

# PIGMENT IMPACTS ON STRENGTH IN A PAPER COATING & MOVEMENT OF BINDER DURING COATING COLOUR CONSOLIDATION

**Authors:** Janet Preston<sup>1</sup>, Martti Toivakka<sup>3</sup>, Andrew Findlay<sup>1</sup>, Rui Sergio Tsukuda<sup>2</sup>, Evandro Oliveira<sup>2</sup>, Edenil Costa<sup>2</sup>

<sup>1</sup> Imerys Minerals Ltd., Par Moor Centre, Par Moor Rd, Par, Cornwall, UK PL253EH

<sup>2</sup> Imerys do Brasil - Av. Valentina M.F. Borestein, 545 - 08735-270 - Mogi das Cruzes/SP

<sup>3</sup> Åbo Akademi, Laboratory of Paper Coating and Converting, Finland

## ABSTRACT

The reduction of binder concentration in coatings, within the constraints of acceptable final paper quality, is a constant focus for cost effective production of paper and board coatings. As binder levels are reduced, issues of strength and printability become more and more critical, due to the increasing probability of creating a heterogeneous binder distribution within the coating structure. Obtaining the maximum strength for a given amount of binder added is a goal for the cost-conscious paper maker.

In this presentation, the complexity of strength measurement of a coating is outlined as well as the factors which impact the IGT dry pick test. The dry pick test is shown to have a good correlation with a commercial press trial; where coating pick on the printing blanket was assessed after a controlled print run; and is more relevant than a laboratory wet pick test using pre-damping water.

Pigment properties such as particle size distribution, surface area and shape factor of the minerals in the coating layer have a profound impact on the resultant strength and these are discussed. The impact of how the latex is added to the slurry is also determined. The broad particle size distribution GCC was separated into two fractions - fine and coarse. The effects of adding the latex binder to either the fine or the coarse fraction separately, or in sequence, was explored, and compared to a situation where the latex is added to the combined blend. It was found that mixing the latex first with the finer pigment fraction and then blending in the coarse fraction does not significantly influence the strength of the coatings or indeed the other properties. It appears that mixing ensured uniform binder distribution herein.

The process of applying a coating colour onto a porous paper substrate results in some loss of the aqueous phase into the substrate. Along with the water, some binder, latex or starch may

be lost, depleting the coating layer and reducing strength. This might be at least partly offset by enrichment of binder at the coating-base interface. In this study, we have also attempted to relate the effects of binder depletion on the type and location of failure observed in the dry pick test. We present evidence that there is a depletion of latex binder from the coating surface during the coating application stage, and a subsequent enrichment of the binder at the coating-basepaper interface. This effect is greatest with an absorbent basepaper and a coating pigment which has poor water retention characteristics.

A total formulation approach, incorporating thickeners and water retention aids is required to obtain an optimised coating solution.

**Keywords:** Coating strength, coating color dewatering, consolidation, IGT dry pick test

## INTRODUCTION

Worldwide, calcium carbonate is the most widely used mineral in the coating of paper. Predominantly, ground natural calcium carbonate (GCC) is used, in both broad and narrow particle size distribution (P.S.D.) variants. Precipitated calcium carbonates (PCC) are also used and as a result of their extremely narrow particle size distribution and high purity, PCCs give the highest light scatter and brightness. Latex binder is added to the coating formulation to promote adhesion between the pigment particles themselves and to the basepaper. After application and before the immobilisation stage, the latex may be redistributed through the coating layer. After the immobilisation stage it is believed that no further changes in latex distribution occur.

The majority of carbonate coated papers are printed by offset lithography. In this process, relatively high tack inks are used and during printing the surface strength of the coating is a critical parameter. Papers can exhibit picking when subjected to the high stresses which develop during ink application. These stresses result from the tack build associated with the loss of ink solvent into the pores of the coating, and the consequent increase in cohesivity of the ink film<sup>[1,2,3]</sup>. Picking as a result of the oil-based ink alone is normally referred to as "dry pick". Additionally, the offset process uses water, which is known to weaken the coating, leading to the phenomenon of "wet pick"<sup>[4,5]</sup>. Picking increases downtime on the press as more blanket washing cycles are required. Therefore, the distribution and optimum use of the latex added to the formulation is vital for cost effective papermaking.

In order to avoid picking, binder must be present in a sufficient amount to give adequate strength for the combination of pigment and base paper in use. This is referred to as the "binder demand" of the pigment. It is widely accepted that surface area is the most important factor determining binder demand, although Cobb<sup>[6]</sup> was unable to show this. Her work clearly established a correlation of binder (casein) demand with the pore volume of the mineral-based coating layer. This is not unexpected, since porosity in a material reduces its strength because the voids have no load-bearing ability. Using this argument, pigments that increase the porosity of the coating, such as PCCs, should require more binder.

Since Cobb's paper, there have been a surprisingly small number of published studies on binder demand. Lepoutre and Hiraharu<sup>[7]</sup> investigated the differences in z-direction strength of coating layers based on GCC and kaolin. Using the IGT pick test with oil, they concluded that the mechanical strength of the GCC coatings was higher than the clay. Petterson et al.<sup>[8]</sup> also investigated the wet pick strength of coated papers and concluded that GCC coatings were stronger than clay coatings under their experimental conditions. They suggested that the role of water was to interfere with the adhesion between latex and pigment. Further studies of the z-directional strength of kaolin and GCC layers were reported by Inoue and Lepoutre<sup>[9]</sup>. They found that the peel energy of GCC layers was higher than kaolin layers at the same binder level.

Techniques to determine the distribution of latex binder within the coating layer have been developed. Hiorns et al.<sup>[10]</sup> used the ATR-IR technique to determine the relative ratio of pigment to latex or plastic pigment in the top 0.5  $\mu\text{m}$  of coated paper surfaces, as did Halttunen et al.<sup>[11]</sup> Other techniques used to study latex binder distribution include Confocal Raman Microscopy<sup>[12]</sup>, XPS<sup>[13]</sup> and

Os staining techniques combined with electron microscopy<sup>[14]</sup>. Recently argon beam etching has been used to prepare cross-sections for SEM without staining, and images from this work are shown in Figures 6 and 7<sup>[15]</sup>.

