"Effect of Coating Color Temperature on Dewatering and Latex Migration"

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ABSTRACT:- The effect of temperature on dewatering and latex mobility towards the surface in coating systems with different polymers was studied. Dewatering was measured by applying coating to paper with a meyer rod and scrapping the coatings off after five seconds. Latex migration was induced by drying the coating with a hot air gun. Increased temperature reduced the viscosity and water holding ability of all the coating colors. Latex showed a tendency toward increased migration and towards the surface with an increase in temperature of the coating color. For each particular coating system the dewatering rate showed a good correlation with low shear viscosity of the coating color. CMC, alginate and polyacrylate were effective in reducing the latex migration towards the surface even at higher coating color temperatures. It is suggested that the increased temperature contributed to the increased dewatering rate through the reduced viscosity of the continuous phase and more open structure believed to accompany more rapid dewatering. It is also suggested that co-binder pigment interactions play a dominent role in controlling latex migration.

KEYWORDS:- COATING, LATEX MIGRATION, DEWATERING, VISCOSITY, TEMPERATURE

INTRODUCTION

Water retention and binder migration are among the most important factors affecting coating machine operation and coated paper properties. This study focussed on the relationship of viscosity and dewatering on latex addition and as well as by increasing the temperature of the coating color. Thus it was possible to change the viscosity with the same chemical composition. It was found that latex migration behaved differently with the change of viscosity depending upon the method with it was varied. It draws an interesting conclusion that caution should be taken while establishing a relationship between latex migration/dewatering and viscosity of different coating colors with different compositions. Moreover, the coatings with the same polymer also behaved differently depending upon whether its viscosity was varied with the addition of polymer or by temperature. This study suggests that interactions between the coating color component play a dominant role in controlling dewatering and latex migration. As various mechanisms are present at the same time in the actual coating process, and it is virtually impossible to isolate one variable from others, therefore, it was decided to use hand draw down method. This study was performed by applying coatings on the paper with a meyer rod to

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have a fundamental knowledge of the factors affecting viscosity and temperature. This study does not simulates the actual coating process, but this does gives a fundamental knowledge of the effect of viscosity and temperature on latex migration and dewatering.

HISTORY OF THE PROBLEM

Various factors affecting binder migration and water retention have been studied in the past and some of the results are contradictory, mainly because of the use of different analytical methods and interpretation of the results. It is generally accepted that polymer addition increases water retention. However there is disagreement as to whether the associated increase in coating viscosity is a factor in improved retention. The situation is complicated by the fact that the polymers by nature increase the viscosity. (1) Stinchfield et al., (2) showed that viscosity had little relation in determination of water retention. Many of the same factors that affect viscosity, also alter water retention in the same direction. He showed that viscosity showed good correlation with water retention when it was varied by temperature, adhesive addition, and solids content of the coatings. However, when viscosity was changed by dispersant and soap addition, water retention didn't show any correlation to viscosity. Mc. Genity et al, (3) found that for the same viscosity of the coating color, with different amounts of CMC, water retention was superior for higher molecular weight CMC. They agreed that molecular weight was more important than viscosity. Sandas et al., (4) used a gravimetric method to measure water retention. They found that for the same amount of CMC addition, dewatering rate increased with shorter chain length of CMC, because of the lower viscosity of the aqueous phase of the color.

Malik and Kline (5) have studied the quantitative effect of polymer addition. They found that there was a negative linear relationship between water loss rate and low shear viscosity. However, they also observed that Alginate was an exception to this. None of the studies found have explained the effect of the temperature of the coating color on latex mobility. In actual practice coating color temperarture is higher than the ambient conditions. The temperature dependent factors which may have an influence on dewatering include liquid phase viscosity, surface tension, and vapor pressure of the water surface. (6) The influence of temperature on viscosity is well known. Viscosity of most aqueous systems decrease as the temperature increase. Vapor pressure of liquid phase increase with the increase of temperature. Surface tension also decreases with increased temperature. All of these factors can contribute to an increase in the dewatering rate at higher temperature.

