EVALUATION OF A FLOCULATION DUAL SYSTEM AS A NOVEL ALTERNATIVE FOR FIBRE-CEMENT MANUFACTURE

LUIS MIGUEL, SANCHEZ; ANGELES, BLANCO; ELENA, FUENTE; CARLOS, NEGRO
Department of Chemical Engineering, Complutense University of Madrid, Avda. Complutense S/N, 28040, Spain

ABSTRACT

Flocculation has been a key issue for fibre cement manufacturing with a crucial effect on plant productivity since cellulose has been used to replace asbestos. This paper compares the behaviour of a flocculation dual system consisting on phenol-formaldehyde resin (PFR) and poly(ethylene oxide) (PEO) with anionic polyacrylamides (A-PAM) commonly used in this industry. Studies about the flocculation process and its effect on product properties were carried out. Results show that the proposed flocculation system induces larger but less stable flocs, improving product properties for all tried doses in comparison with the A-PAM of reference. Doses of PEO and PFR lower than A-PAM ones allowed to improve fibre-cement properties, water removal during pressing and even retention, without significant effects on drainage rate. As consequence, this dual system could be an alternative to the traditional single A-PAM system used on the most of the fibre cement mills if differences on flocculation are controlled.

KEYWORDS

Fibre-cement properties; flocculation; poly(ethylene-oxide); phenol formaldehyde resin; strength.

INTRODUCTION

Since the use of asbestos was forbidden in fibre-cement manufacture, they have been replaced by other fibres. Cellulose and polyvinyl alcohol fibres are the most extensively used nowadays because of the low cost and high availability of the cellulose and the good properties of the polyvinyl alcohol fibres (Hannant, 1995; Coutts, 2005). However, the natural affinity of these organic fibres for the minerals used in fibre-cement manufacture is quite lower than the one presented by the asbestos (Miller, 1988; Savastano et al., 2005).Therefore, the process requires the use of flocculants, the right selection of flocculant is crucial in the industrial process because of its effect on mineral fines retention, dewatering and formation and, as a consequence, on the overall efficiency of the machine (Negro et al., 2006a,b). Most work in this field has been carried out at mill sites and no too much public information is available in the references since flocculant optimization is considered, at this moment, as a competitive key issue for this industry. The most common flocculants used in the Hatcheck machines is the group of A-PAMs. Schultz et al. studied the effect of several flocculants on the aqueous suspensions of fibres and cement, observing that the highest drainage rate and flocculation grade were obtained with a high molecular weight A-PAM (Schultz et al., 1984). Recently, authors of this paper have developed a real-time methodology to study flocculation and flocs properties based on a focused beam reflectance measurement (FBRM) system (Negro et al., 2006a) showing and explaining that A-PAMs are the most suitable polyacrylamides to induce cement flocculation because of their interaction with Ca^{2+}. Furthermore, the influence of the molecular weight and the anionic charge of the A-PAMs on the flocculation behaviour of fibre cement suspensions and on the bending strength of the final product were studied (Negro et al., 2005a). Nevertheless, it has been observed that the carboxylic groups, which are present in fibres and in A-PAMs, can adversely affect cement hydration, reducing product strength (Miller and Moslemi, 1991; Negro et al., 2005a,b). Therefore new alternative flocculants are necessary, in the fibre cement industry, to improve machine runnability at the same time that product quality. This paper

addresses this issue, providing an alternative flocculation system to A-PAM formed by a dual system phenol-formaldehyde resin (PFR) and poly(ethylene oxide) (PEO). This system, novel for the fiber cement industry has been successfully applied in some paper companies, mainly in North America.

