Impact of Pigment Blend and Binder Level on the Structure and Printability of Coated Papers

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ABSTRACT

Formulation practice globally for single coating applications is very diverse ranging from kaolin rich to carbonate rich recipes. Carbonate choice can be based on standard or engineered grades. Likewise kaolin can engineered, delaminated or even ultrafine. Binder type and level also vary considerably. When contrasting these different approaches in a given application, it is often apparent that although the coating recipe may be different the end result in terms of paper properties can often be quite similar. However, differences in pore structure between different coating recipes remain evident and these differences can often show up in the ink-paper interaction.

In this paper we evaluated some commonly used single coating recipes to explore the differences in pore structure and their subsequent impact on paper properties and printability. Both pigment blend and latex level were varied.

Coating structure was characterised using a range of techniques (including mercury porosimetry and wavelength exponents). The critical pigment weight concentration of the mineral blends was also determined using a light scattering technique, and this gave a measure of the amount of binder required to completely surround the pigment particles and fill the voids between them and was found to be a function of the particle packing and surface area of the blends.

Through this work we sought to determine how different pigment blends effect coating structure and how these coating structures respond to latex addition. The implications in terms of key measures of paper and print quality are then discussed.

BACKGROUND

Single coating is still prevalent in LWC applications globally and also in North American coated freesheet applications. Current coated mechanical and coated freesheet markets still account for some 6 million tonnes pigment sales annually, although in the mature markets of North America and Europe volumes have decreased due to falling demand for printing and writing grades.

Globally kaolin commands 44% share, and carbonate 56% but there are big regional variations with North America remaining relative kaolin rich in terms of formulation practice compared to the other geographies (Figure 1.)

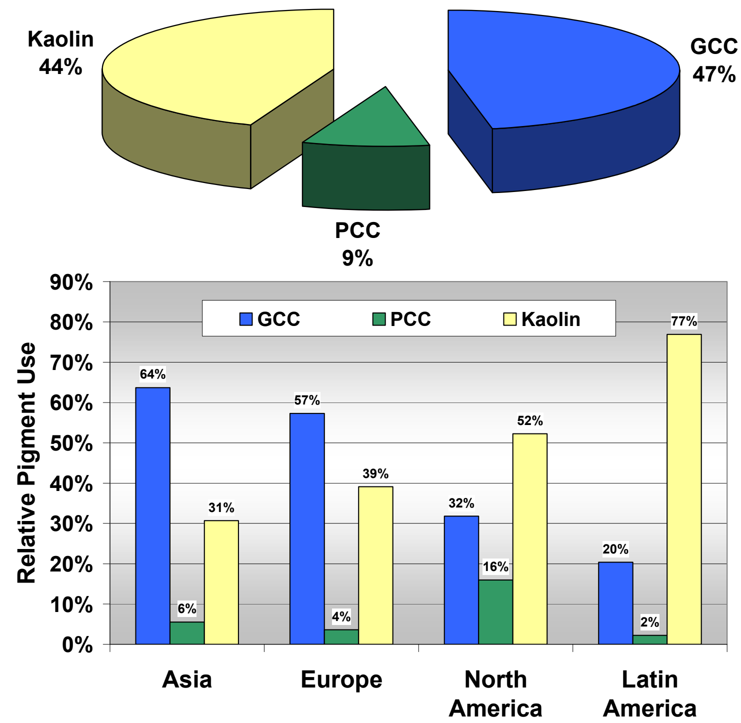

FIGURE 1. GLOBAL AND REGIONAL PIGMENT USE IN SINGLE COATING 2010

Generic formulation practice for the different single coated applications globally is shown below in table I.

	Europe	US CGW	US CFS	Japan	Rest of Asia
Kaolin%	20-60	50-100	25-60	30-70	30-40
Carbonate%	40-80	0-50	40-75	30-70	60-70
Kaolin Types	Engineered	Engineered	Engineered	Engineered	Chinese #1
	Ultrafine Glossing	Delam	#1	Delam	Ultrafine Glossing
		#1 and #2		#1, #2	
Carbonate Types	Standard 90/95	Standard 90	Standard 90	Standard 90	Standard 90/97
	Steep 95	Steep 95	Steep 95	In House	Steep 95
			PCC		In House

TABLE I GLOBAL SINGLE COATING PIGMENT PRACTICE

Formulation practice essentially falls into two categories globally. Traditional single coating recipes tend to be more kaolin rich and were comprised of coarser 90 < 2 µm kaolins with standard or steep GCC.
Over the years the kaolin of choice for this type of recipe has become engineered Brazilian kaolin or local equivalents. However, in Europe and Asia there has been a shift to more carbonate rich recipes. This is a result mainly of cost pressures and the high differential between kaolin and carbonate pricing in these geographies. Indeed the ongoing substitution of kaolin for carbonate remains a global trend as is clearly shown in Figure 2. Together with this shift in mineral practice there has also been a shift in the nature of kaolins used in single coating. Where

carbonate levels are high there is often more pressure for the kaolin to develop sheet gloss and in some cases this has prompted customers to utilise ultrafine glossing kaolins in single coating recipes. This can be seen in the generic recipes cited for Europe and Asia in table I.

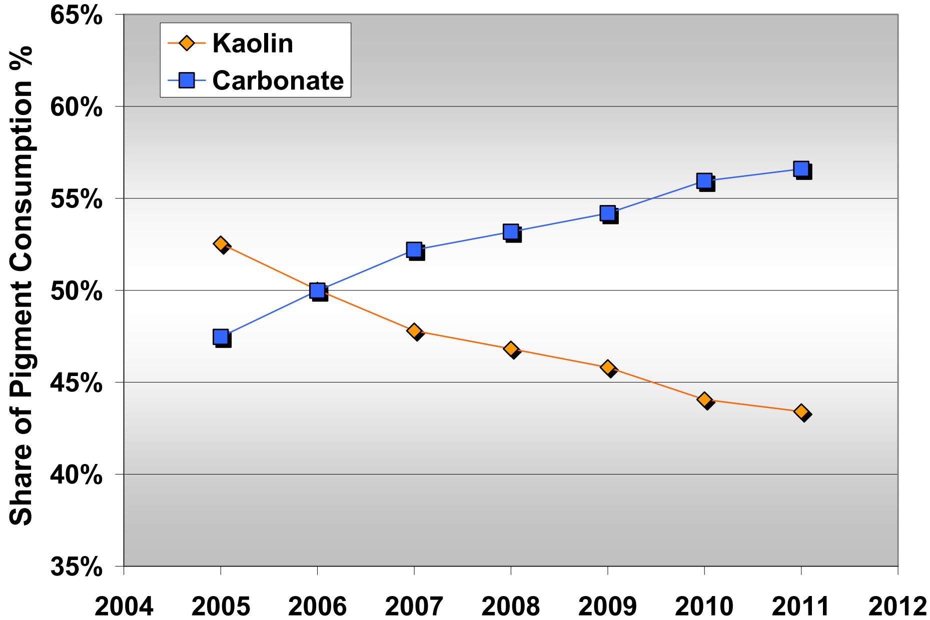

FIGURE 2. KAOLIN AND CARBONATE EVOLUTION IN SINGLE COATING GLOBALLY

So single coating can in essence be distilled to two broad approaches

- Kaolin rich with coarser and engineered kaolins and
- Carbonate rich with ultrafine glossing kaolins.

In considering the fundamentals of these two concepts it is apparent that although it maybe be possible to achieve similar performance in some paper properties, the underlying coating structure is likely to be significantly different. This is illustrated in Figure 3 which shows how the more typical single coating kaolins are very different in their size and shape characteristics compared to the ultrafine glossing kaolins.

Packing with fine or steep carbonates would also be expected to be different leading to very different coating structures and ultimately differences in performance which are perhaps more likely to show up after printing rather than in the coated paper itself.

