Ageing and durability of used tire rubber materials embedded in cement treated soil for their use in civil engineering applications

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1. Introduction: Thought an estimated 87% of the annually generated 103 millions of scrap tires in Japan for 2003 are reused and/or recycled, the share in material recycling sector is constituted by 16% [1]. It is reported that used tires possess properties e.g., lighter, resilient, water-proof, insulating, durable, etc., and such properties are recognized as beneficial to many civil engineering projects [2]. However, this concept is new in Japan, but believed to be relevant due to geological/geographical positions. In this direction, a research project is initiated to explore the possibility of use of scrap tires in civil engineering applications. A few reports on the engineering properties of scrap tire materials are published elsewhere [3,4]. In this study, an attempt is made to evaluate the durability of used tire materials for their acceptance in civil engineering applications. For this purpose, ageing on used tire rubber sheets are performed at first by embedding them in the cement treated soil and then cyclic/tensile tests are conducted for durability evaluation.

2. Experimental Procedure: Cyclic and tensile tests were carried out for highlighting differences in properties, if any, among virgin and aged tire rubbers. For preparing samples, tread parts of used tires were collected and sliced by using a rubber slicing machine for obtaining 2mm thick sheets (Fig.1a). As for the control specimens, new tire rubber sheets were also made. The sliced sheets were then embedded in cement treated soil-mass (q_u~400 kN/m^2) for ageing (Fig.1b). All together two new tire rubber samples (N1, N2) and five used tire rubber samples (S1, S2, S3, S4, S5) are selected for this study. Ageing were performed under controlled laboratory atmosphere (65%RH, 20°C) for duration, viz., 50, 100, 250, and 500 days time in embedment. After the stipulated ageing time, rubber sheets were taken out from the embedment, and dumbbell-shaped specimens were punched out from these sheets (Fig.1c). Cyclic tests were conducted at a strain rate of 100mm/min for 5 cycles and maintained for up to 100% strain level. Tensile tests were performed according to JIS K 6251 test method (Fig.1d).

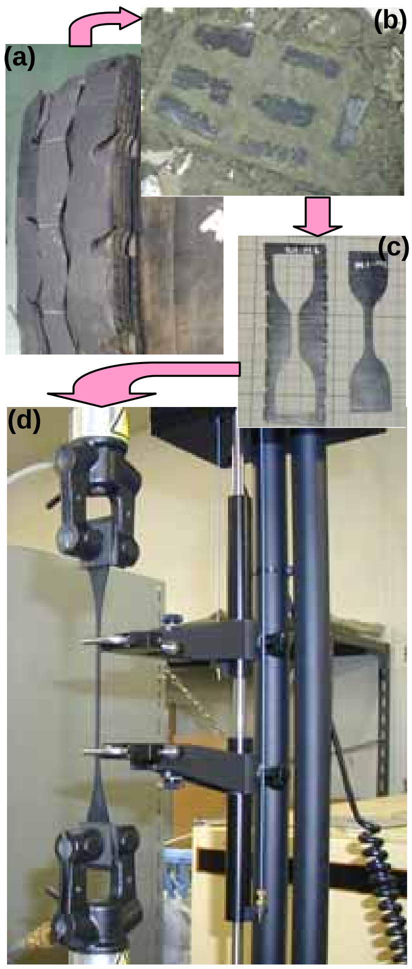

Fig.1 Sample preparation and testing; (a) used tire rubber sheets, (b) ageing in cement treated soil, (c) punching of specimen, (d) cyclic/tensile testing.

3. Results and Discussion: A representative stress-strain paths obtained in cyclic testing are depicted in Fig.2a. As evident, the path stressed in the first cycle is different than those of rest of the cycles. It is essential to mention that this kind of characteristics is inherent to vulcanized rubbers from which actually tires are made. A piece of filled vulcanized rubber under cyclic loading and unloading typically displays pronounced stress softening which is known as Mullins effect [5]. After the first cycle the load is lowered most, but only a small change is observed in the next cycles. Additional to Mullins effect, other pronounced effect that occurs in cyclic loading is the phenomenon of residual strain. In particular, the shape of the rubber after unloading differs from its virgin shape due to residual strains. Nearly all engineering rubbers exhibit some degree of Mullins effect and residual strain. As such, the virgin tire rubber material is isotropic, but when strained it becomes a little anisotropic in nature.

Key Words: used tires, rubber durability, cyclic/tensile test.
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Values of softened-stress and retained-strain between 1st and 5th cycles for rubber samples are shown in Fig. 2b, 2c respectively. The values are normalized by considering the non-aged tire rubber value as 100% in the plots. As evident, new and used tire rubber samples show good range similarities in both stress-softening and strain-retaining levels. The selected tire rubber samples were from different brands that most likely made with different rubber compositions. Similarly, origin, brand, process history, service life, etc., for the selected used tire sections were unknown, and there is a high probability that used tire sections are different from new tire sections, and/or also among themselves. Thus, variations in the properties of new and used tire rubber samples, if one thinks of any in the plots, may more likely be logical phenomena.

