Formulation Optimisation for LWC Printability

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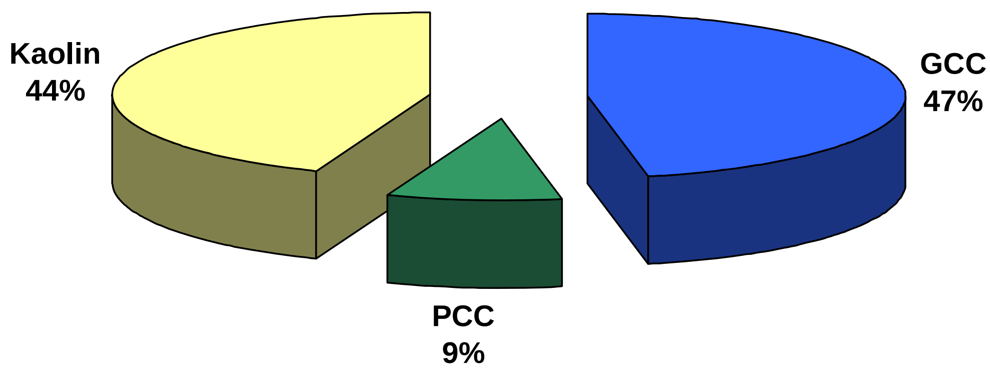
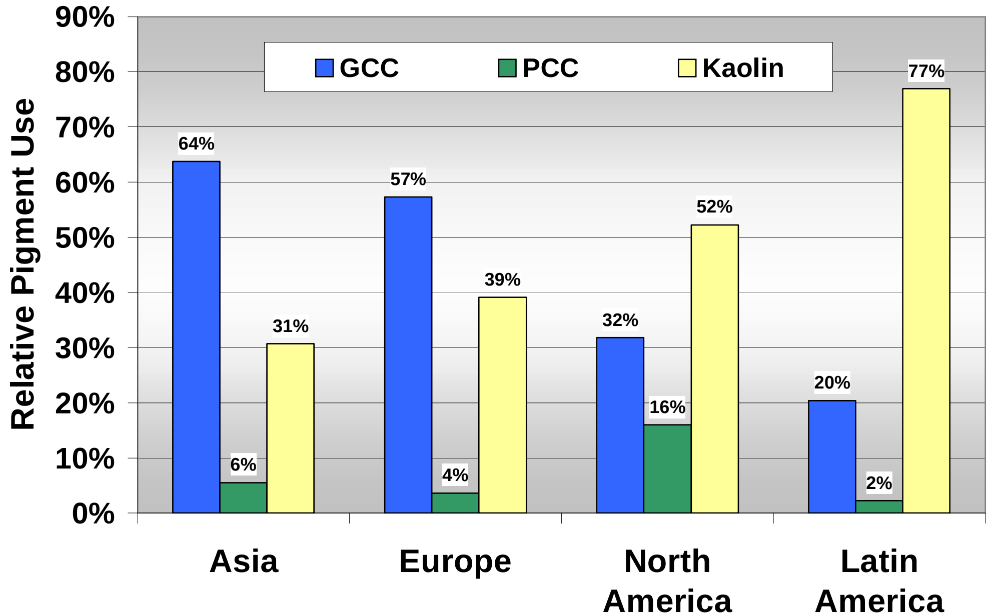
RETHINK PAPER:
Lean and Green

Outline

- Introduction
- Market directions and current formulation practice
- Case Study Pilot Investigations of Pigment Effects on LWC Paper Quality & Printability
  - Paper and print results
- Impact of binder level
  - Laboratory coating and printing
- Study of intrinsic porosity characteristics with varying binder level
  - Critical pigment weight concentration
  - Mercury porosimetry
  - Wavelength exponents
- Summary & Conclusions

Pigment Use in Single Coating Global 2010





- Single coating is still prevalent in Global LWC and North American freesheet applications.
- Current coated mechanical and CFS markets account for some 6 million tonnes of pigment sales
- Globally kaolin still commands 44% share, and carbonate 56%
- Regional variations reflect different market practices

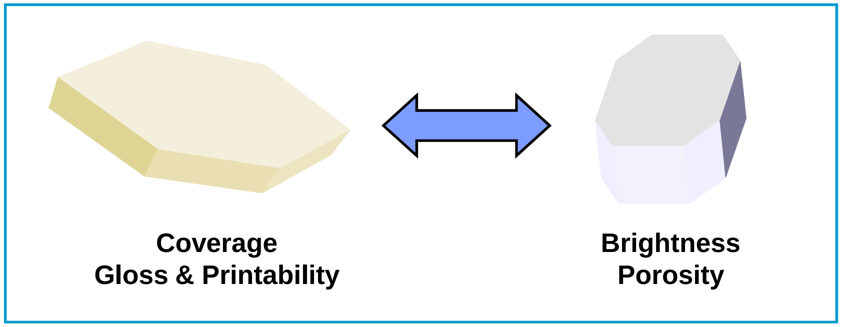
Examples of Formulation Practice in Single Coating

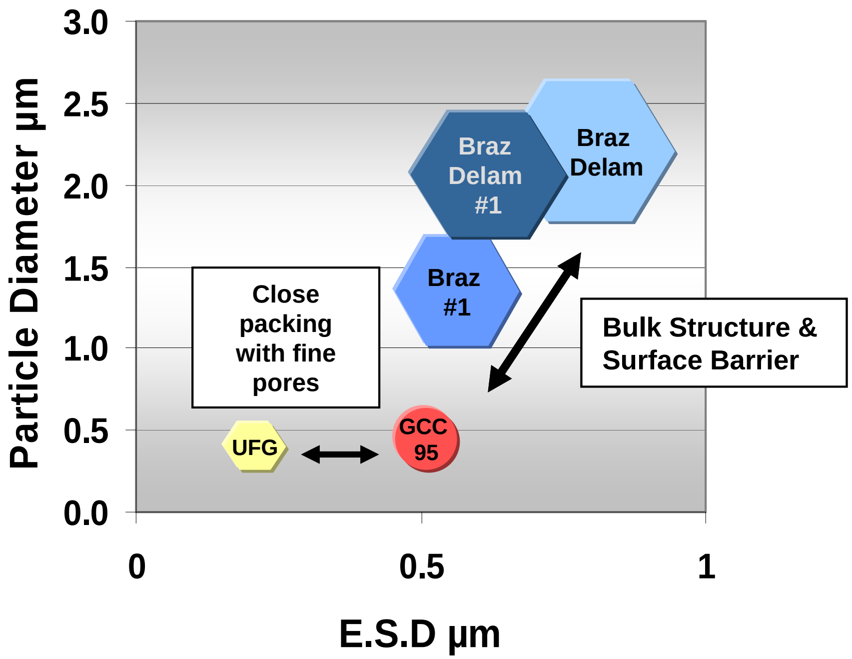
	Europe	US CGW	US CFS	Japan	Rest of Asia
Kaolin%	20-60	50-100	25-60	30-70	30-40
Carbonate%	40-80	0-50	40-75	30-70	60-70
Kaolin Types	Engineered	Engineered	Engineered	Engineered	Chinese #1
	Ultrafine Glossing	Delam	#1	Delam	Ultrafine Glossing
		#1 and #2		#1, #2	
Carbonate Types	Standard 90/95	Standard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

