

Increasing the filler content of PCC-filled alkaline papers

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Papermakers can maximize filler loading while maintaining acceptable paper properties by controlling the size and morphology of the PCC fillers added to the furnish.

Increasing the filler content in paper can provide the papermaker with numerous benefits, including savings in the cost of raw materials, lower steam consumption for drying, improved optical properties, and better print quality. There are, however, limits to the amount of filler that can be substituted for papermaking fiber. At high filler contents, paper can suffer losses in strength, stiffness, and sizing. Highly loaded papers also are prone to dusting at the calender rolls or rewinder and to milking during offset printing. Various wet-end and size-press additives, as well as changes in sheet formation conditions, are reported to help minimize dusting and milking (1). Strength, stiffness, and sizing can be maintained at high filler levels through appropriate selection of filler particle size and morphology.

Precipitated calcium carbonate (PCC) is used extensively as a filler in alkaline paper because of its ability to impart opacity, brightness, and bulk (2). PCC is also relatively easily retained in the wet sheet because of its cationic charge. Of the various PCC morphologies, the scalenohedral (i.e., rosette) form has found the most extensive use as a paper filler. The opacifying power of a scalenohedral PCC is directly related to its average particle size (APS), with maximum opacity occurring at an APS of 1.3–1.4 μm (3). Unfortunately, the opacity achieved within this size range is obtained at the cost of tensile strength, which is at a minimum for filled papers containing scalenohedral PCC particles of 1.3–1.4 μm (4). Increasing the APS of a scalenohedral PCC above the optimum for opacity improves tensile strength and increases stiffness, thus allowing the papermaker to increase the filler content.

PCC particles have a narrow particle size distribution (PSD). The narrow PSD and unique morphologies of PCC play a major role in explaining their superior optical performance. However, particles with narrow PSDs exhibit less-than-optimum packing efficiencies, resulting in greater disruption of fiber–fiber bonding. The PSD is broadened by blending PCCs of different particle size, resulting in more-efficient particle packing and improved sheet strength.

In addition to the scalenohedral form, PCC also can be produced with a discrete solid-particle prismatic morphology.

The prismatic morphology is unique in that its structure is “less open” than scalenohedral PCC. As a result, for a given average particle size, prismatic PCC has a lower specific surface area (SSA) than scalenohedral PCC. The low surface area of prismatic PCC is desirable because it minimizes demand for sizing chemicals at high filler levels and maximizes dewatering and sheet strength. Prismatic PCC can be produced with particle sizes ranging from 0.5 μm to 6.5 μm (5). Optimized blends of scalenohedral and prismatic PCC provide a balance of strength, sizing, and machine runnability.

A new PCC with a clustered prismatic morphology was developed recently (6). This new product consists of tightly bound clusters of small, solid, prismatic PCC particles. Clustered prismatic PCCs provide the strength benefits of discrete-particle prismatic PCC while maintaining optical properties more typical of scalenohedral PCC. The low surface area of clustered prismatic PCC also results in a lower demand for sizing chemicals than scalenohedral PCC.

This report presents several strategies for achieving higher filler levels in alkaline papers using PCC.

Materials and methods

Table I lists the typical properties of the PCC fillers that were used in the handsheet studies and pilot paper machine trials. Scanning electron micrographs of scalenohedral PCC, solid-particle prismatic PCC, and clustered prismatic PCC are shown in Fig. 1.

Handsheet studies

Handsheets were produced to a target basis weight of 60 g/m² using a Nobel-and-Wood-type sheet former. The furnish consisted of a 75:25 blend of bleached hardwood and softwood kraft pulps beaten to 400 mL CSF at pH 7.0. The target filler levels were 15% and 25%. An alkyl ketene dimer (AKD) sizing agent was added to the pulp furnish at a level of 0.25%. A high-molecular-weight cationic polyacrylamide (C-PAM) retention aid was added to the furnish at a level of 0.05%. The sheets were pressed using one nip at a pressure of 25 psi and dried on a rotating chrome-plated drum at 125°C. Paper conditioning and testing were carried out in accordance with the relevant TAPPI Test Methods.

