycled material in Civil Engineering applications in recent years. The use of chipped rubber, particularly waste tires, has proven to have economical and performance benefits while making use of common waste materials. Within the construction and demolition sector, EPDM rubber roofing membranes are now being disposed of by chipping the waste sheets into uniform, angular chips roughly 1–2 mm in nominal diameter. The shredded roofing membrane is fire resistant and has potential to be used as a replacement for conventional materials in Civil Engineering projects. In this study, the geotechnical properties of chipped rubber roofing membrane are investigated both alone and mixed with a sand at various ratios by weight. To determine potential suitability as a lightweight material, Proctor Compaction Tests, Direct Shear Tests, Triaxial Tests, and Permeability tests were performed on EPDM rubber chip-sand mixtures in ratios by weight of 100%, 75%, 50%, and 25%. The results show that the new composite material is light weight but has high permeability and friction angle that are comparable to a granular soil. Based on these properties it is believed that the new material can be used as light weight retaining wall backfill, drainage layer in landfills, insulator in roadway subgrades and embankment fill.

1. Introduction

There are numerous waste products generated each year, and their amount is increasing day by day due to an increasing world population and consumption of raw materials. Recycling the used/waste material can save not only earth's resources, but also help to build sustainable infrastructures. Recycling the construction material from another construction project is one of the ways to remove waste within the same industry. Tire, glass, concrete and asphalt are recycled in civil engineering applications in large quantities. In addition to other applications, shredded tire and glass mixed with or without conventional granular material have been used as retaining wall backfills in the past [2,12,10]. One of the concerns with shredded tire is its susceptibility to fire and its limited uses. Compared to shredded tire, EPDM rubber such as shredded roof membrane has higher fire resistance (flash point $>200\ ^{\circ}C$) and it is relatively nonhazardous, along with many other desirable properties for Civil Engineering applications. Also, the cost of shredding roof membrane is cheaper than shredding tire, because removing the steel wires from the tire adds additional cost. Over 330 million pounds of EPDM rubber are being installed annually [4]. Of the 60% of recyclable EPDM, there is approximately 307 million pounds of EPDM rubber removed from US commercial roofs on an annual basis [4].

The objective of this study is to determine the geotechnical properties of shredded roof membrane and shredded roof membrane-sand mixtures for potential application as a light weight fill and other purposes. Standard Geotechnical Engineering laboratory tests were conducted to measure the geotechnical parameters such as particle size distribution, density, shear strength parameters, and the permeability coefficient of pure shredded roof membrane and membrane-sand mixtures at different weight ratios. Based on the numerical values of the properties measured from the laboratory tests, authors believed that the new composite material can be used in many civil engineering applications including light weight retaining wall backfill, drainage layer in landfills, insulator in roadway subgrades and embankment fill.

2. EPDM rubber and the composite material

The EPDM is derived from the recycling of used roof membrane. The material tested in the study was acquired by RK HydroVac Inc which recycles 1.2 million pounds of such material annually [14]. As shown in Fig. 1, the shredded roof membrane being tested contains fairly large angular flaky like particles with

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Fig. 1. Shredded roof membrane.

an average thickness of 1.27 mm.

In addition to testing the properties of the pure shredded EPDM rubber, the membrane shreds were mixed with a sand at 75:25, 50:50, 25:75 ratios by weight to form various EPDM-sand mixtures which may meet the requirements of different applications. For the sake of completion and comparison, the properties of the pure sand were also measured as part of this study. Due to the fact that the shredded EPDM rubber contains significantly larger particles than the sand, preparing uniform mixtures of these two materials without segregation was challenging, especially at the 25:75 mix ratio. Extreme care was taken to prevent segregation of the sand and EPDM particles during mixing. It must be noted that all of the experiments were repeated to obtain an average value for the properties of interest. The averaged experimental results are presented in this paper.

3. Particle size analysis and parameters

Sieve analyses were conducted on shredded roof membrane and sand following the procedure outlined in ASTM D6913 [1]. The measured particle size distributions are shown in Fig. 2. From the distribution, we can see that the roof membrane is poorly graded with D_{50} and D_{10} of 3.0 mm and 2.1 mm, respectively. The uniformity coefficient (Cu) and the coefficient of curvature (Cc) are 1.52 and 0.93, respectively. The particle size distribution appeared to have the characteristics of uniformly graded gravel according to AASHTO qualifications.