- Historically single coating recipes were more kaolin rich and comprised of coarser 90 < 2 µm kaolins with standard or steep GCC
  - More recently the kaolin of choice for this type of recipe has become engineered Brazilian kaolin
- However, in Europe and Asia where there has been a shift to more carbonate rich recipes, the kaolin has in some cases been altered to ultrafine glossing clay because of sheet gloss pressures

Role of Kaolin in LWC

- The key pigment trade-offs are shape and brightness
- The role of kaolin is principally to provide basesheet coverage, gloss, water retention and a less porous surface needed for good printability.
- Kaolin type is also crucial in this respect.





- The kaolins used in LWC are very different in their characteristics ranging from fine particle sizes good for intrinsic gloss to larger plates good for coverage .
- Packing with carbonate will also be different.
- Would expect very different coating structures and hence printability from the different LWC formulations.

AIMS

- Primarily, the focus of this exercise is to study the different generic paper coating recipes in terms of their paper and print performance.
- The second section of the work looks at the impact of binder demand of the different formulations and the printability
- In the final part of the work the binder impact on the coating structure is assessed.

Case Study Pilot Investigations of Pigment Effects on LWC Paper Quality & Printability

Pilot Trial Plan:

Jet Coater 1500m/min 40 gsm base, 10 gsm/side

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

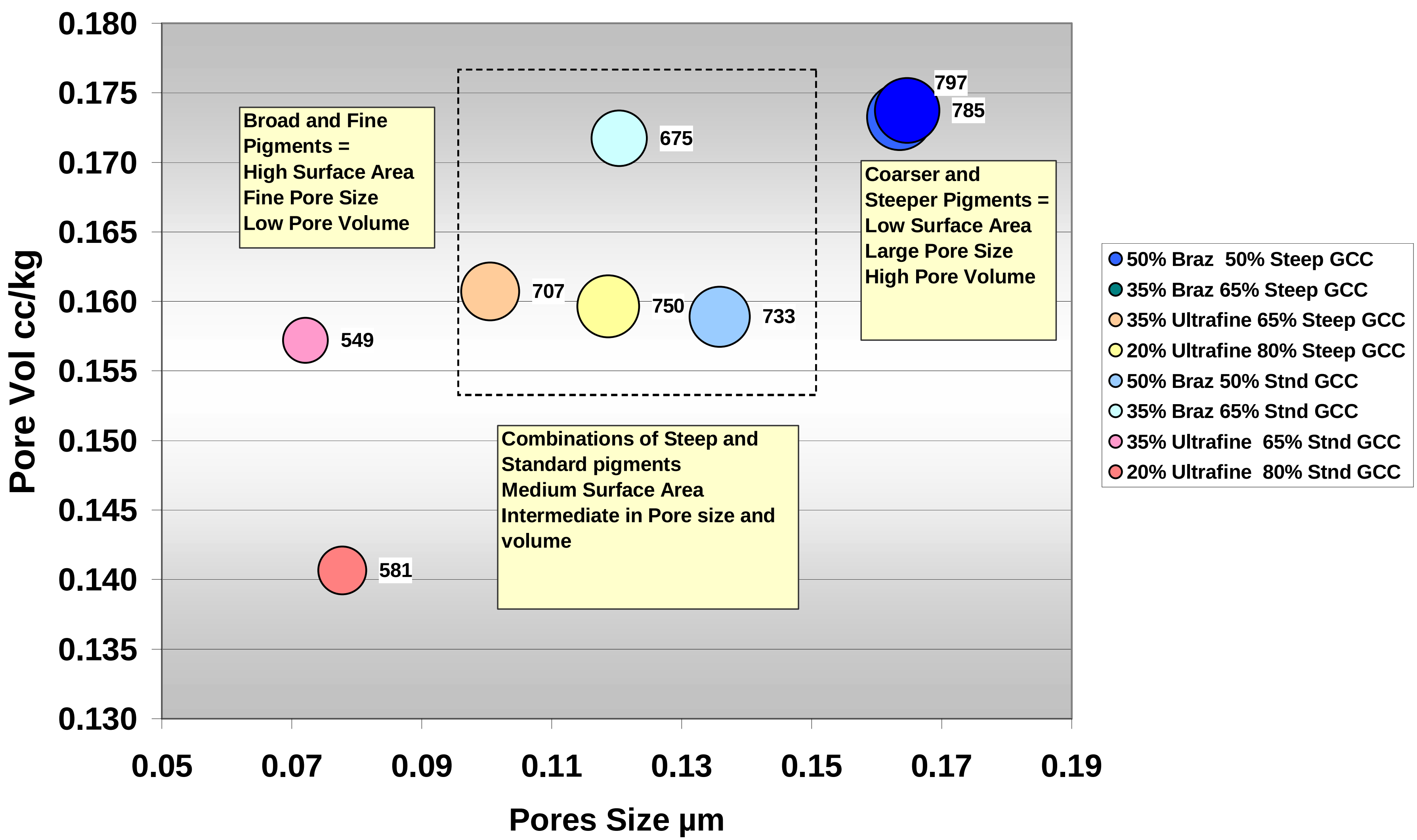
- Trial plan sought to compare clay rich recipes based on Brazilian Engineered kaolin with those using lower levels of fine glossing clay.
- In part 2, the starch level was reduced by 1pph and the binder levels were set at 5, 7 and 9 pph for each pigment system

