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RETENTION OF PRECIPITATED CALCIUM CARBONATE IN OLD CORRUGATED CONTAINER FURNISHES

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ABSTRACT

Filler is not traditionally used in liner board manufacture. However, there has been increasing research and mill experience showing that moderate use of filler in liner board is beneficial. For example, it has been reported that the addition of precipitated calcium carbonate (PCC) filler in recycled old corrugated container (OCC) furnish will improve the appearance and printability of the products and save fiber materials without a noticeable sacrifice of strength properties. It has also been reported that the stickies and wax will be less of a problem when PCC is used in OCC furnishes. Although PCC can be potentially a filler used for OCC, little research has been done on the PCC retention in this specific furnish. In this paper, PCC retention as well as fines retention in three different OCC furnishes were studied. Different retention systems, including cationic PAM, anionic PAM, microparticle and PFR/PEO were investigated. The results showed that PFR/PEO is the most effective retention system.

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INTRODUCTION

The use of recycled fibers has increased dramatically in recent years, and with the current environmental awareness and legislation, this trend is expected to continue. Among all the paper grades recycled, OCC is the largest secondary fiber source. It has been reported that 20.1 million tons of OCC was reused by the US paper industry in 1997 [1]. However, in addition to the common difficulties faced in the recycling industry, such as the high cost of recycling operations, low fiber yield and poor physical properties, residual stickies and wax in the recycled furnish are problems common to OCC use. In the United States, corrugated board is estimated to contain an average of 0.7% wax, and even after recycling, the average wax content in recycled OCC is still as high as 0.05-0.15% [2]. These residual contaminants will significantly affect the wet-end operation in the manufacture of container board. Because fillers have high specific surface area, it is expected that they can act as a sticky control material to clean up the wet end through adsorbing interfering substances, or by adhering to stickies particle surface to reduce the tackiness.

Addition of filler to the furnish has a long history in the paper industry. With the transition of the papermaking process from acidic to neutral or alkaline, PCC as a filler has received increasing attention in recent years. More recently, PCC has been quite successfully introduced into recycled container board as a fiber extender [3]. It is interesting to note that no significant reduction in paper strength was observed when PCC content in paperboard is less than ~5 wt.% [3]. Although preliminary results showed many advantages when PCC was used in recycled OCC, the retention of PCC in this type of furnish has not been studied.

In addition to the stickies and wax mentioned above, additives originally present in OCC, such as retention aids, strength aids, and sizing agents may potentially be carried over into the recycled material. Chemicals used in repulping, dispersion, deinking and

some foreign contaminants may also be introduced. These components exist generally as "anionic trash" and provide a demanding production challenge to the papermaker, namely, first pass retention control [4]. Therefore, an investigation on the PCC and fines retention in container board, particularly in OCC, is of significant interest to the industry and constitute the main thrust of this research.

MATERIALS

Three OCC furnishes were used in the experiments. Two of them were supplied by two Georgia liner board mills. Furnish from mill 1 is 100% recycled OCC without further refining, and furnish from mill 2 contains 70% OCC and 30% mixed office waste(MOW) without further refining. Furnish 3 is obtained by repulping the preconsumer container board purchased from U-HAUL Moving Services. The container board was soaked overnight in water and disintegrated in a pulper at 9% consistency at neutral pH. All the furnishes were diluted to a 0.5% consistency and the pH was adjusted to 8 before the retention experiment. Some physical properties of the furnishes are listed in Table 1.

Table 1. Physical Properties of Recycled OCC Furnishes

Furnish Source	Mill 1	Mill 2	U-HAUL
CSF, mL	580	400	675
Fines Content, %	13.9	22.1	13.9
Original pH	7.2	7.0	6.6
Charge Density of Filtrate Passing DDJ*, μeq/L	-77.6	-130	-68.9
Charge Density of Filtrate Passing Filter Paper*, μeq/L	-17.6	-34.6	-18.4

* Filtrates are from 0.5% pulp suspension.

Information about retention aids used in this study is listed in Table 2. CPAM1, CPAM2, APAM1, silica and coagulant were from Chemical Company 1. CPAM3, APAM2 and bentonite were from Chemical Company 2. PEO was purchased from Aldrich in powder form. Water soluble PFR was supplied by Borden Chemicals with a solids content of 46%.

Table 2. Chemicals Used for Retention

Symbol	Chemical Composition	Molecular Weight	Charge Density
CPAM1	Cationic Polyacrylamide	Very High	Low
CPAM2	Cationic Polyacrylamide	Very High	Low
CPAM3	Cationic Polyacrylamide	High	Low
APAM1	Anionic Polyacrylamide	Very High	Low
APAM2	Anionic Polyacrylamide	Medium	Low
Bentonite	Anionic Bentonite	-	-
Silica	Anionic Silica Sol	-	-
PEO	Poly(ethylene oxide)	$8x10^6$	-
PFR	Phenolic Formaldehyde	13,000	-
Coagulant	Cationic Polyamine	Low	High

PCC was a scalenohedral calcite filler product (Albacar ®HO, Specialty Minerals Inc.) with an average particle size of 1.3 μm and specific surface area of 12 m^2/g. Amphoteric starch (Cato 245) for dry strength was from National Starch and alkyl ketene dimers (AKD) emulsion for sizing was from mill 2.

EXPERIMENTAL

Pulp furnish was first diluted to a consistency of 0.5% and adjusted to a pH of around 8 with NaOH solution. The prepared furnish (500 mL) was poured into a Dynamic Drainage Jar (DDJ) and stirred at 1000 RPM. A 200 mesh wire of DDJ was used unless otherwise mentioned. Next, 5% PCC (based on dry fiber weight) was added. After stirring for 30 seconds, retention aids were then added. For dual-component retention systems, different addition sequences were used and they are given in the legends of the figures. A fixed ratio of polymer/microparticle of 1:5 was used for the microparticle retention system. For the PFR+PEO system, a fixed PFR/PEO ratio of 2:1 was used. Dry strength starch at the dose of 10 lb/ton and AKD sizing at the dose of 8 lb/ton were used only for the furnish from mill 2 to achieve an environment closer to the mill situation. When starch and AKD sizing were used, the addition sequence of the additives is PCC, starch, retention aid(s) and AKD. The first 150 ml filtrate from DDJ was collected 15 seconds after the retention aid(s) was added, and PCC and fines retention were measured. The calcium concentration was analyzed by potential titration using EDTA salt as a titrate. The end point of the titration was measured using a voltmeter, which was equipped with a calcium-selective electrode (Fisher product) and a glass pH reference electrode (Fisher product). The drainage rate test followed the same procedures as in the retention test except that the stirring was stopped before filtrate collection. Drainage rate was expressed as the amount of filtrate collected in the first 25 seconds.