Salminen(7) found that the capillary transport rate is strongly influenced by the liquid temperature, dynamic surface tension of the liquid, and surface chemistry of the solid phase. The capillary transport is also influenced by the viscosity of the liquid. However, for pressure penetration, liquid viscosity is more important than capillary penetration. Surface tension of the liquid phase has only a minor influence under high external pressures. Salminen also found that at increased temperature, the influence of water temperature on liquid peneration for a hydrophobic paper was of such a magnitude that the change in liquid viscosity and surface tension of the liquid phase were insufficient as an explanation. The results could at best be explained by the influence of the increased vapor pressure ahead of the liquid front, and on the rate of diffusion. The importance of interactions between vapor phase and fiber matrix ahead of the liquid front is diminished with an increased hydrophilic character of paper. These experiments were, however, conducted with water and not with the coating color.

EXPERIMENTAL APPROACH

Preparation Of Coating Color:

All coatings were prepared at 55% solids, Clay was dispersed in distilled water at 70% solids under high shear. 12 parts of SBR latex per 100 parts of clay was added and mixed thoroughly. A blank was prepared from this at 55% solids without addition of starch. Coating viscosity was checked by Brookfield viscometer at 10 and 100 rpm.

Coating clay- # 2 clay (HT- Predispersed)
Latex addition - 12 pph (on clay solids)
Starch addition - 1,2,3,4, & 5 pph (on total solids)
CMC addition - 0.3 and 0.6 % (on total solids)
Alginate - 0.3 and 0.6 % (on total solids)
Poly-acrylate - 0.3 and 0.6 % (on total solids)

CMC and Alginate were added at 0.2 % when used with oxidized starch.

Applications of Coatings:

All coatings were applied to a paper substrate of 82 G.S.M. containing 60% softwood and 40% hardwood with an # 18 meyer rod. It was soft sized (hercules sizing 4 secs.) . The following properties of the coating color were evaluated.

1. WATER LOSS RATE (DEWATERING RATE):

The water loss rate (WLR) was measured by scraping the coatings off the paper surface with a razor blade, 5 seconds after application, then dried to find the solids. Coat weight was determined by cutting a strip of coated paper of known area and weighing it.

From these data, the amount of water which had penetrated into the base stock was calculated and thereby the water loss rate in grams per unit area per unit time was found by the formula mentioned below.

Water loss rate = Coat weight $[(1/a) - (1/b)]/5$
Where, a = initial solid fraction.
b = solid fraction 5 secs after application.

The reverse of WLR is the water holding capacity of the coating color, i.e. the lower the WLR, the higher is the water holding capacity.

2. SURFACE LATEX CONCENTRATION:

After coatings were applied to the paper they were dried immediately by the application of hot air with a hot air gun. This was termed as "hot air drying". Coatings were also dried slowly by allowing the coatings to dry at ambient conditions with no air blowing on them. This was termed as "cold air drying". The surface latex concentration was measured by the UV technique as described by Fujiwara and Kline(8).

RESULTS AND DISCUSSION

The Effect of Temperature on Viscosity:

The effect of temperature on viscosity is shown in fig.1. As was expected from theory the increase in temperature invariably reduced viscosity, irrespective of the types of polymer or latex. Fig.1 shows the viscosity as a function of temperature at the representative middle level of addition, 3 pph for starch, 0.3 pph for CMC, PA & ALG. It can easily be seen that viscosities were in a similar region and the amount of reduction was also similar for all systems.