Summary of Paper Properties

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

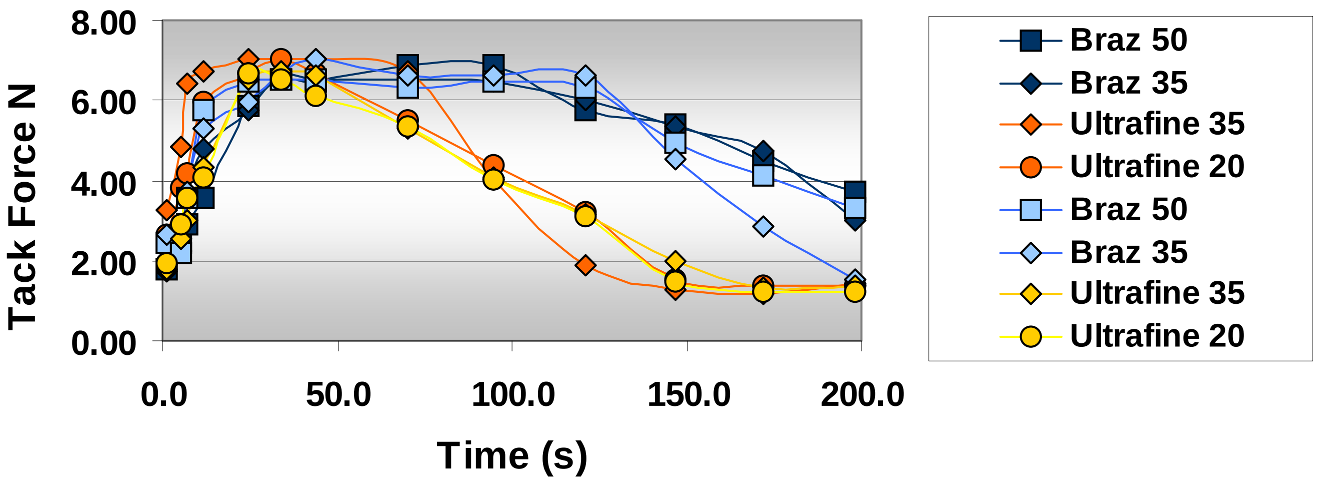
- Results Logical
  - Best performance with engineered kaolin and engineered carbonate together
  - Poorest performance with ultrafine kaolin and standard carbonate together
  - Intermediate performance where one component was engineered
  - Could be either the kaolin or the carbonate

Intrinsic Coating Structure

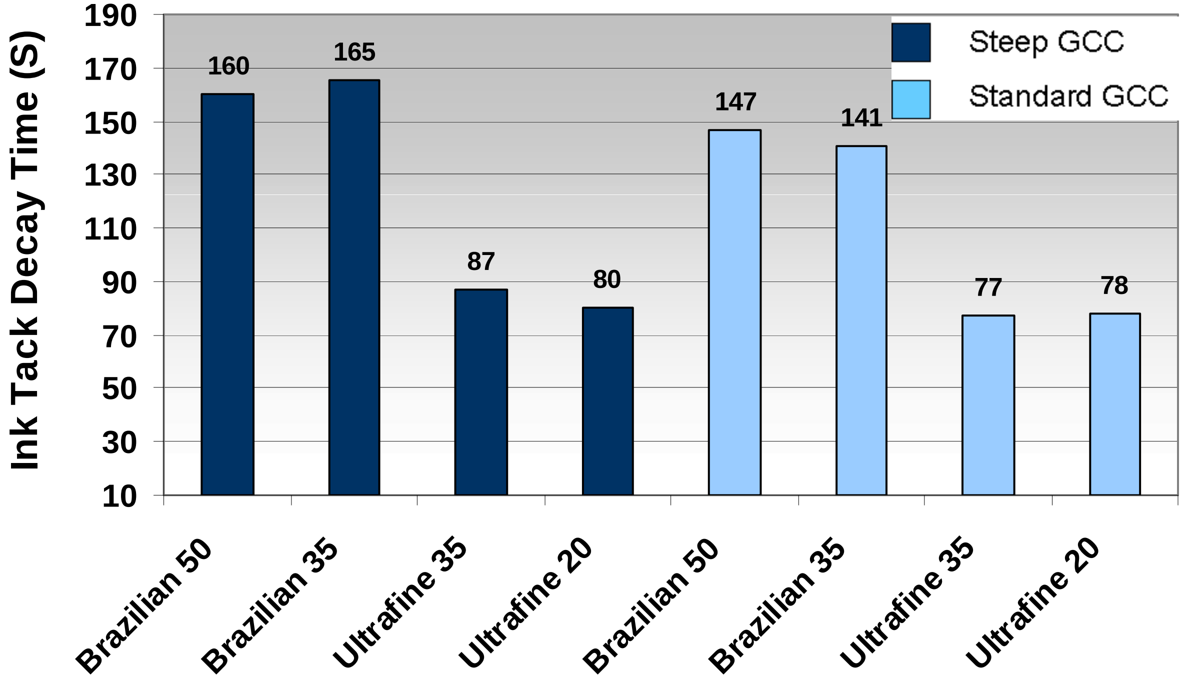


- Optical results broadly correlate with coating structure
- As expected no correlation between gloss (surface dependant) and bulk structure

Ink Tack Development



- Ink tack development curves shown left
- Lighter colours are formulations with standard GCC, darker with steep
- Ink tack decay time plotted below



- Key factor affecting ink tack development is the choice of kaolin
- Formulations with Ultrafine kaolin give more rapid ink tack development suggesting higher tack forces during printing

