Latex modification of urea formaldehyde resins

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ABSTRACT

This paper provides a practical overview of latex modifiers and reviews the basic performance features they require to run without problems. It demonstrates the complexities of defining their performance features with some basic examples and presents some new unconventional approaches to urea formaldehyde resin modification. This includes use of stiff polymers and solution polymers.

Application:

Using acrylic solution polymers and stiff latex modifiers can improve fiberglass shingle mat production.

THE SELECTION OF LATEX modifiers for urea formaldehyde resins used in the wet laid fiberglass roofing mat industry is extremely diverse. Manufacturers can choose from the full range of emulsions technologies: acrylic, vinyl acetate homopolymers, vinyl acrylic copolymers, vinyl chloride and acrylic copolymers, and styrene butadiene resins to complement the urea formaldehyde (UF) resins they use. All the choices of binder types have their benefits and disadvantages. With all these options, one can pose two questions in a generic sense. Is one class of latex modifier better than another? Within a class of polymer chemistry, what type of composition is better than another?

Considering the wide selection of UF resins, fiberglass wet chop, and white water chemicals currently available, the answers are not simple. A simple answer to performance related questions on latex modifiers from the supplier's perspective is that products must run without problems and offer consistent property improvements. Fiberglass mat producers probably also share this sentiment.

This paper will provide a practical overview of latex modifiers. Specifically, it reviews the basic performance features they all require to run without problems. The paper then demonstrates the complexities of defining their performance features with some basic examples. Finally, it presents some new unconventional approaches to UF resin modification that includes the use of stiff polymers with T_g more than 100°C and solution polymers.

LATEX MODIFICATION OF UF RESINS

The role of a latex modifier for the UF resins used to bond wet laid fiberglass mats is straightforward. It provides increased tensile strength, wet strength retention, and tear strength. These properties are critical for processing the mat through a high speed asphalt saturator. To achieve this 15 years ago, the modification levels often ranged up to 25%.

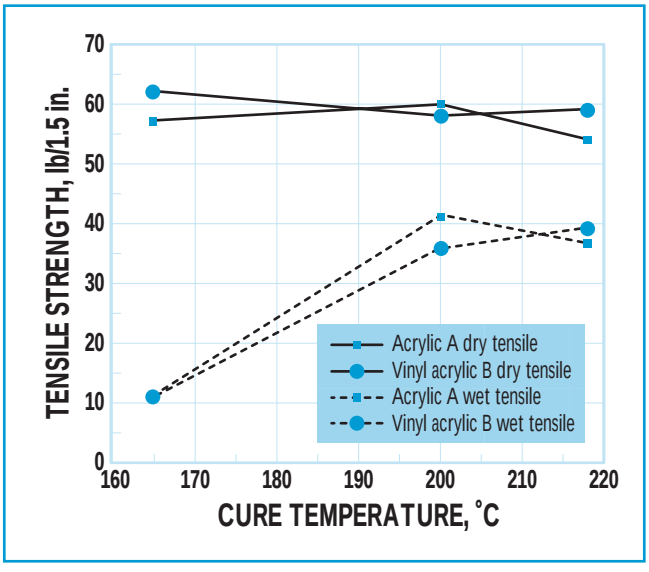
Many improvements have occurred since the early 1980s with improvements in UF resins and changes in glass mat machines, line speeds, forming technologies, and fiberglass wet chop finishes. The result is a reduced level of latex modifier required for fiberglass roofing mat products today. The demands placed on a modifier are higher now because improvement in tensile and tear strengths is necessary at low modification levels of 5%–10%. With the wide range of different UF resins used in the roofing mat industry, what might look like a superior UF resin modifier in one system may be the opposite in another system. The constants that have not changed for UF resin modifiers are the physical properties needed for successful and trouble-free use on wet laid fiberglass mat machines.

