Cement based floors with rubber addition

N. Quaranta, M. Caligaris, H. López & M. Regondi
Universidad Tecnológica Nacional,
Facultad Regional San Nicolás, Argentina

Abstract

In the present work, the characteristics of different cement based floors with the addition of a great amount of granular rubber, 16% in volume approximately, are studied.

During the three years that the experience went on, the samples were subjected to temperatures conditions varying between 43 °C and -2°C, to several episodes of strong wind and intense rain and to continuous crossing.

The samples were characterized by optical microscopy, scanning electron microscopy (SEM), electron diffraction analysis X-ray (EDAX), porosity and Vickers microhardness measurements.

The obtained results set up this application as an important tool for using this waste material which is nowadays disposed in landfills in Argentina.

Keywords: cement floor, rubber, scrap tires.

1 Introduction

The objective of reusing the rubber from scrap tires is to avoid the serious problem that its accumulation produces. These wastes occupy much space in the landfill in which they are disposed.

The rubber dust is used in several applications such as sports field drainage, race courses, road pavement improvement, among others. There exists a great advance in using rubber for plastic material products such as shoe soles, coating plates, and accessories for the automobile industry, but it is usually needed a grinding process and the removal of components as cloth or metal that comes from tire talons, increasing the costs of final products.

Mixing rubber with bitumen and asphalt filling is other important application [1, 2]. In this way, it can be used as binding material or as sealer layer in which case it is called asphalt rubber, or simply as a filling material, without interacting
with other mixture components in which case it is called concrete or cement containing rubber.

Rubber addition to high-strength concrete was studied by F. Hernández and Barluenga [3], in order to reduce the risk of explosive spalling at high temperatures. Their results show that the temperatures reached of fire-tested specimens were reduced as the percentage of rubber was increased.

Siddique and Naik [4] present an overview of some of the research published regarding the use of scrap-tires in portland cement concrete. Disposal of tires has become one of the serious environmental problems and in the last years land filling is becoming unacceptable because of the rapid depletion of available sites for waste disposal, and for other potential problems like toxic emissions in the case of fire hazards, and vermin, rats and mosquitoes presence that find in used tires their breeding grounds. As reported by the authors the promising options are: i) use of tire rubber in asphalt concrete mixtures, ii) incineration of tires for production of steam, iii) reuse of ground tire rubber in a number of plastic and rubber products, and iv) use tires as a fuel for cement kiln and as feedstock for making carbon black.

The objective of the present work is to study the characteristics of different cement based floors with the addition of a great amount of granular rubber, 16% in volume approximately. The behavior of these materials after three years subject to inclemency and regular use is analyzed.

2 Experimental

2.1 Samples preparation

The scrap tires were treated with a reduction process in order to obtain small size particles with adequate characteristics to be incorporated to cement based floors. The tires were cut into pieces of 6 by 10 cm, approximately, from the tread zone, discarding those parts corresponding to the steel belts. These pieces were put into a kiln at 280 °C during 2 hours, to weaken them for making easier their subsequent grinding. The powders obtained after grinding had particle sizes smaller than 0.85 mm. They are composed by granular rubber and textile fiber particles coming from the reinforcement, as can be seen in Figure 1.

Four different mixtures were prepared. From now onwards they are identified as: Ce2, Ce2Ru, Ce1, and Ce1Ru. All of them contain six parts of sand. The mixtures identified with Ce2 have two parts of cement, and those with Ce1 have one part of cement and one of lime. Ru in the names indicates one and a half part of rubber in the mixture. Samples without rubber were prepared using the powders with the addition of 20% H2O and the ones containing rubber with the addition of 25% H2O.

Probes to be used as a reference of these materials were prepared in molds of 15 cm x 10 cm x 4 cm, keeping the denomination of the mixtures. In order to observe the resistance of the floor to regular use, that is continuous walker crossing, and real meteorological conditions, other probes were also made. With this aim sectors of 50 cm x 50 cm of the different mixtures were incorporated
during the construction of the doorway of the San Nicolás Regional Faculty, which constitutes the way in of the students. These sectors remained in use during three years. Figure 2 shows the location of the mentioned sectors in a frontal view of the building, and pieces of them after their removal.

Figure 1: Rubber and textile fiber particles obtained after grinding.

Figure 2: (a) Frontal view of faculty building. (b) Pieces of removed sectors.

Once the floor probes were removed they were analyzed, together with reference samples without use, with traditional techniques. The used samples are identified as the corresponding mixture, with a preceding $U$. 
2.2 Samples characterization

The samples were characterized by optical microscopy, scanning electron microscopy (SEM), electron diffraction analysis X-ray (EDAX), porosity, and Vickers microhardness measurements.

**Porosity measurements**: These determinations were carried out by Archimedes method, according to national standard for bricks.

**Microhardness measurements**: The hardness analyses were made with a Vickers indenter in an HMV-2000 Shimatzu equipment using loads of 300 g during 10 sec.

**Microscopic analysis**: The samples were observed by optical and scanning electron microscopies. The optical observations were made with a Metalloplan Leitz microscope. The SEM analysis was carried out through a Phillips 515 scanning electronic microscope with an X-ray detector.