EXPERIMENTAL

The flocculation lab trials were carried out with 400 mL of a 5 wt % suspension of ASTM type II cement in water saturated with $Ca(OH)_2$. The behaviours of three flocculants were studied: two commercial A-PAMs (A-PAM 1 and A-PAM 2) whose molecular weight are $7.5x10^6$ and $6.3x10^6$ g/mol and anionic charge density is -0.6 and -1.6 meq/g, respectively; and a dual retention system formed by a commercial PFR and a high-molecular-weight non-ionic PEO with a molecular weight of $8x10^6$ g/mol. The flocculation process and the flocs properties were studied using a M500L focused beam reflectance measurement (FBRM) probe. This device is manufactured by Lasentec, Mettler Toledo, Seattle, USA. The FBRM technique provides the chord length distribution of the particles in the suspension in real time. From the chord length distribution it is possible to calculate different statistics such as the mean chord size. The detail methodology to study flocculation processes and floc properties and the principles of the measurements are described in previous papers (Blanco et al., 2002a,b).

To study the influence of the flocculant on fibre cement properties, 6 specimens were prepared at lab scale for each trial from a fibre-cement suspension representative of one of the main fiber-cement manufacture processes (Hannant, 1995), composed of *Pinus Radiata* unbleached Kraft fibers refined at 150 ºCSF (3.2% by mass), polyvinyl alcohol fibres (1.8%) and silica fume (6.5%) in a matrix of ASTM type II cement (88%). A-PAMs and the dual system formed by PFR and PEO were used as flocculants to manufacture fibre-cement specimens. Thickness, density and modulus of rupture tests were carried out, seven days after the specimen was prepared, following the EN 494 Standards.

RESULTS AND DISCUSSION

Full results are not described in this extended abstract focused only on main findings. To optimize the PFR/PEO dose ratio, flocculation was induced by adding different dosages of PFR and PEO. PEO was always added 60 s after the PFR addition, as this was found to be the optimum in a previous lab work. Different doses of A-PAM 1 and A-PAM 2 were also tried for comparison. Figure 1(a) shows the increase in the mean chord size obtained after adding the PEO or the A-PAMs calculated as the difference between the maximum mean chord size reached during flocculation and the initial mean chord size before flocculant addition. It increased with the PFR/PEO ratio and with flocculant dosage, but PFR/PEO ratios over 50 did not improve flocculation significantly. When PFR/PEO ratio was higher than 5, the mean chord size increment produced by the dual system was higher than the one induced by the polyacrylamides even with low PEO doses. Figure 1(b) shows the increase in the mean chord size obtained versus the PFR dosage. These results show that the phenolic resin determines the flocculation grade, which increases strongly with PFR doses lower than 250 g/t. It would be not worthwhile to use doses higher than this one because the same increment of PFR dosage produces a much lower enhancement of flocculation.

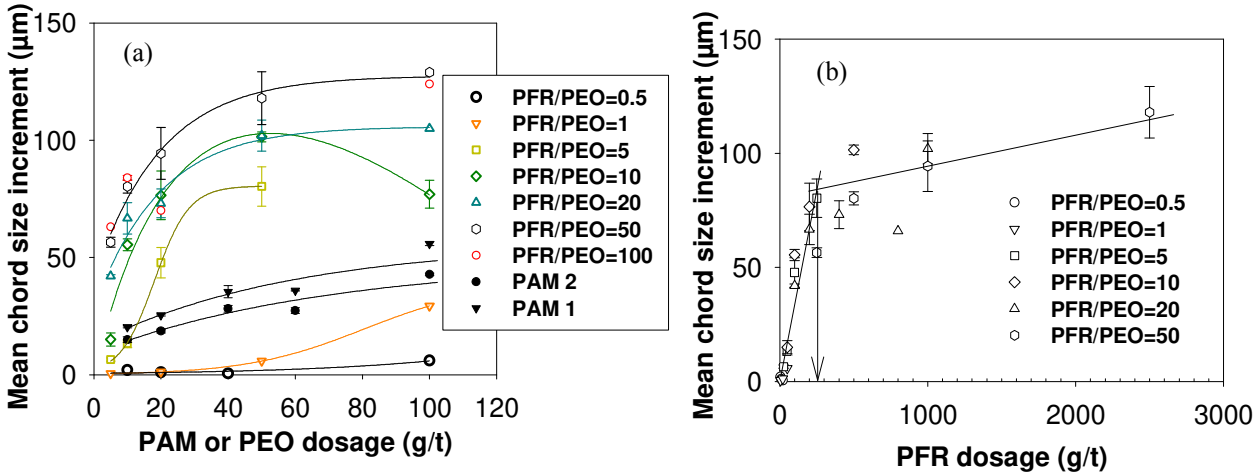

Figure 1 – Effect of PFR/PEO dosage ratio and dosages of flocculant on the maximum mean chord size increment during flocculation: (a) as function of A-PAM or PEO dosage; (b) as function of PFR dosage.