FIG.1 EFFECT OF TEMPERATURE ON VISCOSITY FOR DIFFERENT ADDITIVES

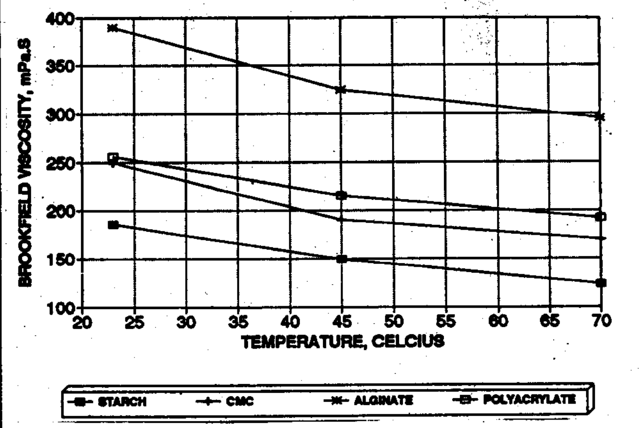
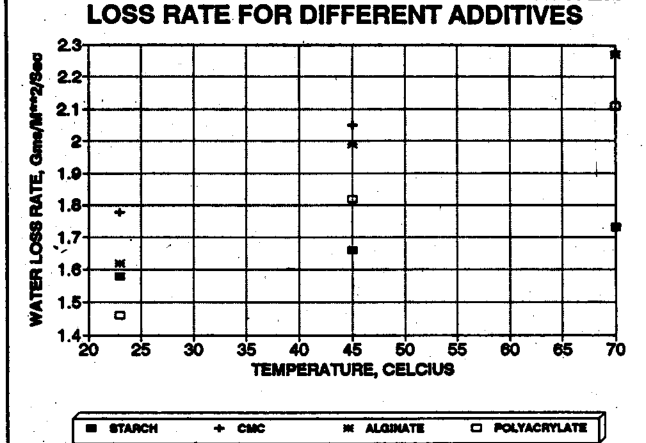


FIG.2 EFFECT OF TEMPERATURE ON WATER LOSS RATE FOR DIFFERENT ADDITIVES



Effect of temperature on Dewatering:

The effect of temperature on dewatering is shown in Fig.2. The dewatering rate decreased with the addition of all additives, and at similar rates. As has been shown in an earlier study (9) it can be seen that the water loss rate is affected by the additive type, but that the effect of temperature was essentially the same on all systems. In all cases the water loss rate increased with increased temperature. Since the viscosity also was seen to decrease with increasing temperature the obvious correlation is that continuous phase viscosity has an influence on water loss rate. Fig.3 shows the effect of temperature at different solids with no polymer addition. The water loss rate was dramatically affected by solids at the low temperature but very little effect