Results of stress-strain behavior for sample S1 are shown in Fig.3a. As evident, sample shows high elongation at failure even after ageing. It is essential to mention that other samples tested show more or less similar failure strain levels (300%~500%). The stress-strain paths traced are in good matching irrespective of the ageing of specimens which strongly advocates that ageing in the cement treated soil (alkaline environment) does not deteriorate rubber quality. The trends of tensile behavior are non-linear in nature that may be advantageous in many civil engineering applications. The values of Young's moduli at 50% and 300% strain are shown in Fig3b, 3c respectively. With respect to the non-aged tire rubber specimens (rated 100 for normalization), aged specimens from all the samples show a well acceptable range of moduli values.

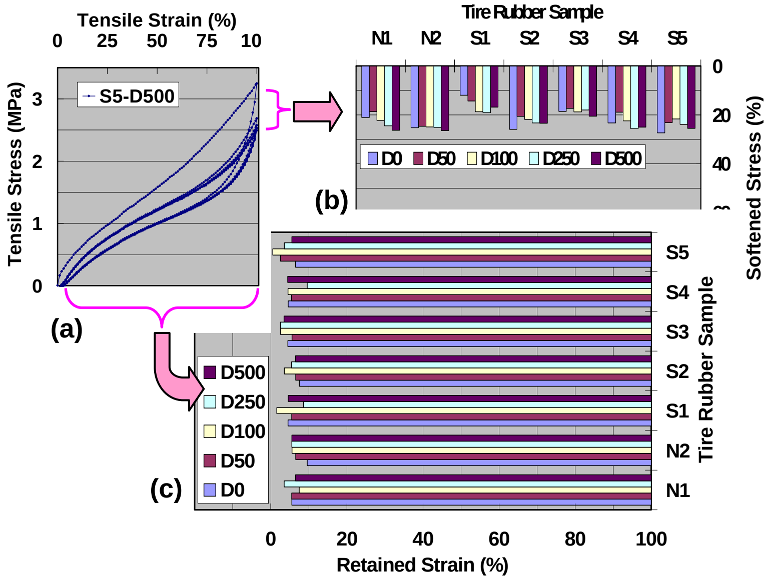

Fig.2 Stress-strain behavior in cyclic testing; (a) stress-strain path, (b) stress-softening levels, (c) retained strain levels.

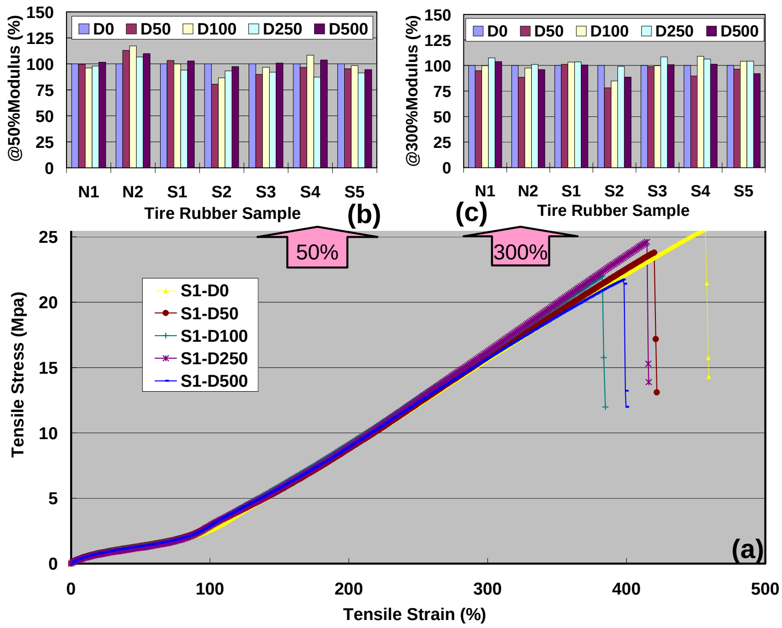

Fig.3 Stress-strain behavior in tensile testing; (a) stress-strain paths for sample S1, (b) modulus at 50% strain, (c) modulus at 300% strain.

4. Summary: The present study is aimed at addressing the durability of used tire rubber materials for their use in civil engineering applications. Towards this direction, ageing of tire rubber materials are performed by embedding them in cement treated soil, and then cyclic/tensile tests are performed to evaluate changes, if any, in rubber properties. Based on this study, it may be said that the used tire rubber is durable even after longer in-situ ageing period, and consequently competent enough for use with cement or likely media in many civil engineering applications.

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