There have been several publications concerning the migration of binder during coating colour application and the consolidation and drying process<sup>[16, 17, 18]</sup> and the dewatering process and interactions between coating colours and basepaper<sup>[19, 20, 21]</sup>. The role of pigment in dewatering and location of the binder have also been reported by Lee<sup>[22]</sup> and Baumeister<sup>[23]</sup>. Baumeister suggested that the dewatering of pigment suspensions is related to the inverse square of the pigment specific surface area. This would lead to possibly more dewatering of the coating fluid phase into the basepaper, including the binder, for the lower surface area PCC coatings. Migration of binder within the coating has also been a subject of discussion for many years, and a good review of the research has been given by Groves<sup>[24]</sup>. It is clear that soluble binders, such as starch, migrate with the water phase. Eames<sup>[25]</sup> investigated the migration of starch from clay coatings on substrates of different pore size and correlated the loss of starch with transverse tensile strength (TTS).

In the first part of this paper the impact of pigment properties on the intrinsic strength of the coating are discussed with a short analysis of the complexity and competing factors which all impact the printing strength of coated paper.

The impact of how the latex is added to the slurry is then also assessed. There is some evidence to suggest that in the final dried coating layer, the latex is clustered around the fine particles, and this part of the experiment seeks to determine if the latex is associated with the particles it 'sees first' on addition to the slurry, or if during the mixing process it is redistributed evenly in the wet state.

The final part of this paper seeks to investigate the distribution of latex binder throughout a coated paper by changing such parameters as pigment design, presence of precoat and coating application solids. These effects are then related to the pick strength. Differences in dewatering were assessed using different pigments and application solids and the amount of latex binder remaining in the coating measured using IR techniques.

## METHODS

### Part 1 - Intrinsic Strength of Pigment Coating

The calcium carbonate pigments used are listed in Table 1 together with their physical properties. These covered a range of mean particle sizes and types, both GCCs (broad and narrow P.S.D.)

**Table 1.** Physical properties of calcium carbonate pigments

Pigment	Description	Particle size distribution by Sedigraph™, wt% below				d50, $\mu\text{m}$	P.S.D. steepness	BET surface area, $\text{m}^2\text{g}^{-1}$
		2 $\mu\text{m}$	1 $\mu\text{m}$	0.5 $\mu\text{m}$	0.25 $\mu\text{m}$			
GCC CB	Coarse broad P.S.D.	61	38	22	11	1.3	30	7.7
GCC FB	Fine broad P.S.D.	92	64	38	21	0.64	35	11.2
GCC UFB	Ultrafine broad P.S.D.	99	87	56	32	0.40	40	18.3
GCC CN	Coarse narrow P.S.D.	84	54	21	7	0.92	44	8.9
GCC MN	Medium narrow P.S.D.	88	58	24	9	0.84	44	9.4
GCC FN	Fine narrow P.S.D.	93	69	30	10	0.71	47	11.1
PCC M	Medium rhombic	94	83	37	4	0.59	59	7.4
PCC F	Fine rhombic	97	91	66	15	0.40	58	9.6

and PCCs. The average particle size is given by the d50 and the P.S.D. steepness is defined as  $(d_{30} / d_{70}) \times 100$  as measured by a Micromeritics sedigraph.

The binder was a styrene-butadiene-acrylonitrile latex having  $T_g = 10^\circ\text{C}$  (with an average particle diameter of 150 nm). Coating colours were prepared using 100 parts of each mineral pigment and a range of latex binder levels from 8 to 12.5 pph. 0.3 pph CMC (Finnfix 10™, CP Kelco) was added to all colours.

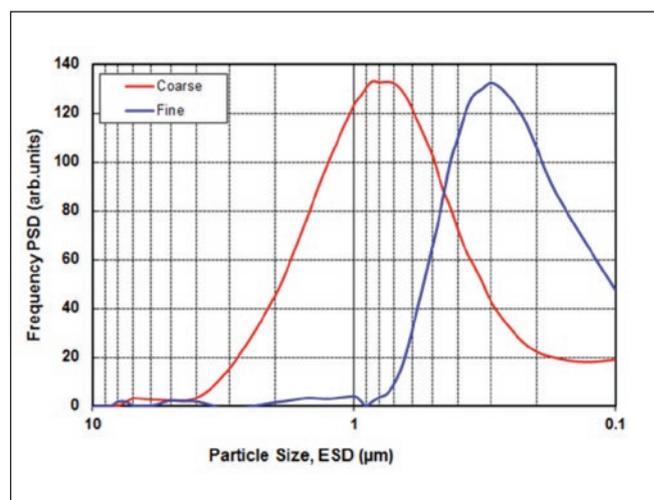
Coatings were applied to a 60  $\text{gm}^{-2}$  woodfree base paper using a Heli-Coater™ with blade metering. Speed was 600  $\text{m min}^{-1}$  and a coat weight of 11 – 12  $\text{gm}^{-2}$  was applied. The coated strips were calendered using a Perkins laboratory calender at 65°C and a linear nip load of 89  $\text{kg cm}^{-1}$ . The mean pore size and volume of unsupported coatings and coated papers were measured by mercury intrusion using a Pascal 240 porosimeter (CE Instruments). Corrections for glassware expansion were applied. When using coated papers, curve fitting was applied to separate the pores associated with the base paper from the smaller coating pores.

The dry pick strength of the coated papers was measured using an AIC2-5 unit (IGT). The unit was run in accelerating mode up to a maximum velocity of 2  $\text{ms}^{-1}$ . 1  $\text{cm}^3$  of a standard single phase polybutyne oil [26] of viscosity 17 Pa.s was applied and the print was assessed visually using low angle illumination to assess the speed and mode of failure, coating or basestock. Measurements were made in triplicate.

## Part 2 - Mixing of Latex to Coarse/Fine Fractions, or to the Whole Particle Size Distribution

A broad particle size distribution ground calcium carbonate was split into 2 size fractions. The sedigraph curves for the 2 different components are shown in Figure 1, and the d50 and surface area of the two fractions is summarised in Table 2.

