

Binder selection for glass, polyester, and blended wet-lay nonwovens

Leo A. Tischer, Ti Chou, and Peter D. Seletzky

B F Goodrich Chemical Co., Elastomers & Latex Division, Avon Lake Technical Center,
P.O. Box 122, Avon Lake, Ohio 44012

ABSTRACT *Manufacturers of wet-lay nonwoven mats manipulate production conditions to obtain a product with the requisite end-use properties. This is often done by changing the fiber type or blend incorporated in the mat, the basis weight of the mat, and the binder type and addition level. A broad range of mat properties can be obtained simply by changing the binder system or the addition level. The effects of various types of binders on mat properties are examined, with the emphasis on latex binders. The effect of addition level, cure time, and cure temperature are also presented. Common problems associated with the use of latex binders are discussed and solutions are presented.*

KEYWORDS

Binders
Fiber mats
Glass fibers
Latex
Mechanical properties
Nonwovens
Polyacrylics
Polyureas
Synthetic fibers

Wet-lay nonwovens made of glass, polyester, and glass/polyester blends are being used increasingly in roofing products, filters, and numerous other applications. Each application requires a different set of mat properties, and manufacturers use a variety of techniques to obtain a nonwoven mat with the required characteristics.

Mat properties can be altered by using a different fiber or fiber blend, by changing the product's basis weight, and by changing either the type of binder or the amount of binder added to the product. However, selection of the proper binder often can provide the desired properties without further modification of basis weight or addition level. Properties that can be controlled by binder selection include dry, hot, and wet tensile strength and tear resistance; folding endurance; elongation; flame retardation; and heat and solvent resistance.

Applications and associated properties

In shingle-roofing applications, manufacturers are concerned primarily with tensile strength, wet/dry tensile retention ratio, and hot tensile strength. Wet tensile strength and tear resistance are also important characteristics. A mat must have a minimum tensile strength of about 25 lb/in. (4.4 kN/m) in order to run through a typical asphalt line. The mat also must have sufficient hot tensile strength to withstand the application of asphalt coatings at temperatures of 500–700°F (260–370°C). The final product must have enough tear resistance to withstand the rigors of installation, and adequate wet tensile strength is needed for continued integrity and weathering resistance.

In modified bituminous roofing applications, elasticity is as important as tensile strength. The material must have some stretch, since it is installed in large sections to form a continuous roof. This roofing material must be capable of accepting periodic heavy

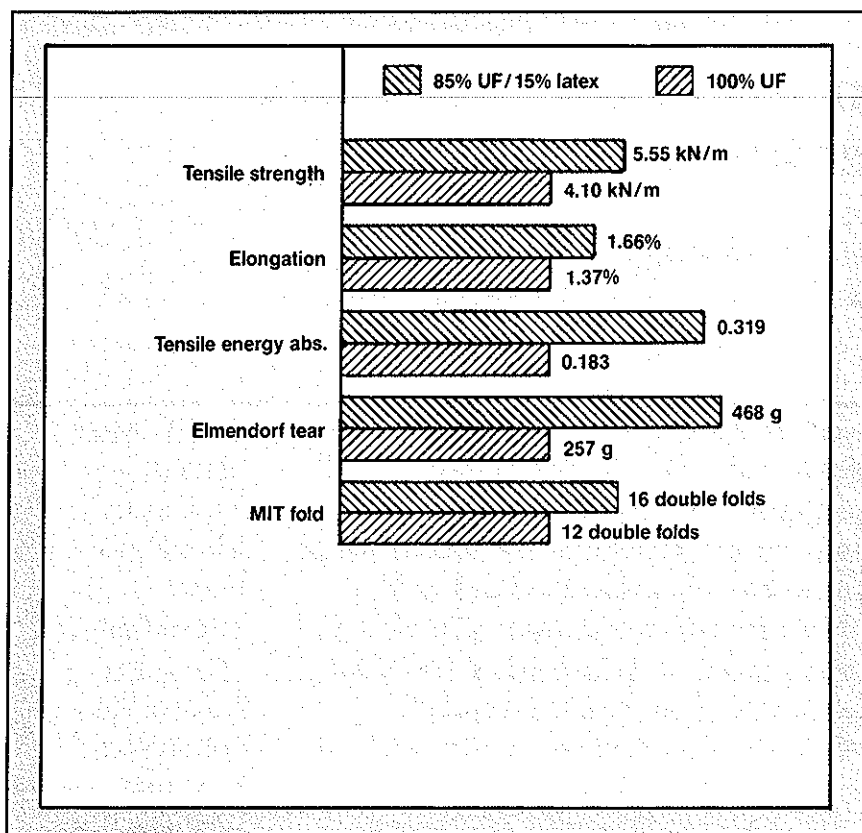
loads and then recovering from them.

