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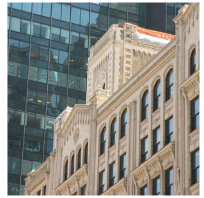


Restoring and Maintaining

Archaic Concrete Floor Systems

By J. Christopher Clements, AIA

Photos courtesy Hoffmann Architects Inc.

FOR A BUILDING OWNER, CONTRACTOR, OR DESIGN PROFESSIONAL, ENCOUNTERING AN UNFAMILIAR MATERIAL CAN BE A TERRIFYING PROSPECT, ESPECIALLY IF THE MATERIAL MAKES UP SOMETHING AS FUNDAMENTAL AS THE FLOOR SLAB. A FLOOR SLAB IN MODERN CONSTRUCTION OFTEN MEANS REINFORCED CONCRETE—UBIQUITOUS AND RELIABLE. HOWEVER, IT WAS NOT ALWAYS SO. PRIOR TO THE RISE OF REINFORCED CONCRETE, MATERIALS USED TO CONSTRUCT FLOOR SLABS INCLUDED BRICK, TERRA COTTA, AND A GROUP OF MATERIALS AND METHODS KNOWN AS ALTERNATIVE CONCRETE SYSTEMS.

It is this last group that is often the most puzzling to deal with, as it represents a myriad of approaches without clear modern parallels. Frustratingly, these systems can appear to be a standard concrete deck until their true nature is revealed through damage or alteration, leaving bewildered contractors and upended schedules. Knowing how to recognize and approach these systems can be invaluable if one is encountered.

History and background: Cities under threat

In the 1800s, America's increasingly dense cities lived under the threat of fire; 19th century fires could be a widespread catastrophe, burning huge swaths of the city. Moreover, they occurred frequently, as in Boston (1872), Chicago (1871 and 1874), and New York (1835 and 1845). San Francisco was the site of seven major fires between 1849 and 1851.

The destruction wrought in this period presented an incredible demand for 'fireproof' construction materials. In 1885, New York added a requirement to its building code that any building more than 21.3 m (70 ft) tall should be fireproof. Similar language was added to other building codes throughout the U.S. during the 1880s and 1890s. While reinforced concrete would eventually come to dominate as the material for slab construction, it was not yet available. At the time, concrete was thought of as a material for foundations, not structural elements. That concrete was not considered a suitable material for floor slabs was primarily due to the lack of adequate reinforcement. The twisted steel bars that would eventually develop into modern rebar were only patented in 1884, and it would be several more years before they were used outside of bridges and other engineering works. Without reinforced concrete, there was no easy answer to the challenge of creating a fireproof building material for floors.

This gap in building technology drew inventors of the late 1800s in droves, and they developed numerous patented flooring systems designed to resist fire while carrying the increasingly heavy floor loads brought by industrialization. These systems included terra cotta and brick arches, 'filled joist' systems where timbers were paired with fire-resistant materials, and alternative concrete systems.

Terra cotta and brick arches, both flat and vaulted, were already in use at the time, but had significant disadvantages. These systems were heavy and thick, taking up a large amount of headroom and adding significant weight to the structure. Construction was laborious, first requiring the construction of a wooden centering, on top of which arches would then be carefully constructed. Filled joist systems had all the structural downsides of wooden joists, with the added weight of fill material. The arrival of alternative concrete systems provided better alternatives, even if each system came with its own challenges and limitations.

Hidden in plain sight, archaic floor systems predominated in the late 19th and early 20th centuries, and many are still in service today. This 1910 building, nestled between glass towers, has a cinder concrete roof.

Alternative concrete systems

Cinder concrete

Cinder concrete—one of the most encountered alternative concrete systems—can be one of the most troublesome due to the unpredictable chemical properties of coal cinders used in its construction. Patented in 1906 by engineers A.W. Buel and C.S. Hill, cinder concrete became a dominant structural slab system in the 1920s to the 1940s. Surviving examples can be found extensively throughout New York City as cinder concrete had several advantages over other systems of the day: high load capacity, fire resistance, low material cost, and ease of assembly.

As indicated by its name, a cinder concrete system is comprised of a cinder fill layer encased on either side by low-strength concrete. This cinder fill is made from the cinder and clinker leftover from coal burning, an abundant waste product at the turn of the century. Anywhere from 101.6 to 203.2 mm (4 to 8 in.) thick, this loose cinder layer provided lightweight fire protection.

Cinders would also be used as an aggregate in the concrete itself, a typical mix being one part concrete and two parts sand mixed with five parts cinders. The resultant concrete weighed 38.5 to 49.9 kg (85 to 110 lbs) per square foot and had a rough, pumice-like texture.

Tensile strength in this system was provided by wire mesh draped between light-gauge steel beams. Laid in this way, this arrangement provides tensile support by means of a catenary system, the strength of which is the basis of many of the various alternative floor systems.

Taken together, the cinder fill provides fire resistance and helps distribute the load, the draped wire mesh provides tensile strength, and the concrete topping provides the walking surface, transfers loads to the mesh, and protects the system from water intrusion. In typical installations, the floor would be covered over with wood sleepers and hardwood floors or, in the case of rooftops, with a loose cinder fill sloped to provide drainage.

Roebling floors

Introduced in 1892, Roebling floors were one of the earliest concrete floor systems used in the U.S. The Roebling models were defined by a series of patents held by William Orr for John A. Roebling's Sons corporation, a producer of wire and wire rope. The genesis of these floors came out of a desire to find new markets for wire cloth, one of the products the company produced.

By adding small gauge rods into the wire mesh at intervals, Orr produced stiffened wire cloth to serve as the basis for the Roebling floor. On its introduction, it was marketed as a lighter and cheaper alternative to the then commonly used brick and terra cotta arches. Two systems were used: System A and System B, with variations for different building types.

System A was comprised of the company's stiffened wire cloth arched between I-beams, providing a formwork onto which lightweight concrete was poured. Often, this would be a cinder concrete of the same type used in the floor systems discussed previously. Above this, wood sleepers and fill material provided the base for wooden flooring.