The latex binder (Styrene butadiene, 0.14 nm,  $T_g$  8°C) was initially added to either the coarse fraction, or the fine fraction and then the

**Figure 1.** Sedigraph curves for the coarse and fine fractions of the GCC**Table 2.** d50 and SA of the 2 fractions

	Coarse	Fine
Surface Area $\text{m}^2/\text{g}$	13.3	32.5
d50 average / $\mu\text{m}$	0.736	0.212

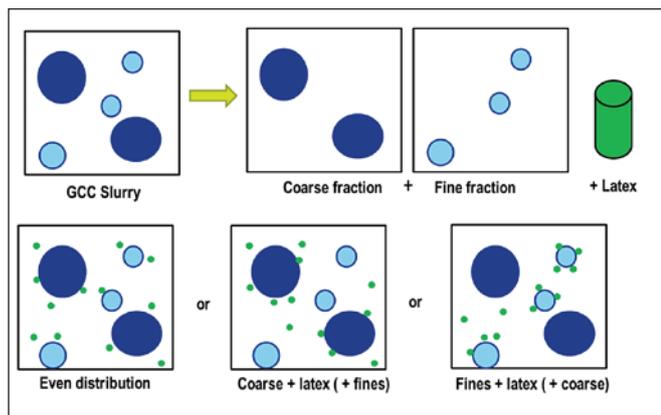


Figure 2. Pictorial representation of premixing experiment

Table 3. Mixing of latex with the different slurry fractions – key to the various mixtures

Pigment, Binder and Mixing Regime	Code
Controls/References	
Coarse + 10 pph Latex	C + 10L
Coarse + 20 pph Latex	C + 20L
Fines + 15 pph Latex	F + 15L
Fines + 30 pph Latex	F + 30L
Trial points, all with 12 pph latex	
(Coarse + 12 pph Latex) + Fines	(C + 12L) + F
(Fines + 12 pph Latex) + Coarse	(F + 12L) + C
(Coarse + 6 pph Latex) + (Fines + 6 pph Latex)	(C + 6L) + (F + 6L)
(Coarse + Fines) + 12 pph Latex	(C + F) + 12L

other slurry component blended in, or to the combined carbonate blend as shown pictorially in Figure 2 and detailed in Table 3. This experiment seeks to determine if the latex is associated with the fraction it is initially combined with, or after mixing it is evenly distributed in the wet coating colour. The key question to answer was if the latex associates preferentially to the particle size fraction that it is first blended with, in the wet state.

### Part 3 - Dewatering and Binder Movement During Consolidation

Two carbonate based pigments were used; a precipitated rhombohedral calcium carbonate (PCC) with a narrow particle size distribution and a fine broad particle size distribution ground calcium carbonates (GCC). For the physical properties of the pigments see Table 4. The binder used in the study was a carboxylated styrene butadiene acrylonitrile copolymer ( $T_g = 10^\circ\text{C}$ ) with an average particle diameter of 150 nm. The pH was adjusted to 9 and each colour was screened at 53  $\mu\text{m}$ .

Table 4. Physical properties of calcium carbonate pigments – dewatering study

Pigment	d50/ $\mu\text{m}$	P.S.D. Steepness d30/d70 x 100	BET Surface Area/ $\text{m}^2 \text{g}^{-1}$
PCC	0.435	66.7	8.6
Fine, broad GCC	0.550	34.1	17.2

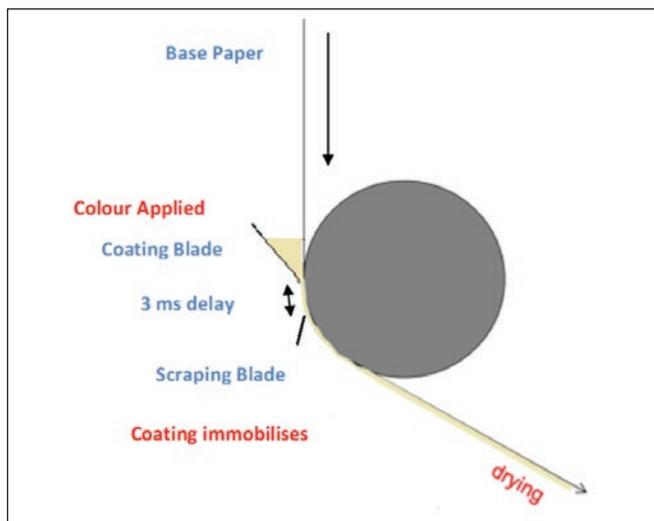


Figure 3. Web coater with scraping blade to remove a portion of the unconsolidated colour

### Web coater – Scraping of unconsolidated coating colour

To bring the work closer to industrial practice, the coatings were also applied to an uncoated and a precoated basepaper. A scraping technique was carried out to remove a portion of the non-immobilised coating colour at very short times ( $\sim 3$  ms) after application, as shown in Figure 3. Colour applied from a syringe to the paper which passes under a doctor blade to create coating layer. A coat weight of  $10 \text{ g m}^{-2}$  was achieved by adjusting the pressure of the blade and keeping the solids constant. A scraping blade was applied underneath the doctor blade, which removed some coating. This was only found to be possible using the precoated basepaper, as the uncoated base caused immobilisation to occur before scraping.

### ATR-IR

Attenuated Total Reflectance Infrared (ATR IR) analysis was used to determine the relative binder content in the surface layers of the coatings. In this technique, the paper sample was mounted against a KRS5 high Refractive Index crystal. The IR beam passed through the crystal and interacted with a thin layer of the coating surface ( $\sim 1 \mu\text{m}$ ). There are a number of different peaks, which are due to either the carbonate or the latex binder (Figure 4). For the calcium carbonate, there are 3 main peaks: two sharp peaks

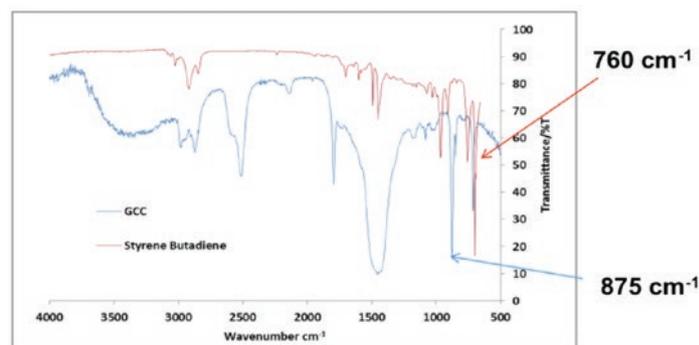
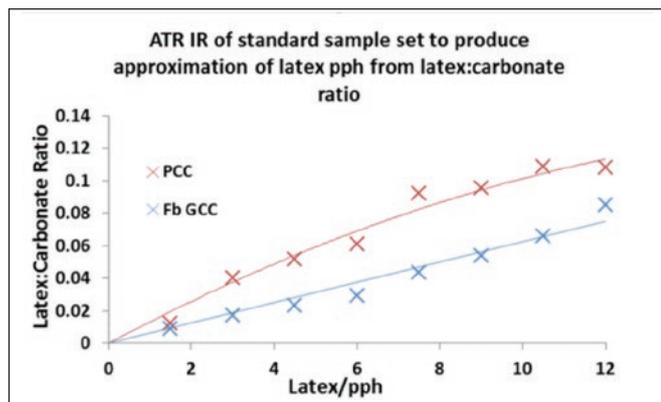


Figure 4. IR spectra of  $\text{CaCO}_3$  and the latex, showing the peaks selected.