UF resin and white water system compatibility

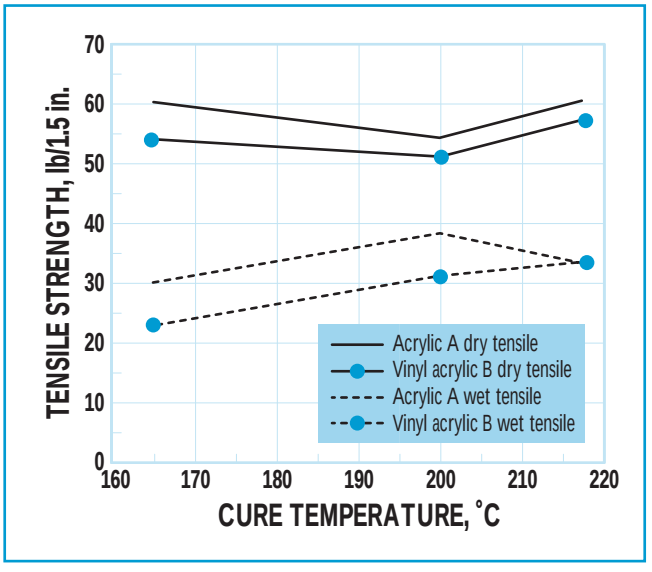
The properties a latex modifier provides to a UF resin do not matter when almost no compatibility exists with the UF resin being used, the white water in the plant, or both. Many different types of testing have been used to screen latex modifiers for compatibility. These include diluting tests, oven-aged stability tests in white water, and pH drift tests. Compatibility will always be a key requirement. Grit accumulation, phase separation, and gels in a system can lead to pump seizures, fouled oven wire screens, and generally poor mat properties.

Mechanical stability

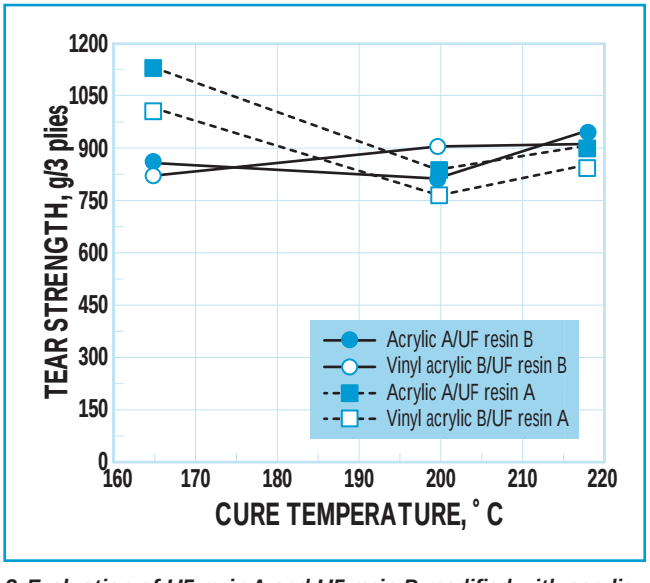
Excellent mechanical stability of latex modifiers used on glass mat machines will always be necessary. The shear forces applied to a latex through the constant pumping, vacuuming, and recirculation of the binder mix on a line can quickly generate grit if the latex is not mechanically stable. This grit can rapidly cause line problems. The type of pump used in a plant will often affect the degree of shear stability required in the latex modifier. Gear or rotary pumps are the most difficult to use. Diaphragm pumps are more forgiving.



1. Evaluation of UF resin B modified with acrylic A and vinyl acrylic B



2. Evaluation of UF resin A modified with acrylic A and vinyl acrylic B



3. Evaluation of UF resin A and UF resin B modified with acrylic A and vinyl acrylic B

Foam control

By definition, latex modifiers or emulsion polymers are surfactant-stabilized colloidal polymers. The types and levels of surfactants typically contribute to foaming. For example, nonionic surfactants are usually less efficient than anionic surfactants for stabilizing emulsions. A comparison of two emulsions stabilized with nonionic or anionic systems would likely reveal the nonionic system to have more foam. With the many cationic additives present in white water systems, latex modifiers often need to contain nonionic surfactants. In any case, a low foaming polymer system is necessary with UF resins. The typical way to achieve this is with polymers having low levels of surfactant, defoamed polymer systems, or addition of defoamer "on-line." Despite the control method, avoiding foam at the saturator has prime importance. Two problems with foam control are possible. One is "over control" of foam. This is due to excess addition of defoamer. It results in streaking and "fish eyes." The other problem is plasticizing the binder system causing poor properties.

These properties are the main physical properties necessary for trouble-free operation of latex modifiers in fiberglass mat application. Other properties that will always have potential concern are VOCs, formaldehyde content as supplied, stability upon storage, resistance to microbial and fungal challenges, and product quality and consistency. A longer term issue with latex modifiers is their effect on aging of final shingles. Most shingle mat producers have their own accelerated aging test procedures to evaluate latex modifier effects.