Zeta potential was measured using Malvern Zetasizer 3000. The machine utilizes a laser to measure particle size and zeta potential through dynamic light scattering.

RESULTS AND DISCUSSION

OCC from Mill 1

The PCC retentions for OCC from mill 1 in the presence of different retention aids are given in Figure 1. The best retention results were obtained from the PFR/PEO system. This is especially true at low polymer addition levels. 1 ppm PEO, which is equivalent to 0.4 lb/ton, resulted in an approximately 90% first-pass retention. High retention (about 90%) could also be achieved with cationic PAM as well as a combination of PAM and bentonite. However, a higher polymer dosage was required. The microparticle retention system of cationic PAM plus bentonite did not work as well for this furnish. At lower dosages, the retention results from this microparticle system were even poorer than that from the single cationic polymer. The least effective retention system is the single anionic PAM. This is in agreement with the research results published by another researcher [5]. The addition of bentonite after anionic PAM improved the retention remarkably. Although the mechanism of improved filler retention by using these two negative systems is not clear, one of the possible explanations is the formation of microparticle bridging. To form this bridging, the APAM first adsorbed onto fiber and fines surfaces by van der Waals force to form negative parches. When bentonite was added, the bentonite microparticles bridged the fibers and fillers through adsorbed APAM molecules. Two types of forces contribute to this interaction, i.e., van der Waals force and hydrogen bonding between the acrylamide groups on PAM and the aluminol groups on bentonite.

It was thought that the anionic trash in the furnish is the major reason for the relatively poor behavior of the cationic PAM as well as its combination with bentonite. In order to study the effect of anionic trash on the performance of CPAM, the soluble anionic trash was removed by washing thoroughly with water and filtrating using a filter paper until the charge density of the washing water reached zero. The fines content of the washed pulp is 10.42, a little lower than that of the unwashed pulp. The charge density of the filtrates (from a 0.5% washed pulp furnish) passing the DDJ changed from -77.6 μeq/L to -40 μeq/L. The PCC retention for the washed pulp is illustrated in Figure 2. It is interesting that in these washed pulp furnishes, the retentions induced by the cationic flocculant and microparticle system were still significantly lower than those induced by the PEO/PFR at lower addition levels. Comparing with the results from unwashed furnish, no increase in the retention efficiency of cationic PAM and the microparticle retention system was found. It seems that the anionic trash in the furnish is not the major reason for the relatively poor performamce of the cationic flocculant and the microparticle in these finishes.

To further test this phenomenon, cationic coagulant was added to neutralize the anionic trash in the unwashed pulp before the addition of a constant 1 ppm cationic PAM (1 ppm PAM + 5 ppm bentonite for the microparticle system). Figure 3 shows that for the single cationic PAM, the coagulant addition has only a slightly positive effect on the retention at low addition levels but has a negative effect at higher addition levels. The reason is obviously that certain anionic charges on the PCC and fines are necessary for the cationic PAM to function effectively. The effect of coagulant addition on the microparticle system is significant. PCC retention increased with increasing coagulant

addition to a high coagulant level (40 ppm). The result suggested that the microparticle system needs more coagulant to achieve the best result than the single cationic flocculant does. The Zeta-potential of the DDJ filtrate as a function of coagulant concentration before retention aid addition is also given in Figure 3. At the coagulant addition level where the best retention was achieved, the particles in the system were still negatively charged. Combining with the results from the washed pulp, it seems that the negatively charged anionic trash in the system has a significant effect on the retention efficiency of the microparticle system, but has less effect if a single CPAM is used. This prompts further study of the retention mechanism of the microparticle system. It can also be seen that the coagulant addition has a positive effect on the retention results for negatively charged flocculant through the patch formation mechanism. However, high retention can not be obtained even at relatively high coagulant addition levels.

It was noted in this study that the PCC retention obtained from DDJ with a 200 mesh wire (76 μm) is much higher compared with the real paper mill situation. Because of these high retention values, the minor difference between the efficiency of different retention systems may have been masked and became insignificant. To investigate if the wire pore size of the DDJ would affect the relative efficiency of different retention systems, a 100 mesh (150 μm) wire was used to repeat some of the experiments and the results are shown in Figure 4. Although the absolute PCC retention values from 100 mesh wire are lower than those from 200 mesh wire, the general trends are in agreement with each other. The PCC retention results from the PFR/PEO system are still significantly higher than those from single cationic PAM and its combination with bentonite.

The fines retention from different retention systems using 200 mesh wire is illustrated in Figure 5. Similar to the situation of PCC retention, the best fines retention was induced by the PFR/PEO system and the poorest retention was from the single cationic PAM.

OCC from Mill 2

Figure 6 shows the PCC retention results for the recycled furnish from mill 2. Similar to the results obtained from the furnish of mill 1, the PFR/PEO system induced the best retention and anionic PAMs the poorest. The retentions from CPAM1 and CPAM1 plus bentonite are close. A combination of cationic PAM1 plus anionic silica microparticle is less effective than a cationic PAM1 and bentonite combination. In addition to the smaller particle size of silica compared with bentonite, higher anionic charge of silica particles may not be desired for this application. The retention induced by CPAM2 is significantly lower than that induced by CPAM1. According to the vendors, both CPAM1 and CPAM2 have very high molecular weight and low charge density. However, from the colloidal titration it was found that the charge density of CPAM2 is higher than that of CPAM1. Cationic PAM is supposed to flocculate anionically charged particles through a bridging mechanism. If the charge density of the PAM is too high, the polymer adsorbed on one particle with the help of electrostatic attraction adopts a flatter conformation and the extended loops or tails will be too short to catch other particles. Therefore, the flocculation efficiency will be lower.

The effect of different retention aids on the drainage rate was also studied and the results are illustrated in Figure 7. PFR/PEO, The cationic PAM and microparticle system

lead to a significant improvement in drainage rates while the effect of anionic PAM on drainage is slight.

OCC Repulped in the Lab

Preconsumer corrugated container board was repulped in the lab and the PCC and fines retentions for this furnish were investigated. The results are given in Figure 8 and Figure 9, respectively. For both PCC and fines retention, the efficiency of different retention systems is similar to that discussed above for the OCC furnishes from paper mills. Two other polyacrylamides, CPAM3 and APAM2 were also tested for this furnish. It can be seen from Figure 10 that PFR/PEO is still significantly more effective than other retention systems. However, an advantage of cationic PAM plus bentonite over single cationic PAM was noticed. It was also found that the addition order of cationic PAM and bentonite has a remarkable effect on the retention efficiency, i.e., if the bentonite was added first, the retention was even less than the cationic PAM only.

