Laboratory Characterization of Saskatoon Tire Derived Aggregate (TDA)

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Abstract:

Tire derived aggregate (TDA) is composed of shreds of scrap tires varying in size. Tire derived aggregate has been used as a replacement for crushed rock aggregate in various Civil Engineering applications including embankments, pavement structures, fill, and leachate collection systems. Using shredded tire in lieu of conventional rock aggregates offers environmental and economic benefits. Tire derived aggregate has good thermal insulator characteristics and can therefore be used to reduce frost penetration. It also promotes good drainage, is lightweight, compressible, and has no harmful leachates. Using tire derived aggregate offers these unique properties at a reduced cost compared to conventional aggregates. Using tire derived aggregate also reduces pressures on aggregate pits and landfills, where the tires would otherwise be discarded.

This study examined the physical characteristics of tire derived aggregate and sand mixes in the laboratory for road sub-structure drainage applications. Non-linear permeability and stiffness analysis of 100% TDA, 100% sand, and various TDA-sand blends was performed. It was found that a 70/30 blend of clean sand and tire derived aggregate provides adequate structural capacity while still maintaining good drainage characteristics. The material properties of these mixes were used as inputs in a three dimensional finite element model to perform simulations and generate road primary response outputs. Based on the analysis performed, it was determined that tire derived aggregate systems exhibit highly non-linear material constitutive behaviour in terms of permeability as well as mechanical primary response with respect to stress state. It was also determined that when designed properly, tire derived aggregate is a technically and economically sound alternative for road substructure drainage layers.

Background:

Tire Derived Aggregate (TDA):

- Recycled from municipal landfills and private stockpiles.
- Comes from shredding scrap tires into dimensions of 50 to 300 mm.
- Main sources are Passenger and Light Truck Tires (PLTT) and discarded Off-The-Road (OTR) tires.
- Tires obtained from Shercom Industries Inc. in Saskatoon.

Different Uses for Derived Tire Aggregates:

- Used in place of conventional construction materials.
- Great substitutes for gravel, sand, and lightweight fill materials.
- Highway Applications:
  - Lightweight fill.
  - Retaining wall backfill.
  - Insulation to limit frost penetration.
- Landfill Applications:
  - Leachate collection layer at the base.
  - Foundation layer beneath the landfill cap.
  - Drainage layer in the landfill cap.

Limitations of Using TDA:

- Tire shreds undergo self-heating reactions.
- The layer of tire thickness ranges from 39.6 to 120 in.
- A maximum of 25 %, by weight, passing a 4.75 mm sieve.
- Metal fragments that protrude from the rubber (shall not exceed 1 in).
- Non-degradable.
- Does not provide structural support.
- Low mechanical stiffness when compared to conventional aggregates.

Benefits in Using Tire Derived Aggregates

- Provides 7 times more thermal insulation than soil.
- Good drainage.
- Weighs 1/3 of the weight of soil.
- High permeability.
- Compressible.
- Half the Earth pressure when compared to soil.
- Reduces shear stress (horizontal stress).
- Economic and environment benefits.

Laboratory Testing:

- Tire shreds were reduced to pieces with maximum dimensions of 12.5 mm to 25 mm.
- Prepared samples consisted of:
  - 100% shredded tire.
  - 1 Tire: 1 Clean Sand (by volume).
  - 1 Tire: 2 Clean Sand.
  - 1 Tire: 3 Clean Sand.

Laboratory Tests Used:

- Grain size distribution.
- Vertical Compressive Strength.
- Rapid Triaxial Frequency Sweep (RaTT Cell).
- Permeability Test.
- California Bearing Ratio (CBR).