FIG 3 - WATER LOSS RATE AT DIFFERENT SOLIDS AND TEMPERATURES

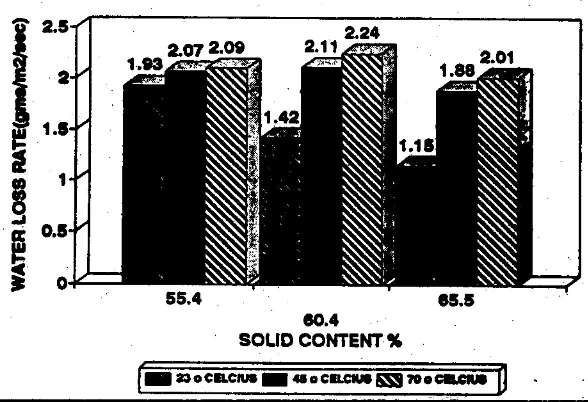


FIG.5 WATER LOSS RATE Vs VISCOSITY FOR CMC & ALGINATE AT DIFF TEMPERATURES

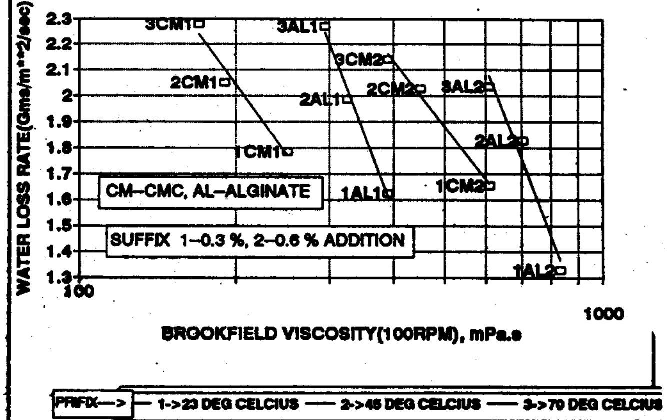


FIG. 4 - WATER LOSS RATE Vs VISCOSITY FOR OXIDIZED STARCH

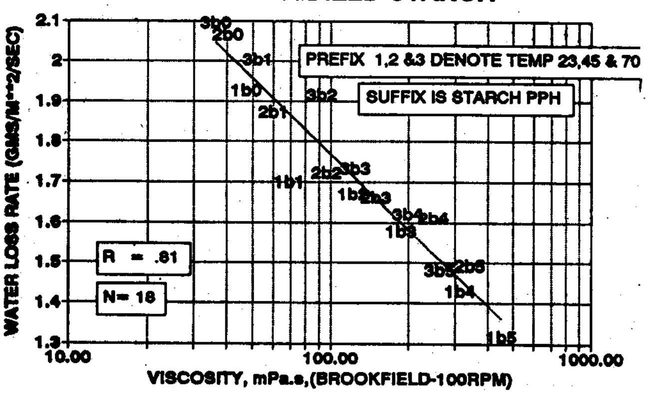
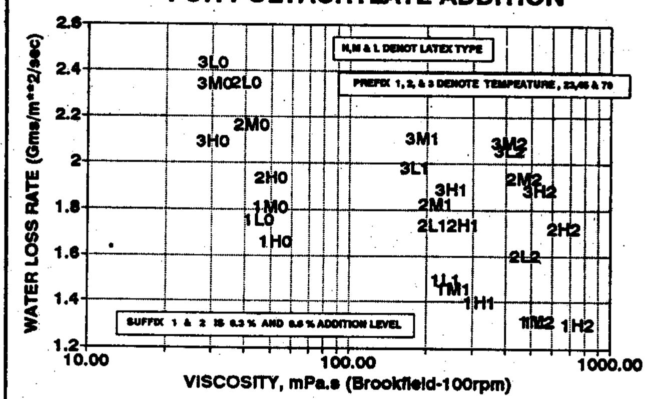


Fig.6 : WATER LOSS RATE Vs VISCOSITY FOR POLYACRYLATE ADDITION



was seen at higher temperatures. The direct correlation between temperature, viscosity and water loss rate is less clear in this set of data.

Effect of Viscosity on Dewatering:

The effect of viscosity on dewatering is shown in Figs. 4,5 and 6 and Tables-1,2,& 3., for oxidized starch, CMC & Alginate, and Polyacrylate. Fig.4, shows a strong correlation for viscosity and dewatering. (r=0.81) for oxidized starch. From this graph we see that whether the viscosity was varied by starch addition or by temperature, increased viscosity always lowered the dewatering rate. It is mentioned in literature that increased temperature increases the vapor pressure of liquid and this increased vapor pressure ahead of the liquid helps in liquid transportation (6, 7, 10, 11). The good correlation between water loss rate and viscosity indicates that for starch the viscosity of continuous phase is the most important factor. Salminen (7) found that for the hydrophilic paper interactions ahead of liquid front were not as significant as that of hydrophobic paper and as the paper used was relatively soft sized, effect of vapor pressure was not as pronounced as that of viscosity.

Fig.5 shows the effect of viscosity on dewatering for CMC and alginate. We are immediately

Table-1

Water loss rate for oxidized starch (Gms/m2/s)**

Starch pph	Temperature in degree celcius 23	45	70
0	1.93	2.07	2.09
1	1.70	1.87	2.00
2	1.67	1.72	1.91
3	1.58	1.66	1.73
4	1.43	1.61	1.62
5	1.32	1.49	1.48

* Mean differences in WLR at three temperatures are significant at $\alpha = .05$

* Interactions are not significant at $\alpha = 0.25$

Table-2

Water loss rate for CMC and Alginate (Gms/m2/s)**

Polymer addition	Temperature in degree celcius		
	23	45	70
CMC 0.3 %	1.78	2.05	2.28
CMC 0.6 %	1.65	2.03	2.14
Alginate 0.3 %	1.62	1.99	2.27
Alginate 0.6 %	1.33	1.83	2.04

* Mean differences in WLR at three temperatures are significant at $\alpha = .05$

* Interactions are not significant at $\alpha = 0.25$

Table-3

Water loss rate for Polyacrylate with three different latexes(Gms/m2/s)**

Polyacrylate addition	Latex type	Temp. in degree celcius		
		23	45	70
0	H	1.66	1.94	2.09
0.3 %	H	1.4	1.73	1.89
0.6 %	H	1.3	1.72	1.88
0	M	1.80	2.16	2.34
0.3 %	M	1.46	1.82	2.11
0.6 %	M	1.32	1.94	2.09
0	L	1.75	2.35	2.43
0.3 %	L	1.5	1.73	1.98
0.6 %	L	1.31	1.60	2.06

* Mean differences in WLR at three temperatures are significant at $\alpha = .05$

* Interactions are not significant at $\alpha = 0.25$

struck by the fact that not all data falls on the same line. When data points for each polymer are connected with a line as shown, it can be seen that there is a WLR - viscosity correlation for each system, and the slope of the lines indicates that the viscosity effect is much stronger than for the starch.