Since damage to wire-reinforced floors may compromise load capacity, invasive probes require experience and planning.

Depending on the situation, the arches could be covered by another layer of stiffened wire cloth stretched between the I-beams and covered with an applied plaster coating or left open with the beams themselves coated in concrete. While this might appear to be a reinforced concrete system, it is not and was not intended to be so, as the wire mesh is positioned distinctly outside of the concrete.

System B, while also considered a Roebling floor, was a much different system. In this case, the concrete was reinforced by flat iron bars laid over top the supporting steel beams, with the wire cloth again providing formwork; though, in this case, the cloth was not arched but rather laid flat underneath the reinforcing bars. This system could accommodate wider spans than System A, by virtue of its tensile reinforcement.

The metropolitan system

The metropolitan system was patented in 1899 by Conrad Freitag. What distinguishes it from other alternative concrete systems is a gypsum binder, instead of Portland cement. In the metropolitan system, gypsum plaster is mixed with treated wood chips and sawdust as aggregate, then poured between steel beams. As with cinder concrete, tensile strength is provided by wire reinforcement in a catenary arch, though in this case the structural support is provided not by wire mesh but by twisted pairs of wires individually secured and strung between the beams. These wires carry almost all the load; the thick but lightweight plaster slab predominantly serves as a base for the walking surface and provides fire resistance.

Other alternative systems

While these three systems may be the most common of the alternative concrete floor systems, they are not the only ones. These systems were typically produced and sold under patent, and this drove diversity of design along with innovation. Many systems exist as slight variations of one another; as an example, one cinder concrete deck was observed to have iron bars laid across the beams in the same fashion as a Roebling System B. General themes are often present: the use of wire reinforcement to provide tensile strength, short spanning distances, and the use of thick slabs to impart fire resistance. Aggregate materials are diverse, and nonstructural materials are often present solely to impart fire resistance.

Problems and solutions

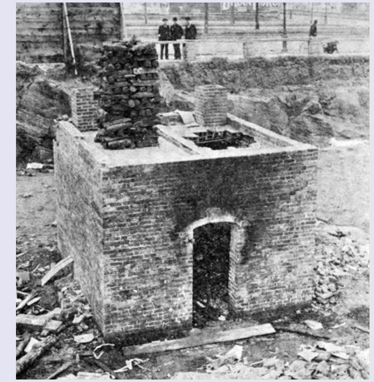
It is important for an owner or building professional to know about the presence of an alternative concrete system, preferably prior to any construction work or even design. While cutting into a slab is the surest way to verify the presence of an alternative concrete system, it is

TESTING ARCHAIC FLOOR SYSTEMS

One of the chief concerns of anyone encountering an alternative concrete floor will always be: “Is it safe?” To best answer this question, one needs to look at the testing carried out at the time these floors were introduced, an informative look back at the history of building codes in the United States.

The most influential battery of tests was carried out by the New York City Bureau of Buildings in 1913, working with Columbia University. Fourteen different types of flooring systems were tested against each other: in the same conditions, using the same methods, and under the supervision of impartial observers. The test involved both traditional brick and terra cotta flooring against novel systems. At the time, there were no standardized tests for material assemblies. These would be the first and would form the basis for testing regimes to follow.

The test protocol was designed to judge fire resistance and was as direct as it was thorough. First, a sample of the floor system was built across four brick walls. The floor was loaded to 732.3 kg/m^2 (150 psf) and, with that load in place, the assembly was subjected to increasing temperatures over a period of five hours, with more than three hours spent at more than 1093.3 C (2000 F). After this, the underside of the floor was hosed down with cool water to simulate the action of extinguishing a fire, and additional load was placed on the floor to bring it up to a total loading of 2929.4 kg/m^2 (600 psf). The floors were monitored during testing, and measurements of deflection made at the final stage. The results of these tests proved these new systems superior to established brick and terra cotta floors and spurred their acceptance. CS



Under intense heat and load for an 1897 empirical test, the Roebling floor, at left, remained intact, while the tile arch collapsed.

The Engineering Record, Vol. XXXV, No. 1, January 2, 1897

Interior of test chamber shows the concrete arch intact and the tile arch after rupture.

probably the least convenient or desirable. Severing the wires in these systems can seriously compromise their structural capacity.

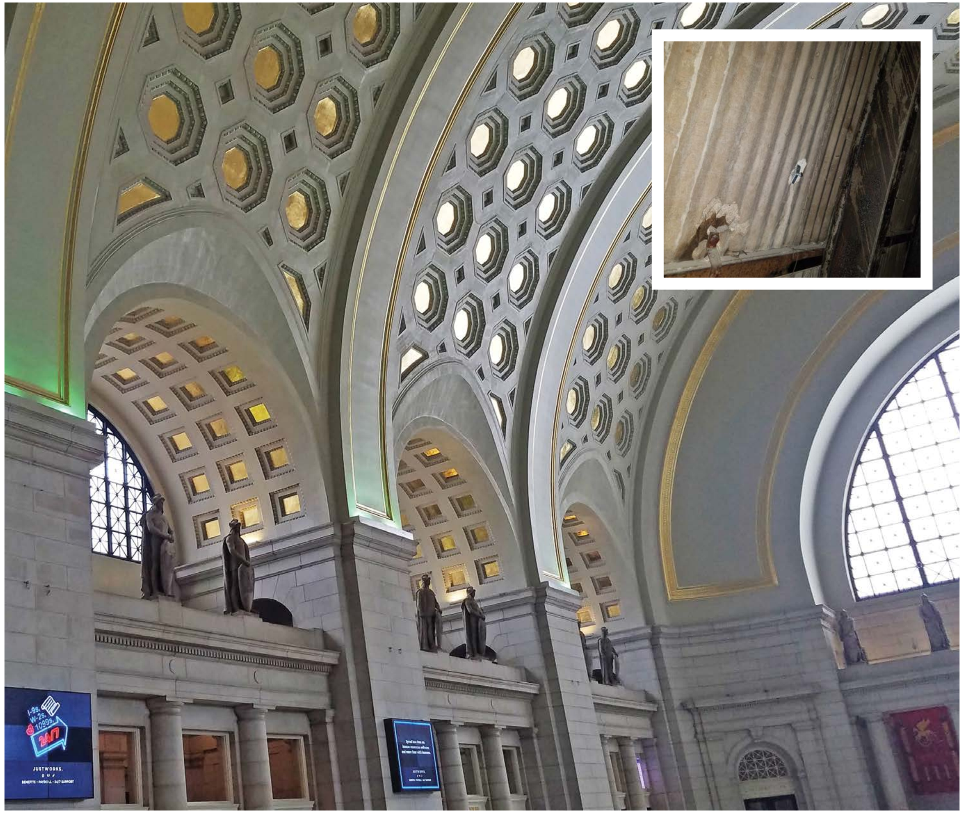
Fortunately, there are some markers to look for suggesting the presence of an alternative concrete system. Building age is perhaps the key initial indicator; any building constructed between 1880 and 1920 has a good chance of having one of these systems in place, though examples can be found as late as 1950. When looking at the slab itself, the presence of unusual aggregate materials such as sawdust, wood chips, or cinders suggests archaic concrete construction. Damaged areas of the slab may expose reinforcing wires or mesh atypical for modern reinforced concrete, particularly on the underside of the slab where the curvature of the catenary may be visible. Less definitive but easier to observe is slab thickness: an unusually thick slab can be evidence for an alternative system.