Figure 2 shows the evolution of the mean chord size after the addition of 10 g/t and 20 g/t of PAM or PEO with different PFR/PEO ratios. Flocculation was quite fast due to the bridge formation between particles, but flocs were not stable and they were almost completely broken after 300 s at 300 rpm. When the stirring intensity increased to 800 rpm, flocs were completely broken down, and they did not reflocculate after the stirring intensity was decreased. Flocs formed by addition of PFR/PEO system are less stable and reversibles as can be deduced from Figure 2. As consequence, industrial use of this system should be conditioned to the injection point selection. However, correct injection point selection could improve flocculation performance on Hatscheck machine. Figure 2 also shows that for relations PFR/PEO over 5, the average mean chord size is higher than the size achieved if flocculation is induced by A-PAMs.

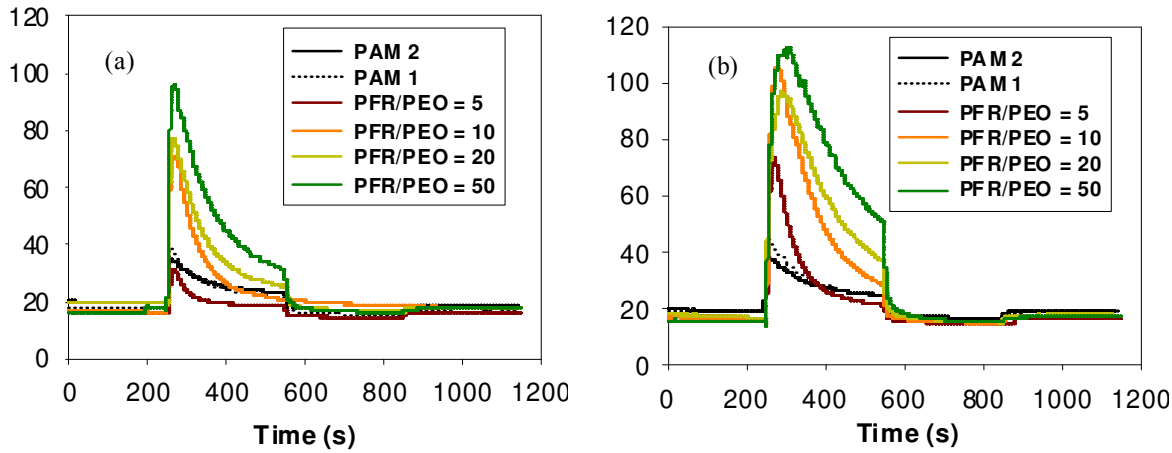

Figure 2 – Evolution of mean chord size during flocculation-deflocculation-reflocculation process with PAM and with different PFR/PEO ratios: (a) 10 g/t PEO or PAM; (b) 20 g/t PEO or PAM.

The modulus of rupture (MOR) also increase when the dual system was used instead of A-PAM, as it is observed in Figure 3. Although the MOR decreased with the dosage and with the PFR/PEO dosage ratio considerably, it was always higher than the value obtained with the A-PAMs. Figure 3 also shows the negative effect of PFR dosage on the MOR. This effect could be due to the phenolic groups present in the PFR as it was observed by several authors, who demonstrated the adverse effect of phenolic compounds on hydration of cement reactions (Miller, 1988; Miller and Moslemi, 1991).

