The Ingredients of PAINT and Their Impact on Paint Properties

Different types and grades of paint provide different application and resistance properties, depending upon the kinds and levels of ingredients used to create the paint. In turn, the properties of a paint determine the general quality of the coating. Some of the many paint properties affected by the ingredients are highlighted below.

APPLICATION AND APPEARANCE PROPERTIES	INTERIOR PAINT PROPERTIES	EXTERIOR PAINT PROPERTIES
Color	Stain Resistance	Color Retention
Hiding	Scrub Resistance	Mildew Resistance
Flow and Leveling	Lack of Yellowing	Blister Resistance
Level of Sheen or Gloss	Resistance to Alkaline Cleaners	Dirt Resistance
Spattering Tendency	Burnish Resistance	Resistance to Peeling
Foaming Tendency	Block Resistance	Alkali Resistance

In general terms, all paints have four basic components that impact these properties. These components are:

PIGMENTS: provide color and hiding; some are used to impart bulk at relatively low cost

BINDER: "binds" the pigment together and provides film integrity and adhesion

LIQUID (or the "carrier"): provides desired consistency and makes it possible to apply the pigment and binder to the surface being painted

ADDITIVES: low-level ingredients that provide specific paint properties such as mildew resistance, defoaming and good flow and leveling

PIGMENTS

PROVIDE COLOR OR WHITENESS, HIDING AND BULK

Pigments are finely ground particles or powders that are dispersed in paints. Many of the same pigments are utilized in latex-based and oil-based paints.

There are two primary categories of pigments: prime and extenders.

PRIME PIGMENTS. These are the pigments that provide whiteness and color. They are also the main source of hiding capability.

Titanium dioxide (TiO_2), is the predominant white pigment, which has these characteristics:

- provides exceptional whiteness by scattering light
- provides whiteness and hiding in flat or glossy paint, whether wet, dry or rewetted
- is relatively expensive
- use of appropriate extender (see section on next page) ensures proper spacing of TiO_2 particles to avoid crowding and loss of hiding, especially in flat and satin paints
- has more chalking tendency in exterior paints than most color and extender pigments

Color pigments provide color by selective absorption of light. There are two main types: organic and inorganic.

- ORGANIC: These include the brighter colors, some of which are not highly durable in exterior use. Examples of organic pigments are phthalocyanine blue and Hansa yellow.
- INORGANIC: Generally not as bright as organic colors (many are described as *earth colors*), these are the most durable exterior pigments. Examples of inorganic pigments are red iron oxide, brown oxide, ochers and umbers.

PAINT TRAINING COURSE LEARNING OBJECTIVES

At the end of this course, you will be able to:

- Understand the four basic components of paint and their impact on paint quality and performance.
- Understand the relationship between pigment and binder levels in paint.
- Understand the mechanisms of paint film formation.
- Appreciate the difference between oil-based and latex-based paints, and their related performance benefits in architectural projects.
- Understand the function of different additives used in the manufacture of paints.
- To take the Paint Training test, log on to architecturemag.com
- Upon successful completion of the Paint Training test you will earn 3 AIA learning credits.

Color pigments are compounded into liquid dispersions called colorants, which are added at the point of sale to tint bases, and to white paints designed for tinting. In the factory, color pigments are used as dry powders and in liquid colorant form to make prepackaged color paints.

EXTENDER PIGMENTS (or "extenders") provide bulk at relatively low cost. They add much less hiding than TiO_2 and impact on many properties, including sheen, scrub resistance, exterior color retention, and others.

Some commonly used extenders are noted below.

- CLAY: Aluminum silicates (also called kaolin and china clay) are used mainly in interior paints, but also in some exterior paints. Calcined (heated to drive off water and create air-particle interfaces) clay provides more hiding than most extenders; delaminated clay enhances stain resistance.
- SILICA AND SILICATES: These provide scrub and abrasion resistance. Many of these exhibit excellent durability in exterior paints.
- DIATOMACEOUS SILICA: This is a form of hydrous silica consisting of ancient fossilized single-cell organisms. It is used to limit sheen in paints and varnishes.
- CALCIUM CARBONATE: Also called chalk, this is a general purpose, low cost, low hiding pigment used in both interior and exterior paints.
- TALC: Magnesium silicate — a relatively soft general purpose extender used in interior and exterior paints.
- ZINC OXIDE: This is a reactive pigment helpful with mildew resistance, corrosion inhibition and stain blocking. It is used mainly in primers and in exterior paints.