These systems can present several problems. Relatively thin layers of concrete, like those used in cinder fill decks, can crack easily, and even without cracks the relatively porous concrete mixes used often admit water. Once inside, water can traverse cavities present in the design and saturate areas of loose fill, which then may remain wet for years, conducting water throughout the slab.

When water meets metal reinforcing materials, corrosion can occur quickly and weaken the slab. Due to their thin gauge, wire- and wire-mesh-based systems are especially susceptible to corrosion damage, which can quickly impact their strength. To make matters worse, chemicals present in cinder fill or aggregate can produce corrosive compounds, such as sulfuric acid, when mixed with water, accelerating deterioration. It is not uncommon to find wires in compromised slabs completely disintegrated, leaving only rust. Even in the absence of corrosive failure, cracking can cause the embedding concrete to lose enough integrity that individual wires are subject to ductile failure, as loads are not effectively distributed.

One question that can arise when encountering a slab with widespread failure of tensile wire is: how was it able to continue standing? The answers are varied. In many cases, loads are transferred

Typically one part cement, two parts sand, and five parts cinders, cinder concrete slabs are structurally unstressed, relying on wires to carry loads.



A test cut into this concrete ceiling reveals wire mesh compromised by corrosion.

Within this soaring vaulted ceiling lurks an archaic concrete system that has been covered over, making it challenging to access and repair. Note the exposed structural wire mesh where fasteners for the roof were added in the 1980s.

At the SoHo, New York headquarters of Scholastic Inc. (built 1890), building envelope restoration included a terra cotta and cast-iron floor system.

to intact areas of the slab. The large number of tension members (wires) present means even a failure of numerous wires, provided they are not all localized, need not cause collapse. In many cases, even if a wire has failed at a given point, friction between the wire and the surrounding matrix allows it still to provide some structural function along the rest of its length. Perhaps most crucial to the survival of these floors is they were designed very conservatively with respect to loads, even by the standards of today, so the loss of some capacity does not necessarily leave them deficient.

Regarding structural capacity, it is also important to know how these floor systems are regarded by modern building codes. While not prohibited, these systems stand outside of modern code requirements. Perhaps the best passage referencing these systems is the *International Building Code (IBC)* 1604.4: "Any system or method of construction to be used shall be based on a rational analysis in accordance with well-established principles of mechanics." While archaic, these systems are still based in sound empirical design and were subjected to testing equivalent to our standards today.

If code analysis needs to be performed, there are methods available to engineers. Any systems based on catenary action can use well-established statics along with spot measurements to determine wire size and spacing to calculate loading capacity. Simplified formulas for this analysis remain part of the building code in New York City today.

Still, there are limitations to the accuracy of these assessments. Damage to the floors can reduce load capacity or fire resistance. Seismic analysis and testing were not part of the original test protocols for these floor systems and may not be possible to evaluate due to the lack of data for some floor types.

Restoration and conservation

Thousands of buildings with these floor systems are still in service today, many more than a 100 years after they came into service. Overall, alternative concrete floor systems are best left undisturbed; if in good repair there is no reason to assume they require replacement. Any repairs or alterations should be made in consultation with a structural engineer who should undertake a detailed examination of the floor system and its condition.

Localized damage to a slab can simply be patched if supporting wires or other reinforcements are intact. This type of repair will not restore the concrete's structural capacity, but this is not crucial as the wires are the structural elements.

If an area has been weakened through the corrosion or cutting of the tension elements, then restoration will require replacement of the entire span between the supporting beams. As the structure relies on continuous tension from beam to beam, the spanning area of the slab cannot be partially replaced and still function. Since tension elements may run continuously from one span to the next, the tops of the beams must be fully exposed, and any wires must be tack welded to the beams before they are cut to maintain the integrity of the adjacent spans.

Alterations to alternative concrete slabs should be made carefully with attention to special details, including any modifications that involve cutting into or drilling through the floor slab. As cutting into a catenary support system will destroy its load capacity, alternative measures must be taken to support the load between the opening and the adjacent steel beams.

In the case of an alternative concrete system as a roof deck, the existing slab may be abandoned in place if found to be compromised and more limited repairs are impossible. For this procedure, the construction team carefully removes the topping slab and cinder fill, then pours a lightweight reinforced slab into the cavity, spanning between the existing steel beams. As the existing cinder layer can be quite thick and heavy, such a repair can have the ancillary benefit of removing up to 244 kg/m^2 (50 psf) of dead load from the floor.

