THE FRP FI

a different approach to door making

WOOD OR METAL, IS THERE ANY OTHER KIND OF door? As pervasive as these two materials are in the fabrication of doors, it would be easy to discount the existence of any other alternatives. But there is an alternative that has been growing in popularity for commercial exterior entrance applications due to performance characteristics that avoid the inherent vulnerabilities of hollow metal and wood doors. This is the FRP flush door, fabricated using Fiberglass Reinforced Polyester (FRP) as the face sheet material.

The use of wood as a door-making material goes back so far into the fog of pre-history that it most likely replaced animal skins. Wood is abundant, easily worked, and offers excellent design flexibility and a warm, traditional look. Unfortunately, being an organic material, wood is vulnerable to moisture damage and microbial attack, is easily damaged in abusive locations, and requires regular maintenance. It's not a very good choice for exposed exterior applications.

Hollow metal doors are so common in commercial exterior entrance applications that they have essentially become a commodity product. They are all quite similar, formed from sheet metal shaped into a hollow box, with spacers, stiffeners or insulation material filling the inside. Hollow metal doors offer advantages over wood in terms of cost and durability but are susceptible to corrosion, denting and scratches, and they still require periodic painting. Both wood and metal doors tend to be fairly heavy, a characteristic that could lead to greater wear and tear on other elements in the opening.

The FRP Door

To answer a need for a door with greater dent, scratch and stain resistance, the use of FRP as a flush door face sheet was pioneered in the early 1980s by a small door manufacturer producing aluminum flush doors for retrofit into school entrances. FRP sheet was the logical choice for the door skin since it was already in use in applications requiring these qualities. The new FRP-skinned doors survived the worst imaginable conditions with very little maintenance, and end-user preference began to drive demand. As sales grew, a number of additional suppliers entered the market with products sporting FRP face sheets. Molded doors with wood or fiberglass internal frames fully encapsulated in FRP are also available, but will not be discussed here.

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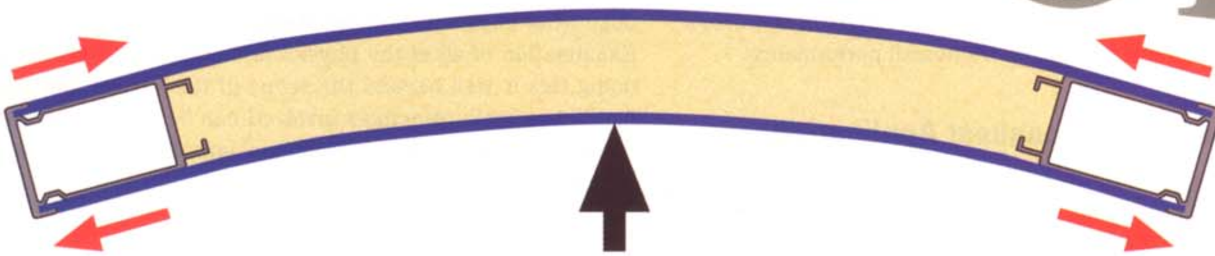
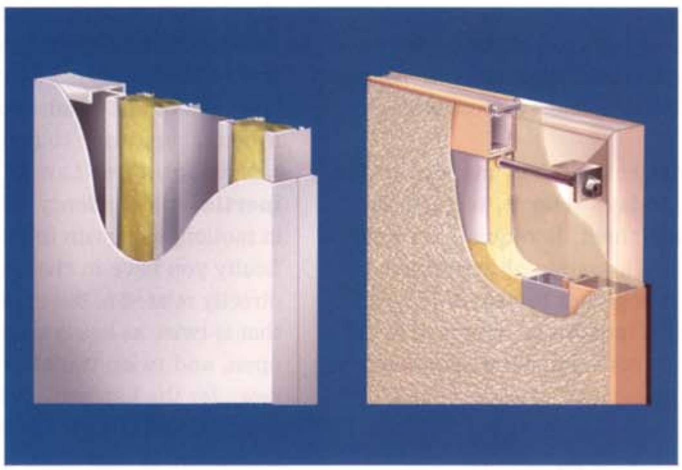
USH DOOR





Normal use and abuse subjects doors to forces which cause them to bow, placing the face sheet on the convex side in tension, while the face sheet on the concave side is in compression. This can fail spot welds or cause wrinkles in the skin of hollow metal doors. With FRP doors, these forces can cause face sheet delamination if glued-in-place or non-structural cores are utilized, which could then lead to progressive loosening of any screw-applied edge capping as the face sheet in compression forces the cap outward.

