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**Technical Note**

# An investigation on its microstructure of the concrete containing waste vehicle tire

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## 1. Introduction

The scanning electron microscope (SEM) is one of the most important instruments available for the examination and analysis of microstructural characteristics of materials. The primary reason for the SEM's advantage is the high resolution that can be obtained when they are examined. The electron microscope has been a powerful tool in the examination of cement and concrete since the early development of them. Microscope was particularly first used to study the hydration process of concrete (Nemati 1997). Then, researchers used the SEM to observe the crack growth and fracture surfaces on the loaded or fractured concrete samples (Diamond and Mindess 1998, Glezie, *et al.* 2003).

Concrete is a heterogeneous multiphase material. On a macroscopic scale, it is a mixture of cement paste and fine and coarse aggregates, with a range of sizes and shapes. With regard to its mechanical behavior, concrete is often considered to be a three-phase composite structure, consisting of aggregate particles, the cement paste matrix in which they are dispersed, and the interfacial transition zone (ITZ) around the aggregate particles and cement paste (Nemati 2000).

In some applications of concrete, it is demanded that concrete should have low unit weight, high strength, high toughness and high impact resistance. Although concrete is the most commonly used construction material, it does not always fulfill these requirements. One of the ways to improve these properties might be the addition of the rubber into concrete as an aggregate. For this purpose, the usage of some industrial waste materials in concrete has been investigated during the past few years (Topcu 1997, Khatib and bayomy 1999).

The objectives of this study are to evaluate morphologies of the crack surface and characteristics of rubberized concrete of ITZ between rubber tires and cement paste and traditional aggregate and therefore, to obtain a preliminary understanding of the interfacial bond between them.

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## 2. Experimental procedure

The materials used in this study were fine aggregate, coarse aggregate, shredded rubber obtained from waste tires and cement. Fine crumb rubber and coarse crumb rubber replacing fine aggregate and coarse aggregate, respectively, were used to prepare the concrete of this study. Hybrid designs of the concrete and specific gravities of mix materials are considered in the calculations of properties.

Two groups of rubberized concrete mixtures were prepared;

- ILB; the concrete in which certain percentages of fine rubber are replaced with fine aggregate
- KLB; the concrete in which certain percentages of coarse rubber are replaced with coarse aggregate

Water/Binder ratio (0.55) and cement content (418 kg/m$^3$) were kept constant in all samples. Four designated rubber contents were selected 5%, 10%, 15% and 20% by volume of total aggregate. To unify the rubber content, the range of rubber content was selected as total aggregate volume of plain concrete. Total 54 cube test specimens, $\Phi$150×300 mm, were prepared for compressive strength, split tensile strength and unit weight tests.

Some of the test results such as compressive strength, split tensile strength and unit weight of plain and rubberized concretes are listed in Table 1.

SEM analysis was carried out in this study to examine the fracture and bond characteristics of rubber reinforced concrete. The SEM samples were collected from the fracture areas after the compressive strength tests. All samples chosen for the SEM analysis were coated with silver/gold for electrical conduction.

## 3. Experimental results and discussion

The rubberized concrete has to confirm certain requirements for mechanical properties. They are particularly compressive and split tensile strengths. Although these values are considerably decrease with the addition of waste tire pieces, their values are still in reasonable range. After the concrete samples were selected for SEM studies, images were taken from each sample. A total of four samples taken from center and edge of the concrete cylinders in axial direction were studied. Fig. 1 shows the SEM image of normal concrete. It is clear that morphology of C-S-H gel appears as type III (denser-almost sphere) in the conventional concrete.

In the rubberized concrete, it is obvious that no interface bonding between cement paste and rubber tire has been maintained. An example of poor adhesion between them is shown in Fig. 2. Without an interface bonding, stress transfer between fibers and cement paste is possible owing to a

Table 1 Mechanical properties of rubberized concrete (28 days)

| Properites | Concrete without rubber | 5% | | 10% | | 15% | | 20% | |
|---|---|---|---|---|---|---|---|---|---|
| | | ILB | KLB | ILB | KLB | ILB | KLB | ILB | KLB |
| Compressive Strength (MPa) | 45.69 | 41.71 | 42.49 | 33.69 | 37.30 | 24.75 | 26.96 | 22.14 | 23.91 |
| Split Tensile Strength (MPa) | 4.191 | 3.087 | 3.741 | 2.928 | 3.141 | 2.622 | 2.676 | 2.346 | 2.238 |
| Unit Weight (kg/m$^3$) | 2258 | 2190 | 2190 | 2120 | 2120 | 2050 | 2050 | 1980 | 1980 |