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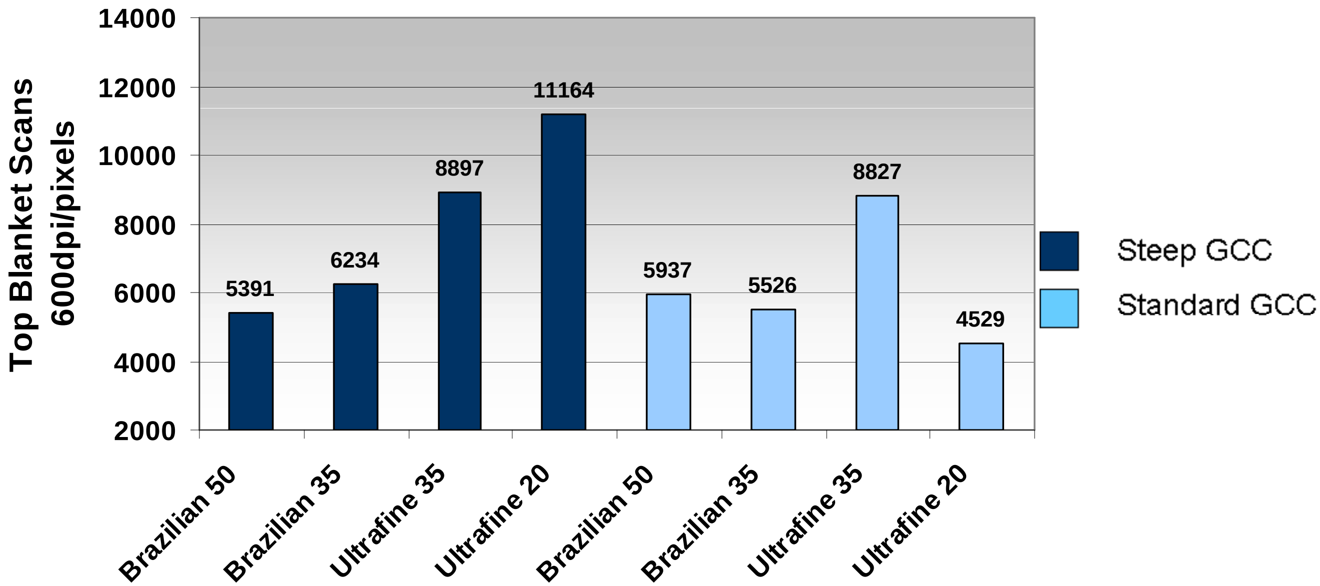
Summary of Print Properties

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



- Engineered kaolin and steep GCC best
- Engineered kaolin with standard carbonate generally better than ultrafine kaolin with steep carbonate especially with respect to ink setting and piling
- Ultrafine kaolin and standard GCC generally worst.
- 20:80 UF:std GCC gave closed rough coating - but better piling than expected…. This was the most macro-rough so is degree of contact important? Is this one intrinsically v strong?

Pilot Trial Summary

	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

- This work has shown that pigment selection in LWC while having a relatively small impact on papermaking cost or indeed paper properties can have a significant influence on quality and press related issues such as piling
- Formulations based on higher levels of Brazilian kaolin give the best overall quality and press runnability
- Formulations based on ultrafine kaolin and high levels of GCC pose the most risk to print quality and press runnability
- However, binder was kept constant in this study……..

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Lab Investigations of Coating Structure Effects with Different Binder Levels

Summary of Changes Occurring with Increasing Binder

- No systematic change in roughness or gloss with varying binder, but light scattering and optical properties such as brightness and opacity decreased with increasing binder.
- Coating strength increased in all cases with increasing binder, but there was a larger increase for the coatings containing steep carbonate,
  - under bound at the lowest latex level?
- The porosity decreased (higher Gurley) in all cases with more latex but 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.