Glass mat is also used extensively as separator membranes in lead-acid batteries. The binder must hold the glass fibers together while providing appropriate stiffness, tear resistance, and tensile strength. The binder must not contaminate the cell or alter the porosity of the glass mat under very acidic conditions.

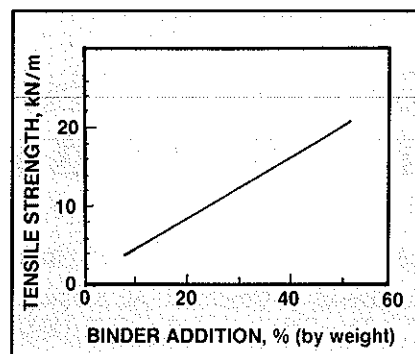
Filtration applications represent another significant market for glass and polyester nonwovens. Different filters dictate a variety of mat properties. Some filters require high tensile and wet strength or resistance to a specific solvent. Others require moldability or a specific flow-through rate. In high-loft filters, compression recovery can be an important property. Flame-retarding ability is required in many applications.

Clearly, it would be impossible to cover such a broad spectrum of property requirements with a single product. Significant differences in end-use requirements require some kind of change in the wet-lay production process. The cost of changing the production process can be reduced by

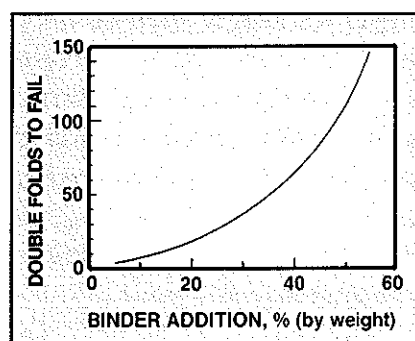
1. Comparison of mat properties for a 100% glass mat (20% add-on level, basis weight = 2.0 lb/100 ft²) bound with UF and with latex-modified UF.



2. Tensile strength as a function of binder (all-latex acrylic) addition for 100% glass mats.



3. MIT folding endurance as a function of binder (all-latex acrylic) addition for 100% glass mats.



minimizing the number of changes. While it is relatively easy to change the mat's fiber composition or its basis weight, such changes may not satisfy end-use requirements. Changing binder systems or addition level can provide a much broader range of properties.

Types of binders

The prevalent binder used in the roofing industry is urea-formaldehyde (UF) resin. Its chief advantages are low cost and high strength. Shingles made from 100% UF-bound glass mats provide adequate strength and performance. However, they are brittle and can easily crack or break during installation. UF resins are also susceptible to attack by water. Many manufacturers now modify their UF resins by adding 15–30% by weight of a latex polymer, typically a uniquely designed acrylic. This increases dry, hot, and wet tensile strength as well as tear resistance. The increased strength and flexibility of the resulting mats provide a highly durable

roofing material.

Some manufacturers of roofing materials use polyvinyl alcohol (PVOH) as a binder. However, most of these manufacturers produce a woven glass mat. PVOH binders typically contain about 90% PVOH and 10% polyvinyl acetate and are water soluble. Although effective, PVOH is extremely sensitive to attack by water.