3 Results and discussion

3.1 Surface characteristics

During the three years that the experience went on, the samples were subjected to temperatures conditions varying between 43°C and −2°C, to several episodes of strong wind and intense rain and to the continuous crossing, because during the analyzed period they were put in the only entrance for students. Surfaces without fissures or material shelling, with rubber particles still held in the structure were observed. Higher surface roughness in samples with rubber addition was determined. The rubber particles have a tendency to accumulate at the surface areas making the samples look dark.

Though structural differences characteristic of the different mixtures composition were found, similar behavior in materials with and without rubber were observed.

3.2 Workability and shrinkage

At mortar production moment the mixtures incorporating rubber particles achieved workabilities comparable to the others used as a comparative materials without rubber shreds. Some authors [5] mentioned that at rubber contents of 40% the concrete resulted not workable manually. This percentage is very high in relation to the used in this work, approximately 16%.

The observations of the reference samples suggest that the incorporation of rubber particles help in reducing shrinkage and the production of cracks. The probes without rubber, Ce2 and Ce1, presented volume shrinkages of about 6% and 5% respectively, while the specimens containing rubber particles, Ce2Ru and Ce1Ru, both showed volume shrinkages of about 3%.

The samples without rubber developed cracks having an average width of about 0.5 mm, while the rubber-probes have average crack widths of about 0.2-0.3 mm. In all cases the cracks density was smaller for rubbered samples.
3.3 Porosity

Figure 3 shows the results of the open porosity essays for samples with and without rubber addition, in reference and used samples. As can be seen the open porosities of the reference samples result higher than the used ones in all cases. Taking into account the same samples with and without addition of rubber, it is possible to note that the presence of rubber particles conduces to more porous materials. Samples porosity increases about 4%-8% owing to the rubber incorporation. This may be due to the higher air content in the rubber-concrete mixtures. The non-polar nature of rubber particles and their tendency to entrap air in their surfaces, added to the fact that these particles repel water [5, 6], increase the air contents in rubber-concrete mixtures, producing materials with higher porosity.
3.4 Optical and scanning electron microscopies

The different phases present in the samples are clearly identified by SEM and EDAX techniques. Figure 4 shows a SEM photograph and the chemical analysis of each aggregate of the mixture which correspond to the more complex specimen which contain sand, lime, cement and rubber particles. Ca rich areas around sand grains in samples with lime addition were observed. It is possible to see the rubber shreds well incorporated into cementicous matrix in all samples, the ones with lime as well as without, but with some areas containing pores.

Figure 5: SEM photograph of Ce2 and UCe2 specimens.

Figure 6: Optical microphotographs of rubbered samples.

At the superficial level of used samples some rubber particles loosening were observed, while the internal structure of the specimen keeps intact. The lime added samples showed higher wear levels after the three years of use. The general superficial aspect of the used samples is similar. Loss of part of the cement and/or lime phases what allows sand grains become the resistant area of the samples, was seen. This superficial change was noted in all samples. Figure 5
shows SEM analysis made on samples Ce2 and UCe2 where this fact can be clearly observed.

By optical microscopy technique it was seen the internal structure of the samples with more details due to the different colors of the present phases, which allows confirming the kind of contact existing between them. Furthermore, it is possible to observe the mentioned fact in relation to the higher porosities of the samples which contain rubber addition. Figure 6 (a) shows rubber particles separated from the cement matrix by pores, and in the case of the bigger added shreds (about 0.85 mm) it is possible to observe pores into them, Figure 6 (b).

### 3.5 Vickers microhardness

Materials microhardness was measured in different areas of the samples because these are specimens which have heterogeneous zones due to their composition.

The microhardness values obtained on the different homogeneous areas, for example sand grains, cement, lime, etc., are slightly lower than the corresponding ones to the pure phases. Values about 570 kg/mm² for sand were measured. In this case, no cracks formation around the indent was observed. In cement and cement-lime matrix the determined average values were 240 kg/mm² and 350 kg/mm² respectively. It can be observed the trend of these phases to form cracks around the indents, but this tendency diminishes toward the areas around rubber particles, suggesting the rubber presence gives more toughness to the specimens.

### 4 Conclusions

Samples of cement based floors with the addition of rubber from scrap tires were studied obtaining very good results in real meteorological conditions resistance just as continuous walker crossing resistance during three years.

It is possible to incorporate an important percentage of rubber wastes coming from used tires, in the production process of the construction industry. Into the structural material the rubber particles were distributed in a homogeneous way and immersed into the cementiceous matrix. Though the rubber addition increases the samples porosities, their behaviour during use was not altered.

Tire rubber could be used in applications that demand concrete properties which could reduce the disposal of used tires to a large extent.

The obtained results set up this application as an important tool for using this waste material which is nowadays disposed in landfills in Argentina.

Researches about process variables are required to optimize the characteristics of these rubbered materials, such as rubber particle size, percentage of rubber, type of cement, use of chemical and mineral additives, pretreatment of rubber shreds, etc.

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References