DEFINING PRODUCT PERFORMANCE

Drawing comparisons and reaching conclusions on chemistry type—acrylic, vinyl acrylic, or vinyl acetate, polymer characteristics among classes of polymer chemistry—T_g, self-crosslinking, or crosslinkable, and the amount of any functionality depend on the system. As mentioned previously, system variables such as UF resin, fiberglass wet chop, and white water can heavily influence the decision on which latex modifier provides acceptable performance. A few examples of their effects follow.

EXAMPLE 1

A comparison of testing between two latex modifiers—acrylic A and vinyl acrylic B—used two different UF resins. UF resin A was a white

cure UF, and UF resin B was a yellow cure UF. Acrylic A was an acrylic self-crosslinking polymer with T_g of +34°C. Resin B was a vinyl acrylic crosslinkable copolymer with T_g of +25°C. The cure ladder for both systems was 3 min at 165°C, 200°C, and 218°C. The dry tensile strength, wet tensile strength using hot soaks at 81°C for 10 min, and Elmendorf tear strength for both modifier systems were evaluated at equivalent modification levels of 8% and 22% loss of ignition (LOI) and a 1.8 lb/square basis weight. Mats were prepared in a white water system with polyacrylamide dispersant using 1 in. M grade fiberglass wet chop. Tensile testing used samples 1.5 in. x 6 in., and tear testing used 2.5 in. x 10 in. samples.

Comparing the performance data in **Figs. 1–3**, two quick conclusions are obvious. Vinyl acrylic B is clearly deficient to acrylic A in cure speed and tensile properties using UF resin A. Under identical conditions, the performance properties of the two modifiers are equivalent when using UF resin B. This shows that a latex modifier complements the UF resin. This occurs through binder placement with the UF resin on the fibers, morphology of the latex within the UF matrix, or acceleration of water release from the UF resin. Depending on the UF resin currently being used by a mat producer and whether that choice is fixed, a mat producer may have a limited or wide range of latex modifier options available considering the performance criteria of the product.

EXAMPLE 2

As mentioned above, the effects of white water chemistry on latex modifier evaluations are important when making comparisons between latex modifiers. Specifically, a latex modifier that appears superior in a hydroxyethyl cellulose (HEC) white water system may be deficient compared with the same product in a cationic polyacryamide dispersant system. This example shows a comparison between two white water systems using two acrylic UF resin modifiers: acrylic A and acrylic B. Both polymers systems have similar T_g and basic polymer backbone and are self-crosslinking. The only differences between these polymer systems are that acrylic A contains more self-crosslinking functionality than acrylic B and acrylic B contains a different surfactant system than acrylic A. Handsheet preparation used 0.75 in. M grade fiberglass and basis weight of 2 lb/square with 20% modification of the same UF resin and achieved 20% LOI. Curing for each system was 3 min at 200°C. Evaluations of dry tensile strength and wet tensile strength after soaking 10 min at 81°C used strips measuring 1 x 4 in. A radial die cut the samples for tear strength testing on an Elmendorf tear tester. **Table I** shows the results of this evaluation.

Modifier	White water system	Dry tensile, lb/in.	Wet tensile, lb/in.	Tear strength, g/ply
Acrylic A	Cationic polyacrylamide dispersant	50	30	260
Acrylic B	Cationic polyacrylamide dispersant	48	28	300
Acrylic A	HEC	42	23	310
Acrylic B	HEC	48	29	315

I. Comparison of physical properties for acrylic A and acrylic B in different white water systems

Without considering the white water system used in the evaluation, any attempt to draw a comparative conclusion between the performance properties of acrylic A and acrylic B modifying the same UF resin on the same fiberglass wet chop would clearly be premature. As mentioned in Example 1, the way a binder reinforces or packs within a UF matrix can often define performance properties of a latex modifier differently. One system may distribute uniformly within a UF matrix, and other latex modifiers may distribute unevenly within a UF matrix. Mat properties can vary from this type of distribution.

EXAMPLE 3

A comparison between acrylic C and acrylic D conducted on fiberglass handsheets used the same white water, fiberglass wet chop, and UF resin. Both latex modifiers had similar composition and T_g and were self-crosslinking. Acrylic D consistently provides greater tear strength than acrylic C. **Table II** shows typical performance properties of acrylic C versus acrylic A in a cationic polyacrylamide dispersant white water system. A 6% modification to the UF resin was selected, and a 22% LOI and 1.7 lb/square basis weight resulted using 1.25 in. M grade fiberglass. Sample cure was 3 min at 175°C.