CONCLUSIONS

For the OCC furnishes used in this study, nonionic retention aid PFR/PEO is most effective for both PCC and fines retentions. Very high retention can be achieved with only moderate amount of PEO addition. The retention results from the traditional microparticle system (cationic polymer + anionic microparticle) varies depending on the polymer and microparticle used and order of addition-CPAM first is best. No definite advantage of the microparticle system over the single cationic flocculant was identified. Removal of the soluble anionic trash in the furnish did not improve the performance of the cationic flocculant and microparticle system. However, preaddition of highly charged

cationic coagulant enhanced the retention efficiency of the microparticle system significantly to a level comparable with that of PFR/PEO.

ACKNOWLEDGMENT

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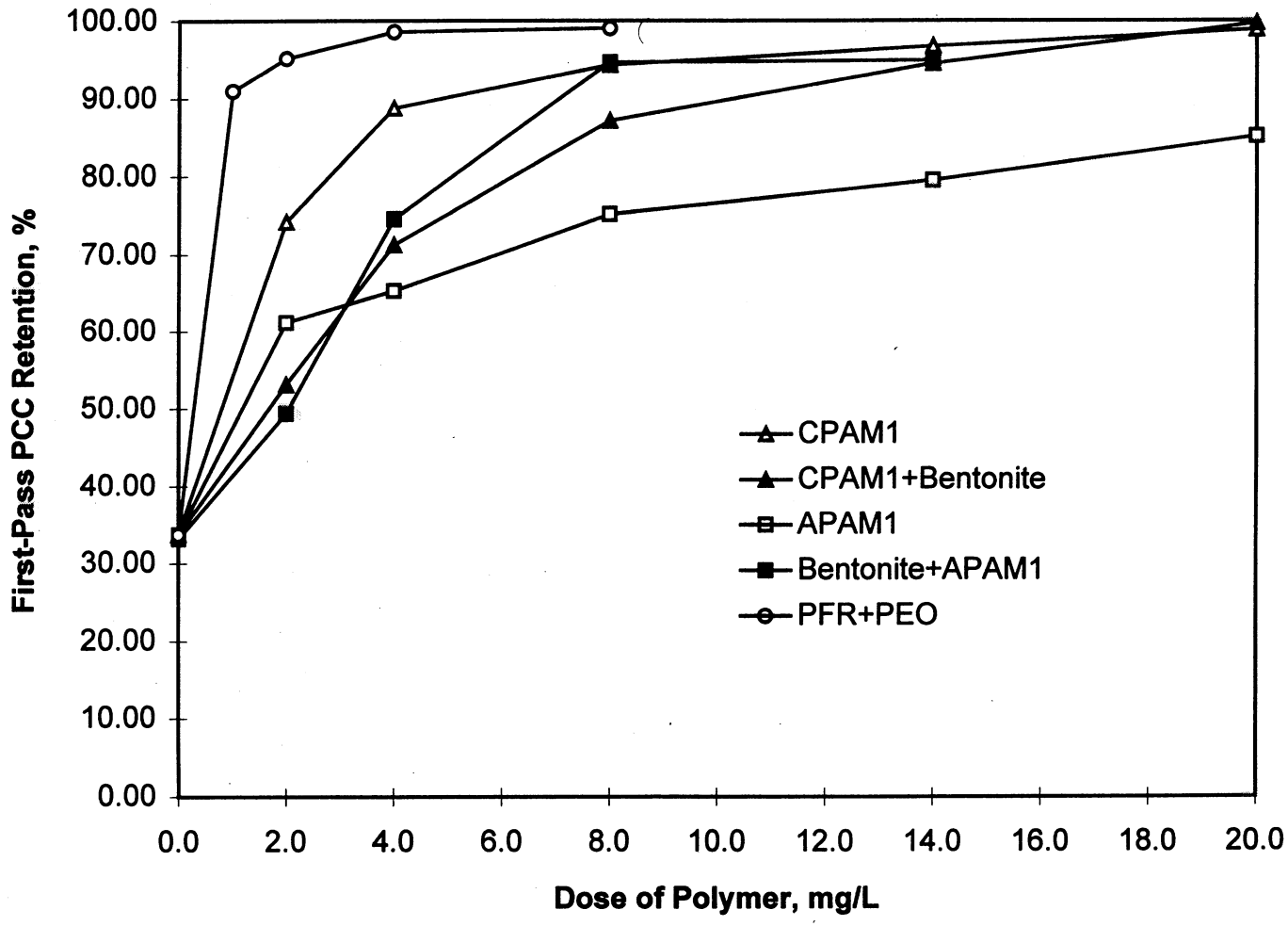

