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Dynamic Response of Dry Rubber Tire Chips and Sand Mixture

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Abstract. The accumulation of the discarded tires in large volume increases loads on the landfills and hence raising a concern to find an alternative beneficial use of these used tires. This study investigates the effect of dynamic loads on a mixture of rubber tire chips, a scrap tire derivative, and sand in its dry state, for possible use of tire chips in various geotechnical applications.

The investigation included a series of strain-controlled cyclic triaxial tests. The parameters like loading frequency, cyclic strain amplitude and confining pressures were kept as variables. A sample of 100mm diameter and 200mm height was considered in the study. The tire chips with 12mm x 20mm as average dimension and having a specific gravity of 1.14 were used. Indian standard sand (Grade II) was considered for the study. The samples were prepared by dry pluviation method at 90 percent relative density.

The tests showed that with the increase in confining pressure the shear modulus increases, and the damping ratio decreases. Increase in strain amplitude decreases the shear modulus but increases the damping ratio. The detailed variation of the shear modulus and damping ratio of the mixture with varying frequency and number of loading cycles are also presented in the paper.

Keywords: Tire Chips, Cyclic Triaxial, Dynamic Response

1 Introduction

The accumulation of the discarded tires in large volume increases loads on the landfills and hence raising a concern to find an alternative beneficial use of these used tires. Again improper disposal of these scrap tires leads to health risk. These stockpiled tires turn into ideal breeding places for mosquitoes, vermin, etc which may lead to the spread of many diseases. Apart from these, the tires heaps are also vulnerable to fires.

ASTM D6270 (2017) specifies three different categories of the scrap tire types used for the application of civil engineering works. They are tire crumbs (length less than 10 mm), tire chips (length in between 10 to 50mm), and tire shreds (the length is greater than 50mm). Use of scrap tire derivatives for various civil engineeering applications have been reported by many such as, light weight backfill materials (Masad et al. 1996, Tweedie et al. 1998, Lee et al.1999, Abiuchou et al. 2004, Shrestha et al. 2016), highway embankments (Bosscher et al. 1997), soil reinforcement (Foose et al. 1996, Hazarika et al. 2010), drainage material (Edil et al. 2004 and Reddy at al. 2010), vibration reduction (Wolfe et al. 2004, Hazarika et al. 2008, Hazarika et al. 2010), ground improvement (Mashiri et al. 2016) to name a few.

This study investigates the effect of dynamic loads on a mixture of rubber tire chips, a scrap tire derivative, and sand in its dry state, for possible use of tire chips in various geotechnical applications.

2 Materials and Methodology

The scrap tire chips used in the study are cut from the available scrap tires. The properties of the tire chips and sand are presented in table 1. The ratio of the mixture of sand to tire chips was taken as 80:20 by weight.

Table 1. Properties of the tire chips used in the study.

Description	Tire Chips	Sand (Gade and Dasaka, 2016)
Specific Gravity	1.136	2.62
Maximum dry density (kN/m^3)	5.32	14.18
Minimum dry density (kN/m^3)	5.17	17.04
Cross sectional dimension (mm x mm)	12 × 12 (average)	-----
Length (mm)	20 (average)	-----
Coefficient of Uniformity (C_u)	------	1.36
Coefficient of Curvature (C_c)	------	0.95
Soil Classification as per USCS	------	SP

The experimental program consisted of 63 cyclic triaxial tests on dry scrap tire chips. The tests were performed using a computer controlled cyclic triaxial apparatus. All the tests were performed in strain controlled condition at different strain amplitudes, confining pressures and frequencies. The different confining pressures (CP) considered were 50kPa, 75kPa and 100kPa. The strain amplitudes considered in the study were 0.075%, 0.1125%, 0.15%, 0.1875%, 0.225%, 0.2625% and 0.3%. The tests were carried out at frequencies of 0.5Hz, 1 Hz and 3Hz.

The tests were carried out on the samples of 100mm diameter and 200mm height. The sample was prepared at a relative density of 90%. The cyclic traixial tests were carried out as per the ASTM D5311 (1992) and ASTM D3999 (1996). There was no saturation stage in the present study as the samples were to be tested dry. Dry pluviation method was employed for the sample preparation and vacuum method was used to properly mount the sample on the pedestal. After the preparation of the sample confining pressure was applied to the sample, which was then followed by the application of the desired strain amplitude in the form of sinusoidal cyclic loading. A data acquisition system was equipped to continuously monitor and record the data during the tests. The sampling frequency was 500Hz.