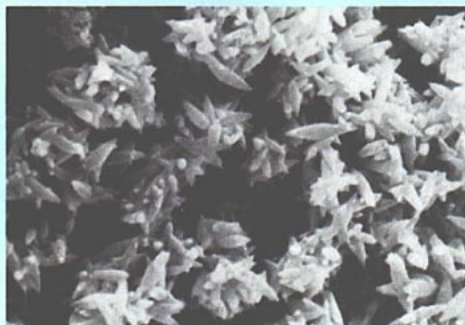
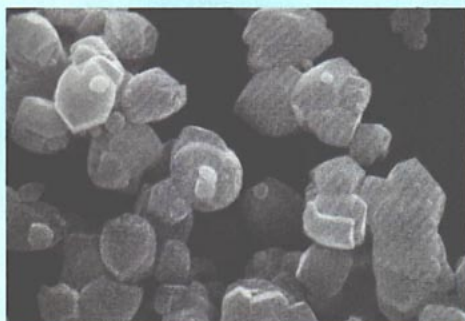
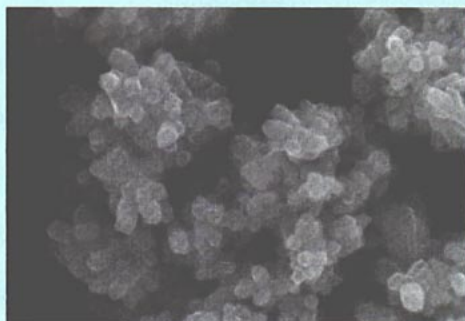
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I. Typical filler characteristics^a

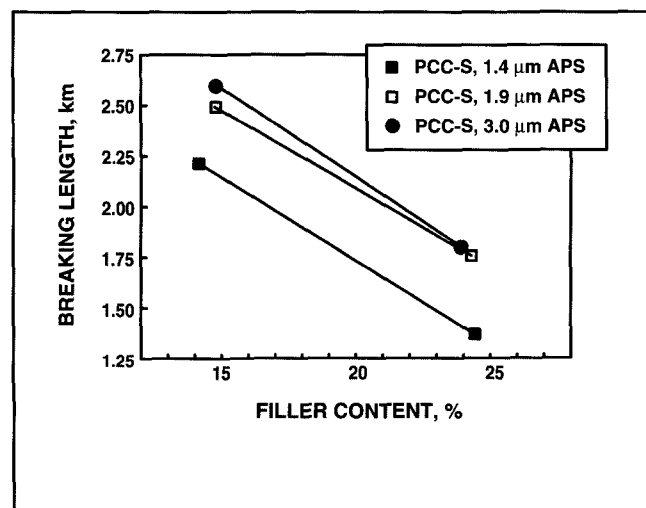
Product ID	Morphology	APS, ^b μm	Normalized PSD, ^c μm	SSA, ^d m^2/g
PCC-S	Scalenohedral	1.4	0.82	11.6
PCC-S	Scalenohedral	1.9	1.3	9.8
PCC-S	Scalenohedral	3.0	0.96	6.2
PCC-S Blend 1	Scalenohedral	1.4	1.6	12.5
PCC-S Blend 2	Scalenohedral	1.4	1.9	12.4
PCC-P	Prismatic	2.0	0.57	3.2
PCC-CP	Clustered prismatic	2.1	0.56	4.7

^aTabular values are representative. Absolute values for materials used in this study may differ slightly.
^bAPS = average particle size.
^cPSD = particle size distribution. Normalized PSD = $(d_{80} - d_{20})/d_{50}$, where d_n = equivalent spherical diameter at the n th quantile.
^dSSA = specific surface area.

