PROPERTIES OF SAND – RUBBER TYRE SHREDS MIXTURES FOR SEISMIC ISOLATION APPLICATIONS

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ABSTRACT

Disposal of scrap rubber tyres is a big challenge and a serious environmental problem. In India, it is estimated that one waste tyre per person is produced annually. The percentage of recycling is very less when compared to the stock piling every year. It is widely known that the rubber is a good damping material. Consequently, there is a big scope for the usage of this scrap rubber for earthquake engineering purposes. The present study involves the characterization of sand-rubber tyre shreds mixtures for the application in seismic base isolation of low rise buildings. The sand-rubber tyre shreds mix is characterized with respect to dynamic properties for various percentages of rubber tyre shreds such as 0%, 10%, 30%, 50% and 100% by weight. In this regard, a series of cyclic triaxial tests were carried out to evaluate strain dependent modulii and damping of the mixtures. It was found that 10% sand-rubber tyre shreds mixture yielded satisfactory dynamic properties required for seismic isolation of low rise buildings.

KEYWORDS: sand-rubber tyre mix, seismic isolation, shear modulus, damping ratio

1 INTRODUCTION

Since the existing methods of seismic isolation of buildings are very expensive for their use in low rise buildings, it becomes very important to find alternative ways. Study on sand-rubber mixtures was carried out by various researchers for various geotechnical applications like usage as backfill materials in retaining structures (Humphrey et al. 1997; Lee et al. 1999), as construction or fill materials (Edil and Bosscher 1994; Foose et al. 1996; Bosscher et al. 1997; Zornberg et al. 2004). Few studies on this material were carried out keeping in view the protection of buildings from earthquake induced vibrations (Tsang 2007; Anastasiadis et al. 2011; Senetakis et al. 2011; Senetakis et al. 2012). As far as dynamic soil properties such as shear modulus and damping ratio are concerned, previous researches are not conclusive on optimum percentage of sand-rubber tyre shreds mixtures yielding satisfactory strain dependent shear moduli and damping ratios. Hence it is imperative to find the behaviour of these mixtures under dynamic loading. This paper presents results of strain controlled cyclic triaxial tests. The strain dependent shear moduli and damping ratios for various percentages of rubber shreds mixed with sand are presented. The rubber content which yields better results at large strain levels is also presented.

2 MATERIALS TESTED AND TESTING EQUIPMENT USED

2.1 Materials

River sand which is widely used for construction purposes was utilized for experimental investigation. The rubber shreds were derived from scrap tyres of vehicles. The size of shreds adopted was 2mm and down. The percentages of rubber content adopted were 0, 10, 30, 50 and 100%. These percentages are gravimetric. Particle size analyses were carried in accordance with IS 2720 (Part 4) - 1985. The materials are classified as Poorly Graded in accordance with Unified Soil Classification System and can be denoted by SP. Figure 1 shows the particle size distribution of the materials. Figure 2 shows the rubber shreds.

The specific gravity, the maximum and minimum unit weights of the materials were found in accordance with IS 2720 (Part 3) - 1980 and IS 2720 (Part 14) - 1983 respectively and the results are summarized in Table 1.

2.2 Testing equipment

The cyclic triaxial tests were carried out on sand-rubber tyre shreds mixture specimens using Wykeham Farrance-UK make servo controlled advanced cyclic triaxial apparatus availabe at the Soil Dynamics and Earthquake Engineering Laboratory, IIT Madras (Figure 3).