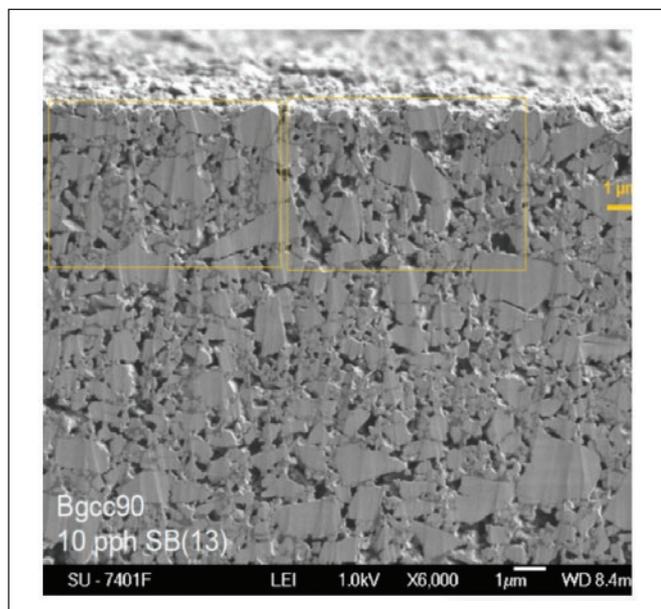


**Figure 5.** Calibration curves for PCC and GCC with different loading levels, by plotting the ratio of the pigment and latex peaks

at  $712\text{ cm}^{-1}$  and  $876\text{ cm}^{-1}$  and a broad peak at  $\sim 1420\text{ cm}^{-1}$ . An estimate of the relative latex level to the  $\text{CaCO}_3$  can be obtained by using either the  $970\text{ cm}^{-1}$  or the  $760\text{ cm}^{-1}$  peaks from the binder. A series of known carbonate-latex control samples were made and the IR peaks measured to obtain a calibration curve (Figure 5). Full details of this technique can be found in Reference 10. In this exercise, the ATR-IR was used to investigate the level of binder remaining at the surface of the coating applied to the precoated and uncoated bases, and that which had migrated downwards, by measuring the surface of the scraped zone.

## RESULTS

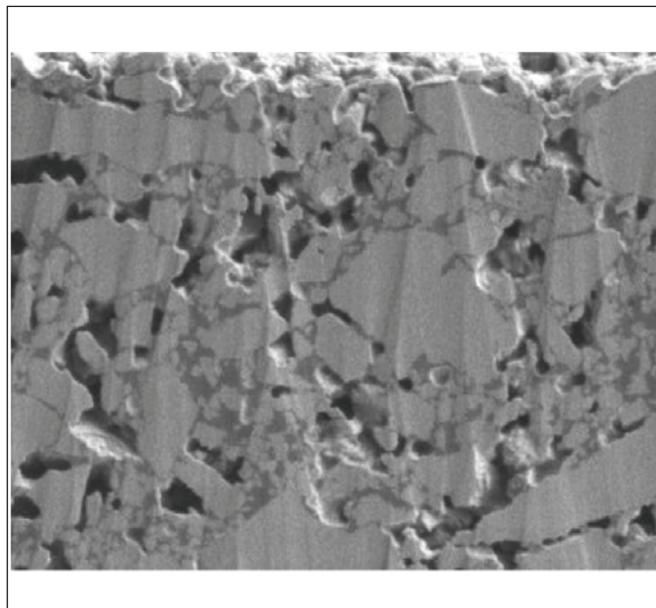
The distribution of binder within a coating is of importance for many aspects of the final coating layer; primarily the strength of



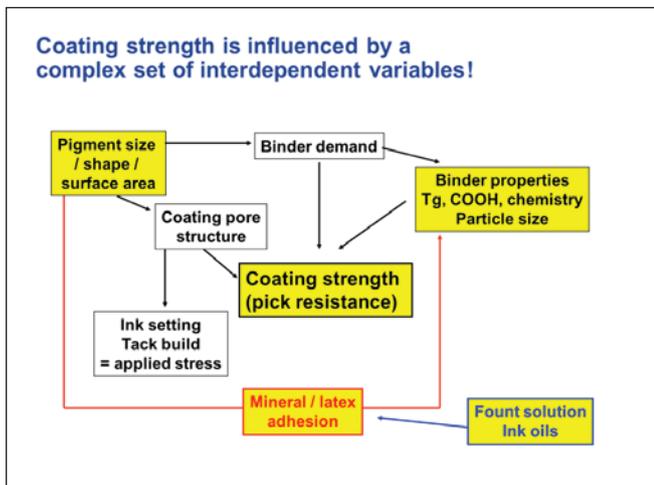
**Figure 6.** Argon etched paper coating section. The area in the left box is more closed than that in the right box (from Strom <sup>[15]</sup>)

the coating where a sufficient number of 'welded' contact points are required to hold the pigment particles together and to the basepaper. The binder distribution also can have a significant impact on the point to point light scattering from the coating, and hence the optical mottle. The porosity variations will also impact the fluid absorption and the print mottle. In the argon etched cross sections of a GCC filled paper coating from Strom et al the location of the binder can clearly be seen. The distribution is not very even within the coating layer, with the portion of the coating in the left-hand side yellow box (Figure 6) being more closed than the right-hand side. Figure 7 is an enlarged image. It can be seen that there's a slightly preferential clustering of the latex associated with the fine particles in the dried coating colour.