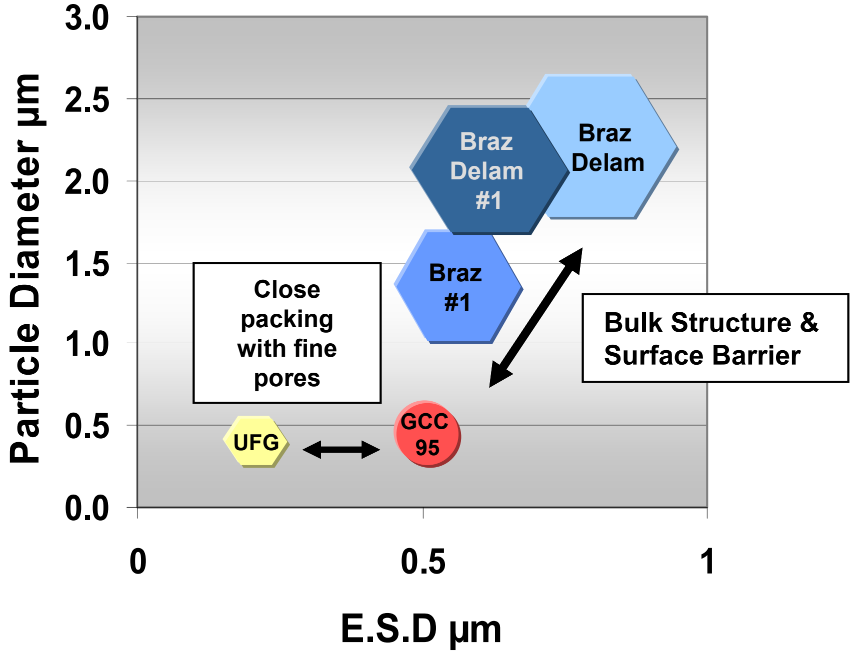

FIGURE 3. COATING STRUCTURE EFFECTS IN SINGLE COATING

Indeed much work has been done over the years assessing different pigment types and mixtures and their impact on coating structure and print quality. In particular the role of kaolin in affecting ink setting rates, ink transfer and ink holdout is well documented. [1,2,3,4,5,6,7]. Paper structure, surface chemistry porosity and surface roughness will be key factors affecting all of the above [8,9,10,11]. Porosity will impact the ink setting rate, ink tack build and water uptake [12,13,14]. Mottle tendency, picking and ink demand can also be linked to the porosity characteristics of the coating [15,16,17, 18,19,20]. Paper topography (gloss and roughness) will affect the print gloss [21,22]. The porosity of the coating layer has an impact on the speed of fluid with drawl from the ink layer, the subsequent ink setting rate and the print gloss achieved. A slower ink setting rate allows greater levelling of the ink and a higher print gloss [23].

For offset printing, surface strength and dimensional stability (especially in sheet fed presses) are also important. This may often be a complex issue as several different strength parameters are important, reflecting both the handling, converting and the end use of the paper. Strength failures can include dusting at the calender as well as picking during printing and the mechanisms of each will clearly differ. Pick within the coating layer itself is different from rupture at the coating / basestock interface. During the converting process, cracking at the fold may indicate inadequate coating tensile strength.

In this publication the focus of the studies was really to compare and contrast the differing single coating recipes in terms of the paper and print performance and their underlying coating structure. We also sought to determine the extent to which the different pigments concepts have different binder requirements and how changing binder level affects coating structure and performance.

METHODS

Paper Preparation

A systematic pilot coating program was put in place to benchmark range of formulation concepts in a single coated mechanical application. In this work the recipes were based on European LWC, but the findings are relevant to any single coating situation. The coating formulations are shown below in Table II and compare kaolin type and kaolin level effects. The kaolin was varied from typical Brazilian engineered coating kaolin to ultrafine glossing kaolin. Both steep and standard 95 grade GCCs were used and kaolin and carbonate ratios varied from 50 to 20% kaolin with the highest kaolin contents restricted to Brazilian kaolin and the lowest to Ultrafine glossing kaolin as discussed in the introduction. The latex used was DL920 Styron LLD, a carboxylated modified styrene butadiene with Tg=8° C, MFFT=9°C and particle size of 140 nm. The CMC is a high molecular weight carboxymethyl cellulose with degree of substitution of 0.7 from CP Kelco. The starch is a modified corn starch from Cargill designed for high speed paper coating. Coating was carried out at 1500 m/min using a jet applicator and 10 gsm of coating was applied to each side of a 40 gsm European LWC basepaper. The papers were calendered using an Optiload Calender at 850 m/min, 11 nips, pressure 200/300 KN and temperature 80/75°C.

Colour	1	2	3	4	5	6	7	8
Brazilian Engineered Kaolin (A)	50	35			50	35		
Ultrafine Glossing Kaolin (B)			35	20			35	20
Standard 95 GCC (C)					50	65	65	80
Steep 95 GCC (D)	50	65	65	80				
Latex - Dow 920	7	7	7	7	7	7	7	7
Starch - C-Film 07312	4	4	4	4	4	4	4	4
OBA - Blancophor P	1	1	1	1	1	1	1	1
CMC – Finnfix 30	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Ca-stearate – Nopcote C104	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Runnable Solids %	63.1	63.5	63.4	63.8	64.1	64.4	64.1	63.9
B100 mPa.s	930	1085	1520	1630	1180	1250	1760	1655
Water Retention gsm	62	66	68	71	55	54	53	76

Kaolin	A	B
2µm	91	98
D50	0.55	0.21
A.R	13	12
B'ness	88.2	88.3

GCC	C	D
2µm	97	96
D50	0.55	0.64
A.R	-	-
B'ness	95.0	95.4

TABLE II PILOT COATER STUDIES OF SINGLE COATING RECIPES

Printing was carried out on an Alberta Frankental Albert A101S HSWO press. Press conditions were carefully set up with respect to fount levels in order to show differences between formulations especially with respect to ink piling. Piling itself was determined from tape pulls from the upper printing blanket after printing of 27000 copies.

Laboratory Coatings

The laboratory study was a repeat of the pilot coating recipes, but with differences in the binder content. In this work the starch level was decreased 1 part from that used in the pilot studies and the latex level varied for each recipe between 5, 7 and 9 parts. The coated papers were prepared on a Helicoater ™. These were applied at their maximum runnable solids using a bent blade at 600 m/min. 12 gm^{-2} of colour was applied to both sides of a woodfree basepaper. The coatings were calendered using a laboratory supercalender 10 nips, 75ºC, 72-78 bar at 34 mpm.

Paper Testing

The coated papers were conditioned at 50% relative humidity and 23°C for at least 24 hours before standard laboratory paper testing was performed. A DataColor Elrepho 3300 was used to measure the optical characteristics of the papers using D65 illumination both calibrated with UV content and with the 400 nm UV cut off filter in place; paper brightness (D65), opacity (DIN), whiteness (D65) and L,a,b (D65). TAPPI 75° gloss on Hunterlab and PPS at 1000 kPa on PrintSurf were determined.

Coating pore size distributions were determined by a PASCAL 240 Porosimeter (CE Instruments) mercury porosimetry. Coatings were prepared by pouring a small amount of the coating colour (~10g) into an aluminium dish and then drying this in an oven at 80°C. The dried colour was then removed from the dish and a small chunk broken off for testing in the mercury porosimeter. This removed the need for removal of the basepaper peaks. Some of the coatings applied to paper were also measured using porosimetry and a good correlation was observed with the pore size between the dish sample and the paper sample. Corrections for the compression of mercury, glassware and oil phase were taken into account by running a blank experiment.

Critical Pigment / Binder Weight Concentration CPWC

In the area of paint research a commonly measured property of the paint is the critical pigment volume concentration (CPVC) this is described as the point where there is enough binder to completely surround the pigment and fill all the voids between the particles. At this point, there will be no light scattering from the voids and the porosity and strength properties of the coating will change radically. There is no excess binder. Carrying out an analysis of this point with the different coating systems used gives some indication of the 'intrinsic binder demand' of the pigment, that being the amount to surround the packed particles.

The method involves drawing down a thin film of coating colour (~15 gsm wet) onto a black impermeable substrate. A spacer ring is placed on the surface to prevent wet coating colour from being transferred to the instrument and the coating placed under the reflectometer. The reflectance is measured as a function of time until the film has dried [24]. As the film dries, the particles in the coating become closer and reflect the light less efficiently and the reflectance decreases. If the coating is fully bound, then the reflectance will reach a plateau when the film has dried. If it is not fully bound, then incorporation of the air during drying will cause the reflectance to increase again. This is therefore a sensitive measure of how well bound the coating is. This was carried out for all of the pigment blends included in this work, however the binder was expressed as a weight rather than a volume (pph or parts of binder per dry parts of pigment) as is common practice in the paper industry, and so is reported as a CPWC.