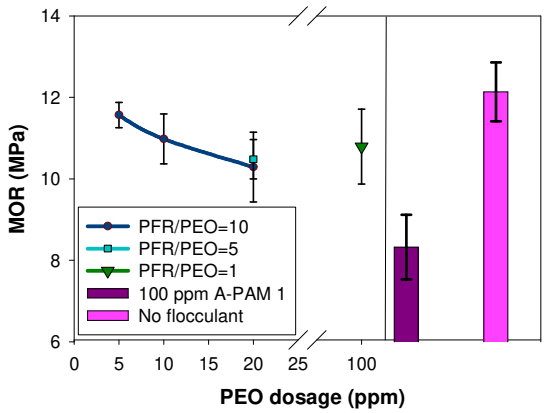

Figure 3 – Effect of PEO and PFR dosage on the module of rupture. Comparison with A-PAM1 and not flocculant used.

CONCLUSIONS

The evaluation of an alternative flocculation system (PFR/PEO) for fiber-cement composite manufacture has been carried out by comparing flocculation and effect on bending strength with the behaviour of traditional A-PAMs. Three flocculant tested induced the formation of flocs that could not reflocculate after decreasing stirring intensity, when they had been broken down by shear forces. Nevertheless, the dual system induced the formation of larger and less stable flocs, even with low PEO doses improving the strength of the fiber-cement specimens obtained in the lab comparing with A-PAM, and, therefore, it could also improve the strength of the fiber-cement product at the mill. As consequence of the results, this dual system could be a good alternative flocculation system for the fiber-cement industry because it could increase the product strength and improve the retention process without affecting the drainage rates notably.

DISEMINATION PLAN

The promise results obtained at lab scale have to be confirmed at industrial scale being this the next step planned for the future. The industrial trial will be performed with the chemical supplier and the fibre cement company.

The thesis will be defended in 2009, already two research papers with the preliminary data has been published in relevant magazines included on the SCI database and it is plan to send at least another paper on this field. The results are in line with IIBCC focus and we have the intention to present it at the conference.

REFERENCES

Blanco, A., Fuente, E., Negro, C. and Tijero, J. 2002a. "Flocculation monitoring: focused beam reflectance measurement as a measurement tool". Can. J. Chem. Eng. 80, 734–740.

Blanco, A., Fuente, E., Negro, C. and Tijero, J. 2002b. "Focused beam reflectant measurement as a tool to measure flocculation". Tappi J. 1, 14–20.

Coutts, R.S.P. 2005. "A review of Australian research into natural fibre cement composites". *Cem. Concr. Compos.,* 27(5), 518-526.

Hannant, D.J. 1995. "Fiber reinforcement in the cement and concrete industry – An Overview". Mater. Sci. Technol., 11, 853-861.

Miller, D.P. 1988. "Wood–cement composites: interactions of wood components with Portland cement". PhD Thesis, USA, University of Idaho.

Miller, D.P. and Moslemi, AA. 1991. "Wood-cement composites - effect of model compounds on hydration characteristics and tensile-strength". Wood Fiber Sci., 23(4), 472-482.

Negro, C., Blanco, A., Fuente, E., Sánchez, L.M. and Tijero, J. 2005a. "Influence of flocculant molecular weight and anionic charge on flocculation behaviour and on the manufacture of fibre cement composites by a Hatschek process". Cem. Concr. Res., 35, 2096-2104.

Negro, C., Sánchez, L.M., Fuente, E., Blanco, A. and Tijero, J. 2005b. "Effects of Flocculants and Sizing Agents on Bending Strength of Fiber Cement Composites". Cem. Concr. Res., 35, 2104-2109.

Negro, C., Blanco, A., Fuente, E., Sánchez, L.M. and Tijero, J. 2006a. "Polyacrylamide induced flocculation of a cement suspension". Chem. Eng. Sci., 61, 2522- 2532.

Negro, C., Blanco, A., San Pío, I. and Tijero, J. 2006b. "Methodology for Flocculant Selection in Fibre-cement Manufacture". Cem. Concr. Compos., 28(1), 90-96.

Savastano, H., Warden, P.G. and Coutts, R.S.P. 2005. "Microstructure and mechanical properties of waste fibre–cement composites". Cem. Concr. Compos., 27(5), 583-592.

Schultz, J., Papier, E. and Nardin, M. 1984. "Physicochemical aspects of the filtration of aqueous suspensions of fibers and cement. 6. Influence of flocculating agents on filtration efficiency". Ind. Eng. Chem. Res. Dev., 23(1), 93-98.