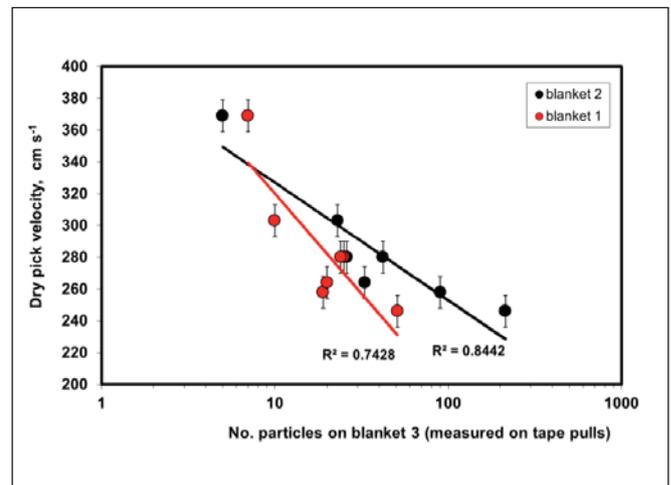
The strength of a coated paper is an extremely complex issue which is impacted by a number of different variables, the pigment size and shape being just one of these. In Figure 8 we outline some of these variables and their interrelations. Firstly, the pigment size and shape and surface area will all combine to determine the coating pore structure which will impact the strength; with tightly packed particles giving a more robust system. This will impact the binder demand. The binder properties also play an important part and the adhesion between the mineral and latex will be impacted partly by the latex chemistry and physical properties. The coating pore structure will also determine the way that the offset ink sets and dries on the coating surface. An ink which builds tack very fast on a very porous coating will incur more stress on the coating as it passes through the various colours on the press. Lastly the fluids involved in the actual printing process will also impact the final coating strength with polar fluids such as fountain solution weakening the adhesion between the latex and pigment surface.



**Figure 7.** An enlarged view clearly showing the location of the latex binder (from Strom <sup>[15]</sup>)



**Figure 8.** The complex and inter-related factors controlling printing strength



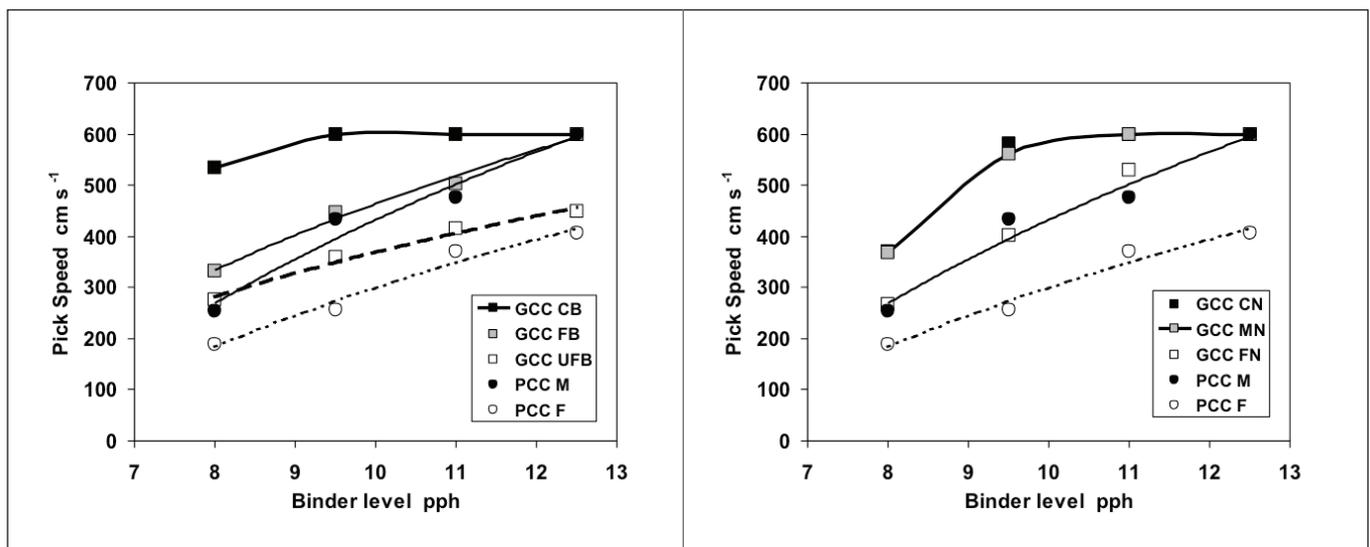
**Figure 9.** Correlation between laboratory IGT Dry Pick test and the number of picks backtrapping onto the 3rd blanket of a sheetfed offset press. Blanket 1, no predamping, blanket 2, after predamping. (KCL Print trial)

The dry pick test carried out using a laboratory IGT unit and single-phase pick oil is a very simplified measure of the coating strength. There is no fountain solution with this test which is known to weaken the coating and also the single-phase oil does not dry and build in tack as a function of time. However, the test does give good agreement with reality. In Figure 9 a series of papers has been tested in using the laboratory IGT dry pick test, and they have also been assessed for strength during a print trial at KCL in Finland. The number of picked particles were removed using tape from the printing blanket after a defined number of copies had been printed. These particles were counted and also visually analysed to see if they were spherical coating particles or fibrous material. A good correlation was seen between the results from the printing press trial and the IGT evaluation.

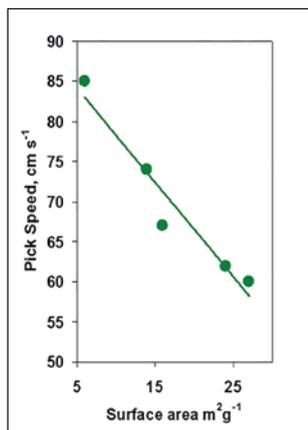
### Pigment Influences on strength of a coating layer

Figure 10 summarises the dry pick strength of the PCC and GCC coatings. Note that velocity values of  $600 \text{ m min}^{-1}$  are the maximum attainable with this oil, and some of the GCC coatings in this plot are "off scale" and had no pick. Increasing levels of latex give increasing strength as expected. The results rank the pigments in order of particle size, with the coarsest pigments giving the strongest coating layers. At latex levels  $>11 \text{ pph}$ , the narrow P.S.D. GCC coatings were slightly stronger than the broad P.S.D. GCCs, probably because they have a larger average size. Below  $11 \text{ pph}$  latex the narrow P.S.D. GCC coatings were weaker. The PCCs gave the weakest coatings in this test. These results are in accord with previous studies by Husband et al [27,28,29].