From the data in Table II, acrylic D provides higher tear strength than acrylic C without compromising tensile strength. What may be unclear is why this is true since both polymers have similar composition. Microscopic examination of the fiberglass handsheets indicates that the binders possess different morphologies within the UF resin matrix.

NEW APPROACHES TO UF RESIN MODIFICATION

Latex modifiers for UF resins are important to achieve improved tensile strength of the binding resin for fiberglass mats. The improvement in tensile strength that a modifier must provide is often the result of the UF resin currently in use. Since varying the mole ratio of formaldehyde to urea influences the tensile strength of a UF resin*, the need for a latex

* Wallace, P. D., Barlett, C. A. and Kennedy, D. J., INDA Technical Conference Proceedings, INDA, Cary, 1981, p. 1.

Binder	Dry tensile, lb/in.	Wet tensile lb/in.	Tear strength, g/ply
Acrylic C	37.5	23.0	300
Acrylic D	36.5	22.5	370

II. Comparison of physical properties using acrylic C and acrylic D as binders

Binder	Dry tensile, lb/in.	Wet tensile lb/in.	Elmendorf strength, g/ply
Acrylic A	35	20	290
Solution polymer A	45	22	295

III. Improvement in physical properties when using a solution polymer

Binder	Dry tensile, lb/in.	Wet tensile lb/in.	Elmendorf strength, g/ply
Acrylic A	37.5	23.0	300
Acrylic D	42	25.5	290

IV. Improvement in physical properties when using a stiff polymer

modifier that increases tensile strength may be greater for a fiberglass mat producer using a less crosslinked UF resin. This is also true where the tear strength of the UF resin has increased by addition of plasticizing agents at the sacrifice of some tensile strength. Some latex modifiers may be better than others to achieve improvements in tensile strength with almost no compromise in tear strength.

A new approach to achieving improved tensile strength of a UF resin system is use of a crosslinkable solution polymer. On a simplistic basis, the solution polymer can increase crosslinked density and therefore enhance tensile strength. Latex polymers must have excessively high molecular weight to influence the crosslinked density of the UF matrix significantly. In addition, a solution polymer can be a more efficient modifier than a latex polymer as **Table III** shows. The data in the table is from mats prepared at 2% modification of the UF resin with cure for 3 min at 175°C. Evaluations of dry tensile strength and wet tensile strength after soaking for 20 min at 81°C used 1 x 4 in strips. A radial die cut the samples for tear strength testing on an Elmendorf tear tester. A large increase in dry tensile strength occurred with 2–4 times less than conventional latex modification levels without adverse effect on tear strength.

As mentioned previously, fiberglass mat uses latex modifiers in low amounts. The challenge is selecting a product that provides the necessary boost in properties to complement the current UF resin system. Any latex modifier that can enhance the UF resin chemically or physically by promoting water release and film formation can potentially improve properties.

An example of this approach to latex modification of UF resins is the use of extremely stiff hydrophobic polymers. The benefits of this polymer system could be due to the T_g value more than 100°C—higher than most latex system currently used. This may influence the way in which the mixture of UF resin and latex releases water. Less film formation may promote faster water release in the UF and latex binder system.

Table IV shows a comparison of strength properties for acrylic D—a stiff polymer—with acrylic A. Acrylic D is a stiff self-crosslinking acrylic polymer with T_g > 100°C. Handsheet preparation for the tests reported in the table used 1.7 lb/square basis weight, 22% LOI, 6% modification of UF resin, and 1.25 in. M grade fiberglass wet chop. Curing of the handsheets used 175°C for 3 minutes.

Acrylic D develops tensile strength faster with the UF resin than Acrylic A. This may contribute to faster line speeds.

CONCLUSIONS

This practical overview of latex modifiers has shown many system related effects on latex modifiers including white water and UF resin systems. Two approaches that are new and unconventional for modifying UF resins are possible—use of acrylic solution polymers and stiff latex modifiers. Many improvements and changes in fiberglass shingle mat production have placed higher demands on UF resin modifiers to achieve better properties. Remembering the "system" effects when evaluating new latex modifiers and having a willingness to venture outside existing conventional latex systems may allow mat producers to achieve performance improvements that meet these demands. TJ

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