3 Results and Discussions

The basic properties of the material used in the study are presented in table 1. The study investigates the dynamic behavior of the sand and scrap tire chips mixture when subjected to cyclic loading. The typical behaviors of the mixture are shown in the Fig. 1 to Fig. 3. The figure shows the results obtained from the sample tested at 50kPa confining pressure, 1Hz loading frequency and 0.3% strain amplitude. Fig 1 shows the response of the deviatoric stress with the strain amplitude at different loading cycles, Fig. 2 shows the variation of the deviatoric stress with number of loading cycles and Fig. 3 shows the strain amplitude with time. From the Fig.1 it can be said that the stiffness of the material did not degrade much with the application of the loading cycles. Fig. 2 shows that the magnitude of maximum deviatoric stress was 123kPa for the initial cycle which decreased to around 115kpa in 30 cycles and then decreased very gradually afterwards i.e. to 109kPa at the end of 500 cycles.

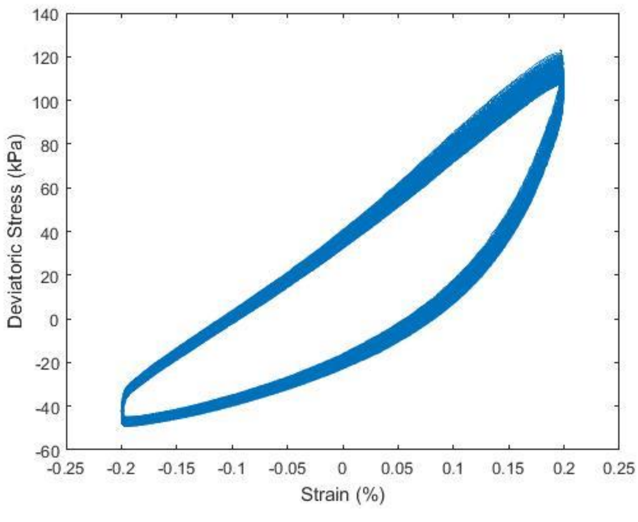

Fig. 1. Variation of deviatoric stress with axial strain amplitude at 0.3% strain amplitude under 50kPa confining pressure at 1Hz frequency.

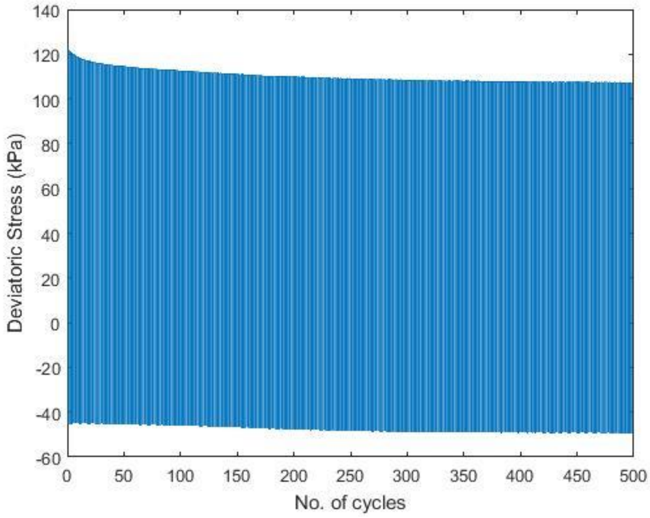

Fig. 2. Variation of deviatoric stress with number of loading cycles at 0.3% strain amplitude under 50kPa confining pressure at 1Hz frequency.