Latex polymers are not limited to use as UF modifiers. They are also used extensively as the sole binder in many systems. Glass filters and battery separators typically use all-latex binder systems, as do many woven glass mats used in roofing. Wet-lay nonwoven polyester and glass/polyester blends also typically use 100% latex binders.

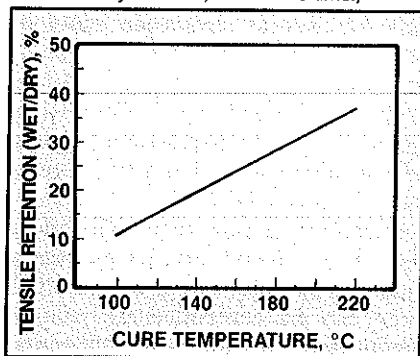
Different latex polymers are used for specific applications. Acrylic latex polymers are widely used for UF modification because they provide the greatest relative property enhancement. In addition to being chemically reactive with UF resins, acrylic latexes also plasticize the UF resin

without loss of strength. The resulting binder system has a greater ability to yield under stress (1). This provides more fiber reorientation in the direction of applied stress and, therefore, higher tensile energy absorption. This same yielding action is also responsible for the increase in tear resistance. Figure 1 compares the properties of 100% glass mats bound with 100% UF and with a blend of 85% UF and 15% acrylic latex.

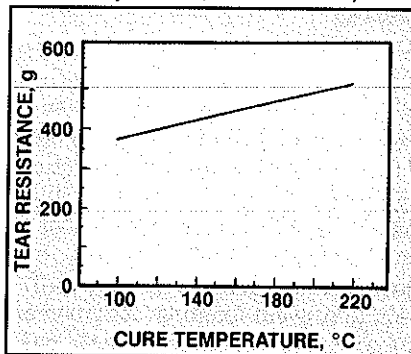
Acrylic latexes are also used as the sole binder for glass/polyester blends and 100% polyester mats. In these fiber systems, some strength is sacrificed in order to improve elongation. Performance depends strongly on the fiber-blend ratio (in glass/polyester systems) and also on testing conditions. The mat strength is dependent on the applied strain rate. The exact fiber blend used will depend on the final application (2).

Other types of latex polymers are also being used to fill specific needs. Polyvinyl chloride (PVC) latexes provide flame-retarding properties. Fiberglass air filters are often flame

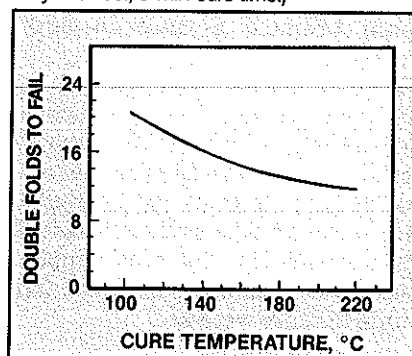
4. Tensile retention (wet/dry) as a function of cure temperature. (100% glass mats, heat-reactive acrylic binder, 5-min cure time.)



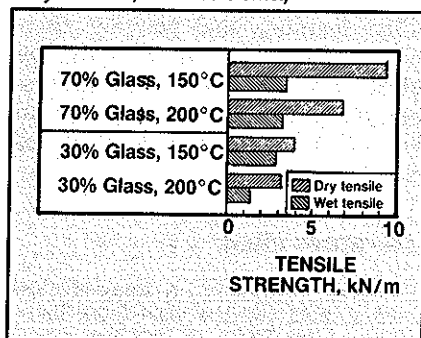
5. Elmendorf tear resistance as a function of cure temperature. (100% glass mats, heat-reactive acrylic binder, 5-min cure time.)



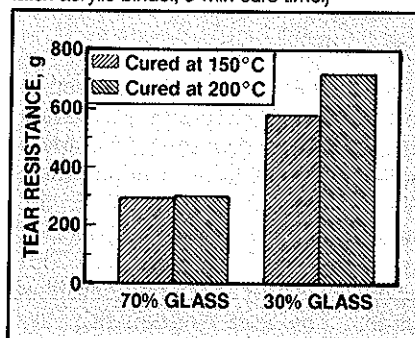
6. MIT folding endurance as a function of cure temperature. (100% glass mats, heat-reactive acrylic binder, 5-min cure time.)