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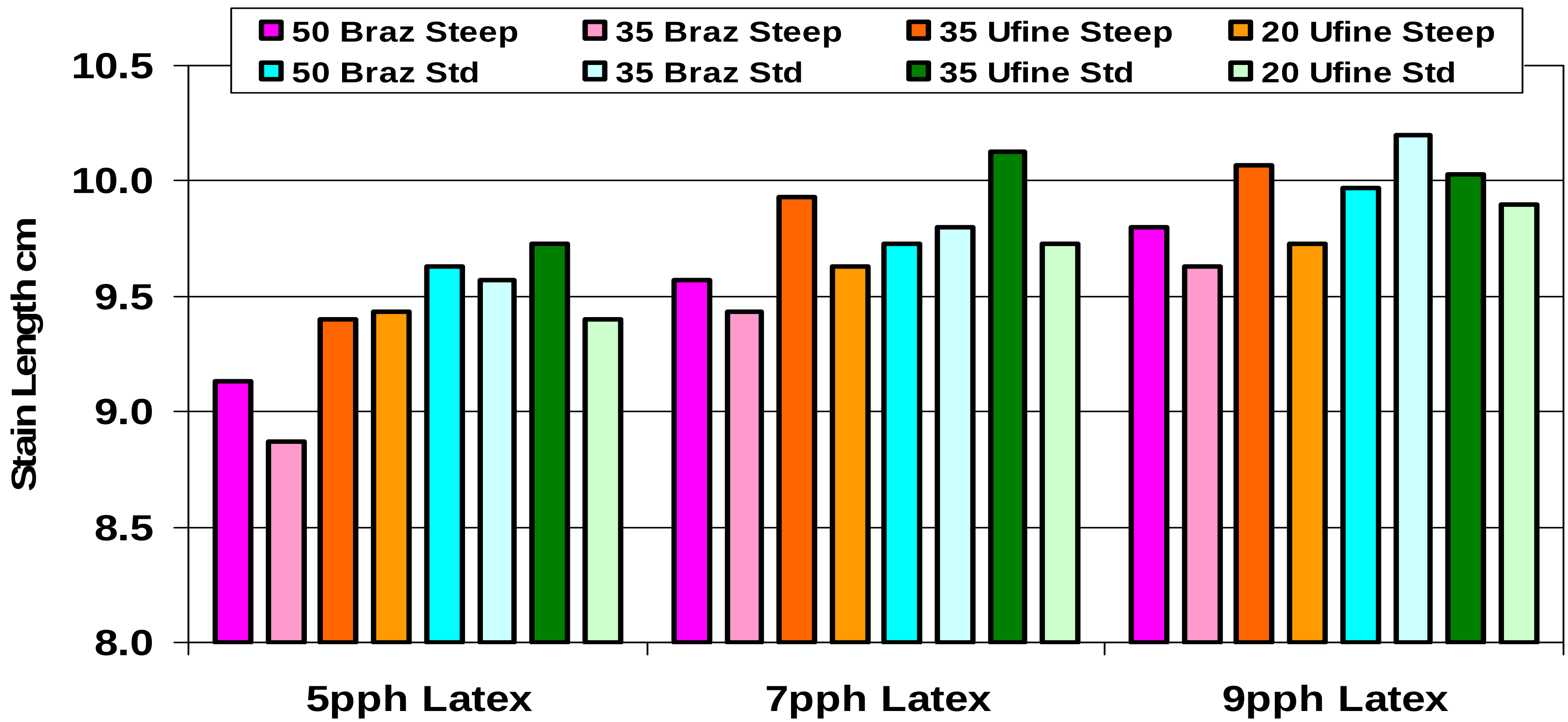
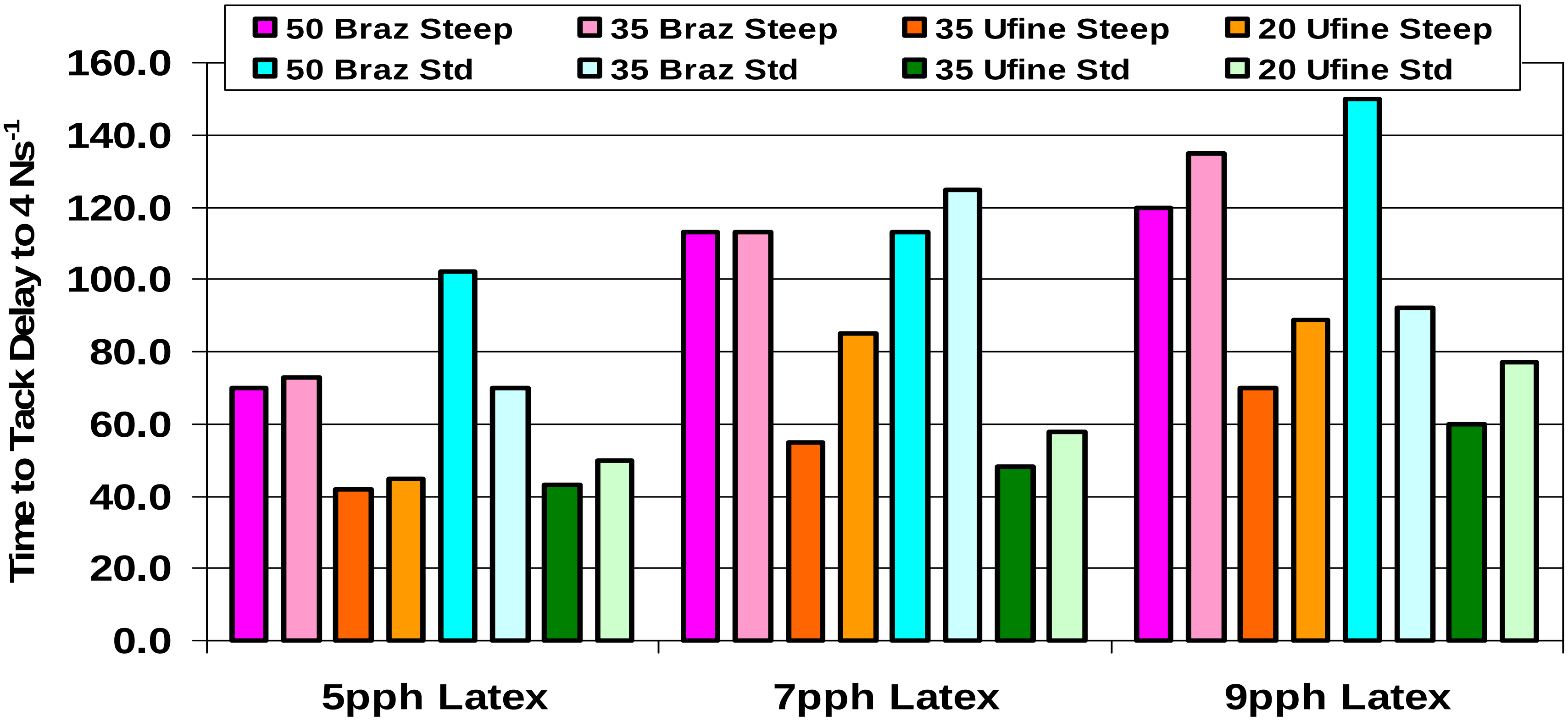
Stain Length



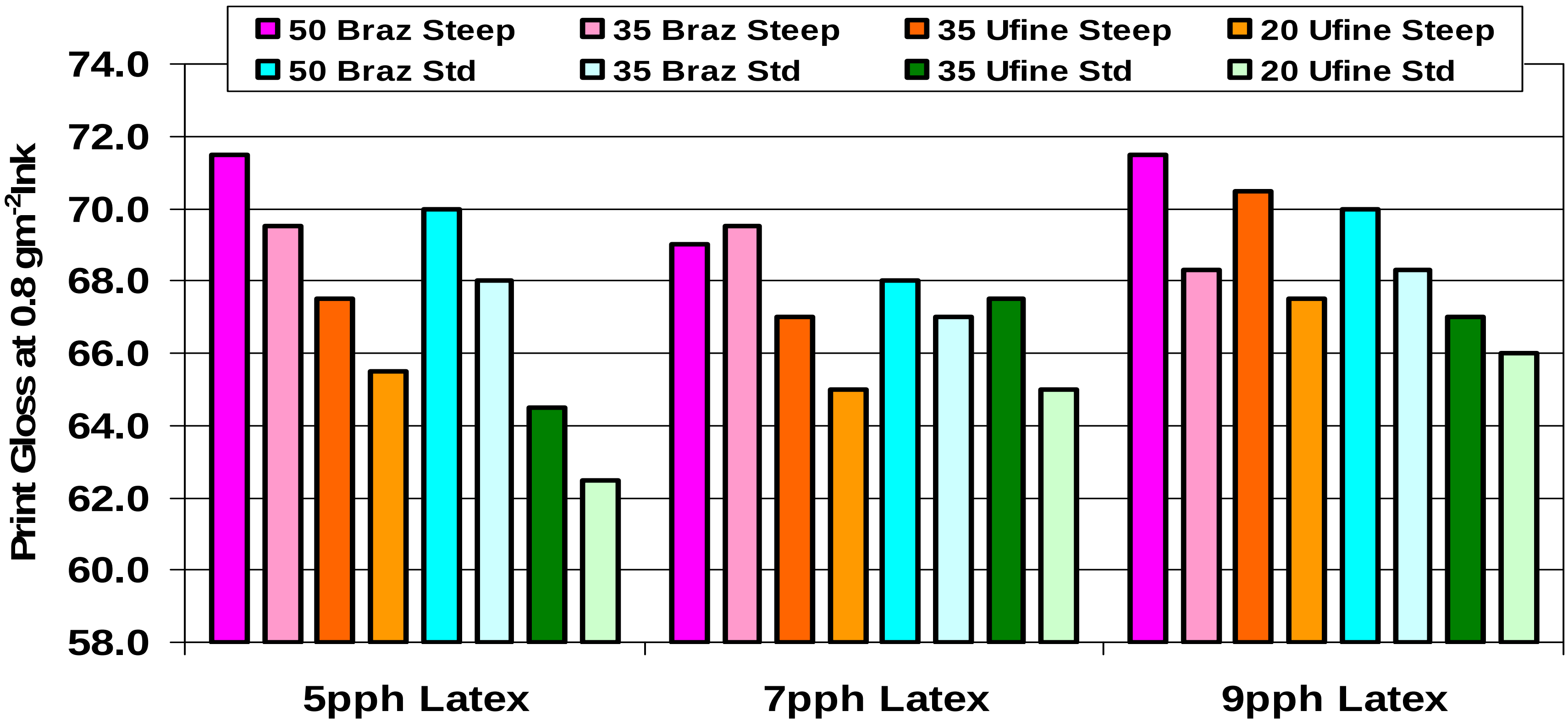
- Increasing stain length with more binder.
- The standard carbonate coatings have less increase with more latex than steep carbonates – better packing of particles & less intrinsic binder demand?