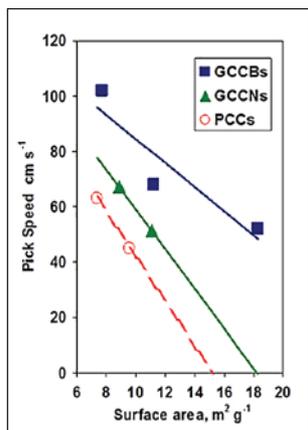
The difference in the strength of the different particle sized GCCs is



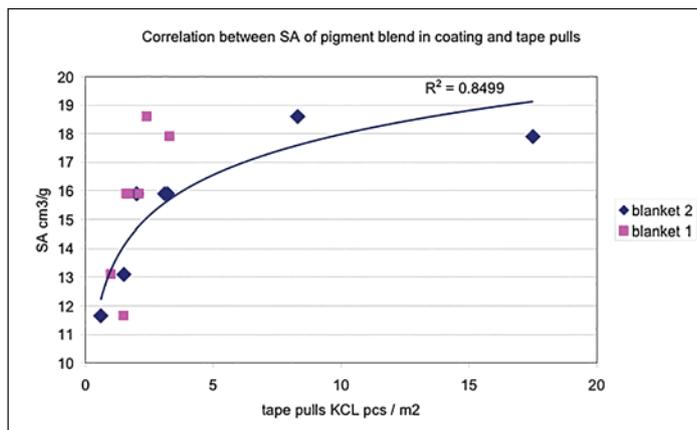
**Figure 10.** Dry pick strength of carbonate coatings, left: broad P.S.D. GCCs, right: narrow GCCs compared to PCCs



**Figure 11.** Higher surface area gives weaker coating at the same binder level



**Figure 12.** For the same pigment surface area & binder level, a narrow P.S.D. gives a weaker coating



**Figure 13.** The relationship between SA and pick strength was also observed for the commercial pick trial

principally determined by the pigment surface area. Figure 11 shows that for a single type of GCC at constant binder level (11 pph) the strength decreases with increasing surface area. This correlation was also seen on the pick trials carried out on the commercial printing press (Figure 13). However, the packing of the particles also has some influence on the coating strength. Particles which are more monosized (have a narrow particle size distribution) will give a more open packing structure which is intrinsically weaker. Figure 12 shows the strength as a function of surface area for 3 different steepness coatings (all at the same binder level). The broad P.S.D. GCC is stronger than the narrow P.S.D. GCC and finally the most open PCC structure is the weakest.

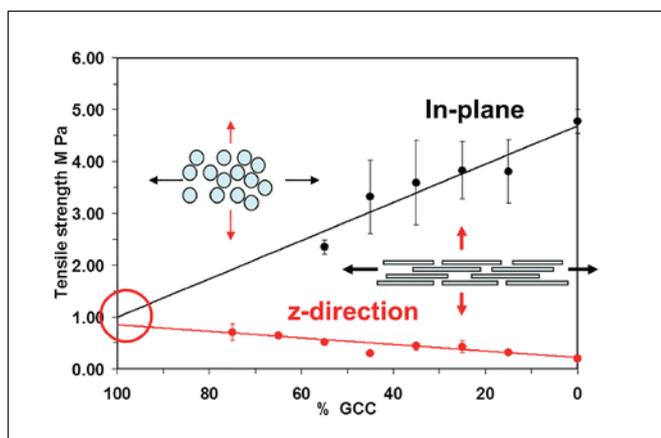
### Impact of particle shape

The particle shape of the pigment in the coating has a profound impact on the strength of the coating. It has been shown that with tensile testing of free films of coating colour, that the more kaolin in the formulation (plate like shape) the higher the strength in the x-y direction and the lower the strength in the z direction. The more anisotropic the particle becomes (more plate like) the greater the

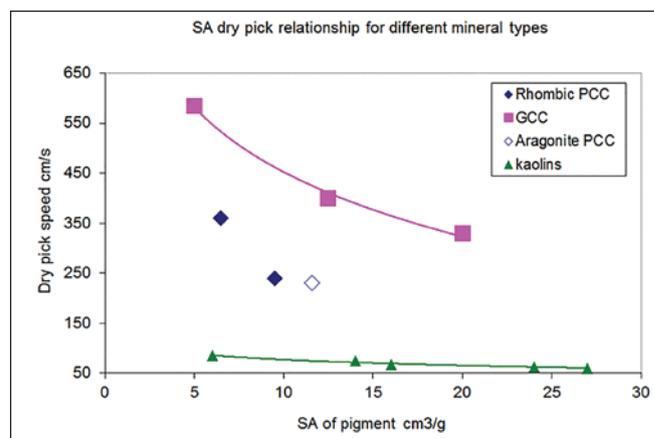
difference in the directionality. Hence kaolins are seen as good for x-y strength and stiffness, but are poorer for pick strength which is a z directional stress as shown in Figure 14. Note that it was not possible to make free standing films of 100% GCC due to the very low x-y strength which caused the coatings to crack and fragment. Therefore, the plot had to be extrapolated to 100% GCC. Interestingly at this point, the coating has the same strength in the x-y and z directions, which would be expected for an anisotropic particle. In Figure 15 the strength is shown for a range of coated papers which contain different mineral types (PCC, GCC and kaolin) but also as a function of their average surface area (as determined by the BET method). The surface area is once again closely tied to the average particle size, with finer particles having much higher surface area as also described above.

### Part 2 - Impact of Mixing regime

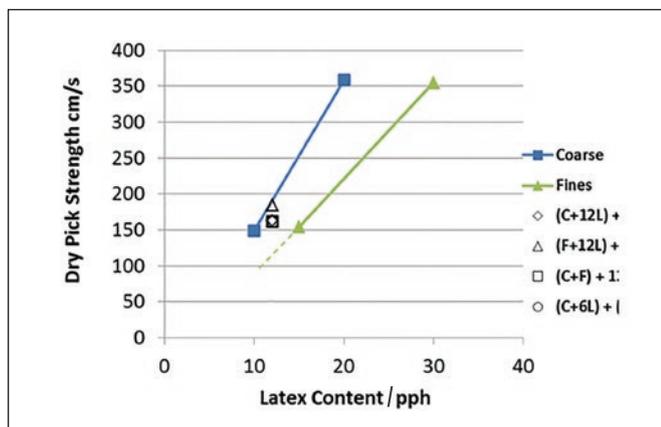
In Figures 6 and 7 it is possible to see the location of the latex binder in the dried coating layer and it can be seen to be preferentially situated around the finer particles rather than the coarser ones. This short experiment was carried out to determine if the way that the