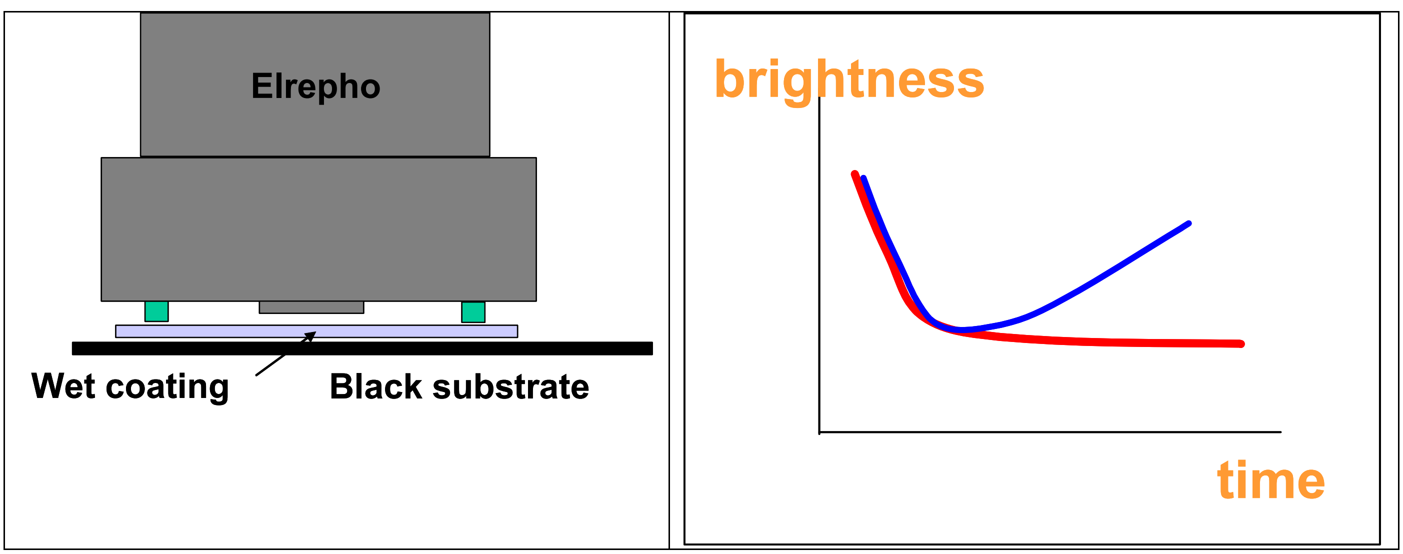

FIGURE 4. SIMPLE SET UP FOR WAVELENGTH EXPONENT MEASUREMENT. THE RED COATING IS FULLY BOUND (WITH PLATEAU) WHEREAS THE BLUE COATING SHOWS INCREASED REFLECTACE DUE TO AIR INCLUSION ON DRYING

Wavelength Exponents

The negative gradient of a log/log plot of light scattering against wavelength depends on the size of the scattering unit in the material being studied. The higher the gradient, normally referred to as the wavelength exponent, the smaller the scatter size.

The light scatter (S) and wavelength (λ) are related by:

$$S \propto \lambda^{-\beta}$$

so a plot of log(S) v log(λ) will have a negative slope of β, the wavelength exponent. The larger the value of β, the smaller the scatter size.

Modern spectrophotometers allow the easy and quick measurement of light scattering at many different wavelengths [25], [26]. An Elrepho 3300 was used to measure the optical characteristics of the papers using D65/10 illumination using a -420nm UV cut-off filter. Kubelka-Munk theory was used to calculate the sheet S and K at 400 to 700nm in 10nm steps. This method was used by Gate to study scattering unit size in coatings in 1972 [27].

PART 1 : PILOT COATING STUDIES COMPARING DIFFERENT PIGMENT CONCEPTS

The paper results from the pilot coating program which benchmarked a range of formulation concepts in European LWC are shown below in Table III. In general the results were as expected with the best performance given with engineered kaolin and engineered carbonate together. Likewise the poorest performance was seen with the combination of ultrafine kaolin and standard carbonate, especially when the kaolin level was very low. Intermediate performance was achieved when either one of the two pigments components was engineered.

Kaolin Level	Kaolin Type	GCC Type	Gloss	PPS	B'ness	Opac
50	Braz -A	Steep	62	1.04	80.6	91.7
35	Braz -A	Steep	60	1.07	81.1	91.6
35	Ultrafine- B	Steep	59	1.17	80.4	91.1
20	Ultrafine - B	Steep	57	1.19	81.1	90.9
50	Braz - A	Standard	58	1.14	80.0	91.1
35	Braz - A	Standard	56	1.18	80.2	90.8
35	Ultrafine - B	Standard	59	1.31	79.5	90.1
20	Ultrafine - B	Standard	54	1.38	80.1	90.0

TABLE III. PAPER PROPERTIES LWC PILOT TRIALS

The optical results can be linked to measures of the intrinsic bulk pore structure of the coating compositions. The pore size and pore volume of these formulation are shown below in Figure 5.

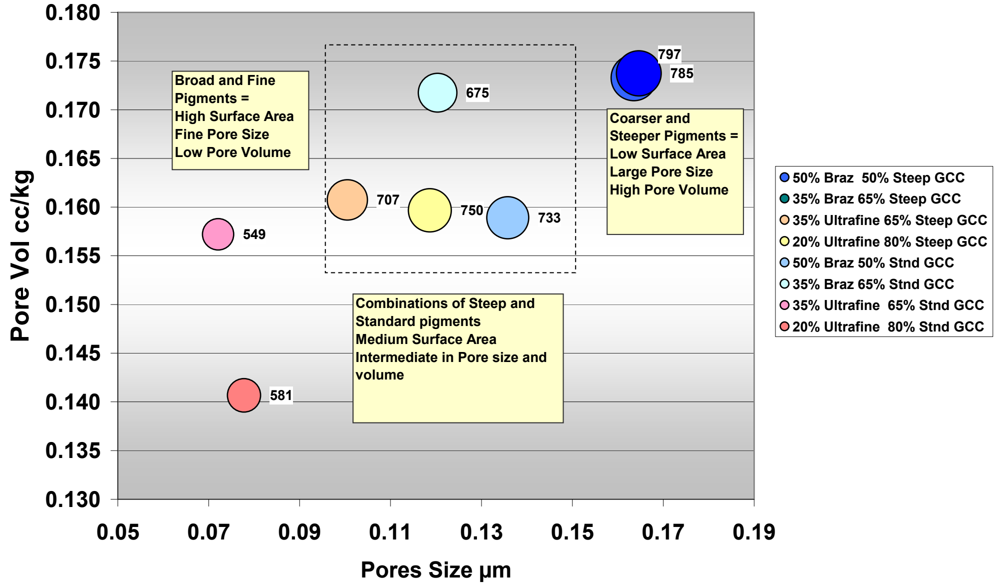

FIGURE 5. INTRINSIC BULK PORE STRUCTURE OF PILOT COATING RECIPES

It is apparent that these coating structure measurements (albeit made on dried coatings) clearly highlight the differences between the extremes in coating concepts. Those comprised of fine standard carbonate and ultrafine kaolin give the lowest pore volumes, finest pore sizes and poorest optical performance. Conversely those containing engineered carbonate and coarser engineered kaolin give the highest pore volume, largest pore size and best optical performance. Not surprisingly the recipes where only one component is engineered tend to give intermediate pore size and pore volume although it wasn't possible to differentiate the subtle differences in structure you would expect from these differing concepts.

One other point is evident from considering the coating structure in relation to the paper properties and that is the clear lack of correlation between bulk pore structure and surface properties after calendering. Indeed the coatings with the most open bulk structure are also those which give the best smoothness and highest sheet gloss. In fact kaolin level is perhaps a better predictor of sheet gloss than coating structure with the highest gloss given by more kaolin rich recipes. This relates to two factors. The first is the strong dependence of gloss on coating coverage in single coating applications which improves with increasing kaolin. The other is the influence of calendering on surface alignment. In coatings containing a significant amount of kaolin, calendering can often lead to a marked difference in surface structure compared to bulk structure, with the surface being more aligned and more densely packed than the bulk. This can improve micro-roughness and hence gloss compared to what would be expected from bulk structure measurements [4].