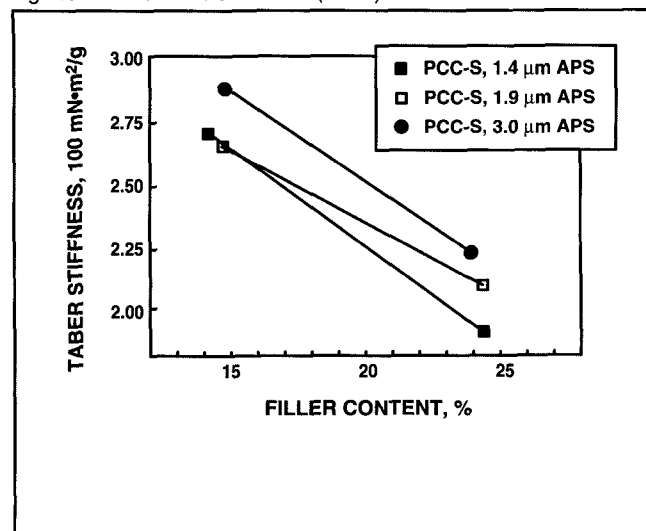
1. SEMs showing morphologies of three different types of PCC particles (Bar = 1 μm). Top: scalenohedral (PCC-S); middle: prismatic (PCC-P); bottom: clustered prismatic (PCC-CP).



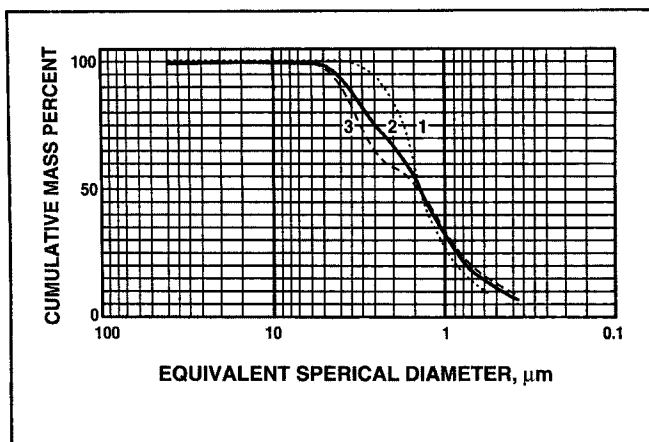
2. Breaking length as a function of filler content for handsheets containing scalenohedral PCC. Control (blank) = 4.19 km.



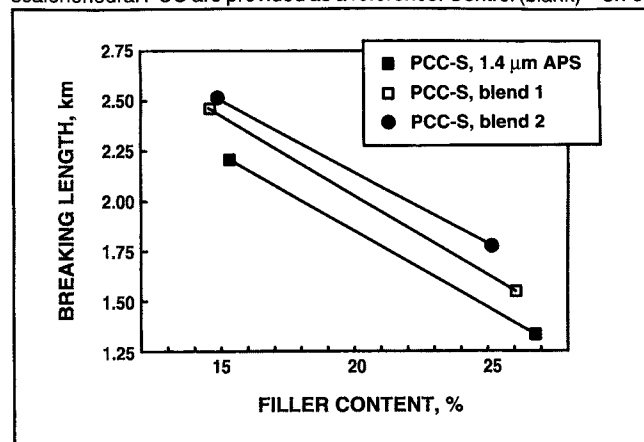
3. Taber stiffness as a function of filler content for handsheets containing scalenohedral PCC. Control (blank) = 3.30.



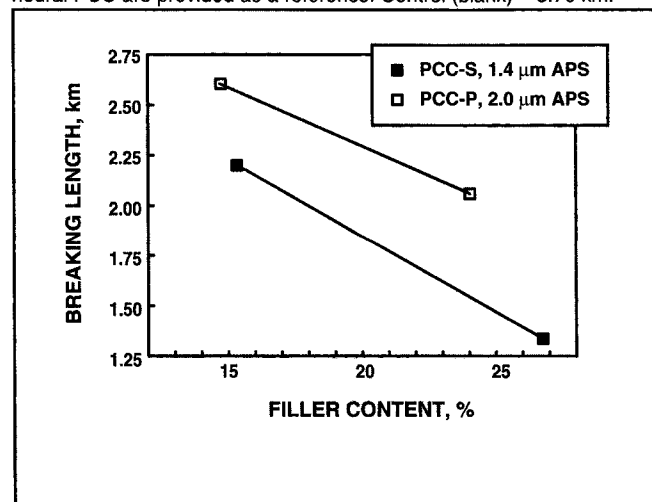
4. Particle size distribution for 1.4- μm PCC-S (Curve 1), PCC-S Blend 1 (Curve 2), and PCC-S Blend 2 (Curve 3)