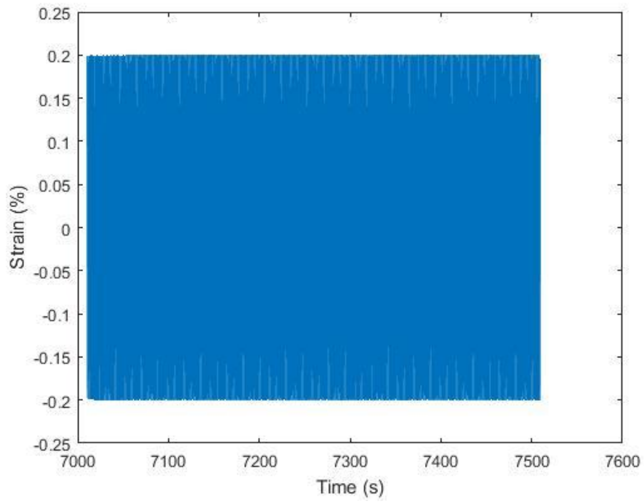

Fig. 3. Variation of axial strain amplitude with time under 50kPa confining pressure at 1Hz frequency.

The dynamic properties, i.e. the shear modulus and the damping ratio, of the mixture were calculated from deviatoric stress versus strain graph. The values were calculated for each loading cycle. The values obtained at the third cycle of the loop were considered as the dynamic properties of the tested sample.

The variation of shear modulus and damping ratio with strain are presented in fig. 4 and fig. 5, respectively for different conditions considered in the study. The effect of confining pressure and strain amplitude at different frequencies are also presented. From the figures it can be said that the shear modulus, representing the stiffness of the mixture, and the damping ratio varies with the confining pressure and the strain amplitude. The stiffness of the mixture increases with the increase in the confining pressure and decreases with the increase in the strain amplitude, whereas the vice versa is true for the damping ratio. Similar behavior is seen for all the three frequencies considered.