Likewise print gloss and ink setting is similarly influenced by these surface structure effects as seen below in Table IV and Figure 5. The best print gloss is given by coatings where coverage is maximised, but the surface is more closed to control ink setting. Engineered carbonate together with higher levels of engineered kaolin, are a powerful combination in this respect. Ultrafine kaolins tend to give faster ink setting and poorer print gloss.

Kaolin Level	Kaolin Type	GCC Type	Sheet Gloss	Print Gloss B100	Print Gloss B400	PPS Print	Dry Pick	Piling Extent
50	Braz -A	Steep	62	74	84	1.37	214	5391
35	Braz -A	Steep	60	71	83	1.40	224	6234
35	Ultrafine - B	Steep	59	72	81	1.45	185	8897
20	Ultrafine - B	Steep	57	68	80	1.47	183	11164
50	Braz - A	Standard	58	70	81	1.44	214	5937
35	Braz - A	Standard	56	67	80	1.58	237	5526
35	Ultrafine - B	Standard	59	67	78	1.69	209	8740
20	Ultrafine - B	Standard	54	66	76	1.73	236	4529

TABLE IV. PRINT PROPERTIES

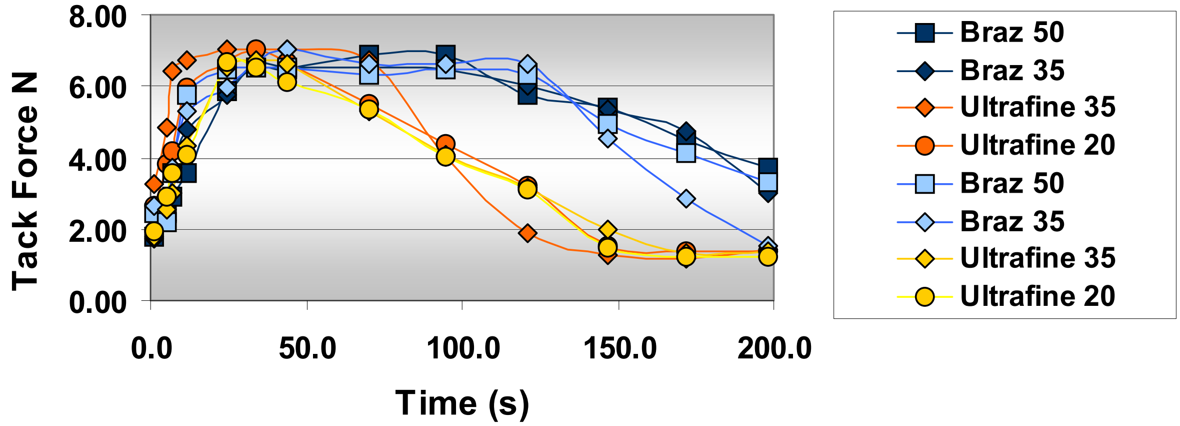

FIGURE 6. INK TACK DEVELOPMENT

The ink setting effects are also an important consideration when considering press runnability effects such as ink piling. In general the greatest ink piling tendency (Table IV) was seen with the coatings which gave the fastest ink setting in combination with lower coating strength. These tended to be based on recipes containing ultrafine kaolin, but with one notable exception which was the system with a low level of ultrafine kaolin (20 parts) and standard carbonate. This was the coating which was clearly the most macro-rough, which may indicate some contact effect in controlling piling, but it was also one of the stronger coatings which lead us to consider the importance of intrinsic binder demand in controlling paper and print properties.

PART 2 : LAB COATING STUDIES CONCENTRATING ON BINDER LEVEL

The full paper and print properties from the laboratory trials are shown in Appendix 1 and were broadly in line with the pilot coater results with respect to the pigment effects at a common binder level.

The magnitude of the differences which occur when increasing binder level from 5 to 9 pph are summarised in Table V. In terms of the variation with binder content there was no systematic change in the sheet gloss or roughness for any of the pigment systems, but light scatter and optics decreased in all cases. As expected, coating strength also increased in all cases with increasing binder. There was on balance a larger increase in strength for the coatings containing steep carbonate, indicating that these systems may well have been under bound at the lowest latex level. The porosity decreased (higher Gurley) in all cases with addition of more latex but in general the decrease was bigger with coatings based on standard carbonate, especially the combination of UF kaolin B with standard GCC. This could indicate that these systems have better intrinsic packing and therefore require less binder to fill up the structure. The standard carbonates also have the lowest change in wavelength exponent and stain length (Figure 7) with increasing binder level. These factors are indicative of a higher intrinsic binder demand in recipes containing significant amounts of steep carbonate.

	Tappi Paper Gloss 75°/%	PPS / µm	Scatter @ 560nm	Gurley Porosity s	B'ness	Opacity	Print Gloss %	Dry Pick Strength	Ink Setting tack decay to 4N	Stain length cm	λ Exp	Mercury Pore Size µm	Pore Vol cm3/kg
50% Kaolin A 50% Steep GCC	-1.2	0.02	-41	702	-0.9	-0.8	0	97	50	0.67	-0.078	0.014	-0.0038
35% Kaolin A 65% Steep GCC	-0.9	0.01	-19	678	-0.6	-0.2	-1.2	102	62	0.77	-0.064	0.003	0.0151
35% Kaolin B 65% Steep GCC	0.0	-0.03	-17	1008	-0.4	-0.4	3	83	28	0.67	-0.059	0.010	-0.0009
20% Kaolin B 80% Steep GCC	-0.7	0.03	-25	800	-0.6	-0.6	2	106	44	0.30	-0.057	0.007	-0.0407
50% Kaolin A 50% Stnd GCC	-2.5	0.05	-27	969	-0.7	-0.7	0	39	48	0.33	-0.070	0.010	-0.0033
35% Kaolin A 65% Stnd GCC	0.6	0.03	-29	1019	-0.6	-0.6	0.3	64	22	0.63	-0.041	0.003	-0.0037
35% Kaolin B 65% Stnd GCC	0.0	0.07	-11	1149	-0.1	-0.3	2.5	58	17	0.30	-0.036	-0.001	0.0009
20% Kaolin B 80% Stnd GCC	-1.5	0.02	-17	1288	-0.4	-0.4	3.5	63	27	0.50	-0.046	-0.004	0.0058

TABLE V. MAGNITUDE AND DIRECTION OF DIFFERENCES OCCURRING WHEN LATEX IS INCREASED FROM 5 TO 9 PPH

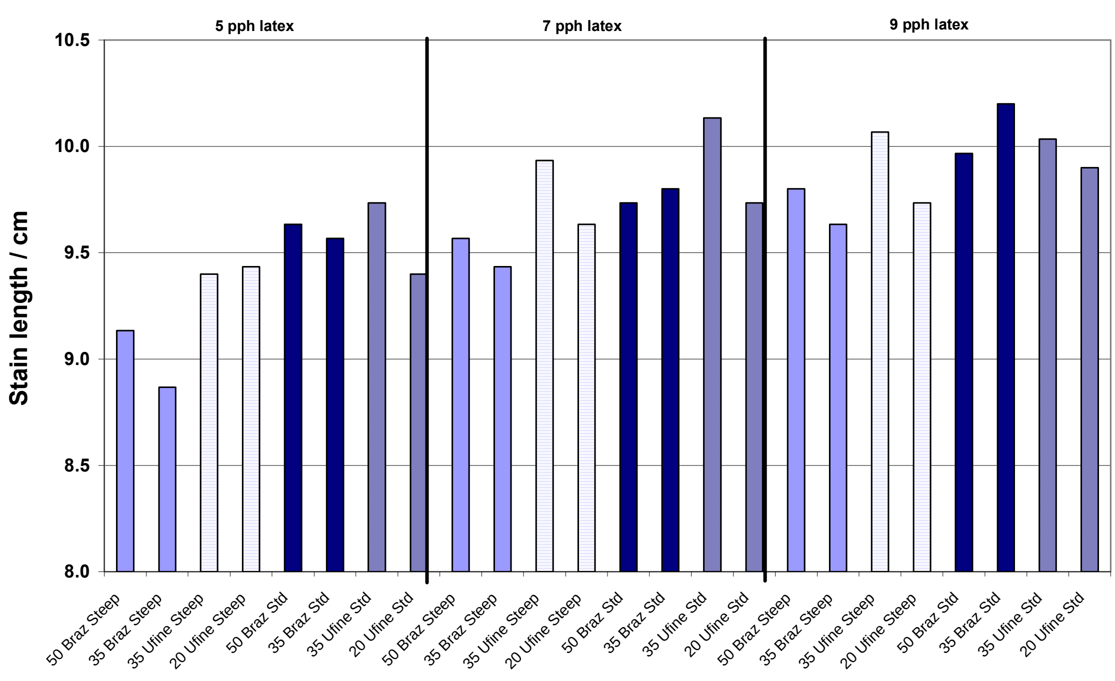

FIGURE 7. STAIN LENGTH FOR LABORATORY COATINGS WITH VARYING BINDER LEVEL

In contrast, the ink tack rise and decay is dominated by the kaolin component rather than the carbonate. It is clear that ultrafine kaolin gives the fastest ink setting at all binder levels. It is also clear that while increasing binder does tend to slow ink setting somewhat, large increases are needed to compensate for inherently fast ink setting. The coatings containing engineered Brazilian kaolin and steep carbonate gave similar ink set rates with 5 parts of latex as coatings containing ultrafine kaolin with 9 parts of latex. The fast ink setting associated with glossing clays is well reported and is due to the high number of pores per unit area in the surface these pigments generate [28]. However, what is surprising is the relative ineffectiveness of binder level as a tool to compensate for this.

