Abstract

Durability and *sustainability* of cementitious materials are two important issues in the field of construction materials. Durability is defined as the ability of cementitious materials to resist weathering action, chemical attack, abrasion or any other process of deterioration. The use of fibers is a viable solution to partially overcome the brittle behavior of such materials. At the same time it is demonstrated that fibers, by reducing cracking phenomena, allow to face the durability related issues. Different fibers have been used according to the aims of composite materials: high strength fibers are generally used for structural purposes (toughness increase) while low modulus synthetic fibers are mainly used to avoid plastic shrinkage cracking. The effectiveness of fibers reinforcing action lies mainly on the fiber/matrix interactions. Three types of interactions can be recognized: i) physical and/or chemical adhesion; ii) friction and iii) mechanical anchorage induced by deformations on the fiber surface (e.g. crimps, hooks, twisted or deformed fibers in general). Sustainability can be identified according to the definition of sustainable development stated in 1987 by Brundtland et al.: "*the development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". Sustainable development should take into account economic growth, social equality and environmental protection. The construction industry involves all these fields: the main concerns are raw materials consumption and CO_2 emissions during cement production. Moreover, also the plastic production and disposal present several environmental issues. Once again, raw materials consumption and the speed with which these materials became waste.

Thus, seen the aforementioned drawbacks related to cementitious materials, this Ph.D. was aimed to study the possibility of using end-of-waste materials (i.e when waste ceases to be waste and becomes a secondary raw material) for the production of synthetic fibers and aggregates characterized by improved mechanical interactions with the cementitious matrix. To this extent, fibers and aggregates with a rough and porous surface, able to offer interlocking positions for the cementitious matrix, were produced in laboratory by melt extrusion-foaming process. Moreover, some chemical treatments (alkaline hydrolysis and sol-gel deposition of nano-silica) were performed on fibers, to improve chemical adhesion with the cement paste. Finally, taking into account the need for reducing the

consumption of raw materials, foamed fibers and aggregates were produced starting from a polymeric end-of-waste material made of a polyolefins blend (HDPE, LDPE and PP).

Alkaline hydrolysis promoted the creation of interlocking positions on fiber surface but the best behavior was recognized for fibers with nano-silica particles on the surface. In this case, a denser ITZ and a great amount of hydration products were observed by SEM investigations. Pull-out tests confirmed the better performances of treated fibers: a higher pull-out peak load was achieved and an increase of pull-out energy was evident.

Subsequently, a foam extrusion process was used to manufacture polymeric fibers (both virgin and recycled) with a rough surface, to improve mechanical friction with the cementitious matrix. Optimizing foaming agent quantity and processing parameters was possible to produce fibers having adequate surface texture and diameter to be used in fiber reinforced mortars. Although fiber reinforced mortars workability decreases at increasing fiber volume fraction, the results demonstrated that this happens to a lower extent for mortars containing foamed fibers. Fibers mechanical properties decreased at increasing fibers porosity but fiber reinforced mortars mechanical properties, flexural and compressive strength, were not influenced by fibers addition nor their morphology. The rougher surface gives rise to a better fiber/matrix adhesion, as confirmed by pull-out tests. Durability investigations on the fiber reinforced mortars reported good results for capillary water absorption, sulfate attack and plastic shrinkage cracking. In particular, fibers length and volume fraction are key parameters in controlling plastic shrinkage cracking. Moreover, mortar samples containing foamed fibers displayed a better control of shrinkage cracking: cracks opening was delayed and the improved fiber/matrix bond was able to reduce crack width, compared to mortars containing smooth fibers.

Finally, lightweight artificial aggregates (LWAs) were produced, starting from foamed strands. At increasing LWAs substitution, a sharp decrease of density was achieved. Also workability and mechanical properties decreased, but a more ductile behaviour was recognizable. Thermal conductivity and water vapor resistance were proportional to mortars density which obviously decreased at increasing natural sand substitutions. Moreover, the use of aggregates porosity as reservoir of internal curing water showed promising preliminary results.

In brief, the results of this study demonstrate that engineered fibers with improved fiber/matrix bond allow to optimize (i.e. to reduce) fibers volume fraction in cementitious mortars. Foamed fibers characteristics can be in turn optimized by changing the manufacturing process conditions. Benefits could be not only in the control of plastic shrinkage cracking but also in the workability of fresh mortars, mechanical strength and durability of the hardened composite. In addition, using end-of-waste materials a more sustainable product can be obtained. In particular, replacing natural aggregates with plastic aggregates, is possible to reduce raw materials consumption and improve mortar properties (mainly unit weight, thermal conductivity and water vapor permeability).