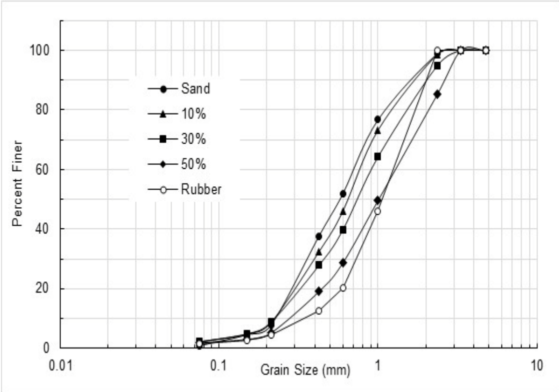

Fig.1 Particle size distribution curves for sand-rubber tyre shreds mixtures

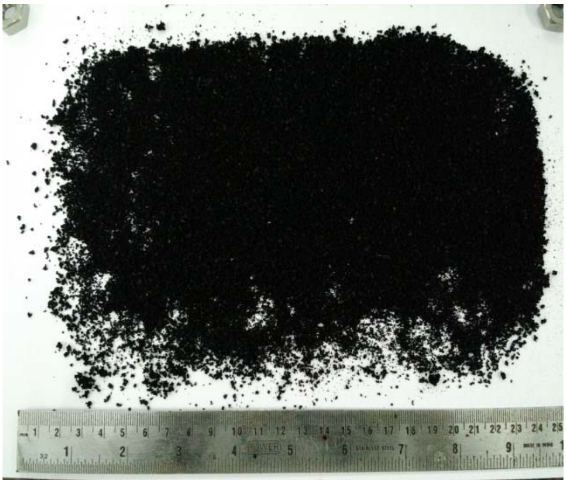

Fig. 2 Rubber tyre shreds

Table 1.Properties of sand-rubber tyre shreds mixtures

Sand-rubber tyre shreds mixture percentage (by weight)	Property		
	Specific Gravity	γ_{dmax} (kN/m^3)	γ_{dmin} (kN/m^3)
0	2.68	17	15
10	2.30	14.1	12
30	1.90	9	7.2
50	1.56	7.5	5.1
100	1.14	5.1	2.7

Fig. 3 Cyclic Triaxial Apparatus

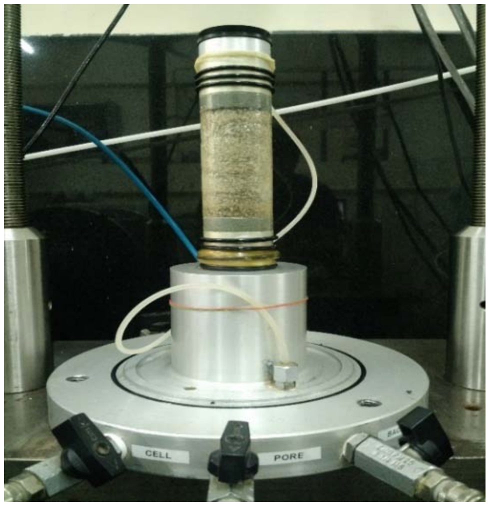

Fig. 4 Specimen prepared from sand-rubber tyre shreds mixture

3 SAMPLE PREPARATION AND TESTING METHODOLOGY

3.1 Preparation of sample

The samples were prepared by dry deposition and tamping method. The relative density adopted was in the range of 75 to 85%. The samples were prepared in 5 layers with each layer given equal number of blows. Since the materials are cohesionless, a vacuum pressure of upto 10kPa was used as aid for preparing samples. The diameter and height adopted were 50mm and 100mm respectively by using vacuum split mould. Figure 4 shows the specimen prepared using the above mentioned procedure.

3.2 Testing procedure

The samples prepared were saturated till Skempton's pore pressure coefficient (B-Value) greater than 0.95 was achieved. Then consolidation was done under an effective confining pressure of 100kPa. A series of strain controlled cyclic triaxial tests were carried out under undrained conditions in accordance with ASTM D3999/D3999M-11. All the tests were carried out at a frequency of 1Hz with 25 number of loading cycles.

4 RESULTS AND DISCUSSION

Typical hysteresis loops obtained from the cyclic triaxial tests carried out on 50% sand-rubber tyre shreds mixture are shown in Figure 5. The shear strain (γ) is calculated from the axial strain (ε) using the formula:

$$\gamma = \varepsilon(1 + \mu) \qquad (1)$$

where, μ is Poisson's ratio and its value is 0.5 for undrained conditions. The secant modulus (E_{sec}) is calculated by taking the slope of the line joining the ends of the loops. The secant shear modulus (G_{sec}) is calculated by using the formula:

$$G_{sec} = \frac{E_{sec}}{2(1+\mu)} \qquad (2)$$

The damping ratio is calculated by using the formula:

$$D = \frac{1}{4\pi}\frac{A_{loop}}{A_{triangle}} \qquad (3)$$

where, A_{loop} is the area of the hysteresis loop and $A_{triangle}$ is the area of the triangle (area of the shaded portion in Figure 6). The shear moduli and damping ratios for all the mixtures were calculated for the 5th cycle.