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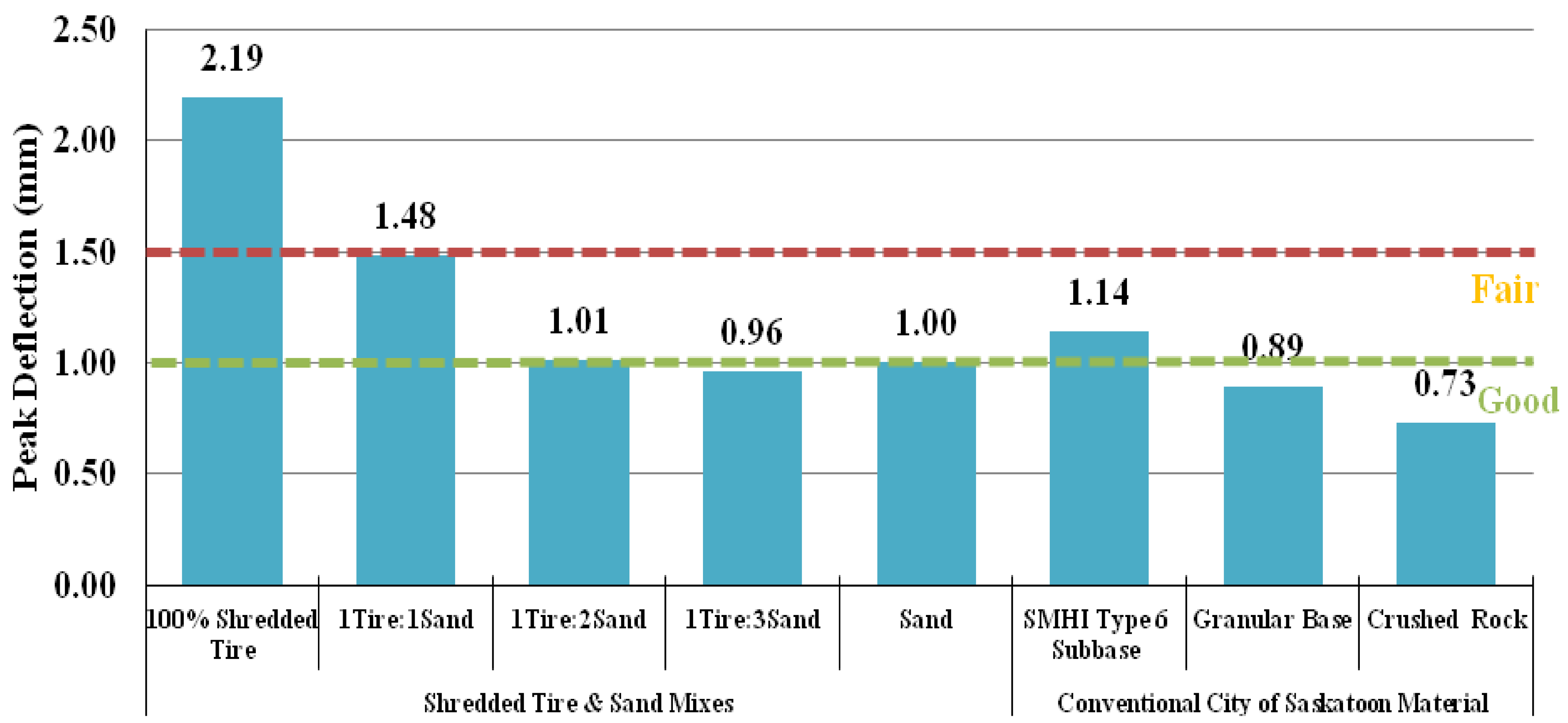