**Figure 14.** Tensile strength of free standing films in the x-y and z directions. The higher the proportion of plate like kaolin in the blend, the stronger the coating in the x-y direction and the weaker in the z direction



**Figure 15.** Pick strength of kaolin, PCC and GCC samples showing their relative pick strengths



**Figure 16.** Dry pick strength for the coarse and fine particle fractions and the 4 different mixing regimes

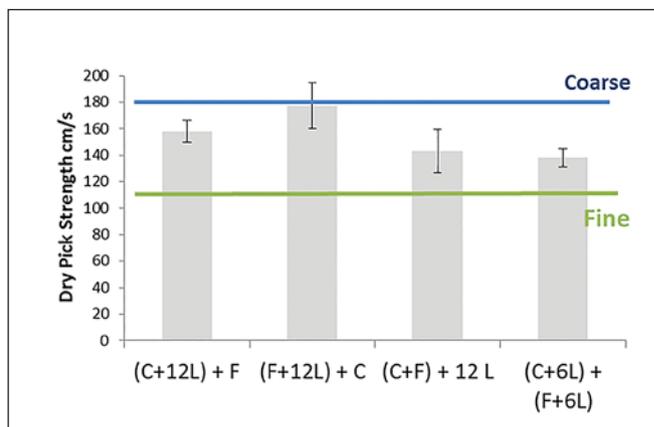
latex was added to the slurry in the coating colour could impact its location in the final dried coating. As depicted in Figure 2, a broad P.S.D. GCC was split into a coarse and fine component and latex was added first to the coarse portion and then the fine portion. The two components were then gently stirred together to give the final coating colour and coated onto a woodfree basepaper.

In Figure 16 it can be seen that for equal IGT surface strength, the coating based on the coarse particle fraction required 1/3 less binder than that based on the fine fraction. This correlates with the surface area, which for the coarse fraction was 40% of that for the fine fraction. The 4 different mixing regime samples lay between the coarse and fine fractions as would be expected. This can be more easily seen in Figure 17, the coarse and fine references have been interpolated to 12 pph latex, so they can be compared with the mixing trial points. Despite scatter they are similar within error, showing that although the pore structure of the final dried coating is highly dependent on pigment particle size in the coating layer, it is not dependent on the processes of pre-adsorption to a mineral fraction. Hence it can be determined that if the latex is added initially to a fine or coarse fraction of the slurry, it is not associated in the wet state with this fraction that it first sees. After mixing the latex is evenly distributed throughout the coating colour, indicating a robust system<sup>[30]</sup>.

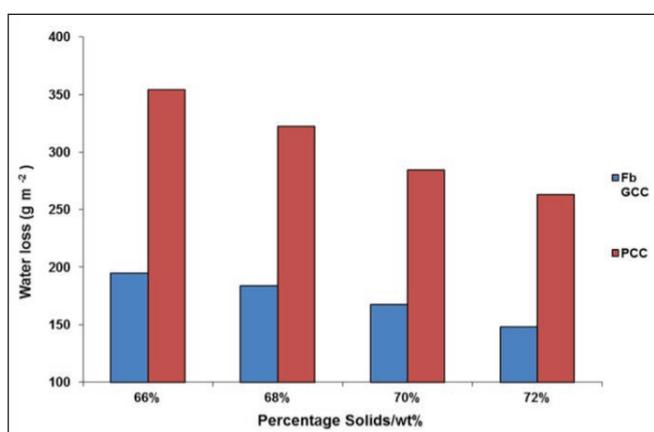
The tendency for the clustering of the latex around the fine component in the carbonate in the dry state is likely to occur during the drying stage. In drying the capillary forces will pull the binder particles into the small pores between particles (contact points), and large particles and pores will be depleted. The small pores / particles however will capture the latex between them. This behaviour has also been observed during the drying of paints for example<sup>[31]</sup>.

### Binder Movement during Consolidation of the Coating

The distribution of the latex binder in the final paper is also impacted by the pigment type, starting solids content of the colour and the rate that it is immobilised. In this section of the paper, the differences in coating colour dewatering and binder distribution in the final coating are explored.



**Figure 17.** When interpolated to 12 pph latex, it can be seen that the 4 mixing trial points lie between the coarse and fine fractions and that there is no significant difference in strength between them



**Figure 18.** Greater dewatering occurred with the PCC containing colour than the GCC colour. As the initial solids content of the colour increases, the less the dewatering occurs

Dewatering of the coating colours was assessed using the AA GWR device. The fine, broad GCC and PCC colours were made down at 4 different solids levels to give an indication of the impact of varying solids content on dewatering. The PCC showed greater dewatering than the GCC (Figure 18). In both pigment cases as the initial solids content increased, the pigments dewatered to a lesser extent.

In Figures 19 and 20 the ratio of latex:carbonate peak height is plotted for the different pigments, at varying solids levels and from different areas of the paper. A higher number represents more latex occurring in the top ~0.5  $\mu\text{m}$  of the coating layer. It can clearly be seen that when comparing the surface binder for the different substrates, that the coating on the precoated base has a higher surface binder content than on the uncoated base. This would indicate that more binder has penetrated into the basepaper in this case and less is present on the surface. The highest binder level is observed in the scraped zone of the paper. This area has had the surface of the coating colour removed by the scraping blade approximately 0.003 s after application. This consistently higher value would indicate that the

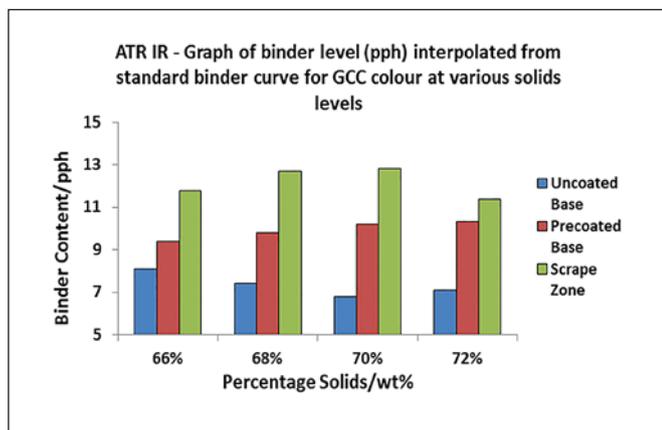


Figure 19. Surface binder content for GCC coatings on different bases and the scraped zone