7. Tensile strength of two glass/polyester blends at two cure temperatures. (All-latex acrylic binder, 5-min cure time.)



8. Elmendorf tear resistance for two glass/polyester blends at two cure temperatures. (All-latex acrylic binder, 5-min cure time.)



retarded for use on engines, electrical equipment, and other applications. The glass itself is flame retardant, and the use of a PVC binder can make an effective flame-retarding system. The PVCs typically compensate for slightly lower toughness at an equivalent level of addition by being more economical. If a particular application requires the higher strength of an acrylic, there are additives available to impart flame-retarding properties to the binder. These materials include halogenated compounds (halides, chlorinated paraffins, etc.), antimony compounds (antimony trioxide, etc.), combustibles inhibitors (phosphate esters, etc.), and others (3). PVCs can also be used as UF modifiers. The property enhancement is still significant compared with that of an unmodified UF system.

Numerous other latex polymers are being studied for their unique properties. Acrylonitrile-butadiene-styrene latexes show good heat resistance and also demonstrate thermoformable properties that may be of use in high-temperature air filters or other

molded applications. Several elastomeric polymers and polyurethanes are being investigated for their stretch-recovery properties. These binders impart a cloth-like feel to glass mats. Such mats can be folded and crumpled without cracking and then spring back to their original dimensions.

Line conditions and their effect on mat properties

The properties of a wet-lay nonwoven mat can be influenced by the amount of binder used, cure temperature, and cure time.

Binder addition level

Binder addition level is directly related to mat properties. A typical production line might operate at a binder addition level of about 20-23% (by weight). However, even small variations can have a significant effect on mat properties, as seen in Figs. 2 and 3. Figure 2 shows that as the level of binder addition increases, tensile strength grows at a

fairly steep linear rate. Figure 3 shows that folding endurance also increases with binder addition. In this case, however, the rate of increase is described by an exponential curve. Folding endurance increases only slightly until high addition levels of around 30-40% are reached.

Cure temperature

The binder's cure temperature has a dramatic effect on mat properties. Figures 4, 5, and 6 show, respectively, wet/dry tensile retention ratio, tear resistance, and folding endurance as functions of cure temperature. As the temperature increases and the polymer approaches full cure, tensile retention and tear resistance also increase, as seen in Figs. 4 and 5, respectively. Since more crosslinking occurs at the higher temperatures, the samples are stiffer and more brittle. Consequently, fold endurance is sacrificed, as seen in Fig. 6.

Cure time

Cure time is a significant factor in determining mat properties. Most line ovens are set between 350-500°F (175-260°C). The dwell time in the oven must be long enough to allow full cure to develop. If the residence time is too long, the polymer will overcure, resulting in degraded properties. Most binder systems have a time/temperature "cure window" in which optimum properties are obtained.

Figures 7 and 8 show tensile strength and tear resistance, respectively, for two glass/polyester blends that were cured for 5 min at two different temperatures using an all-latex acrylic binder. The lower-temperature samples showed increased tensile strength but reduced

tear resistance, indicating that the samples were just beginning to over-cure. Continued exposure to the heat would produce a drop in both properties.

The optimum cure conditions can be determined for any given production line and binder system. The ratio of wet/dry tensile retention is an excellent property to track the degree of cure. A peak in this ratio when plotted against dwell time (or oven temperature for a fixed line speed) will fall within the cure window.