Unlike a regular slab, loads cannot be hung from an alternative concrete system without careful consideration, as the slab itself does not have strength to resist pullout. Existing hangers attached to wire reinforcement may be used with caution. If new hangers are installed,

Cinder concrete decks were favored in the 1920s to 1940s for their load capacity, fire protection, light weight, low cost, and ease of construction.

With a pumice-like texture that is rough and porous, cinder concrete uses byproducts of coal as economical, lightweight, fire-resistant aggregate. Often, a surface of wire lath was suspended below the beams and coated with plaster to provide a finished ceiling.

they should be attached directly to the steel floor beams. If an element must be placed between beams, a rod can be drilled through the entirety of the slab and the load distributed by a wide flange on the top. However, this should be avoided if possible as it risks damaging tension elements during drilling.

Still in service

As a part of the living history of construction, archaic floor systems exist in many buildings despite having been supplanted by modern construction methods. As a building manager or design professional, it is important to be aware these systems are in use today, and to recognize one in place before attempting repairs, alterations, or construction to avoid inadvertently damaging the integrity of a structure. However, these historic systems are proven safe and durable, and with knowledgeable stewardship will be able to prove themselves reliable into the future. **CS**

ADDITIONAL **INFORMATION**

Author

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Key Takeaways

When we think of a floor slab in modern construction we think of reinforced concrete, ubiquitous and reliable. However, it was not always so. Prior to the ascendancy of reinforced concrete, a number of different materials were used to construct floor slabs: brick, terra cotta, and a group of materials and methods we will call alternative concrete systems. It is this last group that can often be the most puzzling to deal with, as it represents a myriad of approaches without clear modern parallels. Frustratingly, these systems can appear to be a more standard concrete deck until their true nature is revealed through damage or alteration, leaving bewildered contractors and upended schedules. Knowing how to recognize and approach these systems can be invaluable if one is encountered.

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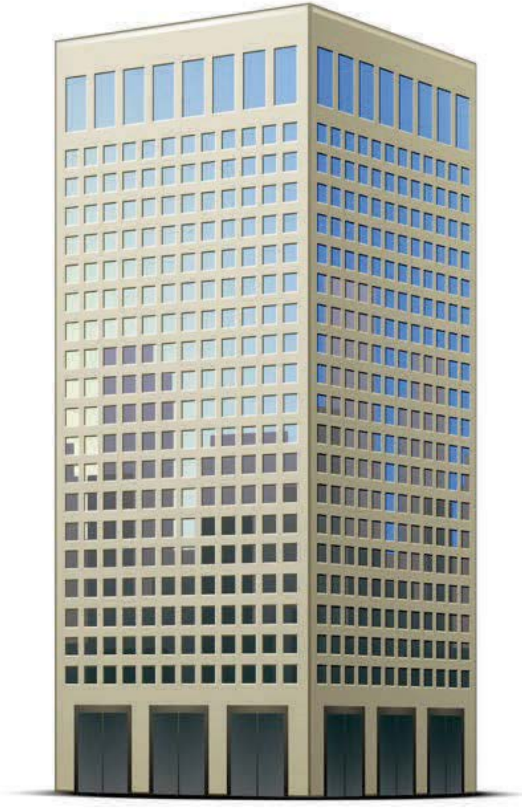
Project A

A Tale of Two Projects

Project B



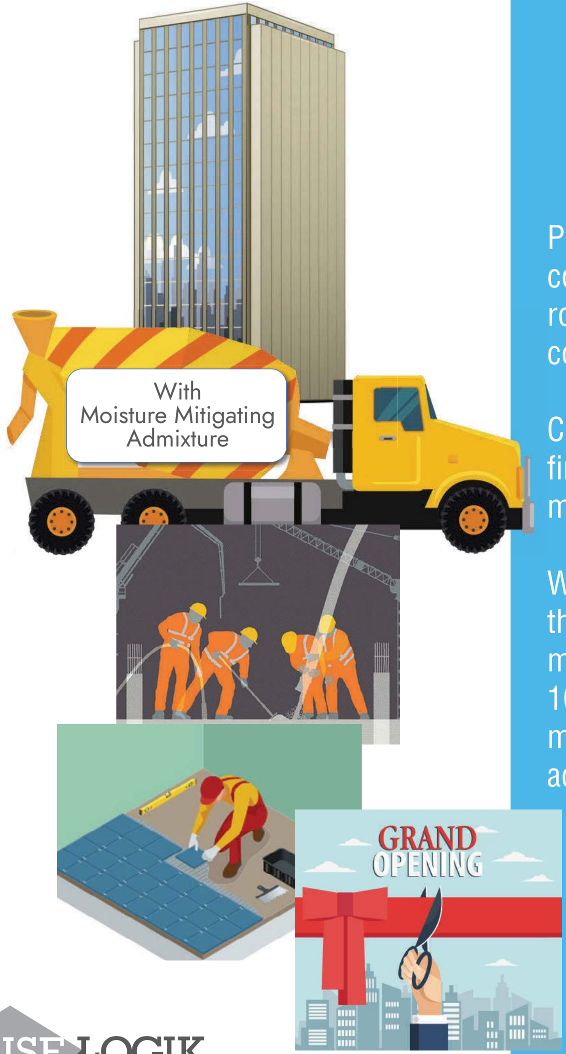
No two projects are ever alike. But without properly preparing the concrete to mitigate moisture vapor transmission, the differences can become dramatic.

For example, take this illustration of two, nearly identical office buildings. Both broke ground at the same time, and both are in the same geographic area. Yet, the outcomes will differ greatly, in terms of cost and completion schedule.

Here's how ...

A Tale of Two Projects

Project A



Project A: Concrete moisture control for floorcoverings, roofing, and coatings is in the concrete.

Concrete is placed and finished with moisture mitigation built-in.

With ISE Logik MVRA 900, the concrete is warranted for moisture control protection to 100% RH, allowing for placement of products without additional steps for concrete moisture control.

