Large Scale Triaxial Tests on Segmented Scrap Tire Shreds for Their Use as Lightweight Geomaterials

OAshoke K Karmokar, Member, Bridgestone Corporation
Hideo Takeichi, Non-Member, Bridgestone Corporation
Kazuya Yasuhara, Member, Ibaraki University
Hiroyuki Kawai, Member, Toa Corporation

1. Introduction: Generation of scrap tires in Japan is about one hundred million annually. It is reported that scrap tires possess many properties that may offer opportunities in material recycling sectors [1]. Though, 89% of total scrap tires generated in 2001 are reused/recycled in Japan, material recycling is limited by 19%, as shown in Fig.1 [2]. In general, scrap tire materials are lighter, resilient, water-proof, insulating, durable, etc., and such properties are recognized as beneficial to many civil engineering projects [3]. This concept is, however, new in Japan, but believed to be relevant due to geological/geographical positions. Consequently, research work is initiated to explore the possibility of use of scrap tire shreds as lightweight geomaterials in civil engineering applications with respect to Japanese context.

A few report on the engineering properties of scrap tire rubber chips of size range 2~15mm, and with no steel/textile cords included in the rubber, was published elsewhere [4, 5]. However, tests on tire shreds having intact steel/textile cords, and also size scale-up are necessary for streamlining research towards in-situ applications. An attempt has been made in this study to evaluate the mechanical behavior of steel/textile cords included scrap tire shreds of sizes 30~50mm by conducting large scale triaxial tests, and discuss the results with respect to their use as lightweight geomaterials.

2. Experimental Procedure: Triaxial compression tests on segmented scrap tire shreds were carried out using a large triaxial cell measuring 300 mm in diameter and 600 mm in height. Whole scrap tires were reduced to shreds of size range 30~50mm by using a segmitizer. As shown in Fig.2, the shreds are almost flat and square, and contain steel/textile cords in it. Protruded steel cords were grinded off up to a little deep inside from the segmented surfaces before placing them in a mold for preparing triaxial specimen. This measure was taken to reduce the chance of puncturing rubber sleeve in the triaxial specimen by those protruded steel cords. It is interesting to note here that for other research reported elsewhere [4, 5], steel/textiles were removed from scrap tires before preparing rubber only granulated materials for testing.

In a separate trial, compacted density of segmented scrap tire shreds in the specimen was reached to a maximum value of 0.785g/cc, and consequently, this compaction density was maintained for all the triaxial specimens. Tests were carried out in consolidated-drained (CD) conditions under four levels of confining pressures (σ_r) namely, 0.1, 0.3, 0.5 and 0.7 MPa. The compression rate was maintained at a rate of 0.5%/min. The load-compression behaviors were recorded for up to a level of 25% strain or above. The load-paths were also recorded during tensioning of the specimens (case of σ_r=0.5MPa is not included as it was abandoned during halfway of the experiment).

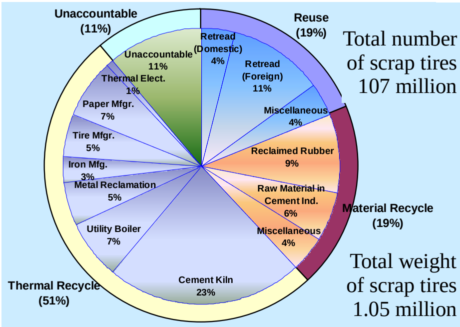

Fig.1 Scrap tires market in 2001.

Fig.2 Segmented scrap tire shreds.

3. Results and Discussion: Proper care was taken to prepare densely packed triaxial specimens using segmented scrap tire shreds. With the application of confining pressure, however, a significant amount of compression in the specimen was observed which is depictive through drained-out water shown in Fig.3. The drain-out of water is, however, got stabilized at only about 10 minutes which may be an indicative of good drainage behavior of scrap tire shreds material.

Key Words: scrap tires, lightweight geomaterials, triaxial compression test.

Corresponding Addresses: Ashoke K. Karmokar, and Hideo Takeichi, Bridgestone Corporation, 3-1-1 Ogawahigashi cho, Kodaira shi, Tokyo 187-8531; Kazuya Yasuhara, Ibaraki University, 4-12-1 Nakanarusawa, Hitachi shi, Ibaraki 316-8511; Hiroyuki Kawai, Toa Corporation, 1-3 Anzen cho, Tsurumi ku, Yokohama shi, Kanagawa 230-0035.

Results of compressive stress vs. compressive strain under four different confining pressures are shown in Fig.4. Volumetric strains of the triaxial specimens during experiment are also shown in the same plot. Unlike many common geomaterials, rubber materials are generally acknowledged as possessing good response to tension and compression. Consequently, loading paths during tensioning of triaxial specimens were also recorded and shown in the plot.