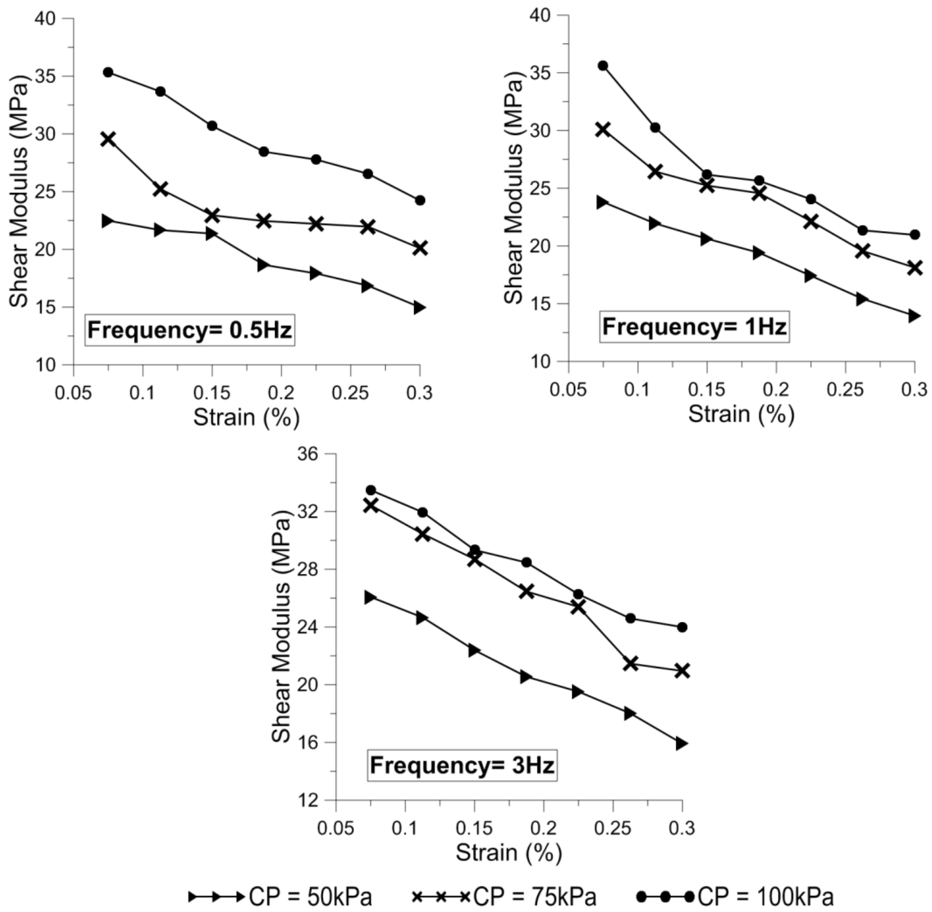

Fig. 4. Variation of shear modulus with strain

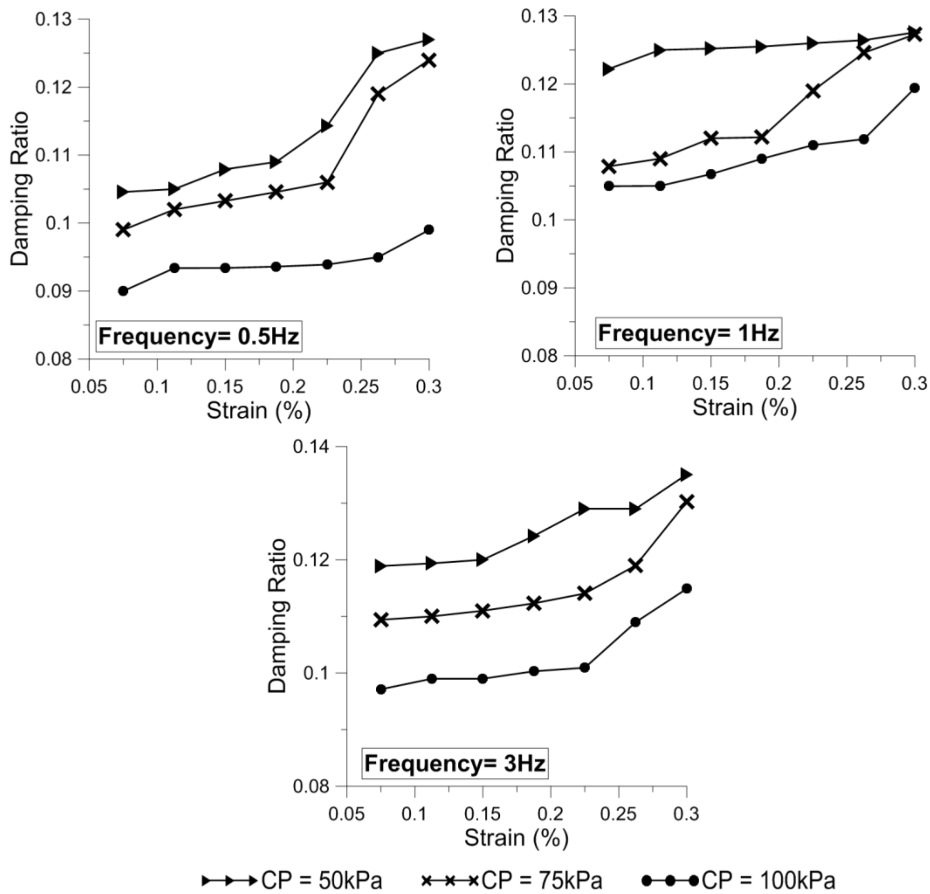

Fig. 5. Variation of damping ratio with strain

The effect of frequency on the shear modulus and damping ratio is not very clear. For the frequency of 0.5Hz, 1Hz and 3Hz the shear modulus values varied between 15MPa to 35MPa, 14MPa to 35MPa and 16MPa to 34MPa, respectively for different confining pressures and strain amplitudes considered. The damping ratios varied from 0.09 to 0.13 for 0.5Hz frequency, 0.1 to 0.13 for 1Hz frequency and 0.097 to 0.135 for 3Hz frequency. For all the three frequencies considered the values remained similar for different conditions considered.

4 Conclusions

This study investigated the dynamic properties of a mixture of rubber tire chips and sand using cyclic triaxial apparatus. Sixty three number of strain controlled cyclic triaxial tests were carried out on the dry samples. For better understanding of the property of the mixture the loading frequency, confining pressures and strain amplitudes were kept as variables.

- The stiffness and damping ratio of the material gets highly affected by the confining pressure. The value of the shear modulus increases, where as the damping ratio value decreases with increase in confining pressure.
- The strain amplitudes also remarkably affected the dynamic properties of the mixture. The shear modulus value decreases and damping ratio value increases with increase in the strain amplitude.
- The frequency of loading didn't show much effect on the dynamic properties. For all the three frequencies considered the material responded the similar way.

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