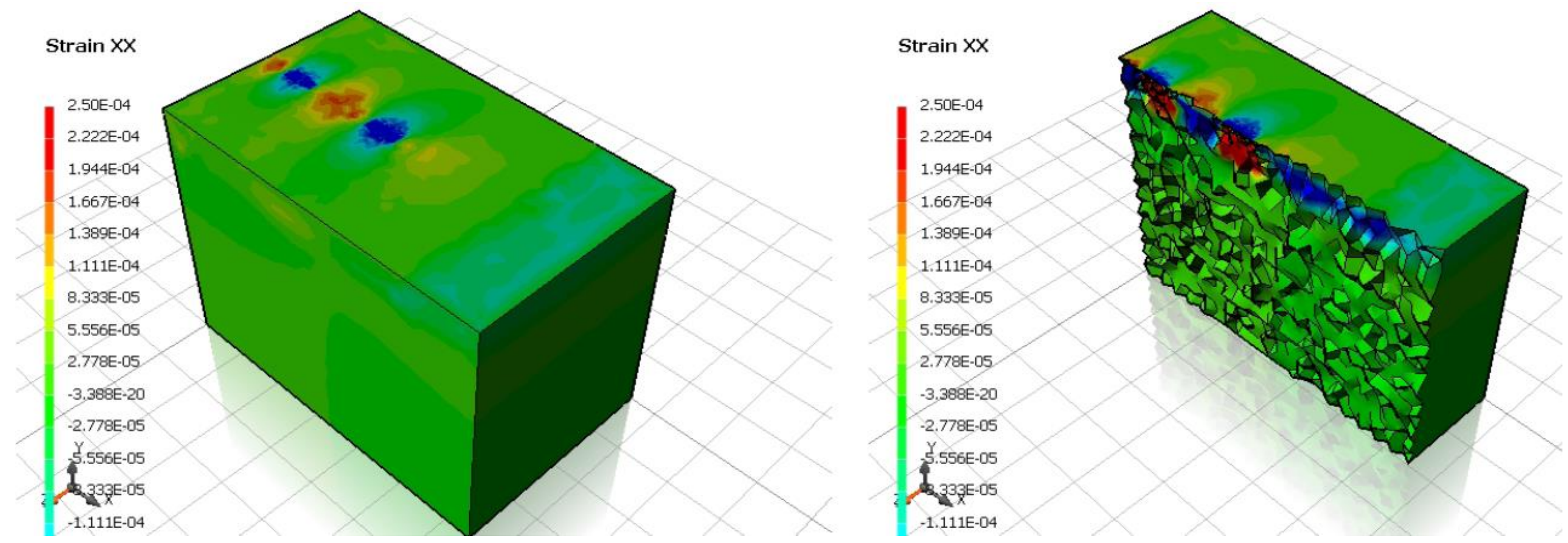
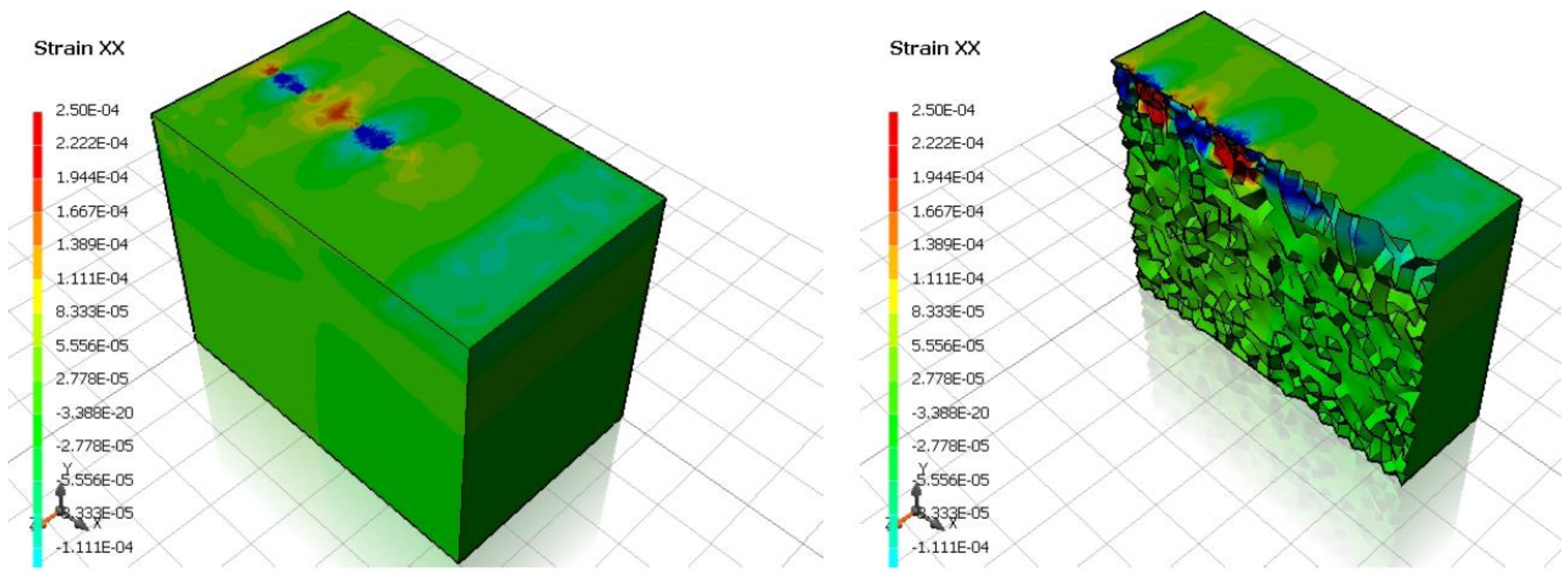
Finite Element Structural Modeling