BINDER

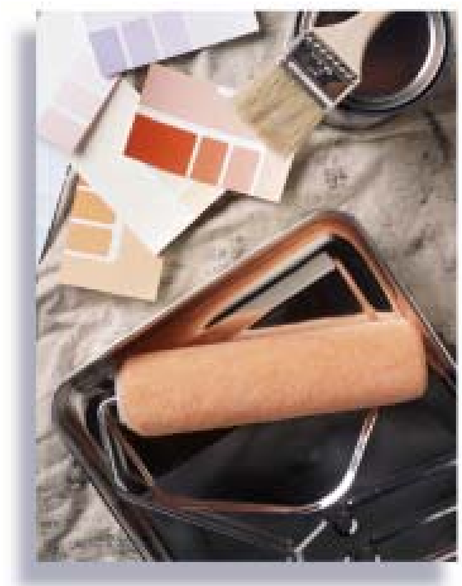
"BINDS" THE PIGMENT AND PROVIDES ADHESION, INTEGRITY AND TOUGHNESS TO THE DRY PAINT FILM

The binder is a very important ingredient that affects almost all properties of the coating, especially the following.

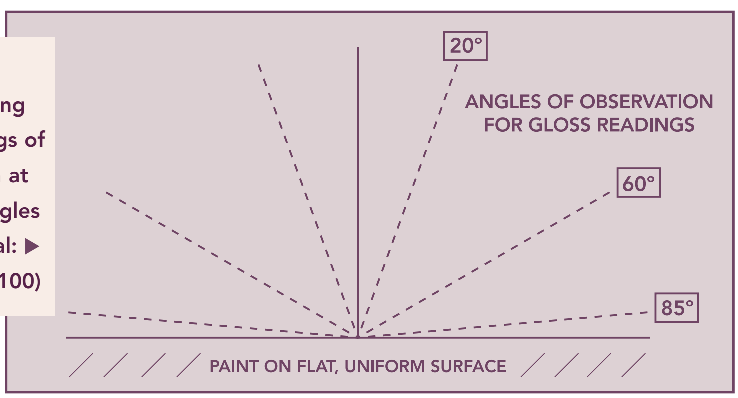
- adhesion and related properties like resistance to blistering, cracking and peeling
- other key resistance properties like resistance to scrubbing, chalking and fading
- application properties like flow, leveling and film build, and gloss development

With no pigment present, most binders would dry to form a clear, glossy film; some binders are used without pigments to make clear finishes and varnishes.

Pigment reduces the shininess, or gloss, of the binder. By incrementally increasing pigment levels, and by using larger particle pigments, the following gloss levels are achieved. ▶



Paint gloss is measured by using instrument readings of reflectivity taken at three different angles from the vertical: ▶ (polished glass = 100)



The gloss reading at 20º serves to describe the "depth of gloss" of gloss and semigloss paints. The reading at 60º is the measurement of gloss referred to most often, and is used with all but dead-flat paints. The 85º reading describes the "sheen" of flat, eggshell and satin paints.

Paints described as flat, satin, semigloss and gloss will have sheen and gloss values falling into the ranges tabulated to the right. ▶

This is not to say that a given product will vary within the range; rather, each value for the product will be designed to be in the range described. For example, a particular semigloss paint might have a 20º gloss reading of 15, and a 60º gloss reading of 55.

GLOSS RANGES

TYPE OF PAINT	20° GLOSS	60° GLOSS	85° GLOSS (SHEEN)
Flat	—	0 – 10	0 – 15
Eggshell	—	2 – 15	5 – 25
Satin	—	5 – 25	10 – 40
Semigloss	5 – 45	25 – 75	—
Gloss	20 – 90	70 – 95+	—

The paint chemist uses a figure called the PVC (pigment volume concentration) to indicate the relative proportion of pigment to binder for the paint formulation. The PVC is a comparison of the relative volumes (not weights) of total pigment and binder, and is calculated as follows:

$$\text{PVC\%} = \frac{\text{Volume of Pigments}}{\text{Volume of Pigments} + \text{Volume of Binder}} \times 100$$

Typical PVC values associated with different levels of paint gloss are noted below.