Ink Tack Decay Time



- The ink tack rise and decay are dominated by the kaolin component rather than the carbonate.
- UF kaolin gives the fastest ink setting at all binder levels, due to a large number of surface pores.
- Increasing binder slows ink setting but large increase needed to compensate for inherently fast ink setting.
  - Brazilian / steep carbonate gave similar ink set rates with 5 pph latex as UF kaolin with 9 pph latex.

Print Gloss



- **The impact of binder increase on print gloss depends on whether the coatings are fast or slow setting.**
  - **For fast ink setting rate UF kaolin increasing latex has slowed down the ink setting giving higher print gloss**
  - **For the already slow setting Brazilian clay coatings, there is little difference suggesting that even at the lowest binder level the setting rate is slow enough to allow ink film levelling.**

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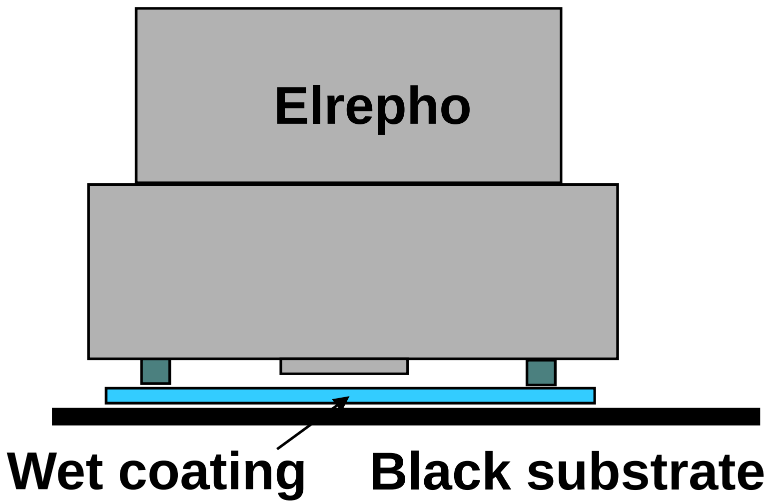
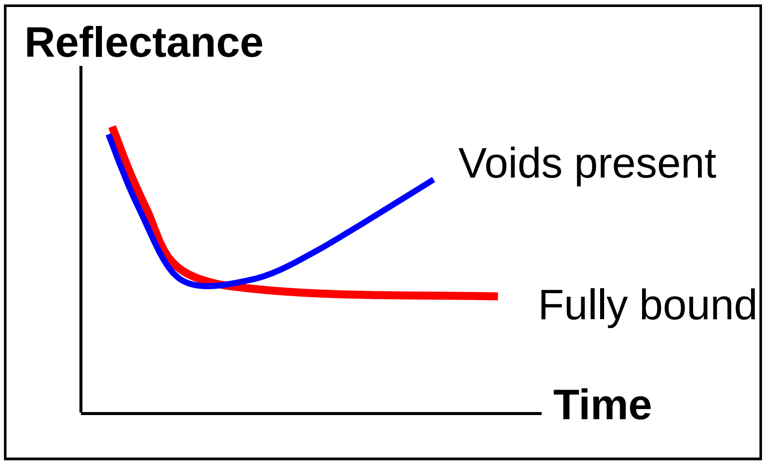
Summary & Binder Impact on Coating Structure