- Structural behavior was determined by using a modeling software, PSIPave3D™.
  - It is a 3D non-linear orthotropic road model used to predict peak surface deflection and three dimensional strain behavior of road structures.
- The plot below represents peak surface deflection.
  - This is a representation of structural integrity which was determined by measuring the peak deflection under specified loading using a heavy weight deflectometer (HWD).
- The four cross sectional photos depict the horizontal strain (transverse) profiles.
  - The red shaded areas on the road profile show the locations of high-induced strains and are most prone to failure.



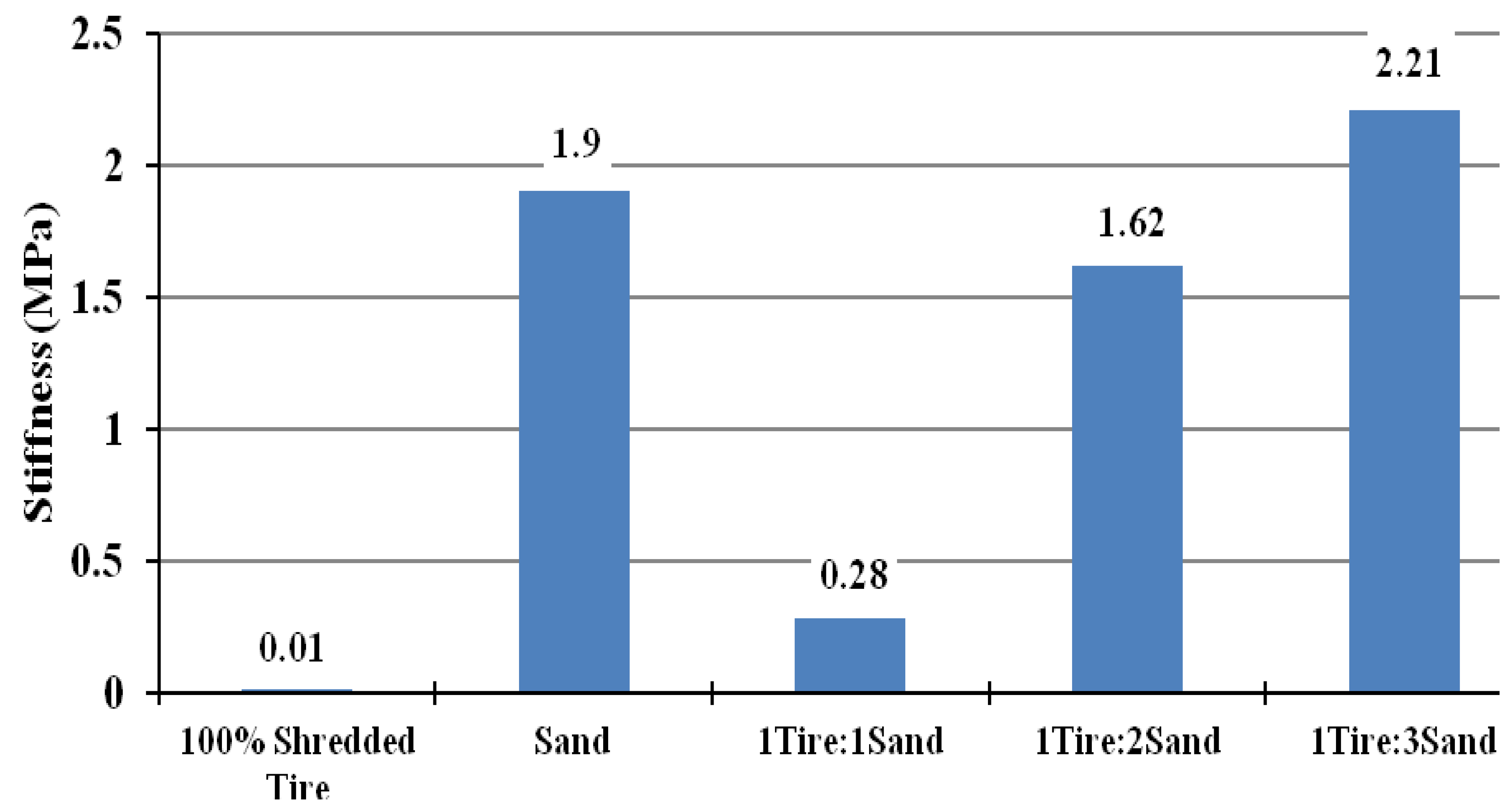


1 Tire: 2 Clean Sand - Horizontal Strain (Transverse) Profile



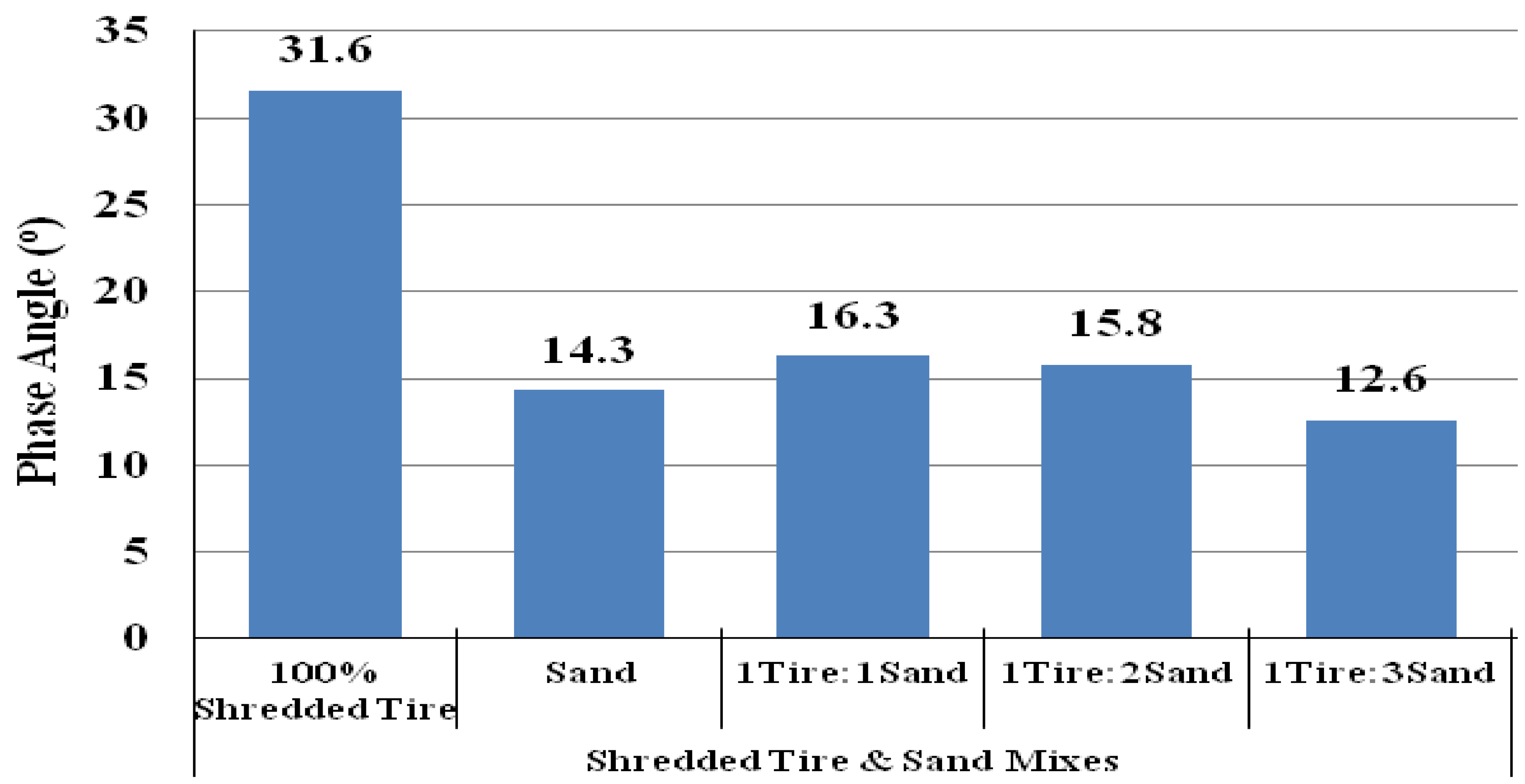
1 Tire: 3 Clean Sand - Horizontal Strain (Transverse) Profile

Tire Derived Aggregate Testing Results:



- The plot above illustrates the quantified stiffness from the compressive strength apparatus. The sample is subjected to confined compressive strength and stiffness.
  - Comparing the shredded tire and shredded tire/sand mixes, the ratio of 1 Tire: 3 Sand presents a higher stiffness.

- The plot to the bottom illustrates the phase angle produced by the RaTT cell.
  - A phase angle of 0 degrees means that material is purely elastic whereas 90 degrees means it is purely viscous.
  - 1 Tire: 3 Sand was observed to have a lower phase angle. This indicates a decrease in energy absorption which in turn means a decrease in deformation.
  - Therefore, an increase of sand within the mixes results in a decrease in phase angle.



Conclusions:

- Using recycled tires reduces the space used in the landfill.
- TDA is versatile and can be used as a substitute material.
- Higher ratio of sand to tire exhibits:
  - A higher stiffness value.
  - A decrease in deformation with a low phase angle.
  - Less horizontal strain.
- Although TDA has low mechanical stiffness compared to conventional materials, TDA demonstrates structural integrity and good peak deflection rates.

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