Figure 1. PCC retention for OCC from Mill 1

Figure 1

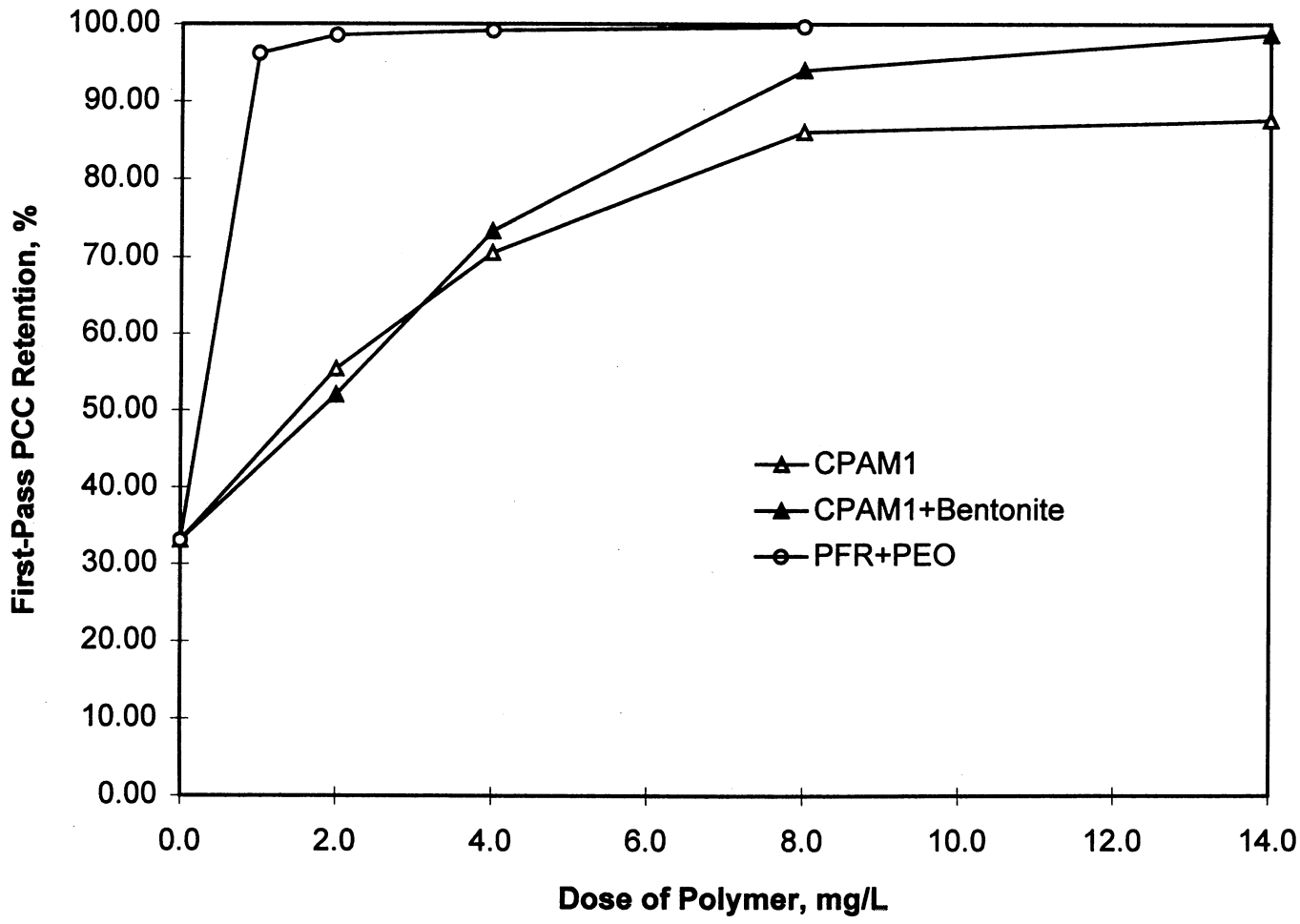

Figure 2. PCC retention for washed OCC from Mill 1

Figure 2

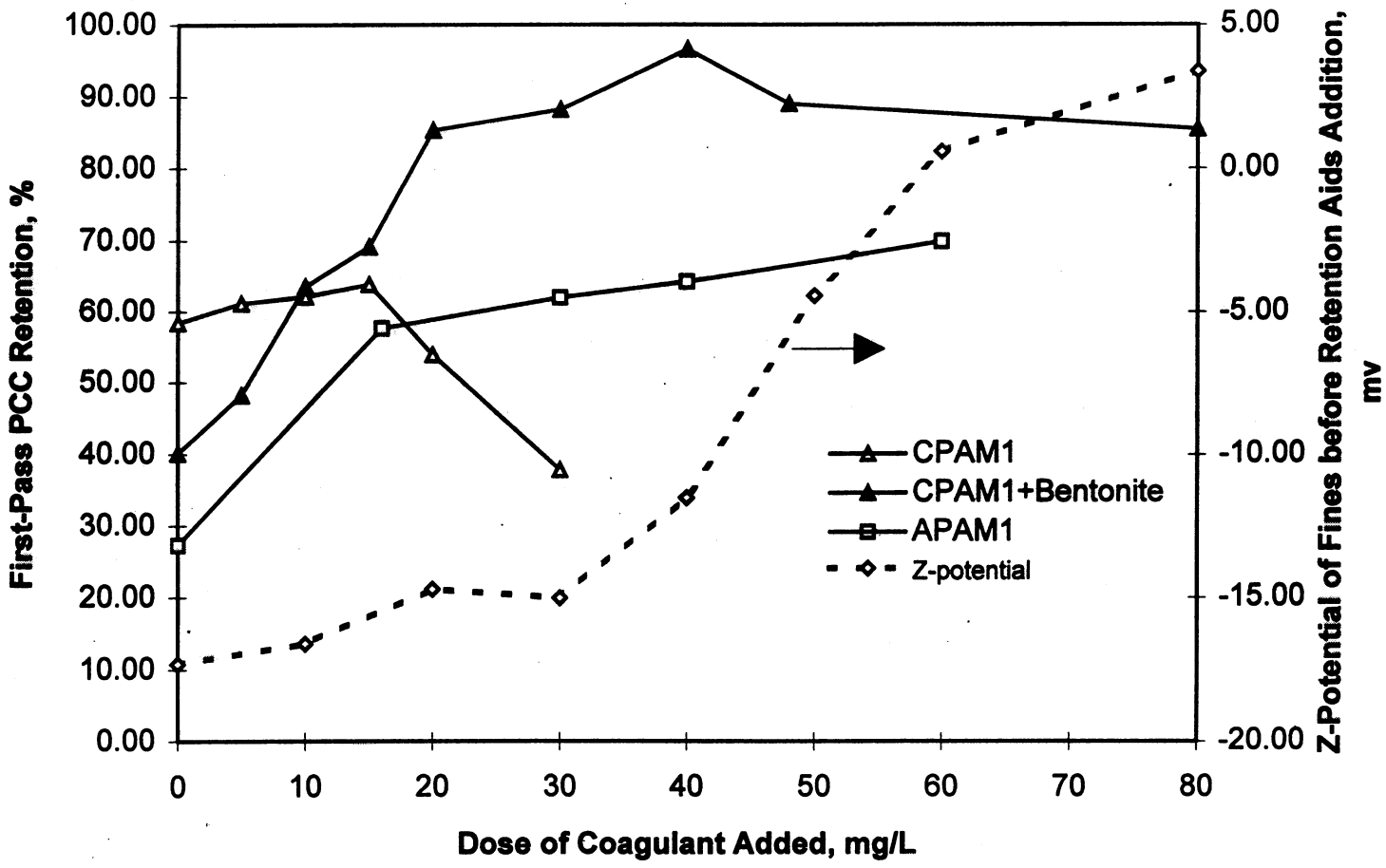

Figure 3. Effect of coagulant addition on the retention of PCC at a constant 1 mg/L retention polymer addition