Fig.6 also shows that viscosity correlated with dewatering for the coatings with the different latexes and amounts of polyacrylate. The data points with the suffix "O" contain no PA. The addition of PA (as denoted by the suffix 1 & 2) increases viscosity and decreases WLR. Again there is a good correlation between temperature (thus viscosity) and WLR at each addition level.

Thus we can conclude that both the nature and level of polymer addition as well as the viscosity play an important role in affecting water holding ability of the coating and that for a given polymer system, a good correlation between viscosity and WLR can be found.

Latex Migration

The surface latex concentration for hot air dried coatings as a function of starch addition at different temperatures is shown in fig. 7, 8 and 9. Fig.7 shows that as oxidized starch addition was increased, binder

FIG.7 LATEX PROFILE/STARCH ADDITION FOR OXIDIZED STARCH

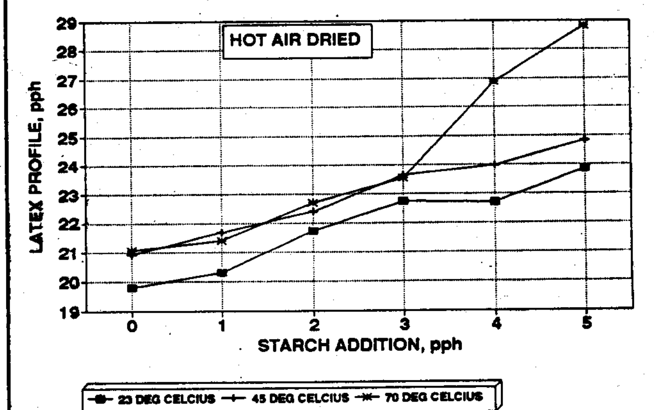


FIG.8 - LATEX PROFILE Vs VISCOSITY FOR OXIDIZED STARCH

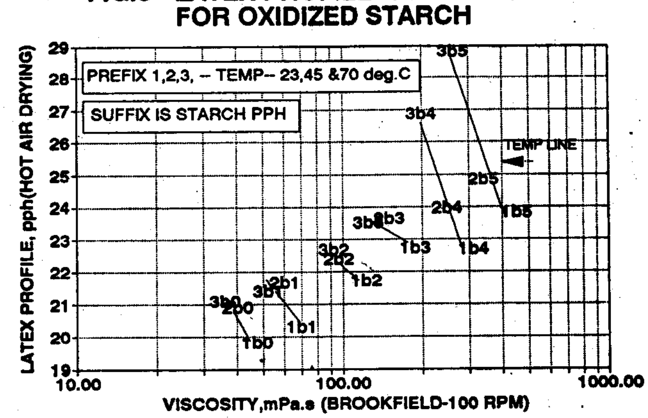


FIG.9 LATEX PROFILE(hot) Vs VISCOSITY FOR CMC AND ALIGINATE

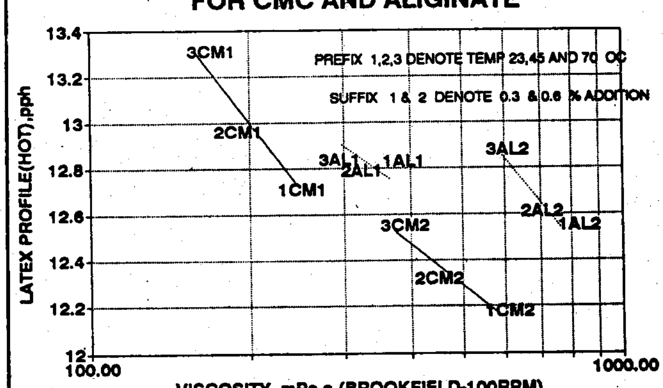


Table-4

Surface Latex Concentration, (pph) for oxidized starch.