- 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

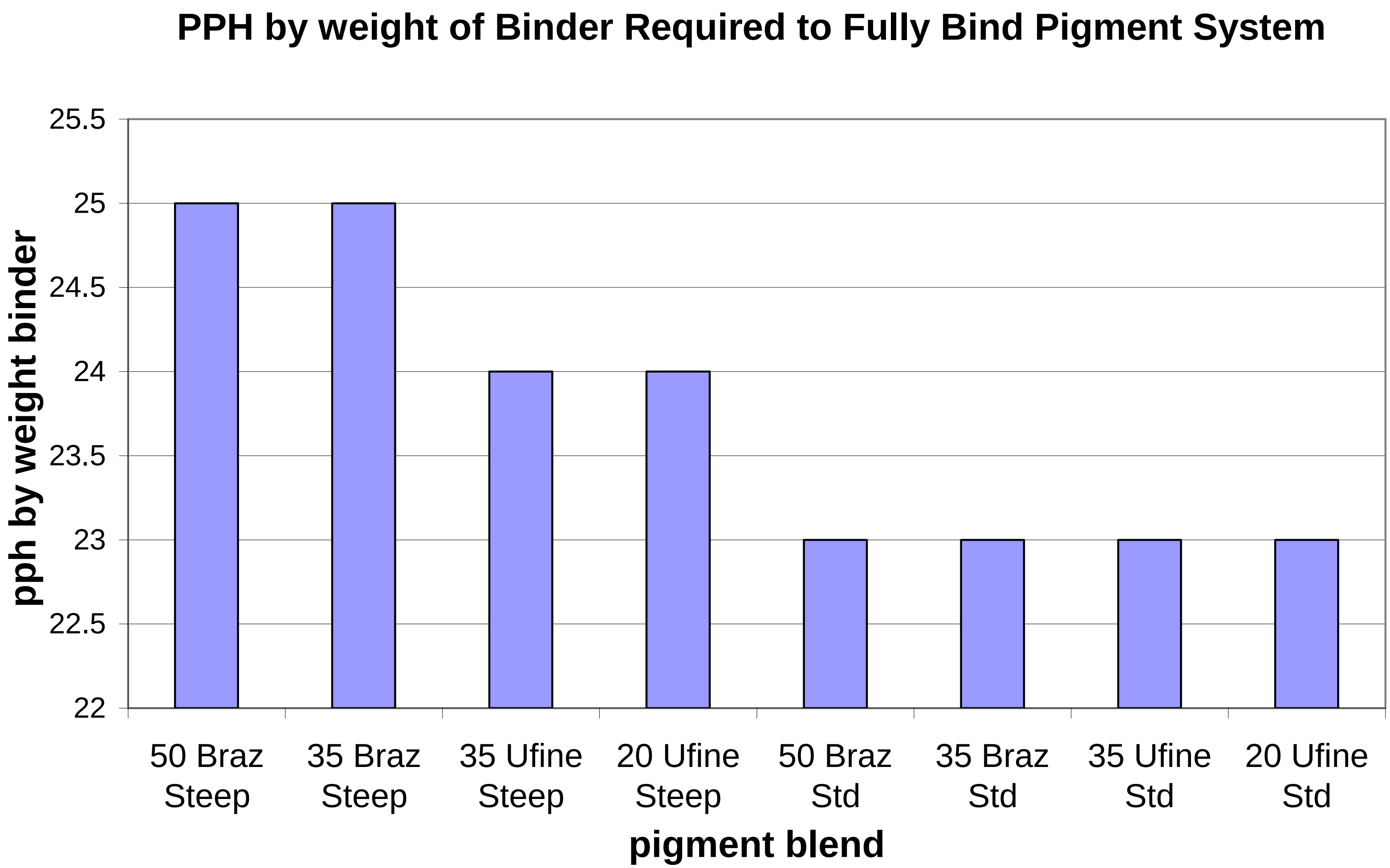
Critical Pigment Weight Test

- This is to determine the point at which there is sufficient binder in the system to completely surround the particles but no extra. Similar to the CPVC from the paint industry
- This test gives a feel for the intrinsic binder demand of the pigment blend as a result of its particle packing – and gives similar information to the oil absorption test.
- As the coating colour dries the reflectance falls, as particles become closer together. If there is air voids present in the coating, they will appear and the reflectance will increase again. If it is fully bound the reflectance will plateau.
- We have quoted this point in terms of pph binder, as is common in the paper industry (CPWC)