Figure 3

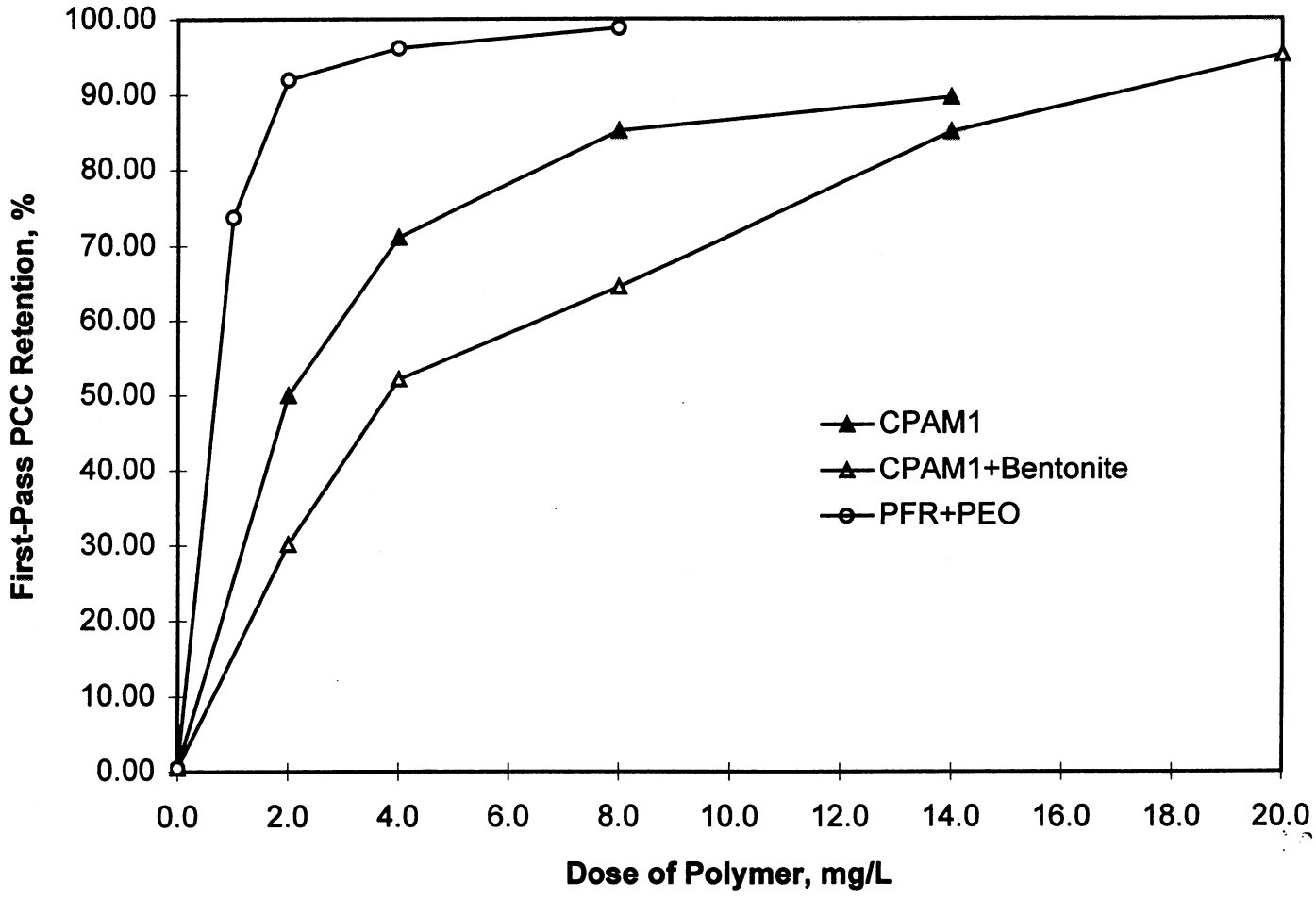

Figure 4. PCC retention for OCC from Mill 1 using 100 mesh wire

Figure 4

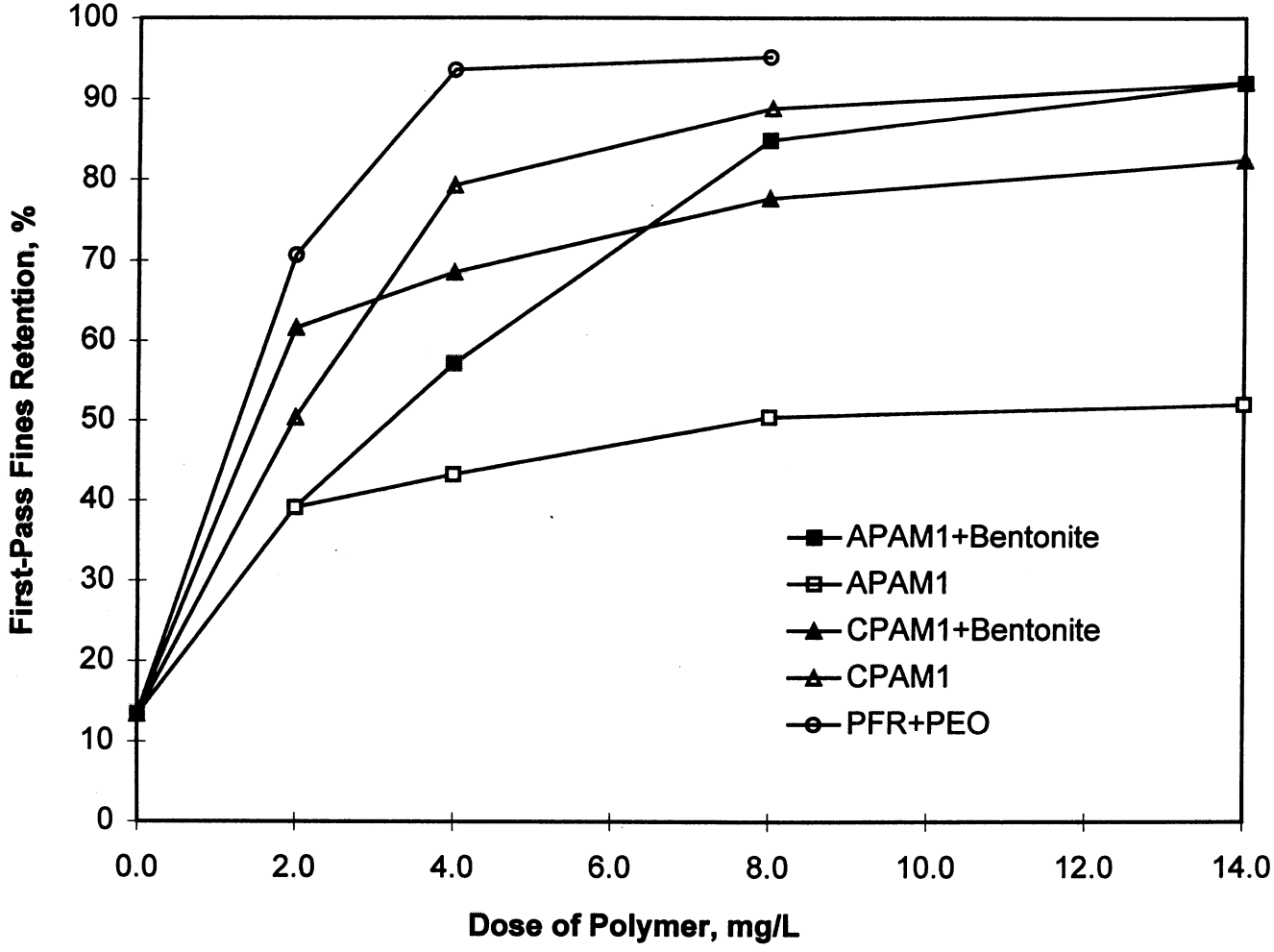