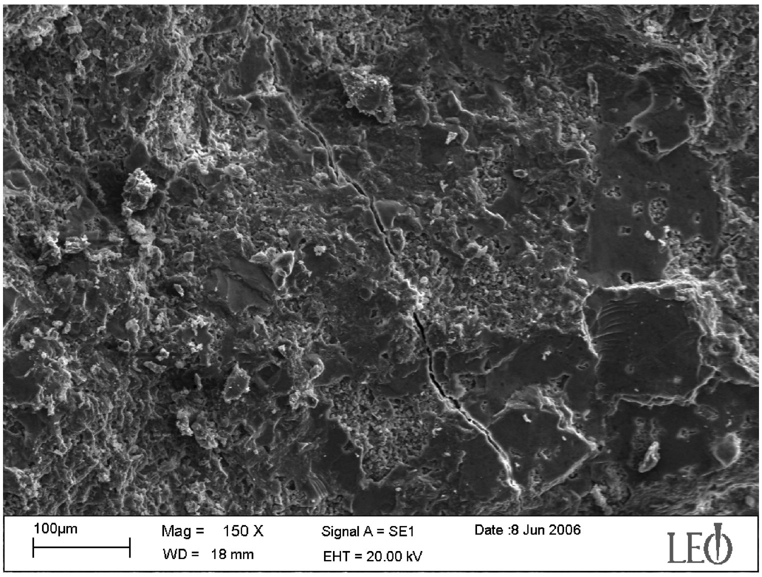


Fig. 1 A SEM picture of fractured surface of control specimen

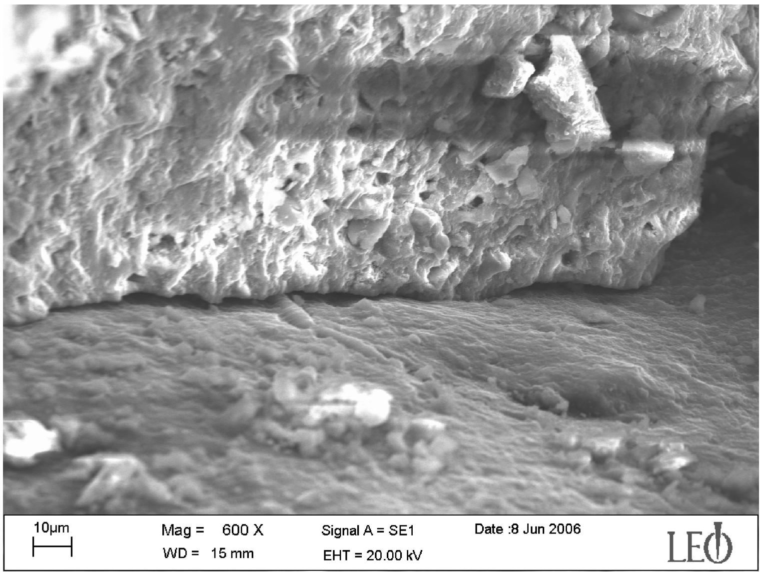


Fig. 2 ITZ between rubber and cement

mechanical interlocking. Seperation or breaking of the rubber was not oftenly observed on the fracture surface and generally the rubber appeared on the fracture surface was in the pulled out form. No transition layer, or even trace of patch of tire material adhering to the interface, was observed. This suggests that the interfacial bonding strength is weak. Fig. 3 shows an example of pulled out a piece of rubber tire. As the rubber tires were being mixed, the hard particles of mix impacted and abraded the rubber surface as well as chopping procedure, causing deformation and so intrusions and extrusions. Grooves and pits also on the surface of the rubber tire fibers, due to its