Starch pph	Temperature in degree celcius 23	45	70
0	19.8	20.9	21.1
1	20.3	21.7	21.4
2	21.7	22.3	22.7
3	22.7	23.6	23.5
4	22.7	24.0	26.9
5	23.8	24.8	28.8

* Mean differences in Latax migration at three temperatures are significant at α = .05

Table-5

Surface latex profile (pph) for Ether starch with two different latexes

Starch addition	Latex type	Temp in celcius 23	50
0	H	21.1	20.7
1	H	20.1	20.2
2	H	19.3	20.1
3	H	20.4	21.8
4	H	21.2	22.2
0	M	20.9	20.7
1	M	20.8	21.7
2	M	20.3	20.9
3	M	21.0	23.3
4	M	23.0	26.2

* Mean differences in Latex migration at three temperatures are significant at α = .05

migration was increased, and that in general, binder migration was higher at higher temperatures. However table-5, shows very little latex migration with ether starch at low level of addition. In earlier work it has been shown that a low level of ether starch addition can decrease migration.(9) Increased temperature increased latex migration in general, but only slightly. The difference in latex migration with different types of starch is due to the different chemical interactions between these starches and clay latex system.(9) With increased interaction between the starch, latex and clay, less migration is seen and accordingly a reduced effect of temperature and viscosity.

Table-6 shows the surface latex concentration as a function of temperature for CMC, & Alginate addition. It is seen that both polymers were effective in reducing the latex migration to the surface, but there was a slight tendency for increased latex migration at higher temperature. However, the migration with temperature was minor as compared to that of oxidized starch. Similarly, table-7 shows the surface latex concentration for polyacrylate. These data show that addition of polyacrylate reduced binder migration to the surface and that changing the coating temperature was not able to influence binder migration significantly.

Table-6

Surface Latex Concentration (pph) for CMC and Alginate

Polymer Addition	Temperature in degree celcius 23	45	70
CMC 0.3 %	12.7	12.9	13.3
CMC 0.6 %	12.2	12.3	12.6
Alginate 0.3	12.8	12.8	12.8
Alginate 0.6	12.5	12.6	12.9

* Mean differences in Latex migration at three temperatures are not significant at α = .05

Table-7

Surface Latex Profile (pph) for Polyacrylate with three different latexes

Polyacrylate addition	Latex type	Temperature in degree celcius 23	45	70
0	H	19.8	20.0	20.1
0.3 %	H	11.6	11.9	11.9
0.6 %	H	10.5	10.7	10.5
0	M	19.4	20.4	20.8
0.3 %	M	12.2	13.0	12.1
0.6 %	M	11.8	12.6	11.3
0	L	19.3	20.3	20.0
0.3 %	L	12.0	12.4	11.6
0.6 %	L	11.7	11.9	10.8

* Mean differences in Latex migration at three temperatures are not significant at α = .05

Fig. 8 shows the latex surface concentration as a function of Brookfield viscosity for oxidized starch. The latex surface concentration increased with increased viscosity as the amount of starch was increased. However, when viscosity decreased due to increased temperature the latex concentration increased considerably. It appears that when we increase the starch addition interactions between starch and coating system play a dominant role in affecting binder migration. The oxidized starch has been shown to act as a pigment dispersant, and that would explain the mobility of latex in those systems. The ether starch can be argued to interact with the other components in a way to hold them together, reducing mobility.

Fig. 9 depicts surface latex concentration as a function of viscosity for CMC and Alginate containing coatings. We observe that for the same concentration of these two polymers, reducing viscosity by increasing the temperature increased migration to the surface, but migration is small compared to the starch and blank. Fig. 10 shows the surface, latex concentration as a function of viscosity for coatings when oxidized starch was added to coatings containing 0.2 % CMC or 0.2 % Alginate. Here we see that in general, when viscosity was lowered by raising the temperature, increased migration resulted and lines on the figure are intended to "tie" points of constant composition but different temperature together. However, no relationship between viscosity and latex concentration could be found for coatings of different chemical composition. This sounds logical, because different chemicals will give different chemical interactions. The viscosity of two coatings of different chemical composition can not be compared.

Fig.11 shows the surface latex concentration as a function of water loss rate for oxidized starch. We observe that when the water loss rate was decreased by starch addition.,the migration increased. However, at the same level of starch addition increased dewatering caused more migration.