TYPE OF PAINT	TYPICAL PVC
Gloss	15%
Semigloss	25%
Satin	35%
Eggshell	35 – 45%
Flat	38 – 80%

Thus, a broad range of pigmentation levels is utilized in designing flat paint formulations. Higher quality flat paints, both interior and exterior, will generally have PVCs in the 38 to 50 percent range. Because these flat paints have more binder available per unit of pigment, they will have better durability than higher-PVC flats, all else being equal, as measured by properties such as scrub resistance and dirt resistance for interior use, and color retention, chalk resistance, mildew resistance and general durability for exterior applications.

Painting contractors often choose more highly pigmented dead-flat paints for new interior construction to hide unevenness of construction (particularly, taped wall joints) and for their uniformity of touch-up. In exterior use, high-PVC flats do not stand up as well as lower-PVC formulations, particularly in freezing climates or in use over wood.

The gloss requirement for paints shinier than flats restricts the range of PVC that can be utilized, compared to the range available with flat finishes. Some product specifications and/or MSDS will indicate the PVC of the product.

OIL-BASED BINDERS. The binder in an oil-based coating is made from a vegetable oil that "dries," or oxidizes, and cross-links when it is exposed to the air, and thus develops the desired properties of the paint product. Drying oils traditionally used in paints and coatings include linseed oil (squeezed from flax seed and refined), tung oil (from the fruit of the chinawood tree) and soya oil (from soybeans). Today, few paints are made with oil alone; rather, they are based on modified oils called alkyds. Alkyds dry harder and faster than oils. Some coatings, particularly exterior primers, are made with combinations of oils and alkyds to achieve appropriate flexibility. The term "oil-based" is commonly used to refer to both oil and alkyd coatings.

FILM FORMATION of oil-based and alkyd-based paints is a two-step process. When the paint is applied to a surface:

1. the liquid evaporates and leaves the binder and pigment on the surface; and

2. the binder then "dries," or oxidizes, as it reacts with the oxygen in the air.

It is this drying, or oxidation, that develops the hard, tough properties of the oil or alkyd paint. However, the oxidation process can ultimately cause this type of paint to harden to the point where it is vulnerable to cracking and chipping. The oxidation also causes yellowing, which typically is bleached out by sunlight, but may be quite noticeable in an area protected from sunlight, e.g., an inside room or closet, or a wall behind a picture frame.

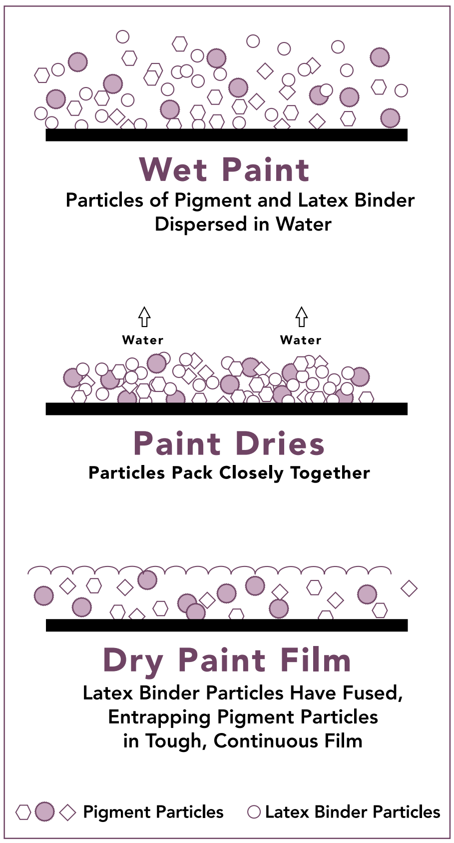
LATEX-BASED BINDERS. Most water-based paints are "latex" paints.* The binder in a latex paint is a solid, plastic-like material dispersed as microscopic particles in water. This dispersion is a milky-white liquid, which is called latex in the paint industry, in that it is reminiscent of natural latex from the rubber tree. Latex is also called emulsion, and in some countries, such as England, latex paints are referred to as emulsion paints.