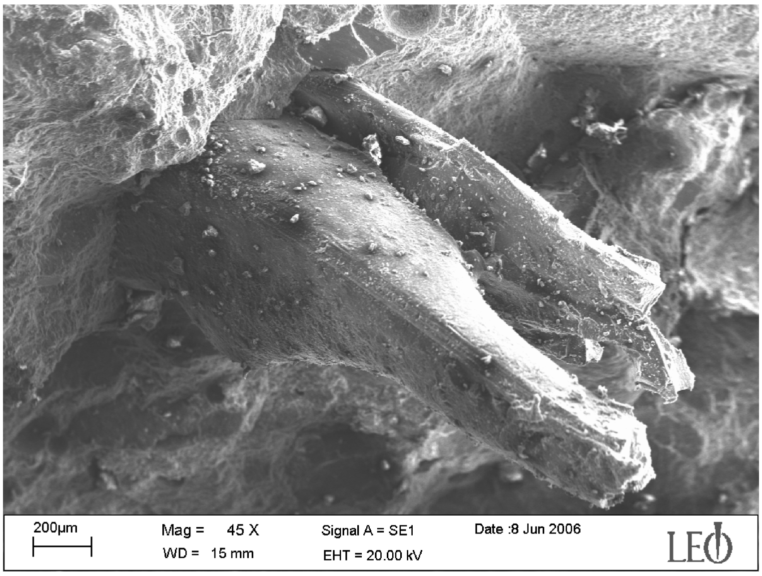


Fig. 3 SEM image of pulled out rubber tire

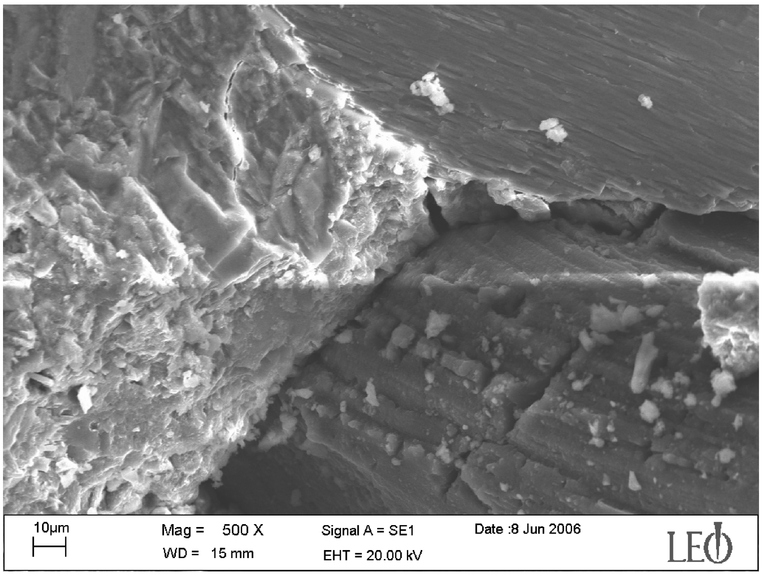


Fig. 4 An image of ITZ between rubber tire, aggregate and cement paste

chopped form, the paste and rubber tightly matched. Therefore, strong mechanical interlocking has been established and no dramatic drop on the bending strength is recorded for a certain volume fraction of rubber tire.

Interface structure of three components, cement paste and aggregate and rubber tire, is shown in Fig. 4. A strong interface bonding between cement paste and aggregate is established but weak interface bonding between rubber tire and aggregate and cement paste is obvious from the picture.

The SEM images of rubberized concrete showed that cracks generated from voids between rubber

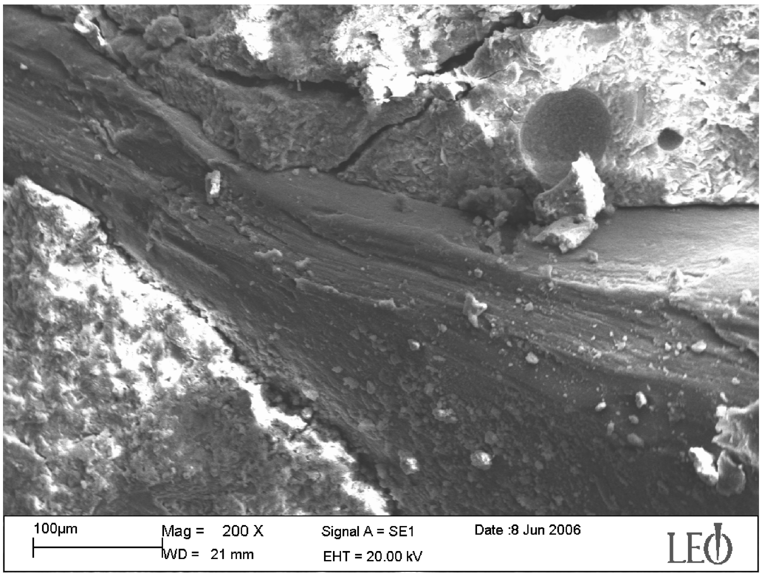


Fig. 5 Scanning electron microscopy picture of rubberized concrete

tire and cement paste in the concrete. Fig. 5 shows a micrograph of microcracks generated from ITZ between rubber tires and cement paste. It was found that these cracks usually start from ITZ between rubber tires and cement paste because of poor bonding characteristic around rubber tires and cement paste. There are a lot of microcracks near ITZ in rubberized concrete. These microcracks seem clearly in Fig. 5.

In rubberized concrete, crack formation is different from plain concrete because bond strength between rubber and cement paste is poor than that of between aggregate and cement paste. Therefore initial cracks were formed around rubber tires and cement paste in rubberized concrete.

## 4. Conclusions

An experimental procedure was conducted which enabled the preservation of the compressive stress-induced microcracks and bonding characteristic in ITZ of rubberized concrete under applied load. Compressive strength and split tensile strength of the rubberized concrete is lower than traditional concrete because bond strength between cement paste and rubber tire particles is poor. Besides, pore structures in rubberized concretes are much more than traditional concrete.

Based on this study, the following conclusions can be said.

1. The ITZ characteristic of rubberized concrete is poor than the traditional concrete. Additionally, strength of a tire rubber is lower than that of traditional aggregate Due to these facts, compressive strength and split tensile strength of rubberized concrete is less than plain concrete.

2. There is systematic reduction in strength data with the increasing of the rubber content in traditional concrete. These reductions are related with the poor bonding characteristic between rubbers and cement paste around the ITZ of rubberized concrete.

3. Although adhesion between the rubber and cement paste was weak, roughening interface is formed and it constructed a mechanical interlock which resisted relative movement of fibers

immediately after cracks initiated.

4. C-S-H morphologies of normal and rubberized concrete are same. From the SEM images, the addition of waste tire rubber in normal concrete has not any harmful effect on the C-S-H formation in concrete.

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