Fig.12 shows surface latex concentration as a function of water loss rate for CMC & alginate containing coatings. In general, increased dewatering tended to cause more migration for the coatings containing CMC, but coatings containing alginate showed little migration at any temperature or addition level. It is again clear that chemical interactions and structures are more significant than the dewatering alone.

Fig.13 shows latex surface concentration as a

FIG.10 LATEX PROFILE Vs VISCOSITY LATEX-L & OXID.STARCH WITH CMC & ALG.

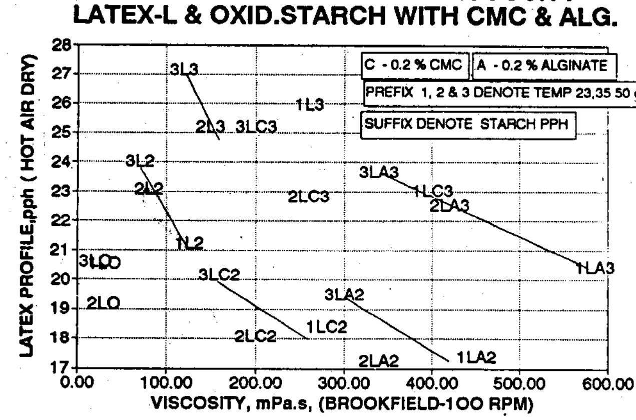


FIG.12 LATEX PROFILE(hot) Vs WATER LOSS RATE FOR CMC AND ALIGINATE

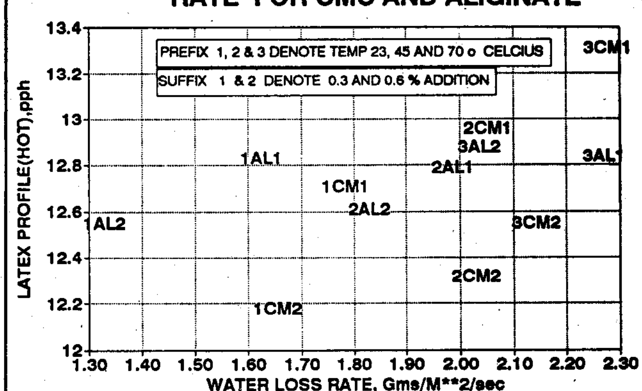


FIG 11 LATEX CONCENTRATION Vs WATER LOSS RATE FOR OXIDIZED STARCH

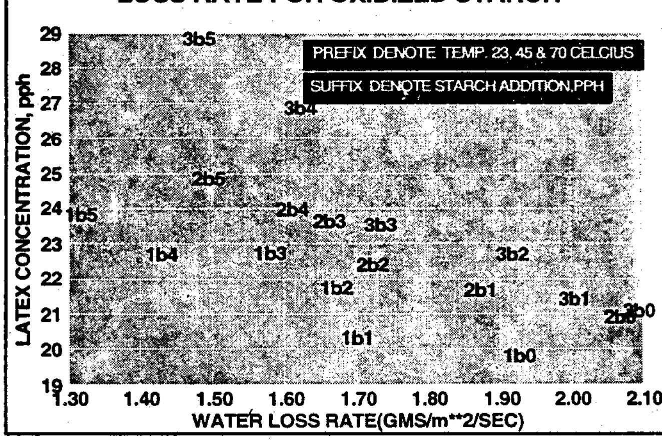
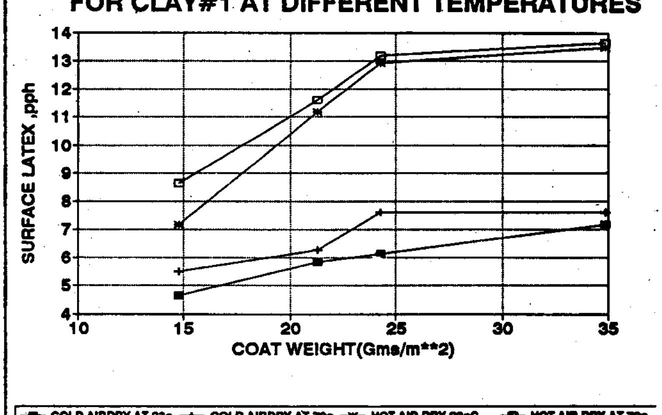


FIG 13 LATEX PROFILE Vs COAT WEIGHT FOR CLAY#1 AT DIFFERENT TEMPERATURES



function of coat weight at different temperatures for clay #1. It is observed that at lower coat weights migration is measured by the difference between hot air drying and ambient air drying decreases. The effect of the coating color temperature at the time of application is not clearly defined in that it resulted in higher surface concentration for both drying methods.