Figure 5. Fines retention for OCC from Mill 1

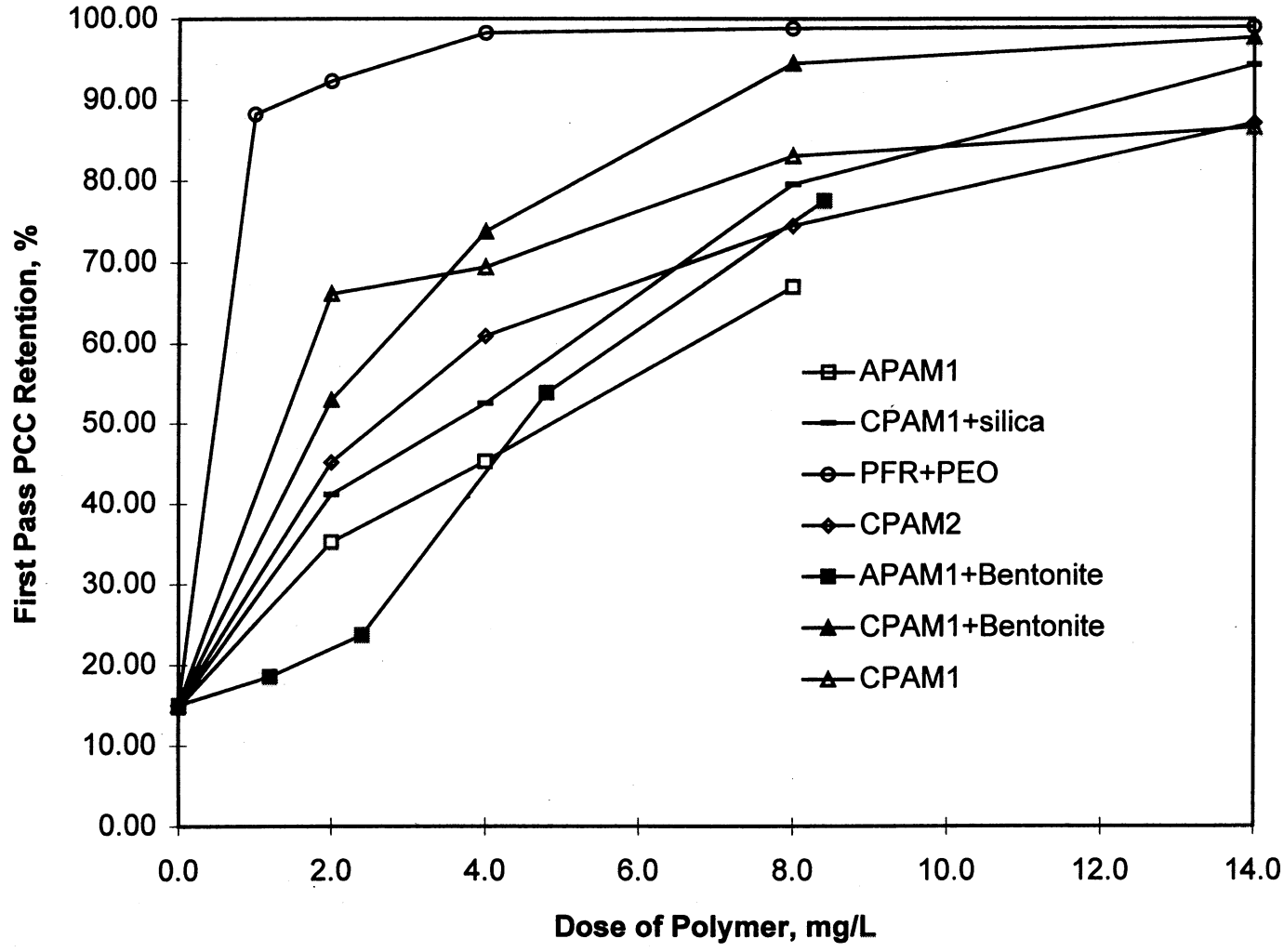

Figure 6. PCC retention for OCC from Mill 2

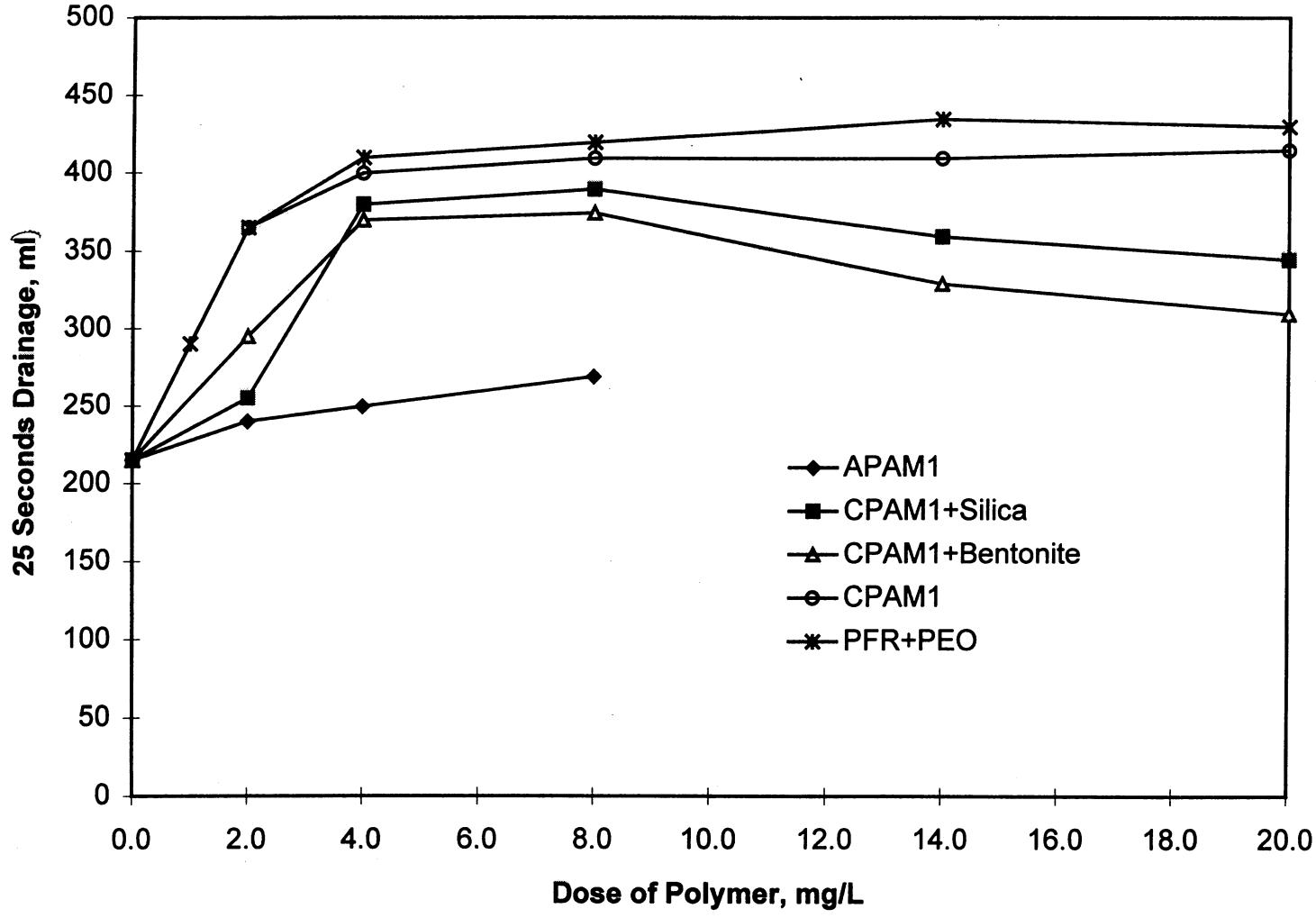