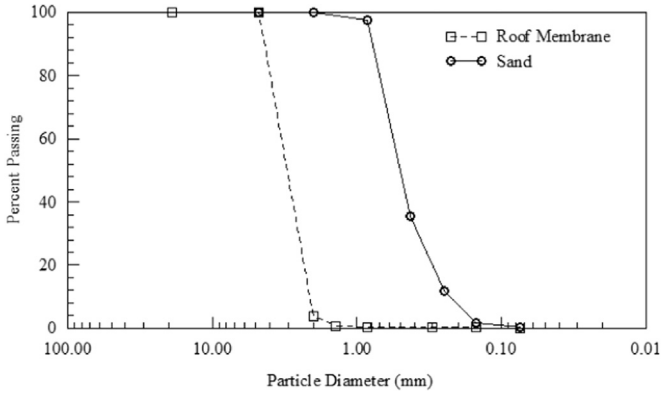

Fig. 2. Particle size distribution curves of model sand and shredded roof membrane.

In the tests performed in this study, the shredded roof membrane was mixed with sand to form different EPDM-sand mixtures. The sieve analysis data of the sand used in the mixtures is also shown in Fig. 2. The particle size distribution appeared to have the characteristics of uniformly graded sand. The D_{50} and D_{10} of the sand are 0.45 mm and 0.24, respectively. The C_u and C_c of the sand are, 2.29 and 0.93, respectively. From Fig. 2, it can be seen that the roof membrane contains significantly larger particles than the sand. The particle size distribution of the mixture at various ratios can be computed based on the particle size distribution of the sand and shredded roof membrane.

4. Unit weight

Unit weights were measured with and without compaction of the material. The Standard Proctor tests were conducted to measure the compacted dry densities, but with 60% of the standard Proctor energy, as suggested by ASTM D 698 and also used by Moo-Young et al. [9] for the shredded tire. The variation of the unit weights of the EPDM rubber chip-sand mixtures are shown in Fig. 3. The dry unit weights of the pure shredded EPDM rubber with and without compaction are 6.24 kN/m^3 and 4.78 kN/m^3, respectively and that of sand are 16.14 kN/m^3 and 14.24 kN/m^3, respectively. Comparison of these numbers clearly shows that EPDM rubber weighs significantly less than the sand. Lighter material as a backfill for retaining walls, one of many potential applications, will induce smaller lateral earth pressure, allowing for the construction of a thinner earth retaining structures. The variation of the unit weight of EPDM-sand mixtures shows a linear variation, as was expected. An appropriate mixture can be selected to meet other engineering requirements if the pure shredded roof membrane is not appropriate for the project in hand.

5. Strength tests and shear strength parameters

Internal friction angle and cohesion are the two most important strength parameters used by geotechnical engineers. It is common to conduct Direct Shear Tests to determine the friction angle of granular soils. However, measuring volume change is difficult when using commonly used direct shear apparatus. In order to obtain accurate data both Direct Shear Tests and Drained Triaxial Tests were conducted to measure the drained friction angle of shredded roof membrane and membrane-sand mixtures. It is worth noting that the volume change during shearing phase was significant, especially when testing pure shredded roof membrane and it occurred quickly at the initial loading. The testing required special arrangements such as videotaping the rise of water level in the burette to accurately calculate the volume change using high speed cameras. The Direct Shear and Triaxial

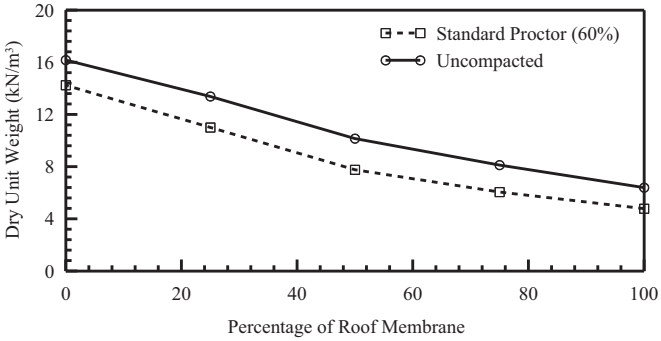

Fig. 3. Variation of dry unit weight of the mixtures.