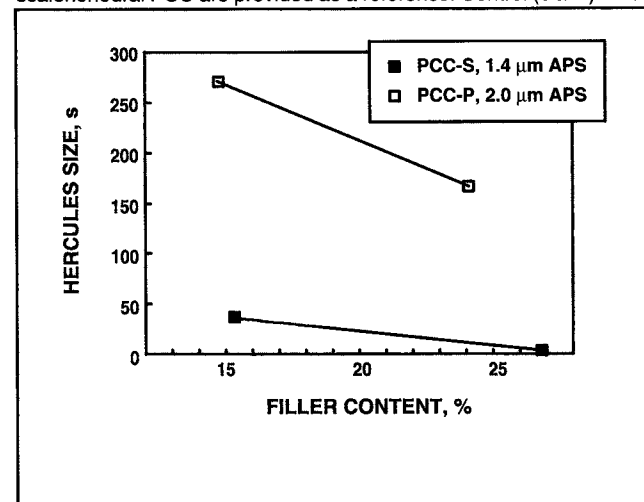
5. Breaking length as a function of filler content for handsheets containing blends of scalenohedral PCC. Results for handsheets containing 1.4- μm scalenohedral PCC are provided as a reference. Control (blank) = 3.76 km.



6. Breaking length as a function of filler content for handsheets containing 2.0- μm prismatic PCC. Results for handsheets containing 1.4- μm scalenohedral PCC are provided as a reference. Control (blank) = 3.76 km.



7. Hercules size as a function of filler content for handsheets containing 2.0- μm prismatic PCC. Results for handsheets containing 1.4- μm scalenohedral PCC are provided as a reference. Control (blank) = 1807 s.



Pilot paper machine trials

The pilot paper machine trials were carried out at the Swedish Forest Products Research Laboratory (STFI) on the FEX machine operating in the twin-wire mode. The machine ran at 800 m/min and produced paper with a basis weight of 65 g/m² using a 60:40 hardwood/softwood pulp blend. Pulps were refined separately (birch = 21–25°SR, pine = 21–26°SR). The paper was passed through the machine's three-nip press section and dried off the machine using a felted, single-can dryer.

For the first trial, a two-component microparticle retention aid was used. The colloidal component usage was held constant at 0.2%, and the cationic polymer usage was varied to meet retention targets (80% first-pass total, 60% first-pass ash). Other additives for this study included cationic starch (0.4%) and AKD size (0.125%). For the second trial, a dual-polymer retention-aid system was used. A cationic promoter was used at a rate of 0.025%, while usage of the anionic retention aid was 0.0175–0.025%. Other additives for this study included cationic starch (0.4%) and AKD size (0.1%).

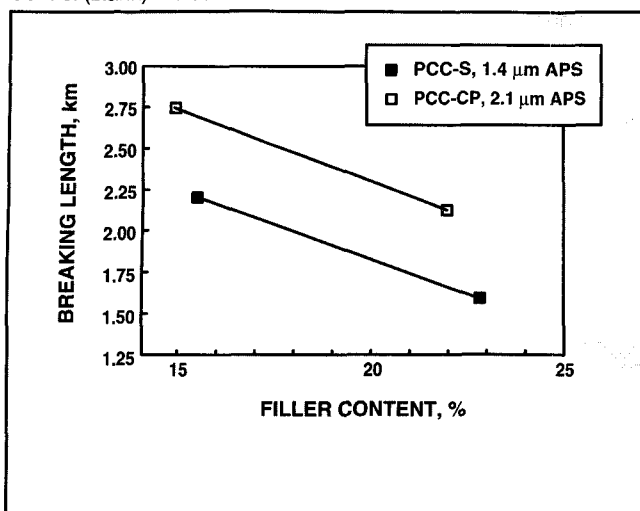
Paper conditioning and testing were carried out in accordance with the relevant TAPPI Test Methods.