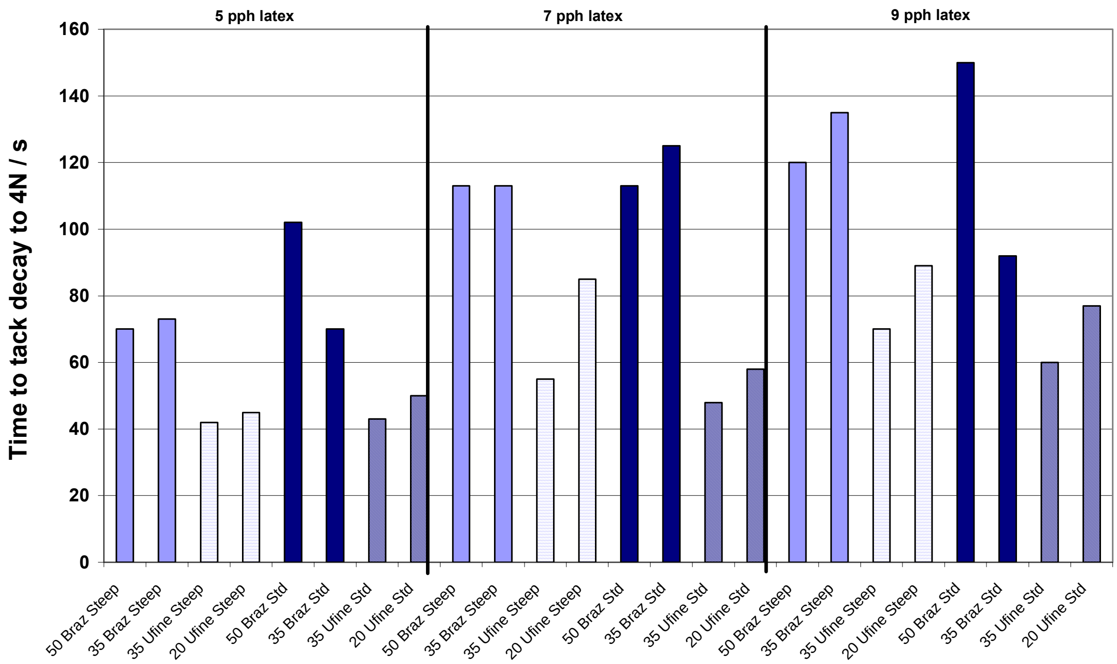

FIGURE 8. TIME FOR INK TACK TO FALL TO 4 N. BRAZILIAN CLAYS GIVE SIGNIFICANTLY SLOWER INK SETTING RATE, AS DOES INCREASING LATEX LEVEL

The print gloss is shown in Figure 9 and is interesting in that the impact of binder increase on print gloss depends on whether the coatings are fast or slow in ink setting rate. For the fast ink setting rate coatings which contain ultrafine kaolin, increasing of latex has slowed down the ink setting rate somewhat and resulted in higher print gloss. However, for the already fairly slow setting Brazilian clay containing coatings, there is little difference with increased binder. This suggests that even at the lowest binder levels the setting rate is already slow enough to allow ink film levelling. Again it is interesting to note that even though print gloss is improved with increasing binder level in the fast setting systems it never quite reaches the same level as that given by the coatings containing Brazilian kaolin.

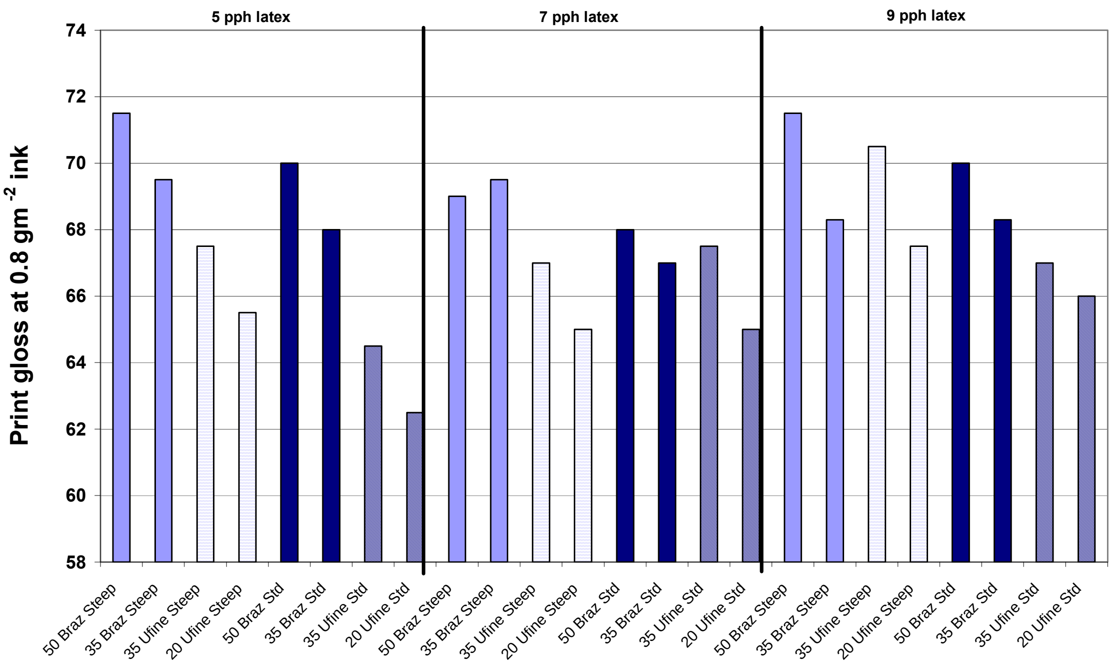

FIGURE 9. PRINT GLOSS FOR LAB. COATINGS INTERPOLATED AT 0.8 GSM INK

PART 3 : BINDER IMPACT ON COATING STRUCTURE

We saw that increasing binder level does impact paper and print performance and that there are differences in how the different pigment systems respond to increasing binder. There were also differences in the intrinsic binder requirement of the different pigment systems. However, we wanted to explore if these effects could be linked to differences in coating structure resulting from the different pigment/binder combinations.

In this section we explore the coating structure by:

- Determining the intrinsic binder demand from the CPWC test
- Using mercury intrusion porosimetry
- Determination of the size of the light scattering unit using wavelength exponents

CPWC Test

Initially the intrinsic binder demand as determined by the packing of the particles was assessed. A series of coatings were prepared which had different binder levels. The amount of binder required to completely surround the particles with none in excess was determined optically. From Figure 10 it is clear that there are varying binder requirements from the different mixes. The amount of binder required to cover the steep pigments is up to 2 pph greater than the blends containing the broad p.s.d. carbonate with the highest amount being needed for the blends containing the Brazilian clay with steep carbonate.

