FiberSystems
521 Kiser Street
Dayton, OH 45404-1641
Tel: 937-222-9000
Fax: 937-222-9020

How To Design, Specify and Purchase Abrasion Resistant FRP Composite Pipe To Achieve Maximum Service Life - The Five Factors to be Considered

Because of it's corrosion resistance, strength and light weight FRP composite pipe is being used for service environments that are also abrasive. Examples include the transport of lime slurries, fly ash, sludge from open hearths, duct handling coal dust, and duct for iron oxide from open hearths.

Developments of new technology, resin systems, and armoring modifiers have evolved from R&D work conducted almost continuously by FiberSystems, and it's sister companies, from the early 1970's. We have found that there are five almost equally important design "factors" that need to be specified for achieving maximum abrasion resistance, and thus the longest possible service life for the end-user.

1. **Selection of the Resin Matrix:** The resin used to make abrasion resistant pipe is the foundation on which all other enhancements build upon. Dow Chemical and Burlington in published literature have reported that using elastomeric toughened vinylester and acrylic modified epoxy resins can double the service life of the FRP composite pipe or duct. These independent test results have been confirmed by our own in-house abrasion testing programs. Yet, to gain a competitive cost advantage, some fabricators continue to use standard vinylester and epoxy resins in this critical inner corrosion and abrasion pipe liner.

   Burlington reported a slight advantage for the epoxy resins over the <u>standard</u> vinylesters. But this was not because the epoxy resins are more abrasion resistant in and of themselves - but rather they have better adhesion to the armoring modifiers, as further discussed below.

   Specifying Tip: **Specify that the resin matrix used in the entire inner corrosion/abrasion barrier and liner should be made using an elastomeric modified epoxy vinylester resin, with a minimum elastomer content of 12%, or greater.**

2. **Selection of the Type of Laminate Reinforcements used in the Corrosion/Abrasion Liner:** Our early tests, conducted in cooperation with Hooker Chemical in the 1970's, demonstrated that the type of reinforcements used in the inner abrasion/corrosion liner also has a significant influence on the abrasion resistance. Our findings were later confirmed by testing by Burlington.

   The use of synthetic reinforcing veils, such as Burlington's Nexus (polyester), or nylon reinforcements have demonstrated that using correct reinforcements can also double the abrasion resistance, and thus service life. Again, to gain a competitive cost advantage some manufacturers continue to use the lower cost C-veils or A-veil reinforcements in this critical inner corrosion/abrasion liner.

   ***Specifying Tip*:** **Specify that the innermost barrier for all abrasion resistant pipe have a minimum 20 to 30 mil synthetic veil reinforcement.**

3. **The Use of an Armoring Modifier in the Abrasion Liner:** To gain maximum service life, abrasion resistant FRP composite pipe and duct must also include in the corrosion and abrasion liner additives that can be best described as armoring modifiers. Over the years a wide range of such "fillers" have been used to obtain enhanced abrasion resistance.

   Dow Chemical, in their abrasion tests evaluated and compared different types of fillers, and different filler levels. Most of these fillers were selected because of their granular hardness. Though recent testing has also shown that thermoplastics; such as nylon, delrin and Kynar can also provide improved abrasion life. Hooker's tests, and confirmed by our own abrasion testing, found that the levels of the armoring modifier were not as important as the proper type and selection of the armoring modifier grades used.

   Early fillers used in fabricating abrasion resistant FRP piping liners included silica sand, silica flour, aluminum oxide, tungsten carbide, and silicon carbide. Building on this earlier work done cooperatively with Hooker Chemical, extensive testing by FiberSystems has continued on hundreds of different armoring modifiers. We have been successful in developing a new type of armoring modifier that has proven to provide superior abrasion resistance of the FRP composite laminate. The armoring modifier we use related in toughness to basalt which, in it's natural form, is often used as an abrasion liner for steel pipe.

   Over the years we have fine tuned the specific grades of this armoring modifier material. Based on testing and recommendations from Reichhold Chemical - we have also confirmed that perhaps more important than total armoring modifier levels - is the selection of the right grades and particle sizes. We have found it is important to achieve a specific combination of particle sizes; so as to obtain maximum "packing". The selection of the right type of armoring modifier, and the right "blend" of particle sizes can increase the abrasion life five fold, or even greater.

   Even with the same class or type of armoring modifier we have found that there can be an over four fold differences in the wear and service life between different manufacturers of armoring modifiers. This difference seems to be related in great part to the shape of the particle, and also perhaps even more importantly the cleanliness (lack of fine dust) on the particle surface.

