Physical and Mechanical Properties of Gravel-Tire Chips Mixture (GTCM)

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1. Introduction

Million tons of tires are disposed in all around the world annually. Stockpiling of scrap tires may pose a serious threat to public health and geo-environment. Aforementioned reasons reflect the importance of recycling of dumped tires each year. Recycling mainly focused on Tire Derived products and Tire-derived fuel for energy production purpose. Due to unique physical and mechanical properties of Scrap Tire Derived Materials (STDM) like low unit weight, low bulk density, high hydraulic conductivity, and high elastic deformability, this has recently found it is way into the civil engineering application with an advance growing interest each year. Retaining wall and bridge abutment backfills, fills for lightweight embankment and landfill liners are just examples of using STDM in civil engineering applications. Researches in recent years focused on the use of sand and STDM mixtures. Outcome of some researches have shown addition of STDM (mostly tire shreds) leads to slightly improvement in shear strength of sand (e.g. Mashiri et al., 2015), however referring to others, it was found to reduce the shear strength of sand (Kawata et al., 2008), on the other hand most of studies unanimously have reported that sand and STDM mixtures experienced high deformation resulted in non-explicit peak point or failure at stress-deformation curves. STDM and sand-STDM mixture are often being used as protective layer due to low liquefaction potential and interesting damping property. However high compressibility and low elastic modulus of tire chips and tire chips and STDM mixture could result in high differential settlement and inadequate bearing capacity of foundation. in order to overcome aforementioned issues, gravel-tire chips mixture (GTCM) as an alternative geomaterial has been introduced (Hazarika and Abdullah, 2016). Very limited researches can be found in literature to identify influential factors on physical and mechanical properties of the GTCM. in this study effect of confining pressure, relative density and gravel fraction (V_{Gravel}/V_{Total}) on shear strength and deformation characteristic of gravel and GTSM has been investigated.

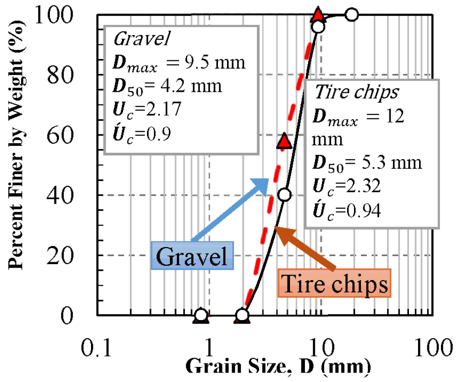

Fig1. Grain size distribution curves

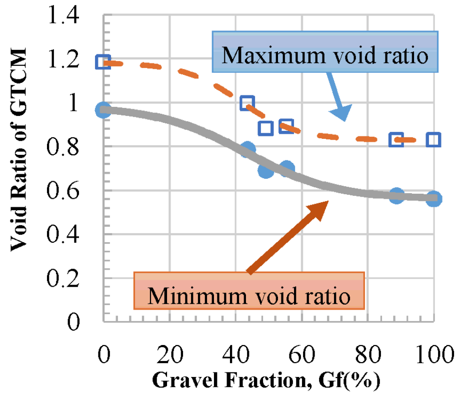

Fig2. Maximum and minimum void ratio of GTCM

2. Material Properties and Test Methodology

Stress controlled drained triaxial compression tests were conducted on the specimens of 100mm in diameter by 200mm in height. In order to prevent segregation between gravel and tire chips particles during preparation of GTCM samples, Base soil and reinforcement with very close particle size distribution curves were selected for present study. Particle size distribution of the gravel and tire chips used in this research is plotted in Fig. 1. The gravel is classified as poorly graded (SP) (JGS-0051). According to ASTM-D6270-12, STDM is classified as Tire chips regarding to their geometrical shape and dimension and classified as poorly graded (JGS-0051 and ASTM6270-12). The specific gravity of gravel and tire chips were obtained 1.17 and 2.81 according to JGS-0111 and ASTM6270-12 recommendations. In order to proceed with preparation of specimens for cyclic triaxial tests at desired relative density, a series of vibratory test were conducted on Gravel and GTCM mixtures according to JGS-0161 standard. Maximum and minimum void ratio of GTCM with different volumetric proportion of Gravel (Gf) is shown in Fig. 2. An empirical expression (Eq.1) is proposed to capture compaction behavior of gravel and GTCM mixture.