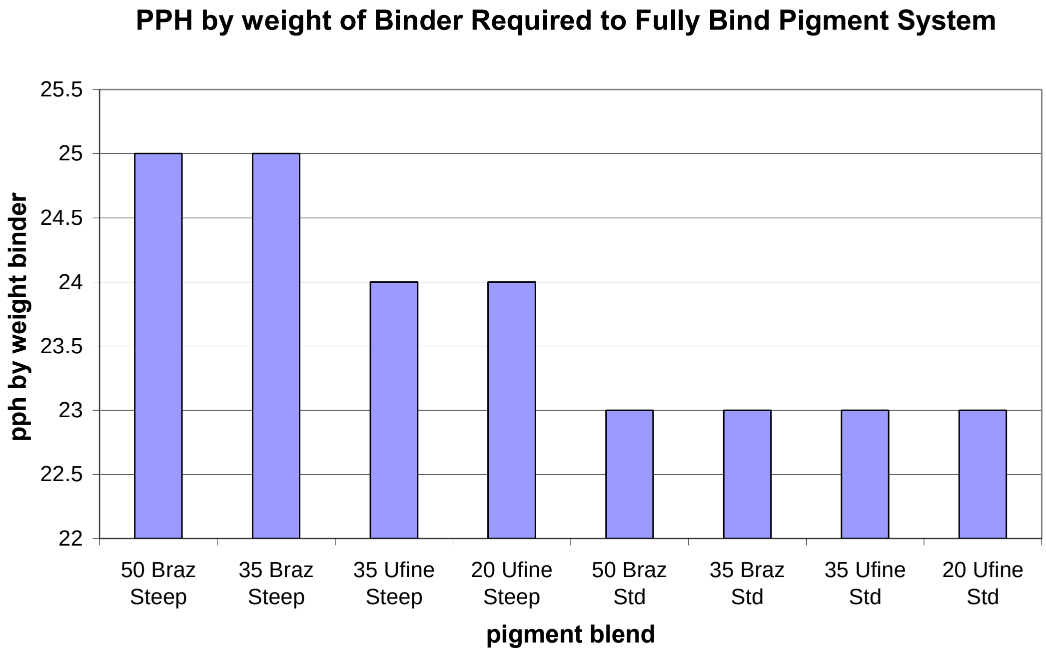

FIGURE 10. PPH BY WEIGHT OF BINDER REQUIRED TO FULLY BIND THE PIGMENT

The mercury porosimetry data is shown below in Figures 11 and 12. There are clear differences afforded by the varying pigment systems. Notably the steep carbonates give larger pore sizes and slightly higher pore volumes than the standard carbonates. The pore size is also impacted by the particle size and surface area of the pigments. In Figure 13 the correlation between pigment blend surface area and pore size is shown. However, while mercury porosimetry showed clear differences between the pigment compositions, it was less effective in differentiating the differences arsing from changes in binder level. In Figures 11 and 13 it is clear that increasing binder has had relatively little effect on the pore size in the coatings. The pore volume data does at least show some variation, but the differences are small and the trends are not consistent. This brings into question how useful mercury porosimetry is for assessing binder differences as clearly the differences in paper optics and ink setting arising from binder increase suggests some change in coating structure.

Clearly another technique was needed to try and understand the impact of binder changes and this lead us to explore wavelength exponents.