☛ NOTE: Except for appearance, the latex used in paint is in no way related to the natural latex used in some kinds of rubber gloves, which have reportedly caused allergic reactions in certain users of the gloves.

* Water-based paints that are not latex-based include watercolors, poster paints, tempera and most finger paints.

The paint manufacturer makes a dispersion of the pigments that will go into a batch of paint, and adds the latex binder. Thus, the paint consists of dispersed pigment and binder, along with some additives and liquid, mainly water (see sections below).

FILM FORMATION of latex paint occurs when the paint is applied and the water evaporates. During this process, the particles of pigment and binder come closer together. As the last vestiges of liquid evaporate, capillary action draws the binder particles together with great force, causing them to fuse and bind the pigment into a continuous film. This process, called coalescence, is depicted in the following graphic. ▼



This mechanism of film formation is what allows water-thinning and water cleanup with latex paints, while providing prompt development of a water- and weather-resistant film shortly after application. The latex paint film retains microscopic openings that allow it to "breathe"; that is, allow moisture vapor to pass through. The latex paint film is thus more tolerant of moisture coming from inside the building than oil or alkyd paints, which form a "tighter" film, and are prone to blister if moisture is behind the paint, e.g., if the oil or alkyd paint is applied over damp wood or stucco.

On the other hand, latex paints may blister from rain, dew or other sources of water on the outside of the coating, if the paint:

- has limited adhesion capability
- was applied over a chalky or otherwise unclean surface, such that the paint's adhesion was compromised
- has not had enough time to dry thoroughly

Under any of these conditions, blistering tendency will be greater if the paint has high levels of tinting color.

The mechanism of latex paint film formation has some limitations. Because the binder particles are thermoplastic (tending to get softer at higher temperature and vice versa), they will get too hard to fuse into a continuous, durable film when applied at too low a temperature. This is the main reason paint manufacturers specify a minimum application temperature (typically, 50ºF) for latex paint products. And if conditions are such that the paint dries very fast, film formation and durability can be compromised, since very quick drying can reduce mobility of the particles before the film is adequately formed. Conditions that can contribute to overly fast drying of exterior paint are very high temperature, wind, low humidity, painting in direct sunshine and painting over a very porous surface.

TYPES OF LATEX BINDER. There are different broad chemical types of polymer used as latex paint binders. The two types used most commonly in North America are:

100 percent acrylic
and
vinyl acrylic*

(*also called PVA, for polyvinyl acetate)

The formulator has many binders of each type from which to choose. These will vary in terms of adhesion, particle size, flow and leveling, hardness, solids content, price and other characteristics.

Assuming that an appropriate binder is used for the intended application, and that all else is equal, 100 percent acrylic binders generally excel in the following properties for exterior applications: ▼

As a result of these properties and benefits, 100 percent acrylic latex paint is often specified for use on exterior surfaces where top-quality performance is required. (Acrylic binders are more expensive than vinyl acrylics by roughly a factor of two.) For interior applications, acrylic binders afford benefits in terms of adhesion under wet conditions, resistance to waterborne stains (food stains like coffee, juice, wine, etc.), resistance to blocking (sticking) and resistance to alkaline cleaners, but the differences are not nearly as pronounced as with exterior applications. Properly formulated, vinyl acrylic latex binders perform very well, particularly in interior wall paints, drywall primers and in satin and semigloss paints.

A third category of latex binder is styrenated acrylic. Styrene is included in the binder for enhanced water resistance, gloss development and cost reduction; however, the amount of styrene that can be used for exterior paints is limited, because too high a level can create a tendency to crack and chalk excessively, leading to fading. These binders are used in some masonry sealers, gloss paints and direct-to-metal coatings.

Property Difference	Related Performance Benefit
A. Adhesion Under Wet Conditions	A-1 Blister Resistance A-2 Resistance to Cracking, Peeling
B. Greater Water Resistance	B-1 Blister Resistance B-2 Resistance to Mildew B-3 Resistance to Dirt Collection
C. Alkali Resistance	C Less Likely to "Burn" Over Fresh or Moist Masonry

LIQUID

THE LIQUID PORTION OF THE PAINT (ALSO REFERRED TO AS THE "CARRIER") PROVIDES A WAY TO GET THE PIGMENT AND THE BINDER FROM THE CONTAINER ONTO THE SURFACE THAT IS TO BE PAINTED.