Modern Materials Offer Superior Performance

The FRP flush door is fabricated using a variety of materials—aluminum, FRP, and a foam core—that all need to work together to provide the desired performance. Many of the performance advantages of FRP doors can be attributed to the materials employed. FRP is a thermoset resin infused with glass fibers to increase impact resistance. The material won't corrode or rot, is scratch and abrasion resistant, and is easily pigmented for consistent color throughout, providing a distinct advantage over painted finishes in abusive environments.

The inherent properties of FRP can be augmented by the use of irregular patterning of the exterior surface, typically referred to as a "pebble grain" texture, which further improves durability by deflecting scratches and limiting the visible evidence of scuffs. In addition, a layer of clear Mylar formed into the surface can further enhance performance by providing additional fade, stain and abrasion resistance.

The aluminum stiles and rails of the FRP door cannot rust, and are typically anodized or painted with architectural finishes

for excellent resistance to the elements. Internal hardware reinforcements should also be aluminum, rather than steel, to avoid the galvanic corrosion that will occur when hardware attachment fasteners connect the two dissimilar metals.

The core material used in construction of the FRP door is critically important to the performance of the door. A variety of materials are used by the various manufacturers, ranging from polystyrene passive fillers to foamed-in-place structural urethane foam that becomes a load-sharing member of the door's structure, contributing to the door's overall performance.

Proven in the Toughest Applications

Acceptance of the FRP door was limited in the early years. There was the predictable resistance to trying anything radically new and different, and perhaps some measure of resistance to installing doors covered with "that restroom wall material." To overcome this objection, the approach taken by the first FRP door manufacturer was to request just one entrance—the worst one on the school—for a trial FRP installation. Exceptional performance led to additional purchases, and eventual preference for the FRP door.

Long-term survival of exterior entrances in any high-traffic, high-abuse environment, like today's schools, requires much more than a tougher door face sheet. It requires an appreciation of the entire entrance as a system of interdependent components that must all work together to deliver longer life and reduced maintenance. And it requires an approach to door design that runs contrary to the conventional wisdom on how to make a tougher door.

A Different Kind of Strength

Using a single material to fabricate doors, like wood for example, traditionally called for using more of the same material to fabricate a stronger door, which added weight and made the door more rigid. This mindset is still evident with hollow metal doors, where heavy-duty grade doors are fabricated of thicker gauge steel with additional steel stiffening channels in the core. Tragically, this approach ignores the impact of these heavier doors on the rest of the entrance. The massive "heavy duty" hollow metal or wood door can exact a severe toll on hardware and framing, increasing maintenance requirements and shortening entrance life.

An entirely different design philosophy is followed by the company that pioneered the FRP flush door. They recognize that the failure of any component in the system impacts all other components in the system. Doors cannot be considered in isolation. It is just one element in a total system that must work together to reduce maintenance requirements and provide the longest possible service life.

Doors are subjected to bending and twisting forces with every open/close cycle, and countless cycles of expansion/contraction due to temperature changes. Instead of fighting a losing battle against these forces, why not roll with them? Rather than add more material to *resist* the physical forces involved with hard use and abuse, why not design the door with the ability to accommodate these real-world forces and bounce back without sustaining damage. In other words, make the door more *compliant,* and lighter rather than heavier.

It may seem counterintuitive to make a door lighter and more flexible to make it more durable, but two decades of success in the most demanding applications imaginable proves out this approach. The goal in designing a door should be to optimize what engineers call the **flexural strength** of the door. Examination of all of the physics and engineering involved in doing this is well beyond the scope of this article, but fortunately the basic principles involved can be illustrated with a quick refresher on some fundamental laws of physics and a few intuitive examples.

The Law Always Wins

If you can't remember anything about Sir Isaac Newton other than his "discovery" of gravity when an apple fell on his head, that's OK. We only need to refresh your memory on his first two Laws of Motion to understand the consequences of the "heavier is better" approach to making heavy-duty doors.

Newton's First Law of Motion deals with the concept of **inertia**—the tendency of a body at rest to remain at rest, or if in motion, to remain in motion. Inertia is a measure of the difficulty you have in changing an object's state of motion and is directly related to the mass of the object. In other words, a door that is twice as heavy as another door takes twice the effort to open, and twice the effort to stop once swinging. That's bad news for the hardware, which will have to work twice as hard to control this heavier door, and for the framing, too, which has to support all that extra weight.

