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CHAPTER 13

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CHAPTER 13

Esa Lehtinen

Coating binders – general

1 Functions of binders

Binders are the second most abundant component in the coating color after the pigment. Here the choice is between many binder types and sub-types. But whatever the choice is, binders are added into coating colors to fulfill certain purposes (Fig. 1):

- Binding of pigment particles to base paper (A)
- Binding of pigment particles to each other (B)
- Partly filling of voids between pigment particles (C) – porous coating structure
- Affecting viscosity and water retention of coating color.

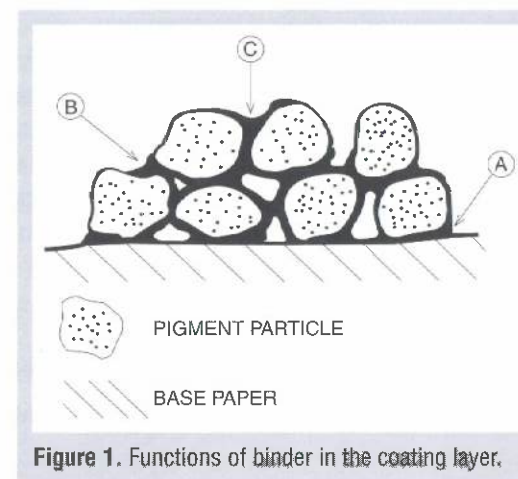


Figure 1. Functions of binder in the coating layer.

2 Ideal binder

An ideal binder can be characterized as follows:

- Good binding power
- Good water retention properties
- Can be mixed or dissolved easily into the water
- General ease of handling
- Good compatibility with other coating components
- Small or desired effect on the viscosity of the coating color
- Mechanical and chemical durability
- Good optical properties
- Good mechanical properties

- Non-odorous and harmless to health
- Low tendency to foaming
- Resistant to bacteria
- Low price and good availability.

Again, as with pigments, there is no single binder, which could meet all these requirements. Latexes meet many of them; however, they often need co-binder or thickener for adjusting the rheology and water retention to the desired level.

3 Types of binders

When considering the relative amounts of binders in coating, one may speak about the (main) binder, co-binder and sole-binder. By sole-binder is meant a single binder that alone can perform all the desired functions of the binder in a coating. Usually the binder systems consist of a combination of two binders, in which the (main) binder is responsible for the binding function. The co-binder is used to affect the rheology and water retention properties of the coating color. Its dosage is smaller than that of the main binder.

The binders can be classified in the following way by their origin and solubility in water:

- Not soluble in water

Latexes	Styrene butadiene latexes	(SB latex)
	Styrene acrylate latexes	(acrylate latex)
	Polyvinyl acetate latexes	(PVAc latex)

- Soluble in water

Derivatives of natural polymers	
	Starches
	Proteins
	Cellulose derivatives
	Carboxy methyl cellulose (CMC)
Fully synthetic	Polyvinyl alcohol (PVA, PVOH)

Also latexes, of course, are fully synthetic. Water-soluble binders give better water retention for the coating layer than latexes that are not soluble in water. They also affect the rheological properties of the coating colors, making them more viscous, and also shear thinning (pseudo plastic) and thixotropic. Some synthetic co-binders have a similar effect.

In principle, there are two kinds of protein binders, casein and soy protein. Casein used to be a central binder type in the past, but nowadays it has only a marginal importance in cast coatings. Soy protein is a very important binder type especially in North

America. That is why, of the two kinds of proteins, casein has been left out of this book and only soy protein is described here.

Latexes are supplied as dispersions, in which there are small polymer spheres dispersed in aqueous medium. The dry solids contents of latex dispersions are slightly less or about 50%. Water-soluble binders are supplied as dry powders, which must be dissolved before use or they can be added into the coating color as such.

4 Criteria for binder choice

The manufacturer of coated papers and boards is in a situation of choosing binder when he or she is modifying an existing coating color or developing a new one or even a new paper grade. Then the criteria are the price, the performance in the coating color (effect on rheology and runnability), performance in the coating layer (effect on strength), how well it is suited for the existing equipment, or how big the investment is for new equipment. Besides strength, it must also be taken into consideration how the binder affects other properties of the coating layer, e.g., porosity, optical properties, and ink absorption. These depend on the dosage of binder.

The starting point in the development of a new coating color recipe is establishing the desired properties of the end product¹. This way an idea of pigment composition and binder types and amounts is created. To produce a color with acceptable runnability, the rheology of the coating color must be adjusted correctly. This is accomplished by finding the appropriate thickener or co-binder dosage and also the

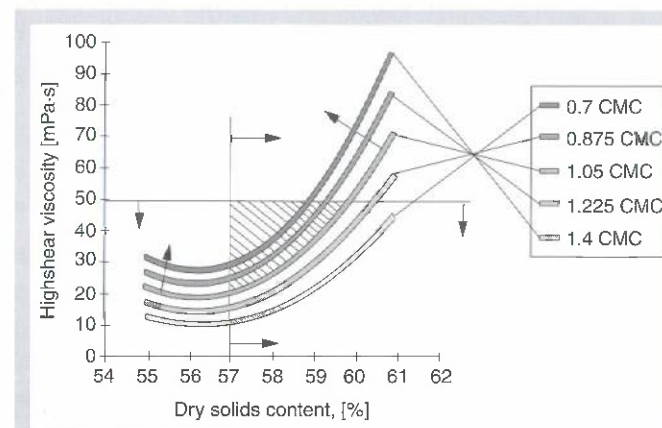


Figure 2. The rheology window of a coating color¹.

dry solids content of the whole color. This ought to be done systematically by measuring a so-called "rheology chart" to the chosen pigment and binder system with a high shear or capillary viscometer (see Fig. 2). The rheology chart shows the dependence of viscosity on dry solids content of the color and thickener content¹.