Project A is completed on-time and on-budget, thanks to a proactive concrete solution.

Project B: Concrete moisture control is handled AFTER concrete placement.

Without warranted integral concrete moisture control system means it must be handled after the concrete has been placed.

Concrete moisture testing is conducted – Will it pass? Are you safe if it passes? What if it doesn't pass?

Multiple delays while waiting on moisture testing results.

Schedule falls behind, costs mount. And Project B is still not open for business.

Project B

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ADMIXTURES • TOPICALS • SUSTAINABILITY • LEARNING

BEST PRACTICES FOR SPECIFYING RESINOUS FLOORING SYSTEMS

By Joe Lasko

Photos courtesy Res-Tek Inc.

THERE ARE SOME FLOORING CHEMISTRIES THAT HAVE EXISTED IN THE UNITED STATES FOR MORE THAN 15 YEARS BUT ARE RARELY SPECIFIED RELATIVE TO THEIR EPOXY COUNTERPARTS. EPOXY HAS BECOME THE KLEENEX OR BAND-AID OF RESINOUS FLOORING. THAT SAID, EVERY CONSTRUCTION PROJECT HAS CERTAIN NEEDS THAT CANNOT ALWAYS BE SOLVED BY ONLY SPECIFYING ONE FLOORING TYPE OR CHEMISTRY.

So, what other resinous flooring options are available? Urethane cements, methyl-methacrylate (MMA), urethanes, and polyaspartics have already been established as viable resinous flooring solutions for a variety of challenges. Urethane cements, for example, are good for resisting thermal shock from steam, grease, and other hot contaminants, while MMA can accept a fresh topcoat at any future time without requiring mechanical preparation.

The best practice for a specifier is to partner with a manufacturer. When partnering with a resinous flooring manufacturer, there are endless combinations of system builds that can be customized to achieve the perfect system for the customer. Epoxy still belongs in certain specifications, but urethane cements, MMAs, and polyaspartics all deserve equal consideration based on the project's demands.

Therefore, it is important for one to understand not only the basics on what resinous flooring is, but also the different chemistries and why they each deserve consideration in specifications.

What is resinous flooring?

Resinous flooring, also known as fluid-applied or poured-in-place flooring, is common in industrial and commercial environments.

Its properties allow for a smooth, non-porous, easily cleanable surface that cannot be achieved with any materials that have grout or seams.

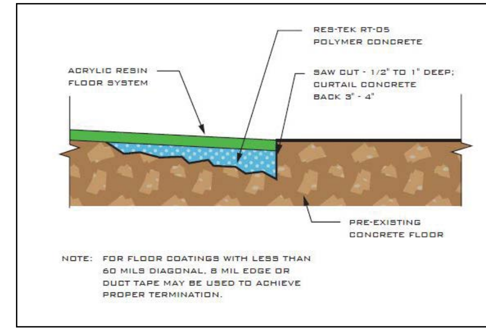
Resins can be a natural or synthetic liquid substance and sometimes have a yellowish or brown color. Resinous flooring comprises specific resin formulas applied in several layers that bond together either adhesively or chemically. Once 'cured' the layers form a hard surface which has various performance properties such as ultraviolet (UV) stability, abrasion resistance, or chemical resistance, among others.

It is important to take all environmental factors and design choices into consideration before choosing a particular type of flooring as resinous flooring is not a one size fits all product. The following are some specific considerations that should always be included in a resinous flooring design and specification.

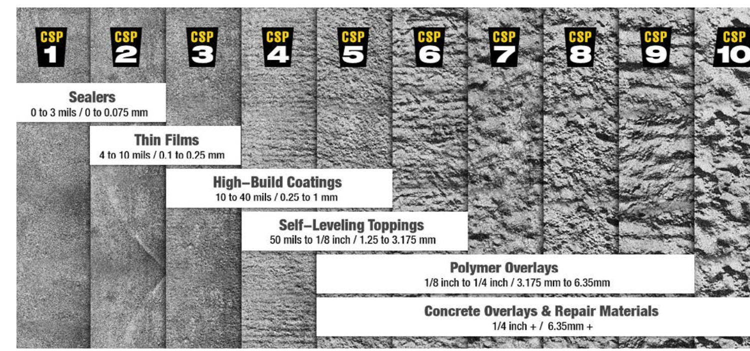
Surface preparation

The most important foundation of a resinous flooring system is the substrate it is being placed on. The most common substrate is a concrete slab that is steel troweled or has a 'darby' finish. The top or 'cap' of the concrete substrate is the weakest part of the slab. Even if the resinous system can penetrate through the top of the slab, the 'cap' still may delaminate from the rest of the slab which would still result in a failure. This is one reason concrete can spall.

Cove base should be specified at 102 or 152 mm (4 or 6 in.). Zinc strips can be used to provide proper height and a smooth transition to the wall.



Keying the substrate: Removal of concrete creates a void that is the correct thickness to accept the resinous system.



Substrates must be mechanically prepared to the specified Concrete Surface Profile (CSP) based on the thickness of the flooring system.

To prevent this from being a weak foundation of the flooring system, a concrete surface profile (CSP) must be specified. That specification is on a one to 10 scale with the latter being the most aggressive profile for products that will be laid thicker than a 6.4 mm (0.25 in.). This is important to specify correctly based on the system because the CSP may show through a thinner system, and the substrate may need to be patched to not telegraph through. On the other hand, if a substrate is not prepared well enough, the product applied may delaminate and fail.

How the CSP is achieved is up to the installer as they are liable for the installation portion of a warrantied project. Depending on the specified profile, project size, and specified system, an installer can choose a range of mechanical surface preparation techniques. Even though there are different methods, the entire substrate must be mechanically prepared to the specified profile. Commonly used equipment includes grinders, shot blasters, scarifiers, scrabelers, hammers, and sometimes even needle guns.