Figure 7. Effect of retention aids addition on the drainage rate

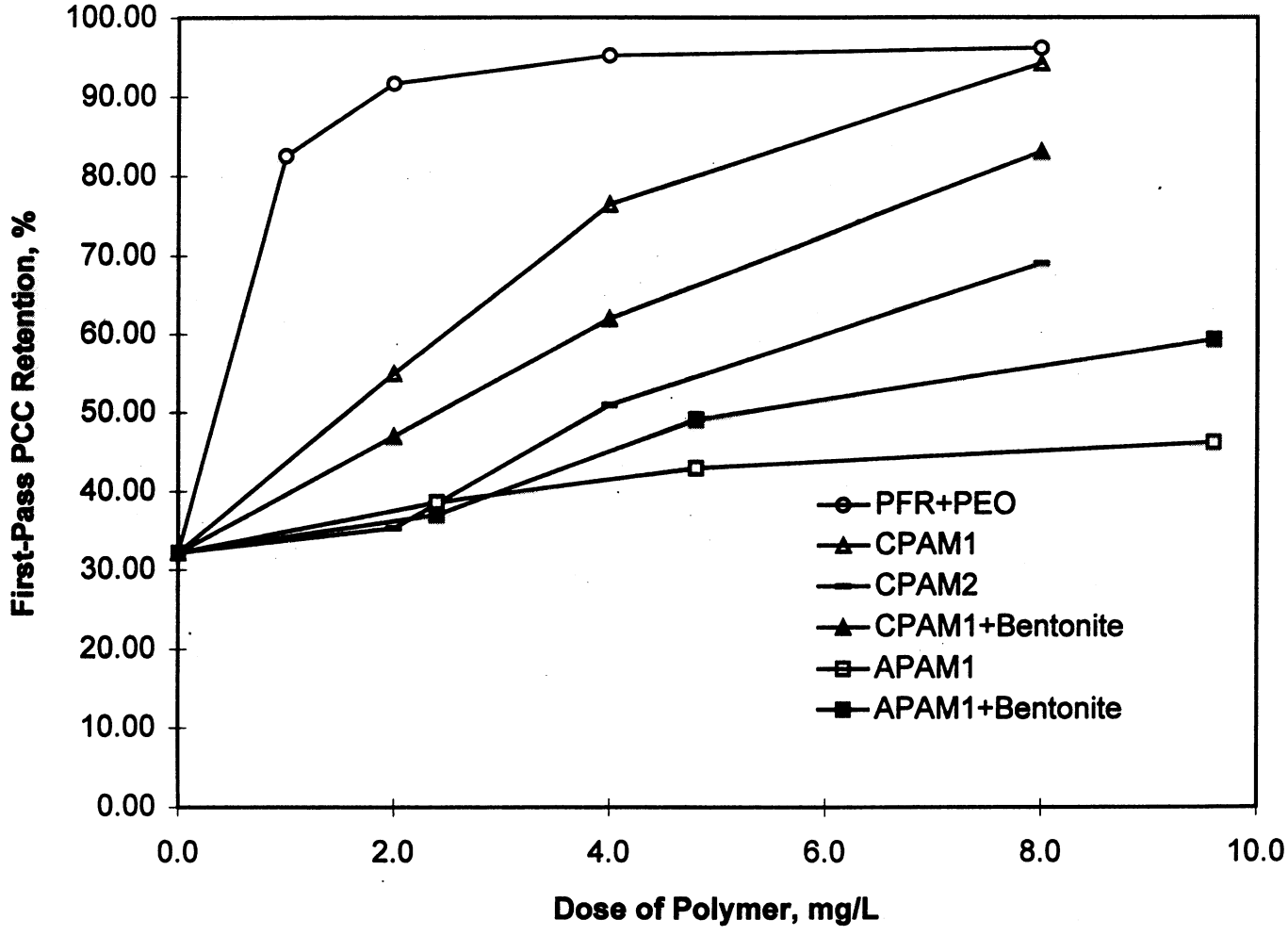

Figure 8. PCC retention for OCC repulped in the lab

