DURABILITY OF SYNTHETIC FIBERS IN FIBER-CEMENT BUILDING MATERIALS

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1. Introduction
Fiber-cement is a versatile building material used for roofing, cladding as well as interior panelling for private houses as well as for agricultural and industrial buildings. Since the early 1980's these materials have been produced using non-asbestos fibers, mainly according to the Hatscheck technology. Steamcured products, whose most important applications are for exterior and interior panelling, are reinforced by wood kraft pulp fibers. Air cured products used in roofing and panelling are reinforced by more expensive alkali-resistant synthetic fibers, among which polyvinylalcohol fibers (PVA), alkali-resistant glass fibers, polyacrylonitrile fibers and polypropylene (PP) fibers and nets. The most successful fiber in this technology has been, by far, the polyvinylalcohol fiber. Recently, we also introduced new types of polypropylene fibers. In the present work, we discuss recent results about the durability of the PVA and of the PP fibers in this application.

2. The role of fibers in fiber-cement
Unreinforced cement has low tensile and bending strengths, and is brittle. While steel bars are used in concrete as main reinforcement, thin cement based boards are reinforced by fibers. The reinforcement depends on stress transfer carried out by the interfacial bond between the fibers and cement. The micromechanical models by Li *et al* (1991) and Lin *et al* (1999) allow to calculate the crack bridging stress as an initial crack extends, by averaging the contributions of the fibres crossing the matrix crack plane. This model allows to predict strength and toughness of fiber-cement which are key properties determining its suitability for the intended uses.

3. The durability of polyvinylalcohol fibers
A multidisciplinary approach was followed (de Lhoneux *et al*, 2002a):

3.1. Degradation of fibers in alkaline solutions
The degradation of PVA fibers in hot cement saturated water was studied by the laboratories of Kuraray Co Ltd and of ETH. Although results from both laboratories differ to some extent, they indicate a decrease of tenacity and/or molecular weight after 6 months when the water temperature exceeds 40°C (ETH) or 60°C (Kuraray). At lower temperature (20°C), no measurable decrease of properties could be observed during the same period of time.

3.2. Simulation of the hygrothermal behaviour of fiber-cement slates
The numerical simulation of the moisture and temperature inside slates exposed to mid-European conditions was carried out using a calculation model which allows to predict heat and mass transfers in building products exposed to defined climatic conditions (Carmeliet and Roels 2001, Carmeliet and Roels 2002, Grunewald 1997). High moisture contents are mainly experienced during the winter, when the temperature is low. High temperatures (40-60°C) in the summer are accompanied by low moisture contents. The combination of high moisture content and high temperature causing a degradation of the fibers has a low probability to occur in the field. Additionally, carbonation of the cement matrix in the course of the weathering reduces alkalinity and thus pore water chemical aggressiveness.

3.3. Accelerated and natural weathering

Fiber-cement sheets were exposed to two types of accelerated ageing tests. No significant change in the properties of the fibres extracted from the fiber-cement could be measured after 1000 cycles wetting/drying in a CO_2 rich environment, and after 200 days exposure to hot water.
Fibers were extracted from slates and corrugated sheets aged for up to 18 years in Belgium and Switzerland. Here also, no significant changes could be observed in the physico-chemical properties of the fibers, hereby confirming the expectations based on the model of the hygrothermal properties and on accelerated weathering studies.

4. The durability of polypropylene fibers

4.1. Fiber development

The micromechanical model reveals that ordinary PP fibers do not efficiently reinforce cement mainly due to low frictional and chemical fiber-cement bonds. Should these be increased, excellent fiber-cement performances are predicted. By using the core/sheath bicomponent fiber spinning technology and by the application of suitable surface coatings, it was possible to optimize the physico-chemical properties of the fibers surface. This improved the fiber-cement interfacial bond, as evidenced by fiber pull out test results and by the fiber-cement mechanical properties (de Lhoneux *et al* 2002b).

4.2. Durability

Previous studies by Hannant (1998) about the long term properties of fiber-cement reinforced by PP nets showed a satisfactory durability of the reinforcement. Own results show that fiber-cement reinforced by ordinary PP fibers tend to have more microcracking than with PVA fibers, as expected from the models. However, no strength losses are observed in accelerated and natural weathering series, indicating that no significant degradation of the fibers themselve occur, similarly to PVA. Further durability studies are under way with the new types of fibers.

5. Conclusions

Thanks to the development of suitable synthetic fibers, durable non asbestos fiber-cement roofing materials have been produced for the past 20 years. On going developments in the fiber manufacturing can still further improve the properties and the range of applications of this building material.

6. References

Carmeliet J. & Roels, S. (2001) Determination of the isothermal moisture transport properties of porous building materials, *Journal of Thermal Envelope and Building Science* **24**: 183-210.

Carmeliet J. & Roels, S. (2002) Determination of the moisture capacity of porous building materials, *Journal of Thermal Envelope and Building Science*, in press.

de Lhoneux B., Akers, S., Alderweireldt, L., Amiya S., Carmeliet, J., Hikasa J., Saenen W., Studinka J., Tomka I. & Vanden Bosch M. (2002a) Durability study of PVA fibres in fibre-cement products. *Proc. IVth Int. Symp. Concrete for a sustainable agriculture* N. De Belie & B. Sonck (Eds), 275-284.

de Lhoneux B., Kalbskopf R., Kim P., Li V., Lin Z., Vidts D., Wang S., Wu H.C. (2002b) Development of high tenacity polypropylene fibres for cementitious composites. *Proc. JCI Int. Worsh. on ductile fiber reinforced cementitious composites*, Japan Concrete Institute, Tokyo, 121-131.

Grunewald , J. (1997) Diffusiver und konvektiver Stoff- und Energietransport in kapillarporöse Baustoffe, PhD Thesis TU Dresden, Germany.

Hannant D. (1998) Durability of polypropylene fibers in Portland cement-based composites: eighteen years of data, *cement and concrete research* **28**, 12, 1809-1817.

Li V., Wang Y. & Backer S. (1991) A micromechanical model of tension softening and bridging toughening of short random fiber reinforced brittle matrix composites, *J. Mech. Phys. Solids* **39**, 5, 607-625.

Lin Z., Kanda T. & Li V. (1999) On interface property characterization and performance of Fiber Reinforced Cementitious Composites *J. concrete Science and engineering* **1** 173-184.