Summary and Interpretation of results

Increased dewatering at higher temperature can be explained by lower continuous phase viscosity, higher vapor pressure of the liquid and reduced surface tension of liquid at higher temperature as explained by Salminen(7). All these factors will result in higher dewatering. Dewatering dependence on both the nature of the polymer and viscosity of the coating color suggests that polymers by their nature (interactions with pigment and latex) are able to hold water. Good correlation of dewatering with low shear viscosity for the same coating color suggest that for capillary penetration the effect of vapor pressure of the liquid and surface tension was not as pronounced. Salminen(7) mentioned that there is only a small change in surface tension of pure water with temperature and it is expected that the change in surface tension for coating color with increased temperature will be even smaller as coating colors have much smaller surface tension than pure water due to presence of coating components. Sized paper surface is a low energy surface and difficult to wet, but vapor phase transport ahead of the liquid front will increase the surface energy and accelerate liquid penetration. Unsized paper has comparatively a high surface energy and thus the effect of liquid vapor phase will not be so significant. The paper used in this study was comparatively soft sized (Hercules sizing 4 secs) and hence the effect of vapor pressure was small, that is why we observed a good correlation of dewatering with low shear viscosity for the coating color of same components.

The binder migration increase at higher temperatures can be explained by the higher dewatering rate of the coating. Lepoutre (12) found that increased water holding of coating color showed down the flow rate of the aqueous phase, and improved the packing efficiency in the filter cake. Increasing the temperature of the coating color can accelerate the rate of settling of coating cake, reducing the packing efficiency in the cake resulting a more open structure. Moreover, lower viscosity at higher temperature should increase the mobility of the continuous phase and increase the amount of latex carried to the surface. Such a correlation between migration and viscosity was observed in oxidized starch and coatings without other interactive polymers

CMC, alginate and polyacrylate form cross linking or three dimensional structures within the continuous phase which withstand low shear rates. Formation of these structural networks should inhibit latex mobility. It is believed that this is the reason these polymers did not show higher migration at higher temperatures. The water can move even though the latex may be adhered to clay by secondary attractive forces. In the case of the oxidized starch, which does not form a network with clay and latex, the effect of higher temperature is more pronounced. The oxidized starch shows higher migration than other polymers. It is expected that the carboxyl group in the oxidized starch will increase the repulsive forces within the latex and clay. Because of these repulsive forces, starch has been shown to act as a good dispersant. This explains why oxidized starch increased latex migration.

The polymers can be classified into two groups. One (oxidized starch) and others (CMC, Alginate and Polyacrylate) based on their effect on binder migration as temperature was increased. Ether starch showed less migration at low level of addition and high migration at high level of addition indicating a more complex interaction. Sandas and Salminen (11) in their study of the pigment co-binder interactions also found that CMC shows a higher interactions with the pigment, forming a strong three dimensional structure at low shear viscosity. They also found that starch shows at most only weak interaction with the pigment. Thus it is clear that these interactions tend to control the mobility of the latex and dewatering. Due to the nature of the carboxylic groups, Alginate and polyacrylate are believed to form cross linking similar to CMC(5). It is seen from the data that alginate and polyacrylate behaved similar to CMC . Other researchers have also shown interactions of polymers with pigment and polymers and latex system.

CONCLUSIONS

This study questions the comparisons of dewatering rate, viscosity and latex migration for different coatings of different composition. It is shown that additives of different chemical composition will have different interactions, and any comparison of viscosity/dewatering with latex may be secondary to that interactions. The followings conclusions are made from this study.

1. Increased temperature reduced viscosity and water holding of all the coating colors. Viscosity correlated with dewatering when varied with temperature.
2. Increased temperature and lower viscosity of coating colors containing oxidized starch, in general, increased surface latex concentration. The same effect was observed for ether starch at higher level of additions (above 3 pph).
3. Coating colors containing CMC, Alginate and Polyacrylate had a slight tendency for increased migration at higher temperature of the coating color, but the differences were not significant.

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