- For most oil-based and alkyd paints, the liquid component is paint thinner, which is a combustible solvent made primarily of mineral spirits, a petroleum distillate of aliphatic hydrocarbons.
- For shellac-based primers and varnishes, the liquid is denatured alcohol.
- For clear and pigmented lacquers, the liquid is usually lacquer thinner or another solvent that is "stronger" and more flammable than paint thinner.
- For latex paints, the liquid is primarily water (but see "Additives" section on next page).

The pigments and the binder are what is left on the surface when the paint dries and the liquid portion evaporates. Together, they are called the solids portion of the paint:

PIGMENTS + BINDER = SOLIDS

The coating (e.g., paint, stain, primer) consists of the solids and the liquid:

SOLIDS + LIQUID = COATING

TYPICAL SOLIDS CONTENT

WHEN A PAINT IS APPLIED AT A GIVEN THICKNESS AND DRIES, THE PROPORTION OF SOLIDS AND LIQUID DETERMINES HOW THICK THE DRIED PAINT FILM WILL BE.

Thus, a higher solids content can provide a thicker dry paint film, which results in better hiding and durability. For this reason, it is recommended that paints not be thinned unless necessary (such as for application by spraying), since thinning reduces the solids content of the paint per unit of volume. The solids content of a paint may be in its spec sheet. This can be expressed by weight or volume. The weight solids of a paint are usually higher than its volume solids. Volume solids are the better indicator of performance. Latex paints generally range from 25 percent to about 40 percent volume solids, depending on type and quality. Alkyd and oil-based paints can exceed 50 percent volume solids.

ADDITIVES

ADDITIONAL INGREDIENTS THAT AFFECT AND ENHANCE MANY PAINT PROPERTIES

Below is a list of additives used in the manufacture of latex paints and a description of how they affect the properties of those paints.

1

THICKENERS AND RHEOLOGY MODIFIERS: *(rheology is the science of how a liquid tends to flow)*

- *provide adequate viscosity (thickness), so the paint may be applied properly*
- *impact how thick the paint goes on and how well it flows out when applied*
- *modern rheology modifiers help latex paints to:*
  - *resist spattering when applied by roller*
  - *flow out smoothly*
  - *be less likely to spoil than those modified with older-generation thickeners (with spoilage, the paint may smell putrid and/or lose viscosity)*

2

SURFACTANTS: *(specialized soaps)*

- *stabilize the paint so that it will not separate or become too thick to use*
- *keep pigments dispersed for maximum gloss and hiding*
- *help "wet" the surface being painted, so the paint won't "crawl" (move about) when it is applied*
- *provide compatibility with tinting colorants so that the correct color will be obtained . . . and help ensure that it won't change before the paint is used*

3

BIOCIDES: *two types are used in latex paints*

- *a preservative to keep bacteria from growing in the paint. (This is especially important for paint stored in containers that are repeatedly opened and closed, because contamination can occur.)*
- *a mildewcide, to discourage mildew from growing on the surface of the paint after it has been applied. (This is used mainly in exterior products, although some interior paints, such as those formulated for use in damp areas, e.g., kitchens and baths, may also contain mildewcide.)*

4

DEFOAMERS: *break bubbles as they are formed in the paint when*

- *the paint is mixed in the factory*
- *it is put on the shaker or stirred*
- *it is applied to the surface (especially important when rolling the paint on)*

5

CO-SOLVENTS: *additional liquids, other than water, that*

- *aid the binder in forming a good film when applied down to the minimum recommended application temperature*
- *help the liquid paint resist damage if frozen*
- *enhance brushing properties, including flow and "open time" (the time during which the paint can be applied and worked, before it sets up)*

The co-solvents are generally volatile organic compounds (VOCs).

In conclusion, the properties of paint, and thus its overall quality, are determined by all four categories of ingredients:

PIGMENTS
Types and Levels Used

BINDER
Types and Ratio to Pigment Used

LIQUID
Solids Content

ADDITIVES
Types and Levels Used

Thus, no single dimension can assure top quality.

Information provided by The Rohm and Haas Paint Quality Institute
www.paintquality.com