Handsheet results

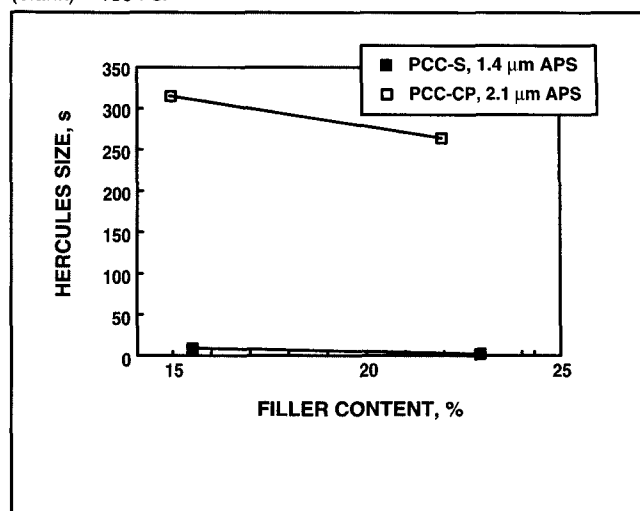
Scalenohedral PCC

Increased APS. The effect of increasing the average particle size of scalenohedral PCC on paper strength and stiffness is shown in Figs. 2 and 3, respectively. The increase in tensile strength that occurs with increasing APS is associated with the decreased void volume (i.e., better packing efficiency) of the larger particles as well as with the fact that there are fewer particles present at a given filler level to disrupt fiber–fiber bonding (?). For a given filler level, the bulk, stiffness, sizing, and porosity increase with increasing APS. Thus, depending on requirements for specific paper grades, increasing the average particle size of scalenohedral PCC provides an opportunity for moderate increases in filler levels.

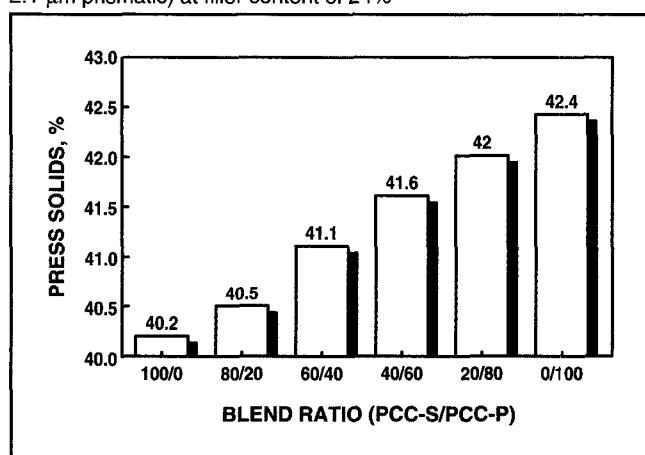
8. Breaking length as a function of filler content for handsheets containing 2.1- μm clustered prismatic PCC. Results for handsheets containing 1.4- μm scalenohedral PCC are provided as a reference. Control (blank) = 3.39 km.



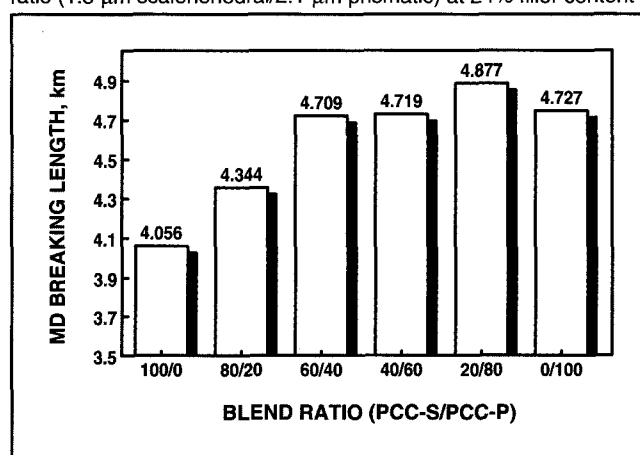
9. Hercules size as a function of filler content for handsheets containing 2.1- μm clustered prismatic PCC. Results for handsheets containing 1.4- μm scalenohedral PCC are provided as a reference. Control (blank) = 1594 s.