Binder-related application problems and their solutions

Even with the best of binders, Murphy's Law dictates that problems will occur. Common problems include pH drift, binder storage life and compatibility, foaming, and latex polymer thermomigration. Although bothersome, each of these problems can be solved with a minimal amount of experimentation.

pH drift

The pH of resin binders tends to drift downward with age. As this occurs, the resin can begin to prereact and thicken, causing poor mat strength as well as buildup in the machinery. Most commercial binders contain additives to prevent this, but some systems still drift. The only safeguard is to periodically check the binder pH in the tank with a hand-held pH meter. If the pH has drifted, it should be adjusted or the material should be considered suspect for use. The pH in UF-containing systems should not be adjusted with chemicals containing the ammonium ion (NH_4^+). These chemicals will co-condense with formaldehyde and compete with the curing reactions and also produce undesirable odors (4).

Binder storage

Some latex binders become unstable when stored for an extended period of time. Latex binders are colloidal materials and thus have a tendency to settle. The best way to avoid this is to maintain appropriate agitation in the storage tank and consult with your supplier. The tendency toward settling is greater once the binder has been blended with UF. Blended material should be used immediately. In addition, some UF systems degrade

over time and show markedly poorer performance.

Foaming

Some binder systems have a tendency to foam when subjected to rigorous agitation or flow. Although low-foam products are available, even the best of these may still foam when agitated vigorously in air (as in a curtain coater). In such cases, addition of a small amount of defoamer (0.1- 0.2 parts per hundred) is usually sufficient to prevent foaming. Addition of defoamer to the binder tank will produce results within minutes. Selection of a defoamer should be discussed with your supplier, since some binder systems prohibit the use of certain types of defoamer.

Polymer thermomigration

A problem frequently encountered in polyester and glass/polyester mats (and, to a lesser degree, in 100% glass mats) is that of latex polymer thermomigration. During drying, the polymer tends to migrate to the mat surface as water is driven off. This leaves the center of the mat devoid of binder. The mat consequently has much poorer physical properties, including low tensile strength, firmer hand, and a higher tendency to delaminate (i.e., failure in the z-direction). There are ways to reduce the migration problem.

One common solution involves the use of heat-sensitizing agents, which typically contain polyether linkages and often are silane compounds. These materials interact with the colloidal system of the latex, causing rapid gelation at a certain temperature. Heat-sensitizing agents have a negative solubility, i.e., the agent becomes less soluble and liberates water as the temperature increases. The polyether segments then associate and gel the latex particles. The gelation temperature can range between 85 -175°F (30-80°C).

In many cases, a migration problem can be solved without the use of a heat sensitizer. Uniform distribution of the latex throughout the mat often can be maintained simply by increasing the binder viscosity, thus reducing the mobility of the particles. In many cases it is worthwhile to experiment with different binder viscosities.

Conclusions

The number of binder systems available for wet-lay nonwoven mats is growing. Binder selection depends primarily on the desired end-use properties. Latex binders offer a wide range of polymer composition and can be used alone or in blends with urea-formaldehyde resins.

Tensile strength, tear resistance, flexibility, moldability, flame retardation, and water and solvent resistance can be controlled by proper binder selection and use. Optimum mat properties can be obtained by adjusting addition level and finding the "cure window" for the specific system involved. Most binder-related problems (pH drift, mechanical stability, foaming, and polymer thermomigration) can be avoided by selecting an appropriate binder system. Persistent problems usually can be solved with a minimum of experimentation. □

Literature cited

1. Tischer, L. A. *et al.*, A study of glass fiber mats and the glass-latex interphase using ESCA, in 1987 Nonwovens Conference Proceedings, TAPPI PRESS, Atlanta, pp.87-95.
2. Shiffler, D. A., Properties of polyester/fiberglass blend wet-lay nonwoven fabrics, in 1987 Nonwovens Conference Proceedings, TAPPI PRESS, Atlanta, pp.105-11.
3. Weil, E. D., *Nonwovens Ind.* 17(9): 43(1986).
4. Meyer, B., *Urea-Formaldehyde Resins*, Addison-Wesley, Reading, Mass., 1979.

The authors gratefully acknowledge Steven F. Nielsen and Celanese Industrial Fibers for their help and technical expertise and for supplying the nonwoven materials.

Received for review March 15, 1988.

Accepted Sept. 19, 1988.

Presented at the 1988 Nonwovens Conference.