Moisture mitigation

The best way to avoid needing to specify a moisture mitigation component is to specify a vapor barrier (a.k.a. vapor retarder) under the concrete slab. A concrete slab on grade acts like a sponge and will absorb moisture from the soil or ground. In some cases, when this moisture is left unchecked, it can force the resinous system off the substrate causing a failure by delamination.

When writing a specification, it is important to include what the highest amount of moisture a resinous flooring or coating system can take before delamination occurs. This way testing can be performed and, if the result is higher than the upper limit of the product, a mitigation solution from the manufacturer can be used prior to the specified system to prevent the rest of the floor or coating from lifting off of the substrate.

The two most common testing methods are calcium chloride and relative humidity (RH) probe/meter. Both provide numbers correlating to the amount of moisture coming through the slab allowing a recommendation to be made to curb the moisture and still allow a successful flooring or coating installation. ASTM International standards for the two testing methods are ASTM F1869 as well as ASTM F2170.

Cove base

One of the most popular reasons for specifying a resinous flooring system is because they are impermeable to water. So, a resinous system can act as both a user-friendly flooring system and as a waterproofing system. An important aspect of creating a floor that has a 'bathtub effect' is to specify a cove/wall base.

Examples of both good and bad drain terminations shows chipping and delamination at the drain.

Typically, projects will only need a 102 or 152 mm (4 or 6 in.) cove base. Most projects will need 102 mm, while commercial kitchens and other wet areas will require 152 mm. Depending on the finish and the chemistry of the system, one may be able to specify that a product goes even higher up the wall.

Transitions and terminations

One important detail often overlooked in a specification is knowing what terminations and transitions to call out. This varies based on what type of flooring the resinous flooring is finishing up against. For example, if meeting up with a polished concrete finish, the resinous system will need to finish at 'zero' or flush with the concrete substrate that is going to be polished.

The most important consideration regarding transitions and terminations is the resinous system cannot be placed thin at these locations. If the thickness is not correct or matching the rest of the system, the terminations will be a weak point in the flooring system and will be the first points of failure either by delamination or chipping. After this has occurred, it can spread to the rest of the system leading to further failure. The correct way to install these terminations is to 'key' them in. 'Keying' the substrate means to remove a certain amount of concrete to create a void that is the correct thickness to accept the resinous system as it is poured in place.

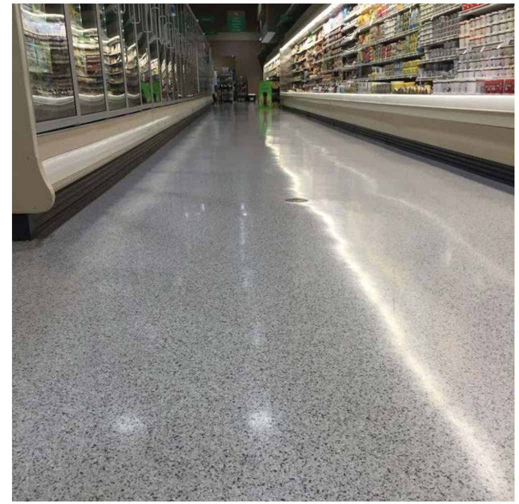
With the best practices established for all resinous flooring, it is important to also look at the pros and cons of the most common resinous flooring chemistries.

1. Epoxy

Probably the most well-known chemistry in resinous flooring, epoxy is one specific class of polymers that contain epoxide groups, hence their name. There is an extremely large range of quality in epoxies. Flooring and coatings typically fall in the middle of that range. While these are not the same high-end formulations NASA uses, the space agency sources the same base chemistry as flooring, paint, and adhesive manufacturers.

The number of system designs using epoxy is endless and covers a wide spectrum of styles—from thin mil all the way to troweled down mortar systems. A few pros for using an epoxy system are its relatively reasonable material cost, epoxy systems usually have an attractive high-gloss finish and, depending on the formulation, can have zero VOCs in their make up.

Some cons to using epoxies are not all are formulated or produced with the same quality. For example, there is a difference in residential-grade versus industrial-grade epoxy. Typically, they all have a long cure time (eight to 12 hours) which only amounts to about 95 percent cured. Reaching 100 percent cured usually takes between seven and 10 days. Epoxy is also not UV stable, which means it will eventually yellow and color shift when exposed to UV light. This is especially important when using these flooring systems in an area exposed to sunlight or fluorescent light for extended periods such as grow houses or exterior applications. Although a system may use epoxy, it is rare one will find a manufacturer that will recommend finishing with an epoxy topcoat versus applying a urethane or polyaspartic topcoat due to them having better physical characteristics.



This methyl-methacrylate (MMA) colored flake flooring in a supermarket is more than 12 years old and still looks new.

Urethane cement used in food processing area.

Further, because of the wide variety of epoxy system designs and qualities available, it is important that a specification be very specific. This can include the manufacturer's system name or, at a minimum, type of resin, the application method, finish selection for texture and color, and an overall system thickness.

2. Methyl-methacrylate (MMA)

Next, is a lesser-known chemistry, MMA. This organic compound is most commonly used in acrylic plastics like plexiglass or airplane windows. Pharmaceutical grade MMA is even used as a cement or glue in joint replacements, like a hip.

Known for its durability, MMA makes a great base chemistry for flooring and coating systems. The two largest pros for MMA are its ability to cure 100 percent in one hour and down to -26 C (-15 F) or up to 38 C (100 F) as MMA is not temperature dependent. It is also known for being UV stable which means it can be installed outdoors and will not yellow over time.

The two main cons of MMA are it has a relatively higher material price compared to epoxy. The second is it does give off an odor during installation. It has been described as a sharp, fruity aroma or one that is like a nail salon. Odors need to be managed and considered during any MMA project but is not usually a problem when proper ventilation methods are implemented.

Typically, the advantages of MMA chemistries listed above and its ability to accommodate recoating without mechanical preparation years later, can offset the higher costs of installation and stronger odors. One thing to keep in mind is no resinous system is odorless. Some systems just have less odor than others. MMA contractors are typically highly skilled installers and receive special training to be able to mitigate the odors with airflow. They also have crews prepared to work with a shorter pot life that still allows for an excellent installation curing in one hour.