10. Press solids as a function of PCC blend ratio (1.5- μm scalenohedral/2.1- μm prismatic) at filler content of 24%



11. Machine-direction breaking length as a function of PCC blend ratio (1.5- μm scalenohedral/2.1- μm prismatic) at 24% filler content

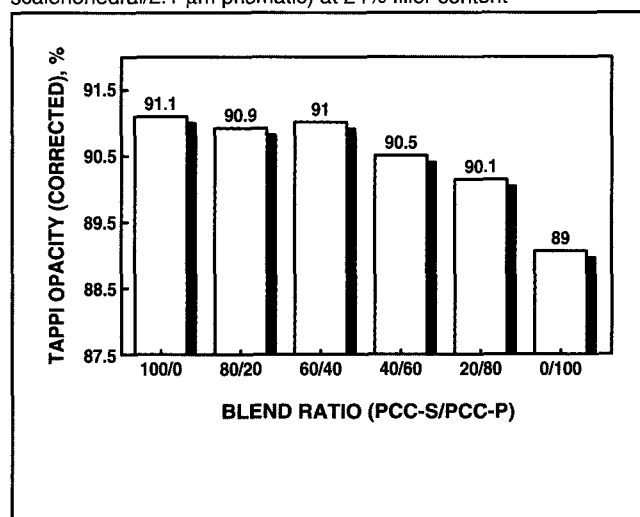


Blends. The effect of blending scalenohedral PCCs on various paper properties also was studied. Three scalenohedral PCCs with APS of 0.9 μm , 1.4 μm , and 3.0 μm were used. The PCCs were blended such that the APS was held constant at 1.4 μm while broadening the PSD. Figure 4 shows the PSD of the 1.4- μm PCC-S and the two PCC-S blends. Figure 5 shows that the tensile strength of the handsheets increased with increasing breadth of the PSD. The improvement in tensile strength is related to improved PCC packing efficiency, resulting in less disruption of fiber-fiber bonding.

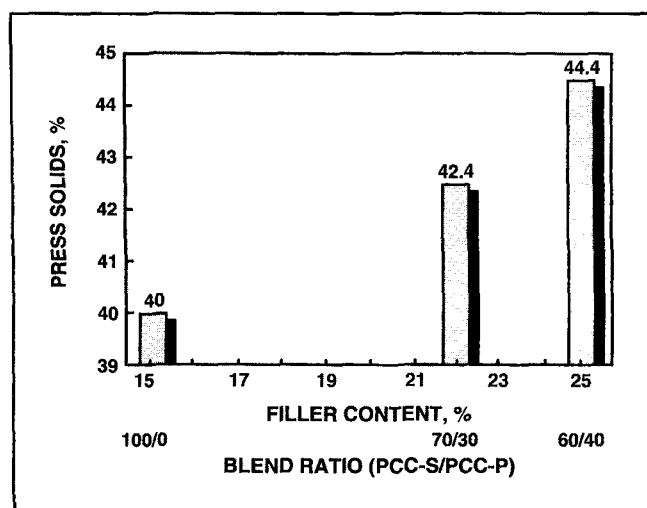
Prismatic PCC

A discrete-particle prismatic PCC (APS = 2 μm , SSA = 3.8 m^2/g) provides excellent strength, stiffness, and sizing in paper. Figure 6 shows that papers containing 2.0- μm prismatic PCC had greater strength than papers filled with scalenohedral PCC (APS = 1.4 μm , SSA = 12 m^2/g). Figure 7 shows that the 2.0- μm prismatic PCC provided better sizing

12. Corrected TAPPI opacity as a function of PCC blend ratio (1.5- μm scalenohedral/2.1- μm prismatic) at 24% filler content



13. Press solids as a function of PCC blend ratio (1.5- μ m scalenohedral/2.2- μ m prismatic) at three levels of filler content



than the 1.4- μ m scalenohedral PCC. The use of a 2- μ m prismatic PCC as a filler allows for increased filler loading levels in paper. For a balance of strength and optics, a 2- μ m prismatic PCC can be blended with an opacifying pigment such as a 1.4- μ m scalenohedral PCC.