$e_{min,GTC}, e_{max,GTC} = A + B/(1+10^{(C-(Gf(\%))\times D)})$, $D_{50,Tc}/D_{50,s} \approx 1.2, D_{50,Tc} = 6\text{mm}$ (1)

Where A, B, C, D are fitting parameters listed in table 1. Where Gf is Gravel fraction (%). Under-compaction method was used for preparation of specimens. Gravel and tire chips were measured by mass corresponds to desired volume of gravel in mixture and afterwards mixed carefully by hand and placed into mold and sequentially compacted into 10 layers. Sample were saturated by allowing de-aired water flow through from bottom of the sample. 200 kPa back pressure was applied to specimen in order to assure high degree of saturation (B > 0.95). An isotropic consolidation pressure was applied to sample while maintaining initial backpressure constant. Specimen was undergone shearing with constant axial strain rate of 0.1%/min until axial strain of 20% was achieved. In this study effect of relative density, confining pressure and gravel fraction (Gf) in mixture on shear strength and deformation characteristics of gravel and GTCM was investigated. So to this end gravel fraction by volume (Gf) in GTCM mixtures varies between 0 (pure tire chips) and 100% (pure gravel). Confining pressures are considered to vary in the range of 50 kPa and 200 kPa and three different relative density D_r =35%, 50% and 75% were taken into account for this study.

Table1. Fitting parameters for maximum and minimum void

Parameters	Maximum Void Ratio	Minimum Void Ratio
A	0.828	0.558
B	0.355	0.424
C	41.391	43.265
D	-0.05	-0.032

Keywords: Gravel tire chips mixture, shear strength, triaxial testing.
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3. Results and Discussion

As can be seen in Fig. 3 deviatoric stress decreases with a decrease in percentage of gravel fraction (Gf) in GTCM. Three different behavioral zone of GTCM are distinguishable in the figure. Gravel like behavior was observed for Gf > 83% where essentially gravel particles forms GTCM soil matrix and stresses are mainly transmitted by gravel to gravel contact forces. Distinct peak deviatoric stress and highly dilatative behavior can be observed. Tire chips like behavior is evident for Gf < 55%. Tire chips particles are dominant in GTCM, so as a results force chains are mainly formed between tire chips particles, so as a result mixture shows significant reduce in shear strength and demonstrates properties which can be found in tire chips. For GTCM with 55% < Gf < 83%, very ductile behavior was observed when deviatoric stress reaches to peak point. Slightly dilative behavior follows by clear contractive behavior can be seen in figure. As can be seen Fig. 4 shear strength of GTCM with Gf=83% has been remarkably improved by increasing confining pressure. GTCM sample shows completely contractive behavior at high confining pressure ($\acute{\sigma}_3$ = 200 kPa). At lower confining pressures majority of gravel particles are still in contact and as a result stresses transmitted mainly by gravel particle and was found to carry its properties that could be the reason for aformentioned phenomena. As it can be observed in Fig. 5, relative density doesn't have pronounced impact on improving shear strength and volumetric strain behaviour of GTCM with Gf=55%. Similar results have been reported by other researches. (e.g. Mashiri et al., 2015)