3. Urethanes

Urethane coatings are typically applied at a thin millage and as a final topcoat or seal coat to other flooring systems. Urethanes are most commonly created by reacting isocyanates with polyols. Other than floor coatings, urethane chemistry can be used in direct metal paint, truck bed or tank linings, and generic waterproofing.

Urethanes for flooring topcoats are known for their high abrasion resistance, chemical resistance, and UV stability. Most urethanes see their best usage in large, high traffic areas or over top of an epoxy or hybrid system. The downside to urethanes is their sensitivity to moisture and temperature fluctuation. It must be installed within a certain temperature range. Also, like epoxies, urethanes have a longer

Urethane in containment area.

curing time—varying between eight and 24 hours—which varies by manufacturer as well.

4. Polyaspartics

Polyaspartics, which are like polyurethanes, are relatively new to the coatings market compared to other systems with their updated chemistry. Other than for resinous flooring, they are used in spray applied tank linings.

Manufacturers vary in opinion on typical uses for polyaspartics as a flooring material. They can be moisture sensitive when applied directly to a substrate. Most are used as broadcast coats or topcoats/finish coats in hybrid systems. Polyaspartics are great topcoats due to their fast cure times and the fact they are UV stable. They also cure very hard which means they may not accept recoats later without aggressive mechanical preparation; this can vary slightly by manufacturer as well. While the chemistry is the other fast curing product—one to four hours—its pound-to-pound price is higher than MMA and epoxies.

5. Urethane Cement

Urethane cement, also known as cementitious urethane, is exactly as it sounds—a urethane that is modified with cement. This chemistry has become a mainstay in resinous flooring due to its toughness. Two of its main strengths are its ability to withstand thermal shock of up to 115.5 C (240 F) and that it can be moisture resistant up to 9 kg (20 lbs) by calcium chloride test or 99 percent RH by RH in-situ probe testing.

Some negatives to urethane cements are slower cure times—eight to 12 hours between coats—and the install temperature needs to be maintained between 15.5 to 26.6 C (60 to 80 F) give or take. Still, the pros of being extremely durable and one of the toughest chemistries on the market will typically outweigh the cons depending on the project scope.

A word about topcoats

Different performance objectives can be achieved by choosing an appropriate topcoat, since this is the flooring system's first line of defense. It is becoming rarer to find an epoxy product as a topcoat as the other chemistries perform better.

In hybrid flooring systems, often found in commercial kitchens, urethane cement is used as the body but different topcoats like MMA, polyaspartics, or urethanes can still give the customer the performance they need while providing different options for the finishes they are trying to achieve in their facility.

After the spec

The specification has now been published, what else can be done to ensure the customer's needs will be met and that one's design is honored as intended? Making sure a qualified applicator is setup to install the specified system is a great first step. An installer should be able to provide references to previously installed projects that are similar in size or scope, as well as be able to provide a letter or certificate that they have been trained and are authorized in the specified manufacturers' system. These are two steps in submittals that can help protect a project's integrity and warranties. **CS**

ADDITIONAL **INFORMATION**

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Key Takeaways

There are two flooring chemistries that have both existed in the United States for more than 15 years but are rarely specified relative to their epoxy counterparts. Urethane cements and methyl methacrylate (MMA) have already been established as viable resinous flooring solutions for a variety of challenges. Urethane cements are one of the best solutions for resisting thermal shock from steam, grease, and other hot contaminants, while MMA can accept a fresh topcoat at any future time without requiring any mechanical preparation.

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Resilient Flooring The sustainable specification

By Jane Rohde, AIA, FIIDA, ASID, ACHA, CHID, LEED AP BD+C, GGA-EB, GGF

Photo © Richard Burger/courtesy JSR Associates Inc.

WHEN SPECIFYING FLOORING, ONE SHOULD CONSIDER BOTH SUSTAINABILITY AND PERFORMANCE. THEY ARE NOT MUTUALLY EXCLUSIVE, BUT RATHER COMPLETELY INTEGRATED. BOTH ARE AFFECTED BY THE MATERIAL SCIENCE THAT GOES INTO THE PRODUCT: HOW ARE THEY CONSTRUCTED? WHERE DO THE MATERIALS COME FROM THAT MAKE THESE PRODUCTS? THESE FACTORS NOT ONLY CONTRIBUTE TO THE SUSTAINABILITY OF THE FLOORING, BUT HOW IT PERFORMS.

The materiality of different resilient flooring products may alter some perceptions regarding sustainability. For example, how many are aware that salt is the main ingredient in vinyl? In fact, how many know it is used in many resilient flooring types? Do most people think all rubber comes from a rubber tree? Yes, trees are certainly one source, but this is not necessarily the case. There is natural and synthetic rubber—the synthetic kind was born out of necessity during World War II and is the predominant type of rubber used in flooring. Cork does come from trees, but trees that regenerate themselves (and their cork bark) many times over their lifespan being used for underlayments, flooring, and in composites.

Even sustainably made floors must be installed correctly

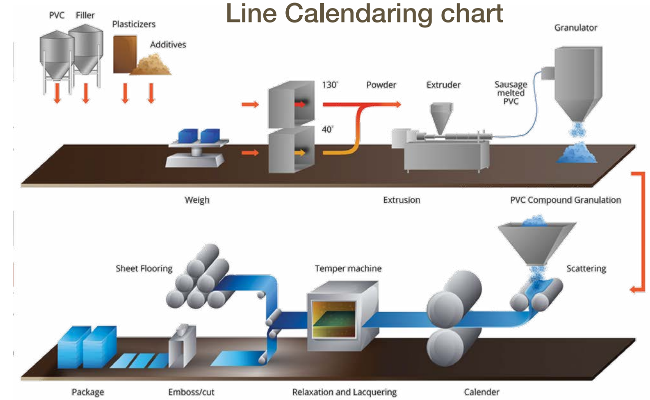
From a performance standpoint, even a sustainably made floor must be installed correctly to be truly sustainable. Otherwise, its service life can be cut short due to any number of failures. It is such a waste. So much of resilient flooring in commercial applications is installed over concrete slabs. While the non-porous nature of resilient sheet vinyl or luxury vinyl tile (LVT) has numerous advantages, it can also be problematic if not installed by a well-trained installer using proper moisture testing methods, appropriate adhesives, and moisture mitigating coatings. It is all about avoiding premature product failure due to subfloor, adhesive, installation, or moisture conditions.