Clustered prismatic PCC

A clustered prismatic PCC (APS = 2.1 μ m, SSA = 4.7 m²/g) provides a balance of strength, stiffness, opacity, and sizing. Figure 8 shows that papers containing 2.1- μ m clustered prismatic PCC had greater strength than papers filled with scalenohedral PCC (APS = 1.4 μ m, SSA = 12 m²/g). Figure 9 shows that the 2.1- μ m clustered prismatic PCC provided better sizing than the 1.4- μ m scalenohedral PCC. The improvements in strength, stiffness, and sizing provided by clustered prismatic PCC allow for increased filler usage in paper. Clustered prismatic PCC also provides good opacity and brightness even at higher filler levels. Strength and optical properties can be optimized by blending clustered prismatic PCC with a 1.4- μ m scalenohedral PCC.

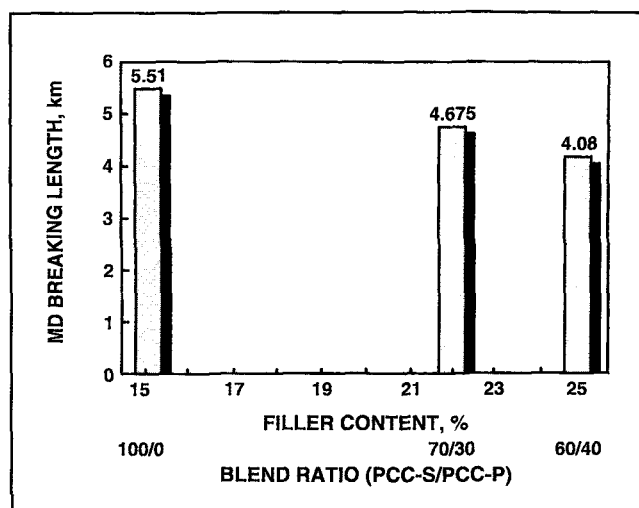
Results from paper machine trials

Prismatic/scalenohedral PCC blends—Trial 1

The objective of this pilot paper machine trial was to evaluate the effect of blending different ratios of scalenohedral PCC (APS = 1.5 μ m, SSA = 13 m²/g) and discrete particle prismatic PCC (APS = 2.1 μ m, SSA = 3.8 m²/g) on drainage/dewatering characteristics and various paper properties. For this study, the filler level was held constant at 24%.

Drainage/dewatering properties. The solids content of the paper web exiting the tri-nip press is shown in Fig. 10 as a function of scalenohedral/prismatic PCC blend ratio. The resulting press solids show a significant upward trend with an increasing proportion of prismatic PCC in the blend. The results show that PCCs can be selected and blended to pro-

14. Machine-direction breaking length as a function of PCC blend ratio (1.5- μ m scalenohedral/2.2- μ m prismatic) at three levels of filler content



vide excellent drainage and dewatering characteristics at high filler levels.

Paper properties. The effects of varying the scalenohedral/prismatic blend ratio on paper strength and opacity are shown in Figs. 11 and 12, respectively. In general, increasing the proportion of prismatic PCC in the blend resulted in improved tensile strength at the expense of some loss in opacity. The results suggest that a 60/40 blend of scalenohedral/prismatic PCC yields the best balance of strength and opacity.

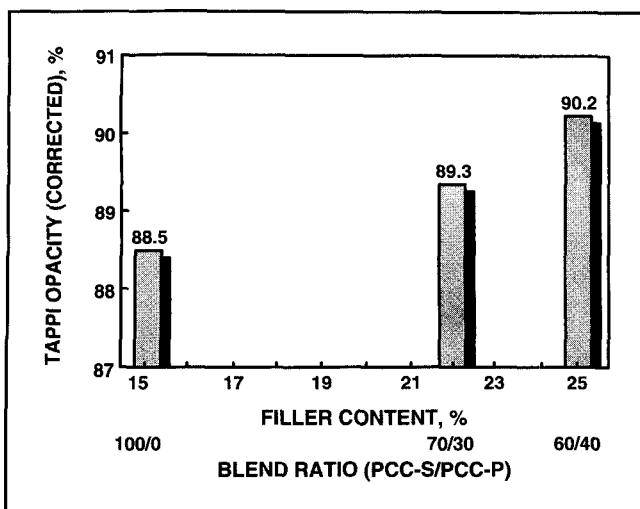
Prismatic/scalenohedral PCC blends—Trial 2