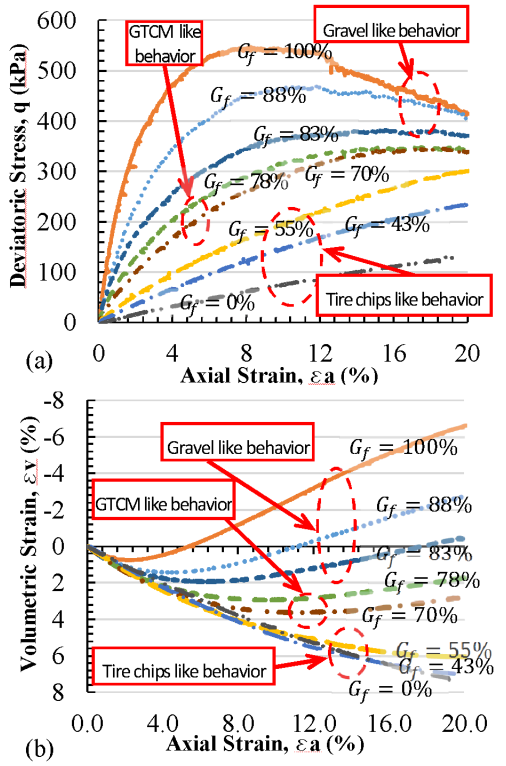

Fig3. (a) Deviatoric stress-axial strain (b) Volumetric strain-axial strain relation of GTCM at different gravel fraction (D_r = 50%, $\acute{\sigma}_3$ = 100 kPa)

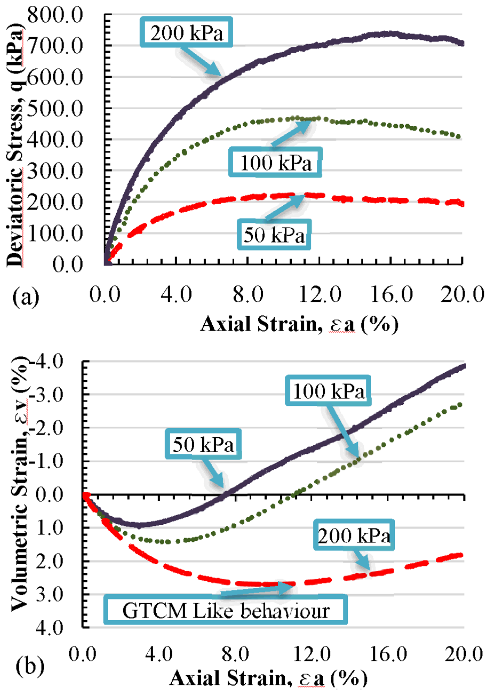

Fig4. (a) Deviatoric stress-axial strain (b) Volumetric strain -axial strain relation of GTCM at different confining pressure (D_r = 50%, Gf = 88%)

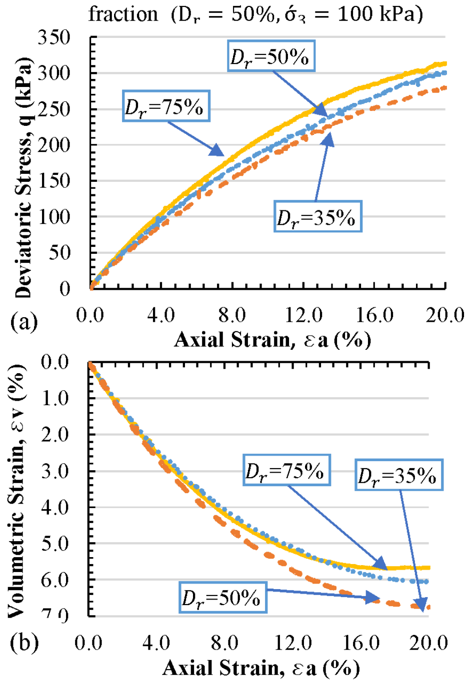

Fig5. (a) Deviatoric stress-axial strain (b) Volumetric strain -axial strain relation of GTCM at different relative density (Gf = 55%, $\acute{\sigma}_3$ = 100 kPa)

4. Conclusion

This paper presents the results of a series of triaxial test conducted on Gravel-Tire Chips Mixture (GTCM). A new relationship has been proposed to predict maximum and minimum void ratio of GTCM as a function of gravel fraction by volume in mixture. Three different behavioral zones, gravel like, gravel-tire chips like and tire chips like behaviors has been observed. In first zone gravel particles forms GTCM material matrix and in zone three tire chips forms GTCM matrix and zone 2 is established by binary matrix where gravel and tire chips has contributed in forming GTCM material matrix. Effect of confining pressure on stress-strain and dilatancy behavior of GTCM was investigated. Shear strength increases with increasing confining pressure and dilatancy has been found to be significantly influenced by confining pressure. Shear strength of GTCM has been found to be improved by increasing relative density of mixture although up to limited extent in comparison to confining pressure.

5. References

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