As evident, scrap tire rubber materials show unique stress-strain behavior. No peak was observed with in the range of strain we measured (ε≥25%). This behavior may believed to be different than the conventionally used geomaterials, and in fact, such trends were also observed with rubber grain specimens [4]. The increase of confining pressure increases the compressive stress. However, the levels of volumetric strain are quite close during experiment. This is in contrast to the result of volume change under confining pressure (consolidation) as shown in Fig.3. Therefore, it may be believed that once primary consolidation of tire shreds is properly done during installation, secondary consolidation of tire shreds material under additional operating loads is quite unlikely. This phenomenon with tire shred materials was also reported elsewhere [3]. In general, tire rubber is considered as a material possessing constant volumetric characteristics. Consequently, the changes in volume of triaxial specimen due to confining pressure could be regarded as apparent one, which may occur from changes in the shape of tire shreds for covering up voids in the triaxial specimen.

Figure 5 shows the Mohr circles of scrap tire rubber shreds for 15% and 25% strain levels. For comparison, results of rubber grain with size range 2~3mm, as reported elsewhere [4], are also shown. Segmented tire shreds show better failure envelope than rubber grains. As segmented tire shreds contain steel/textile cords in it, local reinforcement of rubbers by steel/textile cords are likely to occur which in turn exerts better resistance against deformation. This effect of local rubber reinforcement is also added-up by the size scale-up effect (large sized shreds). A model test to observe the change in shape of rubber particles is reported elsewhere [5].

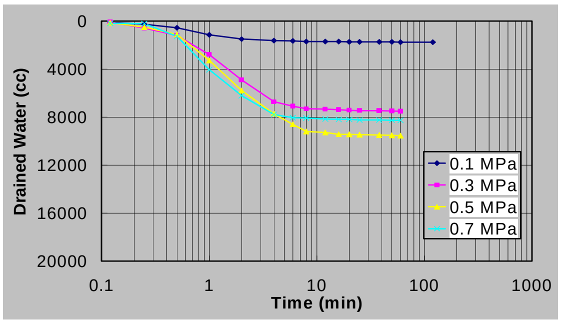

Fig.3 Confining pressure related consolidation.

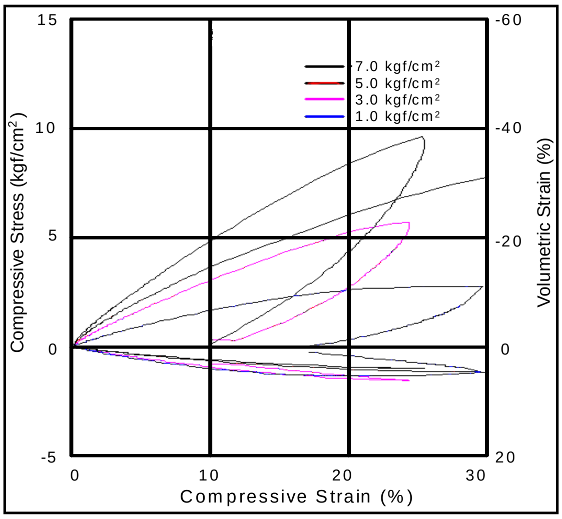

Fig.4 Triaxial test results of scrap tire shreds.

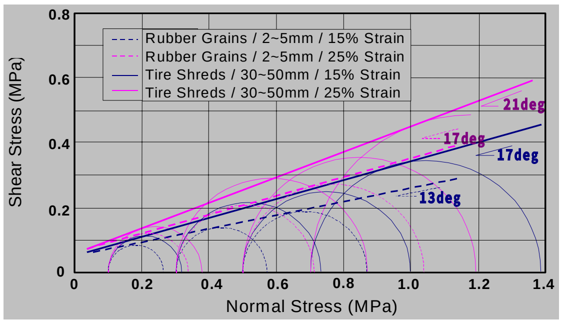

Fig.5 Mohr circles of scrap tire grains/shreds.

4. Summary: Large scale triaxial tests has been carried out on segmented scrap tire shreds for exploring the possibility of their use as lightweight geomaterials in civil engineering applications. Local reinforcement of individual rubber shreds due to presence of steel/textile cords provide resistance against deformation of shred under loading, which in turn causes higher stress levels in the triaxial tests. Result of volumetric strain indicates that once primary consolidation of tire shred materials is done properly during installation stage, secondary consolidation of the tire shred materials under additional operative loading is unlikely. It is essential, therefore, proper care be taken in the primary consolidation process.

References:

1. STMC, "Scrap Tire Use/Disposal Study," Scrap Tire Management Council, Washington, DC 20005, USA, 1997.
2. JATMA/JTRA, “Tyre Recycling Handbook,” Japan Automobile Tire Manufacturers Association & Japan Tire Recycle Association, Tokyo 105-0001, Japan, 2001.
3. Humphrey, D.N., and Manion, W.P., “Properties of tire chips for lightweight fill,” Grouting, Soil Improvement, and Geosynthetics, ASCE, Vol. 2, pp. 1344-1355, 1992.
4. Karmokar, A.K., Takeichi, H., Yasuhara, K., "Triaxial compression tests on granulated scrap tire rubber for their use as lightweight geomaterials," Proc. Intl. Workshop on LGM, Tokyo, Japan, pp.127-134, 2002.
5. Karmokar, A.K., Takeichi, H., Yasuhara, K., "Compression tests on scrap tire rubber grains for their use as lightweight geomaterials," Proc. JGS Annual Symp. #37, Osaka, Japan, 2002.