Then the experience-based knowledge about the maximum-allowed viscosity and minimum-allowed dry solids content of the coating color suitable for the coating machinery is added into the rheology chart. This way the so-called "rheology window" for the amount of thickener or co-binder and dry matter content is obtained. Naturally the rheology window depends on the particular coating color and coating machine¹.

The coating color must have certain water retention in order to stay in the rheology window. Most often, the water retention is also adjusted with the thickener or the co-binder. This must be taken into account when deciding the dosage of thickener or co-binder. The area limited by maximum viscosity, minimum dry solids content, and minimum amount of thickener or co-binder should be acceptable for the runnability of the color¹.

Sometimes such a situation arises that a runnable color cannot be made at any sensible dry solids content. Then the only alternative is to change the composition of the coating color and start again from the beginning¹.

It must be noticed that the final proof of the runnability of a coating color can be obtained only in pilot-scale trials. Laboratory tests, even with ultra highshear viscometers, can only give indications. However, laboratory tests can reveal totally unsuitable colors and these can be eliminated from further testing.

5 Binding power of binders

Relative binding power of different binders can be expressed as the relative amount needed for obtaining the same coating strength, which is obtained with the highest binding strength binder, i.e., polyvinyl alcohol²:

Polyvinyl alcohol	1
Carboxy methyl cellulose	1
Styrene butadiene latex	2–2.5
Acrylic latex	2–2.5
Polyvinyl acetate latex (copolymer)	2–2.5
Polyvinyl acetate latex (homopolymer)	2.5–3
Soy protein	2.5–3
Starch	2.5–3

This should be interpreted so that, e.g., to obtain the same strength for the coating when PVA has been replaced by SB-latex, the amount of SB-latex needed is 2–2.5 times the amount of PVA. Also when, e.g., starch is being replaced by, e.g., SB-latex, the amount of latex needed is 66%–83% of the amount of starch.

In practice, the comparison cannot be as straightforward as described here because the base paper, the color solids, the application, and drying conditions also have an effect².

6 Binder demand of pigment

“Binder demand” of a pigment means the amount of binder in the coating required to achieve the desired strength of the coating. Binder demand depends on the binder type, application solids of the coating, degree of the dispersion of pigments, and pigment properties. It is desirable to optimize the binder dosage because binders in general are quite expensive³.

Binder type affects the binding strength, as described previously. The better the dispersion of pigments is, the lower is the binder demand³.

The crucial pigment property affecting binder demand is packing of pigment, i.e., void volume of packed pigment. The better the packing is, the lower is the binder demand. The void volume is given by the formula^{3, 4}:

$$V_v = 1 - \frac{1}{S_R}$$

(1)

where V_v is void volume and S_R relative sediment volume.

Decrease of the void volume leads to the decreased binder demand of a pigment. The amount of binder needed depends on all the factors mentioned above.

7 Co-binders and thickeners

Co-binders and thickeners are the main additives that are used to modify the rheological properties of coating colors. They have a profound effect on the runnability of coating colors on account of their thickening action, their characteristic rheology at different shear rates, and their water retention.

Co-binders and thickeners can be roughly divided up into “natural” and “synthetic” products. The natural products, i.e., products derived from natural raw materials, can in turn be divided up into proteins (casein, soy protein) and polysaccharides (starch, alginates and cellulose ethers). Figure 3 lists the most commonly used co-binders and thickeners.

	Product type	Delivery form	Pretreatment	Thickening effect	Comments
Natural Products	Starch	Powder	Cooking	+	Co-binders, low affinity for pigments, yellowing
	Soy Protein	Powder	Cooking	+	Mainly for cast coating
	Casein	Powder	Cooking	++	All-round-product
	CMC	Powder, Solution	Added as supplied Dissolved	+++	Low water retention, mainly used in USA
	HEC	Powder, Solution	Added as supplied	+++	High water retention, expensive, mainly used in USA
	Alginates	Powder	Added as supplied Dissolved	+++	
Synth. Prod.	PVOH	Powder	Cooking	+	Best activator for OBA
	Acrylic Polymers	Solution, Latex	Added as supplied	+++	Versatile, easy to handle
	Associative Thickeners	Latex	Added as supplied	++++	Good runnability, low water retention

+ low ++++ high

Figure 3. Co-binders and thickeners in paper coating.

Casein, starch, and soy protein were the main binders that were used in the early days of paper coating. Apart from binding the pigments to the paper, these products also impart the necessary viscosity and water retention to coating colors. However, they were unable to satisfy the increasing demands that were placed on runnability and coating quality, and they have gradually been superseded by synthetic binders (dispersions of styrene/butadiene, styrene/acrylic ester, and vinyl acetate polymers). The result is

that natural products, principally starch and soy protein, are nowadays only used as co-binders. Casein is only used in cast coating because it has some special features which makes it difficult to replace with synthetic products.

Alginates and hydroxyethyl cellulose (HEC) are mainly used in the United States and Japan, and they have not been adopted to any significant extent in Europe.

Carboxymethyl cellulose (CMC) is a versatile product with an all-round range of properties, and it is popular in many regions.

The synthetic products comprise polyvinyl alcohol (PVOH), acrylic copolymers, and associative thickeners. Coaters have also recently begun to use polyvinyl pyrrolidone (PVP) as a co-binder, mainly in combination with PVOH.

8 This book

The following chapters discuss different binders and co-binders. The synthetic dispersions are treated first, followed by the water-soluble substances. This order is no indication of their importance because this kind of ranking is impossible.

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