Figure 7 shows the plot of shear modulus versus shear strain for all the mixtures. As shear strain increases, the shear modulus decreases for all the rubber contents. The modulus reduction is highest for the pure sand and least for the pure rubber. The sand-rubber shreds mixture with 10% rubber content shows higher value of shear modulus in comparison with other mixtures but less than that of pure sand. Figure 8 plots the damping ratio versus shear strain for all rubber contents. It can be observed that the damping ratio increases with shear strain. At any shear strain

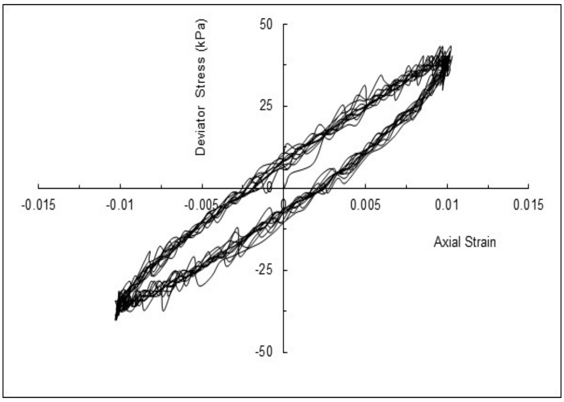

Fig. 5 Typical hysteresis loops for 50% rubber content showing 25 number of cycles at 1% strain

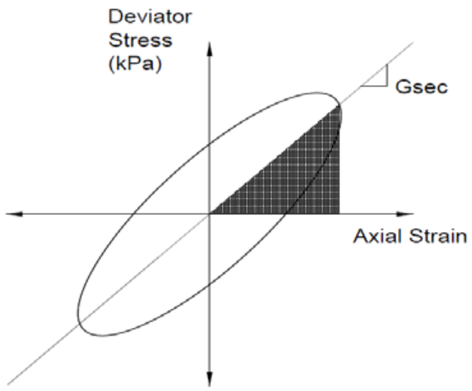

Fig. 6 Schematic diagram of hysteresis loop

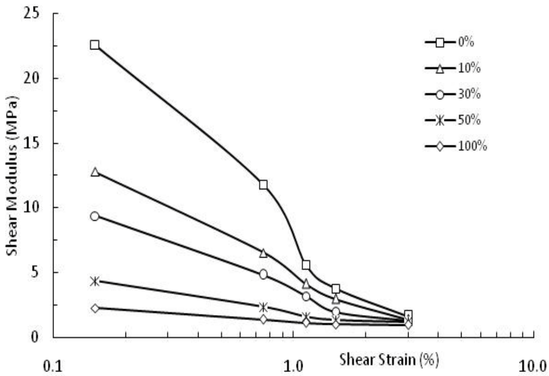

Fig. 7 Plot of shear modulus versus shear strain for sand-rubber tyre shreds mixtures

level, with increase in the percentage of rubber, the damping ratio is decreasing. It is only for the 10% rubber content, the maximum damping ratio is observed at all strain levels. It is intriguing to note that the pure rubber is showing the least damping ratio at all the strain levels. Authors believe that at 10% rubber content, the interaction between the soil and rubber particles is highest and this may be due to the size of the sand and rubber particles adopted for experimental investigation which is very small.

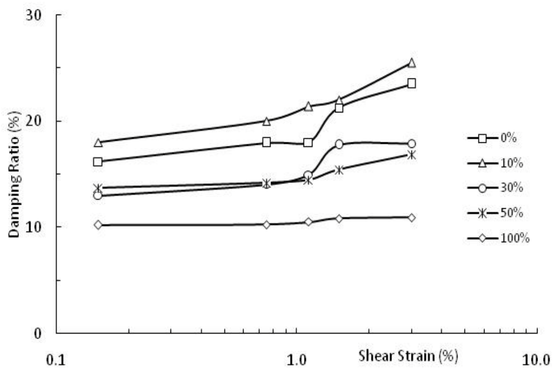

Fig. 8 Plot of damping ratio versus shear strain for sand-rubber tyre shreds mixtures

5 CONCLUSIONS

From the experimental study, the following conclusions can be made:

With increase in shear strain, the shear modulus reduces for all the percentages of rubber in sand-rubber tyre shreds mixtures.

The modulus reduction increases with decrease in percentage of rubber. The modulus reduction is highest for the sand and lowest for the rubber.

The damping ratio increases with increase in strain levels. Lesser damping ratios are observed for higher percentages of rubber. The pure rubber shows least damping ratio. This behavior is mainly due to the size of the sand and rubber particles adopted for experimental investigation.

The 10 percent rubber content by weight shows higher shear modulus and damping ratio values compared to all other percentages. Hence, 10 percent rubber content possess satisfactory shear moduli and damping ratios at large strain levels and may be effectively used as a material for seismic base isolation applications.

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