Newton's Second Law of Motion presents this relationship: **Force = Mass × Acceleration.** The implications of this principle upon entrance life will be obvious to anyone near a school entrance when the bell rings at the end of class. People naturally open doors with whatever force is required to maintain their walking, or running, speed. So with door opening speed more or less a constant, as door mass increases the forces transmitted into the hardware and framing increase proportionally. A door that is twice as heavy hits the stops with twice the force. Still more bad news for the entrance components.

Don't Jump to Conclusions

Doors with less mass are easier to open and transmit smaller forces into the rest of the entrance system, reducing wear and tear. But that's only half the story. The other half has to do with **compliance** and **elasticity**, two properties of materials or structures with profound implications for total entrance system life.

To understand the importance of compliance and elasticity in a door, consider what it would be like to bungee jump—not with a big rubber band attached to your ankle, but a nice, sturdy chain. The chain would certainly stop your fall and prevent you

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from hitting the ground, right? The chain and the bungee cord would both exert the same stopping force to halt your plunge. Unfortunately, the negligible elasticity of the chain would stop you instantaneously, forcing your ankle joint to do all of the complying to absorb the kinetic energy of your falling body. The bungee cord, on the other hand, complies with the force of your kinetic energy by stretching elastically to stop your fall over a period of time. So you get to keep your feet. Like the chain, a rigid door forces other entrance system components to do the complying—at their own expense.

Need another example? Consider this question: would you rather accidentally drop a frozen turkey on your foot in the kitchen, or one that's been thawed? Even if they weighed the same, it sure wouldn't feel the same. That's what rigid doors do to the rest of the entrance. Ouch! So not only is our hypothetically twice-as-heavy door pounding on the hardware and framing with twice the force, it's giving them the "frozen turkey" treatment by transmitting the forces with a sharp blow to a concentrated area, like the bird did to your foot.

Stop the Turkeys!

The key to producing long-lasting doors and entrances is to reduce the magnitude of the forces involved by reducing door weight and to reduce the "frozen turkey factor" with an appropriate degree of compliance and elasticity in the door leaf. The secret to making an FRP door with this essential flexural strength is to engineer all aspects of the door's design and fabrication to be compatible with each other as they respond to the forces encountered in the real world, whether human or environmental in origin. When *all* of the materials in the door contribute to its overall performance, less can actually be more. The compliance of a door with flexural strength enables it to be the "bungee cord" for the hardware and framing by absorbing and dissipating impacts in a manner that extends entrance life.

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Designing for Flexural Strength

To build an FRP door with optimal flexural strength, careful attention must be paid to the size and shape of all door components, the materials used, and the methods of fabrication to control rates of thermal expansion, elasticity and the locations of stress concentration. The stiles and rails must be sized to flex at a rate compatible with the flexibility of the bonded face sheet/foam core system. The core material itself must have sufficient shear strength and adhesion to bond all door components together into a single integral unit. Face sheets must be secured on all four sides by reglets in the stiles and rails so stress loads can be shared evenly between the perimeter frame and skin/core system without concentrating at a few screw locations as occurs with applied capping.

Stresses tend to concentrate at the corners of a door, as evidenced by buckling, splitting or "witness marks" in the finish of a door that is beginning to fail. Mitered corner joints secured by corner clips and full-width tie rods are essential to allow adequate elasticity without the permanent deformation or progressive metal fatigue that plague mechanically fastened or welded butted corners. Corners can be designed so that a 3/8" steel tie rod will comply elastically under foreseeable forces, rather than relying on the wall thickness strength of mortise and tenon features in aluminum tubing to resist these forces.

The goal of an engineered approach to door design is strength through flexibility, *i.e.* flexural strength. Doors should only be heavy and rigid enough to serve their intended purpose of keeping out the elements and securing the building. Any more than that is counterproductive and may even be destructive. Only the original manufacturer of FRP doors truly designs their doors for optimized flexural strength. Newcomers to FRP door manufacturing still follow the "more of the same" approach and rely on the added "strength" of larger stiles and rails or other construction techniques that merely add weight and rigidity, with the usual consequences.

Traditional door design approaches that ignore the basic laws of physics and the inherent weaknesses of the materials used compromise the service life of the entire entrance system and increase maintenance costs. The best solution today for longer entrance life is something altogether different: the FRP door. Today's facility managers, specifiers and architects have a new alternative for exterior entrances designed not to offer the lowest purchase price, but to deliver the lowest possible overall cost of ownership.