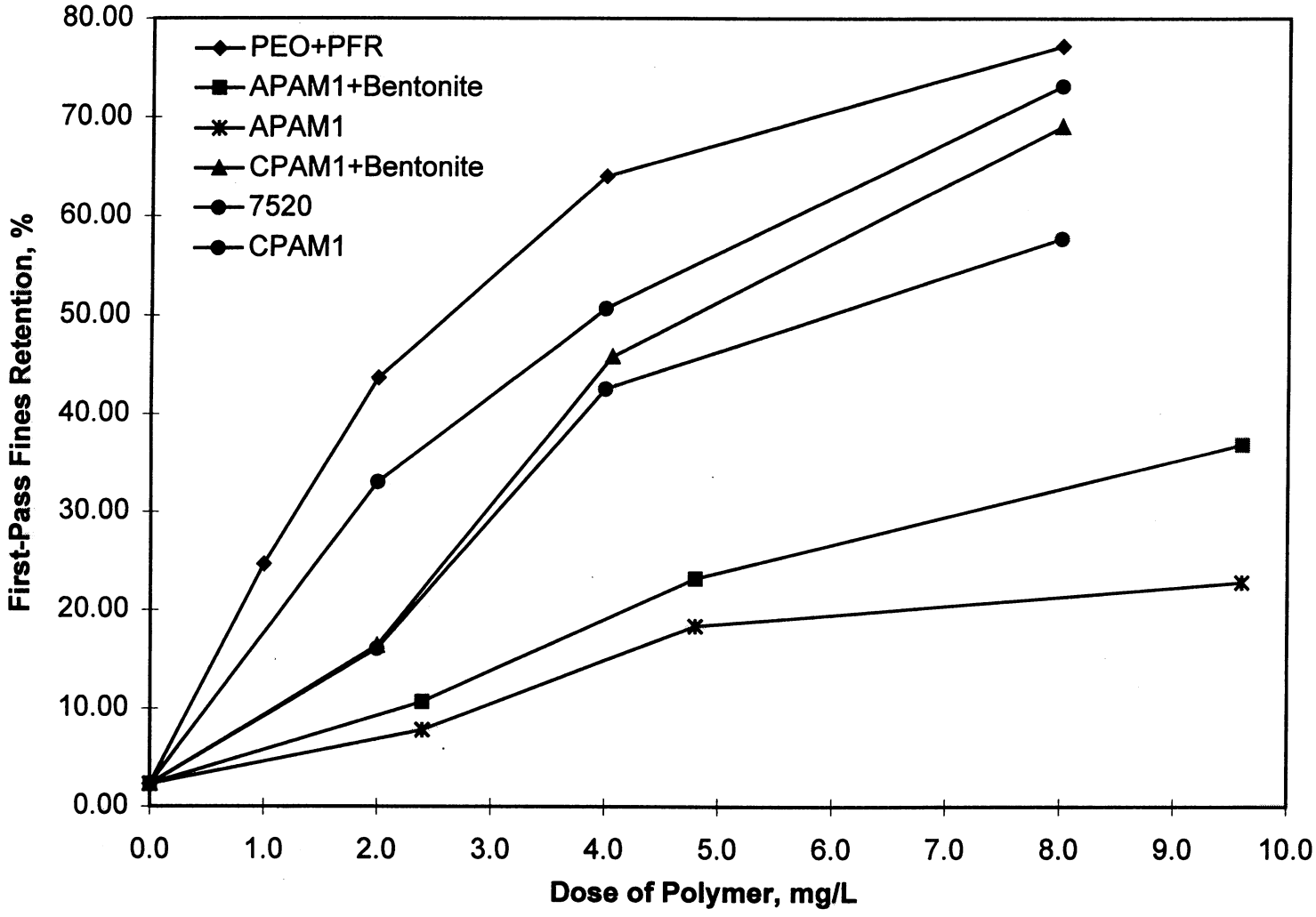

Figure 9. Fines retention for OCC repulped in the lab

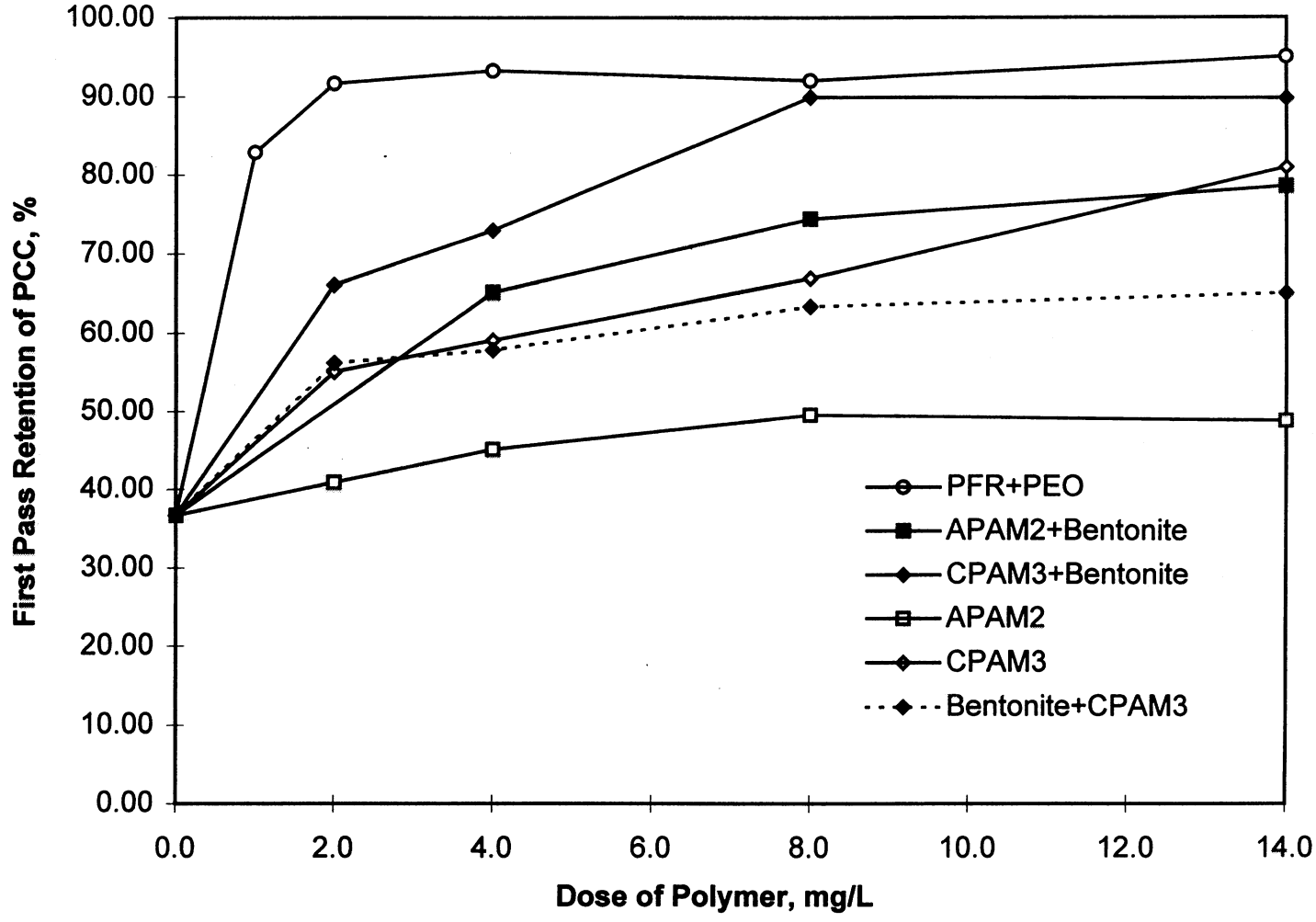

Figure 10. PCC retention for OCC repulped in the lab