The objective of this pilot paper machine trial was to increase filler levels from 15% to 22% and 25% by adding incremental amounts of discrete-particle prismatic PCC (APS = 2.2 μ m, SSA = 3.6 m²/g) to paper containing 15% scalenohedral PCC (APS = 1.5 μ m, SSA = 11 m²/g). The resulting scalenohedral/prismatic PCC ratio was 70/30 at 22% filler and 60/40 at 25% filler.

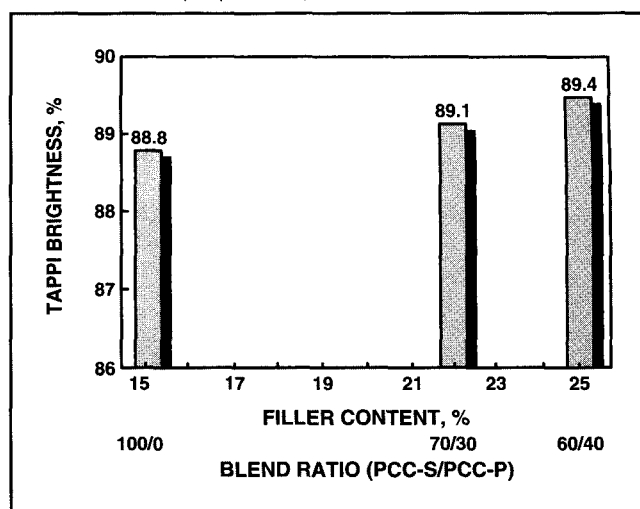
Drainage/dewatering properties. Figure 13 shows the after-press solids as a function of percent filler and scalenohedral/prismatic PCC blend ratio. The results show a significant improvement in press solids, which can be attributed to a combination of increased filler levels and the higher content of PCC-P, which has a solid-particle morphology.

Paper properties. The effect of increasing filler levels by incremental addition of prismatic PCC on various paper properties is shown in Figs. 14–16. Both opacity and brightness increased with higher filler levels, while tensile strength decreased. The 60/40 blend of scalenohedral/prismatic PCC at 25% filler content provided a 1.7-point increase in opacity and a 0.6-point improvement in brightness at the expense of a 25% loss in tensile strength compared with the paper filled with 15% scalenohedral PCC. The results suggest that, for this paper furnish, an optimum blend of scalenohedral/prismatic PCC at 25% filler would contain a larger proportion of prismatic PCC. More prismatic PCC in the blend at 25% filler would reduce opacity and increase tensile strength, resulting in properties

15. Corrected TAPPI opacity as a function of PCC blend ratio (1.5- μ m scalenohedral/2.2- μ m prismatic) at three levels of filler content



16. TAPPI brightness as a function of PCC blend ratio (1.5- μ m scalenohedral/2.2- μ m prismatic) at three levels of filler content



closer to the paper filled with 15% scalenohedral PCC.

Conclusion

Filler levels in alkaline papers can be increased by selectively applying PCCs with different morphologies. Papermakers

who are currently using a PCC filler with a particular morphology (usually scalenohedral) can maximize its usage by (a) switching to a PCC with a larger average particle size or (b) broadening the particle size distribution by blending PCCs of different particle size. Filler content also can be increased by switching to a solid-particle PCC such as discrete prismatic PCC or clustered prismatic PCC. This approach provides excellent drainage/dewatering characteristics and low size demand at high filler loading levels. Finally, blends of scalenohedral and prismatic PCC can be optimized to achieve more filler for fiber substitution while still meeting requirements for strength, stiffness, optics, and sizing. □

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