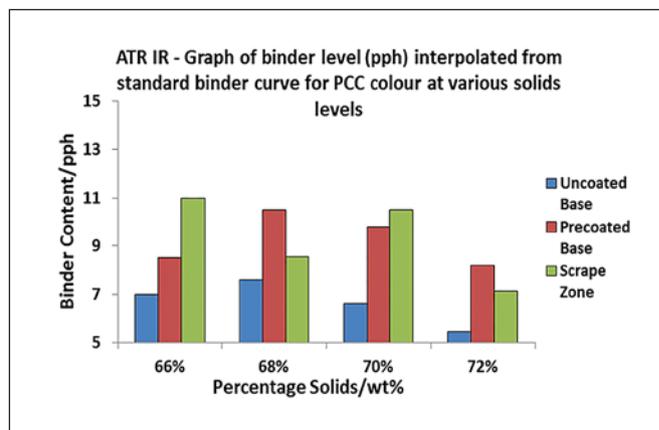


Figure 20. Surface binder content for PCC coatings on different bases and the scraped zone

binder has been moving downwards as the colour dewaters, possibly depleting it from the surface of the coating and concentrating it towards the coating-base interface. The trends are very clear for the fine, broad GCC, but a little less so for the PCC colours; possibly due to faster immobilisation. No clear difference with solids content is observed.

**Dry Pick Results**

Results show that PCC has the lowest pick strength possibly due to the increased level of binder migration shown previously. (Figure 22 PCC compared to Figure 21 GCC). It is also shown that coatings on the precoated base are far stronger than coatings on the uncoated base. This suggests that the presence of the precoat limits the amount of latex passing into the base paper. The scrape zone also shows increased strength as the binder-depleted aqueous layer has been scraped off leaving a latex-enriched coating behind.

There is less difference between precoat and scraped areas as solids increases. This would indicate once again that at higher solids content the coating is immobilised faster leading to less binder redistribution.

**CONCLUSIONS**

Coating strength is a complex topic and there are many factors which impact the strength of an offset printed coated paper in practice. The types of pigments used within the coating layer are one of the most important factors. Dry pick test results have been shown to correlate well with picking occurring on a sheet fed offset printing press; more so than those obtained with application of predamping water during the test.

In this work, we have shown that the surface area of the coating pigment is of prime importance, with finer particles having a larger surface area and requiring more binder for the same strength. The steepness of the particle size distribution determines how the particles will pack together and more monosized (steep) particles will give a more open and slightly weaker coating for the same surface area. Plate like particles such as kaolins give improved strength in the x-y direction, contributing to greater stiffness, but not in the z direction, and so are poorer for pick strength.

The pre-mixing experiments demonstrated that for equal IGT surface the coating containing the coarse fraction (low SA) required 1/3 less binder than the finer fraction (high SA) as found previously.

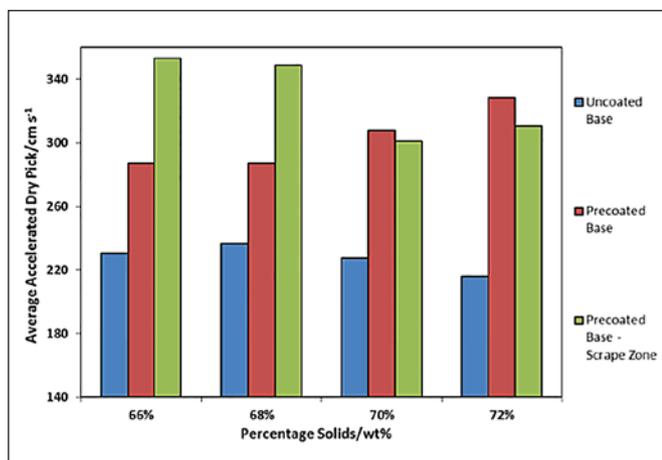


Figure 21. Dry pick results at 6 m s<sup>-1</sup> for GCC coatings analysed in Figure 21

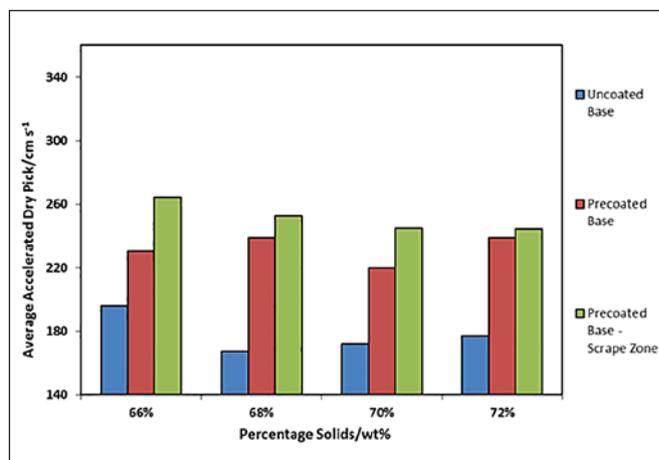


Figure 22. Dry pick results at 6 m s<sup>-1</sup> for PCC coatings analysed in Figure 22

However, the order of latex addition to the coarse of fine carbonate fraction in the wet state had an insignificant influence on the strength properties of the final dried coating.

The degree of dewatering and the type of pigment in the coating will also impact the location of the binder in the final consolidated and dried coating. In all cases PCC is weaker than GCC - weaker coating pick and also by weaker basepaper-coating failure. The point at which the basepaper tears also occurs at lower velocity with the PCC coating, even though the basepaper used is the same. A narrow P.S.D. pigment such as PCC will allow more drainage of the binder into the basepaper before consolidation and the coating becomes weaker. The basepaper is also likely to fail more quickly, possibly due to the deeper penetration of the water. ATR-IR has shown that when a portion of the topcoat is removed by scraping, that the binder is indeed richer in the centre of the coating than at the surface, indicating that the binder has moved down towards the coating-base interface.

This is less apparent for PCC than GCC as the rate of immobilisation is faster. The uncoated base, which had a lower surface binder level as the surface was less sealed, showed increased dewatering, and therefore greater binder migration.

It is apparent that the pick test is complex and not straightforward to interpret! Choice of pigment must be coupled with the correct total formulation to ensure the best runnability and performance of the pigment. Blends of minerals may also be utilised to help optimise the dewatering and strength of the coating. Clearly there is also benefit in applying the coating colour at maximum possible solids content.

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