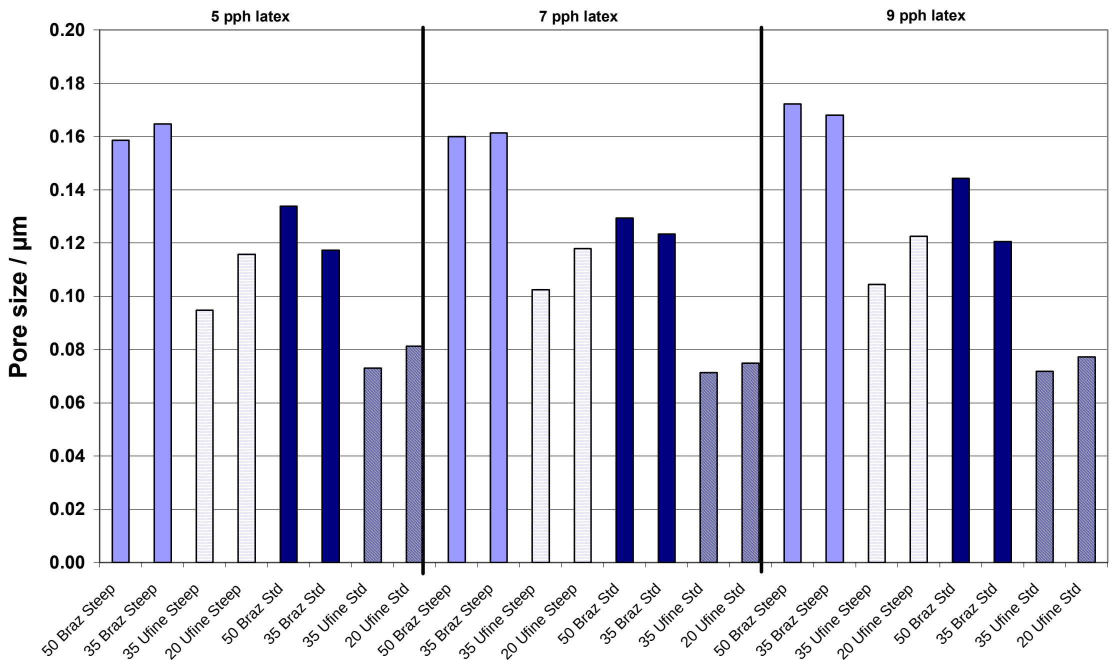

FIGURE 11 MERCURY POROSIMETRY – INDICATIVE (MODAL) COATING PORE SIZE

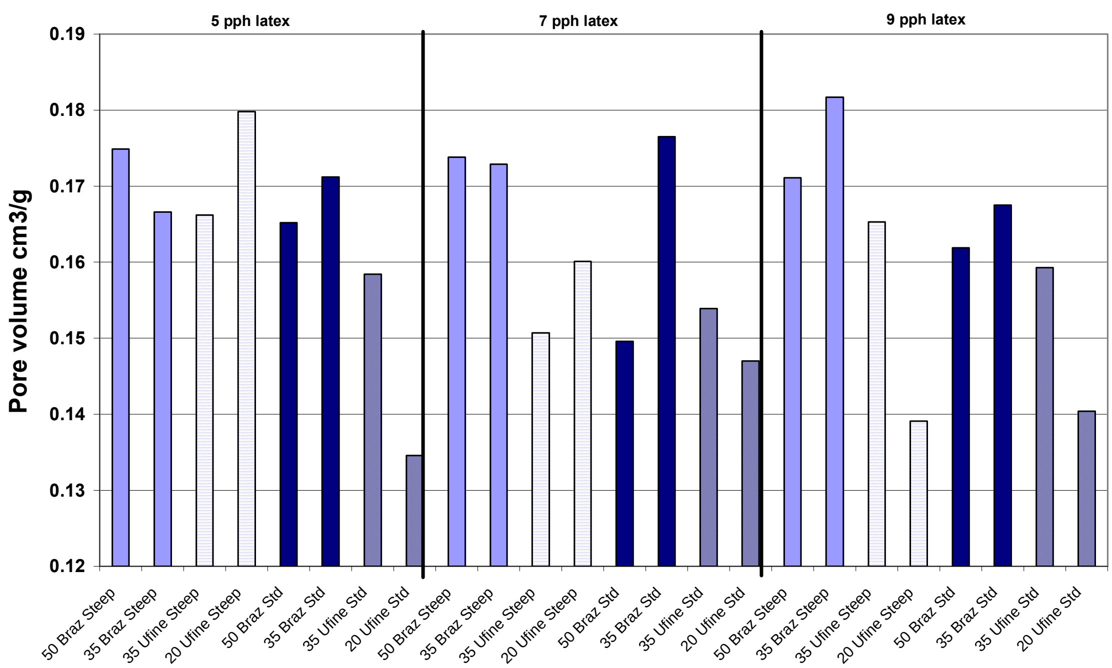

FIGURE 12 MERCURY POROSIMETRY – COATING PORE VOLUME

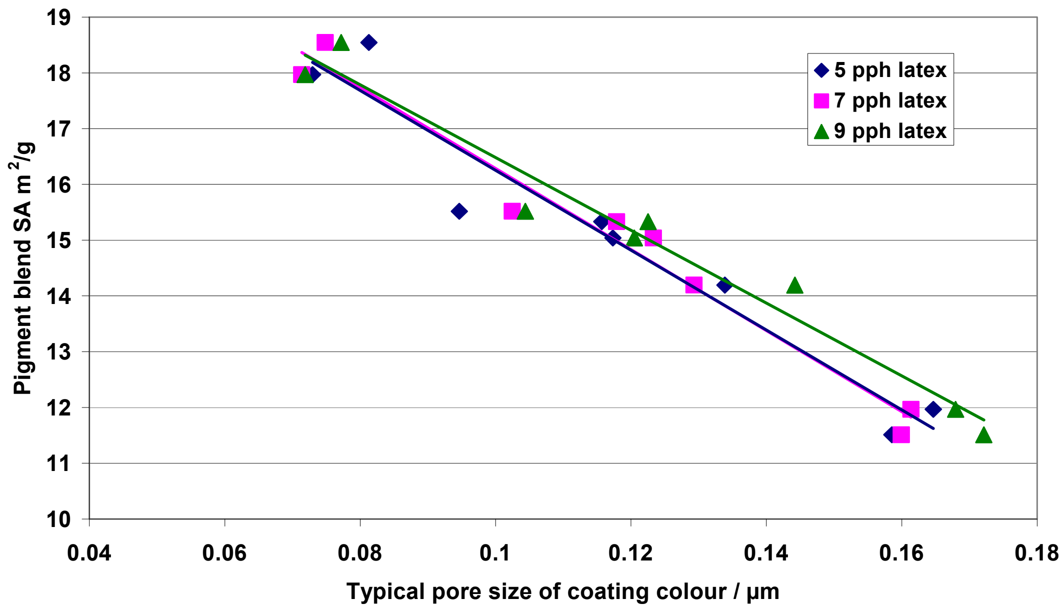

FIGURE 13 A HIGHER SURFACE AREA OF THE PIGMENT RESULTS IN SMALLER PORES IN THE COATING

More information concerning the coating structure can be given by the wavelength exponents. These are plotted in Figure 14. In this plot a higher bar is a higher –β and represents the fact that the light scattering is given from a smaller scattering unit. It can be seen that the size of the scattering unit is influenced by both the pigment and binder selection. The largest pigment effect relates to the inclusion of ultrafine glossing clay in the recipe. This has a marked effect in shifting the scattering unit to a smaller sub-optimal size. No differences between the two 95 grade steep and standard GCCs was less evident.

Perhaps more interesting though was the effect of binder level on scattering unit size. Intuitively one would expect that adding more binder would perhaps reduce the scattering unit size but this data clearly shows the inverse effect. Although the increase in scattering unit size with increasing binder is small it is systematic. It can be postulated that this effect may be because the film formed binder is filling some of the smaller pores or that the binder around the pigment is appearing to enlarge the pigment particle giving a larger scattering unit. In either event suggests that if the scattering unit is increased in size then the reason for reduced light scatter with increased binder must relate to a decrease in the number of scattering units.

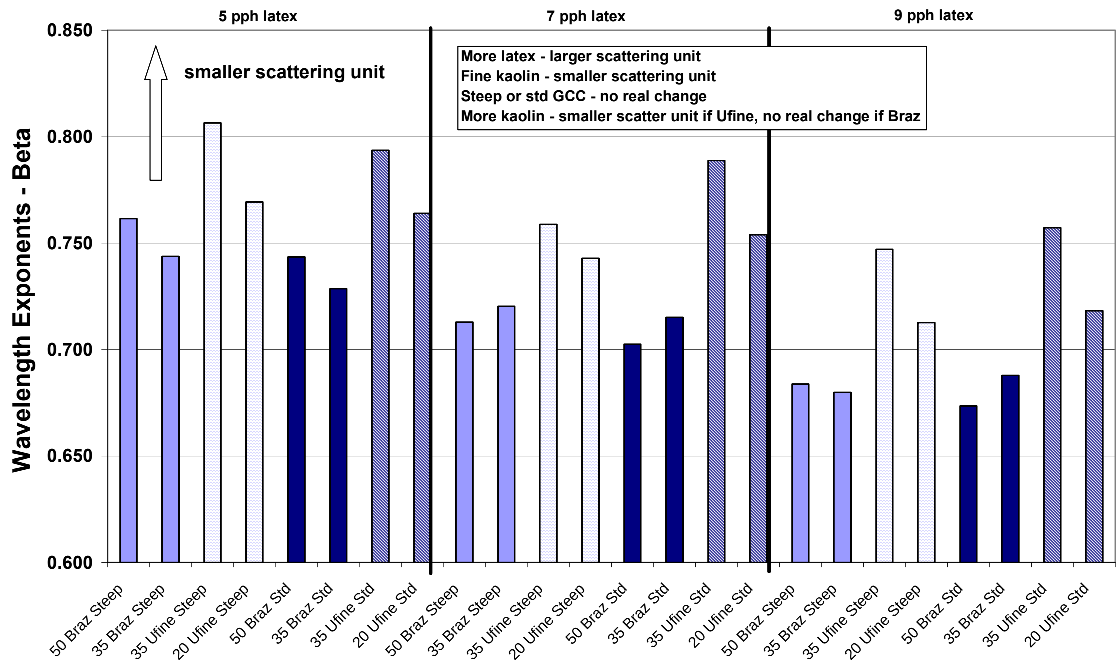

FIGURE 14. WAVELENGTH EXPONENTS INDICATING VARIATION IN SIZE OF SCATTERING UNIT FOR BOTH PIGMENT AND BINDER VARIATION

SUMMARY ANDCONCLUSIONS

In this paper we evaluated some commonly used single coating recipes to explore the differences in pore structure and their subsequent impact on paper properties and printability. Both pigment blend and latex level were varied.

In assessing the results it is clear that there were extremes in terms of both paper and print performance from the different formulation concepts, but there was also middle ground in which more than one approach lead to broadly similar performance in terms of paper properties. Table VI summarise the relative rankings of the different pigment concepts when evaluated at a common binder level

	Paper Quality	Print Quality	Press Runnability	Overall Ranking
50:50 Braz/Steep	1	1	1	1
35:65 Braz/Steep	2	2	1	2
50:50 Braz/Stnd	3	3	1	3
35:65 Braz/Stnd	4	4	1	4
35:65 UF/Steep	3	3	4	5
20:80 UF/Steep	3	3	5	6
35:65 UF/Stnd	5	5	4	7
20:80 UF/Stnd	6	6	1	8

TABLE VI. SUMMARY OF PIGMENT EFFECTS IN LWC

It was clear that the highly engineered pigment systems (both kaolin and carbonate) gave the best overall performance while those based on fine broad p.s.d combination gave the poorest performance. Moreover, these findings could be linked to coating structure differences in so much that these concepts also gave the extremes in terms of coating structure. Overall the best performance in single coating was given by coatings with the most open bulk structure but closed surface. A higher level of kaolin was also desirable because of the benefits to coating coverage and gloss generation.

However, it was clear that binder level and intrinsic binder demand of pigment concepts could also influence their attractiveness in terms of cost and performance. In assessing the impact of binder content we saw that increasing binder level does impact paper and print performance. Some common themes across all pigment systems with increasing binder were

- No systematic impact on gloss and roughness
- A reduction in porosity (bulk and surface)
- Increased scattering unit size, but reduced light scatter and optics due to reduced number of scatterers (reduced pore volume)
- Increased coating strength
- Slower ink setting

There were also differences in how the different pigment systems responded to increasing binder. In general the finer more densely packed coatings appeared to have a lower intrinsic binder requirement (2 parts) than the more open structures, with the presence of steep carbonate being the key factor for increased binder demand. However, binder demand can be judged by more than one factor. In terms of properties such as ink setting, print gloss and ink piling the presence of ultrafine glossing clay was the most influential factor. In this work it was seen that up to 4 parts more latex was need to slow ink setting to the same level as that given by coatings containing Brazilian kaolin. Even then print gloss failed to quite reach that achieved with higher levels of Brazilian kaolin in the recipe.

This highlights the importance of controlling and optimising coating structure through pigment selection as using binder level as a tool to compensate for a sub-optimal system can be costly and not entirely effective.

APPENDIX 1.