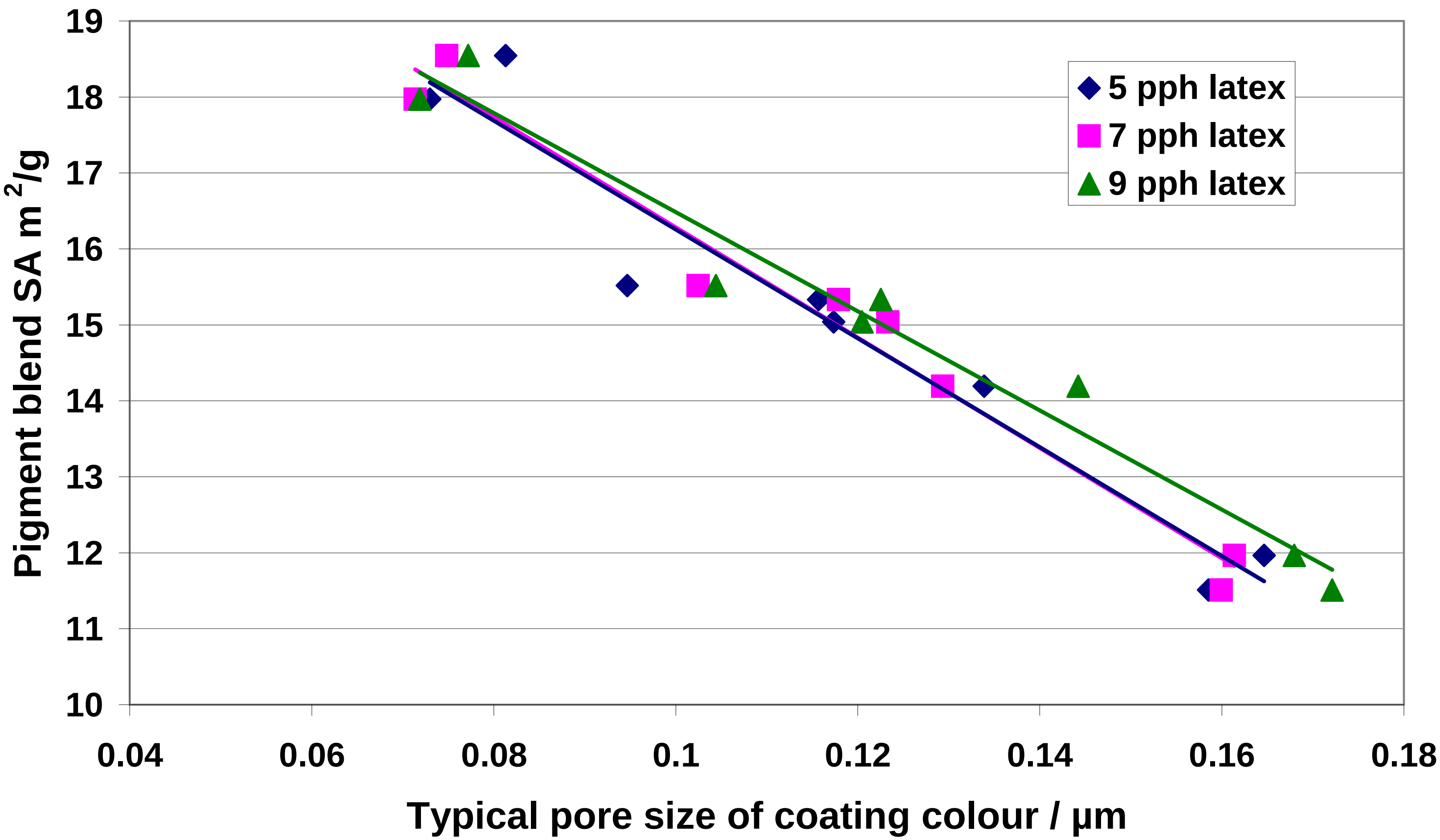


CPWC



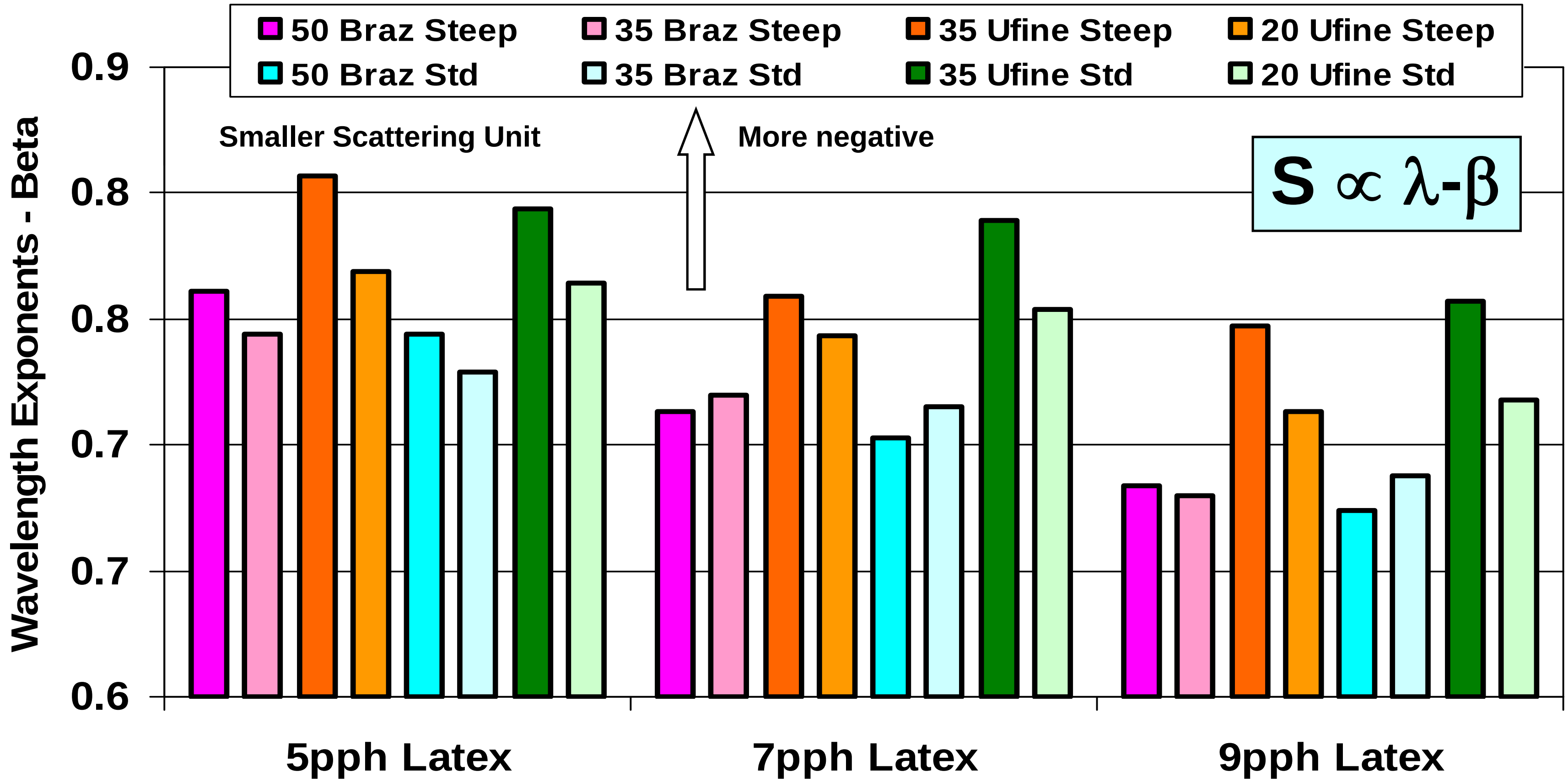
- **Pigment blend choices impact the intrinsic binder demand**
- **The amount of binder required to cover the steep pigments is up to 2 pph greater than those containing the broad p.s.d. carbonate. The highest amount being needed for the blends containing the Brazilian clay with steep carbonate.**

Mercury Porosimetry



- 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.
- Surprisingly little difference in pore size with increasing binder

Wavelength Exponents



- The size of the scattering unit is influenced by both the pigment and binder selection.
  - More UF clay => smaller scattering unit
  - No real impact of carbonate
  - More latex => larger scattering unit

Discussion

- The impact of binder on the paper properties and printability of paper is linked to the pigment formulation concept used.
- The shape, and psd of the pigments impact how they pack together in the coating and their intrinsic binder requirement, higher surface area pigments require more binder. Narrow psd pigments are designed to give larger pores, for higher optical efficiency, but this may result in weaker coatings.
- The steep carbonates have a larger change in wavelength exponent and stain length with increasing binder level than standard ones. This is indicative of a higher intrinsic binder demand in recipes containing significant amounts of steep carbonate.
- The impact of binder addition on the size of scattering unit is interesting
  - Intuitively one would expect that adding more binder would perhaps reduce the scattering unit size, but data clearly shows the inverse effect.
  - 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.
  - 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.

Conclusions

- Formulation practice for LWC papers is very diverse, yet the final paper physical properties can appear quite similar
- Pigment selection has a significant influence on print quality and press related issues such as piling
- Formulations based on higher levels of Brazilian kaolin give the best overall quality and press runnability
- Formulations based on ultrafine kaolin and high levels of GCC pose the most risk to print quality (print gloss) and press runnability (piling)
- Addition of more binder altered the optical properties, strength and porosity of the coatings, but the degree of impact depended upon the pigment blend
- In general the more densely packed coatings had a lower porosity and intrinsically a lower binder demand. The strength of the coating is influenced by surface area of the pigment and a finer pigment will have a higher SA and require more binder
- Techniques such as the study of wavelength exponents give insight into the size of the light scattering unit, and the intrinsic binder demand
- CPWC test can give additional information and can help tease out effects such as the impact of binder addition, where mercury porosimetry was not successful as in this case.

Dedication

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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