   ***Specifying Tip*: Specify that the internal corrosion barrier of the pipe or duct is to also include FiberSystems special abrasion resistant armoring modifier AM-373.**

4. **The Use of Wetting Surfactants and Bonding Agents for the Armoring Modifier:** As was found in Burlington's original testing it is critical for achieving maximum abrasion resistance that there be a good "bond" between the resin matrix and the armoring modifier. This is how, in those tests, the epoxy resins gained an advantage over the polyester resins. That advantage was not because of the additional wear obtained from the epoxy matrix, but because the epoxy achieved better adhesion to the armoring modifiers.

   If this bond or wetting of the armoring modifier particle is not obtained, in abrasive service the particle can "pop out" of the resin, with the laminate then losing much of its enhanced abrasion resistance. The elastomeric modified epoxy vinylester resins, when used at the the higher elastomer contents, also achieve this better grip or bond to the armoring modifier.

In recent years we have also learned that just as important as the proper selection of the armoring modifier is the selection and use of the proper wetting surfactant additives and surface bonding agents. Just as all fiberglass and carbon reinforcements have chemical surface treatments or bonding agents to provide maximum "hook" between the reinforcements and the resin matrix - these same types of surface treatments are critical to obtaining the same adhesion or bond to the armoring modifiers. Just as with fiberglass and carbon reinforcements, where the sizing treatments are specific to the type of resin and type of glass being used; the surfacing treatments (additives) are also specific to the types of armoring modifier fillers being used.

We use a tested blend of wetting agents and surfactants to make sure we get the best possible adhesion between the armoring modifier particle surface and the resin matrix. But, we do not just stop with wetting agents. We have also determined that we get significant enhanced abrasion resistance by also using the proper silane surface treatment. Recent tests have shown that the use of the correct and proper quantities of wetting agents and surface treatment surfactants have increased the wear resistance of the composite laminate over seven fold.

On recent tests conducted on our FRP composite laminates used on the surface of manhole covers, we found, when we used the optimum surface treatment additives, achieving this seven fold increase in abrasion resistance - we literally shredded the carbide wheels of the Taber abrasion tester.

Wetting agents and surface treatment chemicals are not cheap. To gain a competitive price advantage this "factor" is sometimes not used by other manufacturers of abrasion resistant pipe. But, we have found, and confirmed by our on going testing, that the use of such surface enhancement additives are just as important, as the type and grade of armoring modifier used.

Specifying Tip: **Include in your specifications a requirement that all resins include not only air release agents, but also wetting agents from a company such as BYK; along with silane surface enhancement chemicals (surfactants) that have proven by testing to be compatible with the armoring modifiers being used.**

5. **Select and Specify the Proper Thickness of the Corrosion/Abrasion Liner for Your Specific Service Conditions:** Once all four of the above design steps (factors) have been satisfied, the final design factor is to select and specify the proper total thickness of the inner corrosion and abrasion liner to be provided, based upon the specific service conditions.

   It is our belief, and that of knowledgeable end-users, that the minimum inner liner for abrasion resistant pipe should be 110 mils. Again, to gain a competitive advantage, and to use their existing mandrels, we have seen pipe specified and quoted with corrosion liners as thin as 50 or 70 mils. (For competitive situations, we have mandrels that will allow us to provide these same thinner liners, even though we many not agree they are the proper thicknesses).

For piping systems that have very high velocities, or for piping immediately adjacent to the output of pumps, we often recommend even heavier abrasion liners than 110 mils. Also in the areas in change of direction, including elbows, tapered reducers, laterals, etc. we recommend that the thickness of the abrasion liner be increased beyond the minimum 110 mils.

We have had customers elect to use 150, 200 and even 250 mil corrosion and abrasion liners at these points of high wear. Obviously there is a direct correlation between the total thickness of the abrasion liner and the years of service life. It is often wise to spend the small extra dollars now for the increased liner thickness, so as not to have to replace critical wear piping sections in the future.

Specifying Tip: **Select and specify the correct total abrasion liner thickness required for you application. Do not let those liner thickness be set by the low bidder**.

To gain maximum abrasion resistance from FRP composite pipe and duct, takes careful attention and selection of all the above five factors or design considerations. We can provide you Guide Specifications that will help you, and your clients, obtain their maximum service life, and thus their best buy in abrasion resistant FRP composites.

For additional engineering discussion on abrasion resistance, wear, and the factors that influence the wear, we recommend obtaining and reading our additional Technical Bulletins: **(1)** *Abrasion Resistant Pipe and Duct;* **(2)** *Abrasion Wear - Prevention of "Wear"*; **(3)** *Slurry Handling Piping, and Velocity as a Consideration in Abrasion Resistant Pipe*. We would also be glad to share with you published results from Dow Chemical and Burlington on their independent testing of abrasion resistant FRP composite laminates.

Finally, be sure to request a custom prepared Guide Specification for your next corrosion and abrasion resistant FRP composite piping and/or ducting project to obtain your lowest cost per year of ownership.