	50 braz steep	35 Braz steep	35 UF steep	20 UF steep	50 Braz std	35 Braz std	35 UF std	20 UF std
Coatweight	10.8	10.4	10.7	10.7	10.6	10.5	10.5	10.4
H-Gloss-75	60.3	56.6	61.4	56.0	60.0	55.9	60.7	55.1
Bness-F8 (-UV)	78.2	78.4	77.1	78.1	77.3	77.4	76.1	76.8
Yness (-UV)	3.9	3.6	3.8	3.4	3.9	3.6	3.7	3.3
Opacity	90.7	90.4	89.7	90.0	90.1	90.0	89.3	89.2
Bness-F8 (+UV)	84.0	84.2	83.1	84.2	83.2	83.4	81.7	82.8
Wness (+UV)	88.2	89.0	87.7	89.9	87.2	88.2	85.9	88.2
PPS1000	0.73	0.80	0.87	0.90	0.78	0.84	0.91	1.06
Gurley Porosity	1038	992	1483	1247	1418	1477	1939	1759
Bulk	1.11	1.13	1.13	1.11	1.12	1.12	1.12	1.11
Sheet S (460nm)	766	757	706	728	718	713	665	673
Sheet K (460nm)	23.4	22.6	23.9	22.4	23.8	23.4	25.0	23.7
Sheet S (560nm)	680	673	619	642	639	634	583	592
Sheet K (560nm)	16.6	16.4	17.1	16.5	17.1	17.2	18.3	17.7
cm / sec	123.82	129.28	126.25	117.75	166.31	164.48	150.52	159.02
std dev'n	3.8	12.9	16.9	6.6	1.1	10.0	13.7	13.9
Absorption mottle within 2 minute interval	3	2	2	6	3	3	2	2
Overall absorption mottle	6	5	5	7	5	4	6	4
Ink absorption	2	2	3	2	3	4	3	3
secondary mottle	Severe Pick	Severe Pick	Severe Pick	Bad pick	Slight pick	No mottle	Severe Pick	Bad pick
isit max tack	23	24	12	13	23	20	13	12
isit decay 4n	70	73	42	45	102	70	43	50
Stain length	9.13	8.87	9.40	9.43	9.63	9.57	9.73	9.40
pore size µm	0.15853	0.16465	0.09466	0.11569	0.13388	0.11734	0.07297	0.08129
pore vol cm3/g	0.1749	0.1666	0.1662	0.1798	0.1652	0.1712	0.1584	0.1346
Print gloss at .008g	71.5	69.5	67.5	65.5	70	68	64.5	62.5
print density at 0.8 gsm ink	1.25	1.28	1.28	1.24	1.28	1.24	1.26	1.26
Ecklund GWR 60's @ 1 bar (gsm)	99	108	100	108	74	74	90	83

TABLE VI. PAPER AND PRINT PROPERTIES OF LAB SAMPLES CONTAINING 5 PPH LATEX

	50 braz steep	35 Braz steep	35 UF steep	20 UF steep	50 Braz std	35 Braz std	35 UF std	20 UF std
Coatweight	10.8	10.4	10.7	10.7	10.6	10.5	10.5	10.4
H-Gloss-75	60.3	56.6	61.4	56.0	60.0	55.9	60.7	55.1
Bness-F8 (-UV)	78.2	78.4	77.1	78.1	77.3	77.4	76.1	76.8
Yness (-UV)	3.9	3.6	3.8	3.4	3.9	3.6	3.7	3.3
Opacity	90.7	90.4	89.7	90.0	90.1	90.0	89.3	89.2
Bness-F8 (+UV)	84.0	84.2	83.1	84.2	83.2	83.4	81.7	82.8
Wness (+UV)	88.2	89.0	87.7	89.9	87.2	88.2	85.9	88.2
PPS1000	0.73	0.80	0.87	0.90	0.78	0.84	0.91	1.06
Gurley Porosity	1038	992	1483	1247	1418	1477	1939	1759
Bulk	1.11	1.13	1.13	1.11	1.12	1.12	1.12	1.11
Sheet S (460nm)	766	757	706	728	718	713	665	673
Sheet K (460nm)	23.4	22.6	23.9	22.4	23.8	23.4	25.0	23.7
Sheet S (560nm)	680	673	619	642	639	634	583	592
Sheet K (560nm)	16.6	16.4	17.1	16.5	17.1	17.2	18.3	17.7
Dry Pick cm / sec	123.82	129.28	126.25	117.75	166.31	164.48	150.52	159.02
Absorption mottle within 2 minute interval	3	2	2	6	3	3	2	2
Overall absorption mottle	6	5	5	7	5	4	6	4
Ink absorption	2	2	3	2	3	4	3	3
secondary mottle	Severe Pick	Severe Pick	Severe Pick	Bad pick	Slight pick	No mottle	Severe Pick	Bad pick
isit max tack	23	24	12	13	23	20	13	12
isit decay 4n	70	73	42	45	102	70	43	50
Stain length	9.13	8.87	9.40	9.43	9.63	9.57	9.73	9.40
Pore size µm	0.15853	0.16465	0.09466	0.11569	0.13388	0.11734	0.07297	0.08129
Pore vol cm3/g	0.1749	0.1666	0.1662	0.1798	0.1652	0.1712	0.1584	0.1346
Print gloss at .008g	71.5	69.5	67.5	65.5	70	68	64.5	62.5
Print density at 0.8 gsm ink	1.25	1.28	1.28	1.24	1.28	1.24	1.26	1.26
Ecklund GWR 60's @ 1 bar (gsm)	99	108	100	108	74	74	90	83

TABLE VII. PAPER AND PRINT PROPERTIES OF LAB SAMPLES CONTAINING 7 PPH LATEX

	50 Braz steep	35 Braz steep	35 UF steep	20 UF steep	50 Braz std	35 Braz std	35 UF std	20 UF std
Coatweight	10.2	10.6	10.6	10.7	10.2	10.6	10.9	10.8
H-Gloss-75	58.0	56.0	59.6	55.0	56.0	54.3	60.2	56.2
Bness-F8 (-UV)	77.5	78.2	76.8	77.6	76.8	77.3	76.2	76.7
Yness (-UV)	4.2	3.8	4.0	3.5	4.0	3.7	3.8	3.6
Opacity	90.0	90.4	89.6	90.0	89.9	89.8	89.1	89.1
Bness-F8 (+UV)	83.1	84.2	82.5	83.7	82.2	83.3	82.1	82.8
Wness (+UV)	86.1	88.8	86.3	88.9	85.1	88.1	86.4	87.9
PPS1000	0.78	0.77	0.91	0.95	0.92	1.00	1.01	1.04
Gurley Porosity	1270	1266	1752	1606	1613	1857	2499	2475
Bulk	1.13	1.11	1.10	1.12	1.13	1.13	1.11	1.12
Sheet S (460nm)	726	749	697	716	700	704	660	662
Sheet K (460nm)	23.8	22.8	24.3	23.1	24.5	23.4	24.5	23.5
Sheet S (560nm)	650	669	615	635	626	627	579	584
Sheet K (560nm)	16.9	16.4	17.3	17.0	17.8	17.1	17.8	17.3
Dry Pick cm / sec	225.00	218.00	199.00	252.00	233.00	225.00	219.00	225.00
Absorption mottle within 2 minute interval	7	6	4	3	6	8	2	3
Overall absorption mottle	8	7	7	6	4	3	4	4
Ink absorption	2	2	3	3	4	4	4	4
secondary mottle	Slight pick	Very SlightPick	No mottle	No mottle	No mottle	Very slight mottl	Slight pick	No mottle
isit max tack	23	35	10	20	34	30	13	23
isit decay 4n	113	113	55	85	113	125	48	58
Stain length	9.57	9.43	9.93	9.63	9.73	9.80	10.13	9.73
Pore size µm	0.15995	0.16137	0.10246	0.11788	0.12933	0.12331	0.07137	0.07484
Pore vol cm3/g	0.1738	0.1729	0.1507	0.1601	0.1496	0.1765	0.1539	0.147
Print gloss at .008g	69	69.5	67	65	68	67	67.5	65
Print density at 0.8 gsm ink	1.29	1.29	1.3	1.31	1.27	1.28	1.32	1.3
Ecklund GWR 60's @ 1 bar (gsm)	97	105	97	105	77	73	94	83

TABLE VIII. PAPER AND PRINT PROPERTIES OF LAB SAMPLES CONTAINING 9 PPH LATEX

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This paper is dedicated to the memory of Dr Len Gate, who sadly passed away in December 2010. Among his many contributions to the world of minerals and optical physics was the use of wavelength exponents in paper. He is and will be missed by us all.

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