As a designer and trained architect, the author discovered through her own research she needed to have a better understanding about the materiality of resilient flooring and its relationship to sustainability and performance. The author has also found many younger architects and designers may be well versed in the technology of the profession, but not as much in the material science of the products they specify to meet owner's project requirements (OPR).

At the Resilient Floor Covering Institute (RFCI) the author created an American Institute of Architects (AIA) approved continuing education unit (CEU) "Resilient Flooring & Materiality—Transparency, Product Service Life & Performance." It addresses the OPR as the starting point for the selection of resilient flooring products. It is all a matter of balance for arriving at the best specification through a series of questions, covering criteria from performance characteristics to health and wellness goals to aesthetics, cleaning and disinfection, maintenance, and cost, among others. The author recommends reviewing this in a pre-construction meeting with flooring contractors, as well as identifying installer teams who have the training and experience with the resilient flooring that is specified. The correct flooring specification is one of the most important decisions that will be made, impacting the quality of the experience within the space, the economics of cycle renovations, and the related costs resulting from premature product failure. Therefore, evaluating the best flooring solution for the application certainly warrants time and consideration.

It is recommended one looks at a variety of key indicators for the correct resilient flooring specification when developing the OPR. Here are just a few:

Figure 1 **Homogenous Sheet Vinyl Line Calendaring chart**



Homogenous sheet vinyl is a multi-layered product available in wide widths for seamless installation.

Illustration courtesy ERMFI

- What is the application for the flooring product including wear layer required based on the traffic level?
- How frequently should flooring product be replaced?
- What is the cleaning and disinfection protocol for each different flooring product specified?
- Has one had issues or concerns with maintaining any existing product previously installed?
- What are the project sustainability priorities based upon performance, service life, and application?
- Is the goal to achieve certification from a green building rating system?
- Has COVID-19 created any additional considerations for flooring specifications?

Tied to OPR are the overall performance and testing requirements based on American Society for Testing and Materials (ASTM) F06.20 on Test Methods for various types of testing for all resilient flooring products. This is available by manufacturer in their technical data sheets per selected style and usually downloadable from their websites.

Flooring specifiers will look at characteristics such as:
- square-ness;
- thickness;
- dimensional stability; and
- resistant to chemicals.

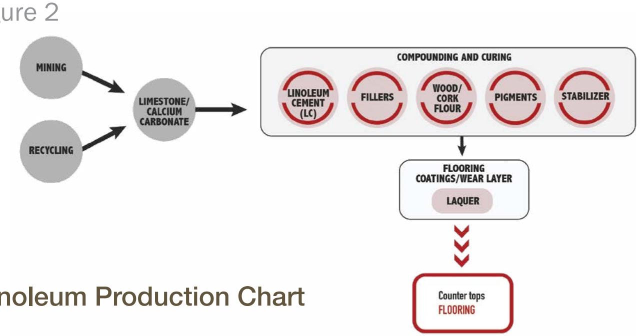
It is all about specifying the right product for the right application (or project conditions) with attention paid with the right resilient floor and proper installation for creating an 'envelope' for the floor (sealed seams, clean-ability, disinfection, etc.) Every structure for every product is different. This may lead to a different performance outcome. In healthcare, sheet vinyl, rubber sheet, or linoleum may be used because it has fewer seams where contagions can hide and can be heat welded with coved base. In senior living communities, LVT is specified often because it provides a nice homey feel for the residents and is durable for mobility device traffic. For residential or multi-family apartments, cork may be selected for its acoustic properties.

Selecting resilient flooring for sustainability

Architects, designers, and project specifiers can select resilient flooring for sustainability, health, and wellness criteria with confidence. Resilient flooring products of today are the most technologically advanced products of their kind ever made. These flooring products are designed and engineered to not only be aesthetically pleasing, but to also satisfy needs for durability, performance, and cleaning and disinfection for all types of settings within various vertical commercial markets.

The Resilient Floor Covering Institute (RFCI), a trade organization that represents more than 90 percent of the resilient flooring manufacturers in the U.S., was founded in 1995 to, among other things, promote voluntary product and industry programs that support safe, healthy, and sustainable environments. The resilient flooring category is made up of a range of materials, surfaces, and their attendant advantages available to the architect and interior designer.

Figure 2

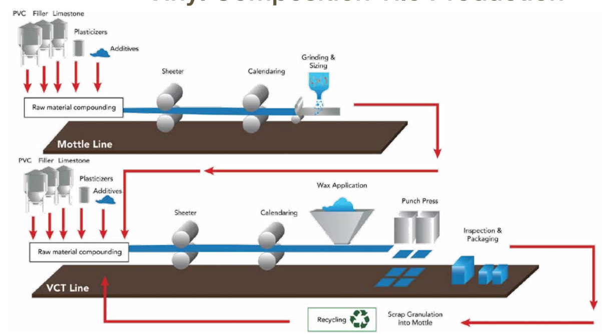


Linoleum Production Chart

Linoleum is made with all natural ingredients and is available in sheets or tiles.

Illustration courtesy Tarkett

Figure 3 Vinyl Composition Tile Production



The primary ingredient is limestone, with vinyl and color pigments added. It has a long life and can withstand heavy traffic and rolling loads.

Illustration courtesy Congoleum

There are vinyl sheet goods (heterogeneous and homogeneous), luxury vinyl planks and tiles, solid vinyl tile, vinyl composition tile (VCT), linoleum sheet and tile, rubber sheet and tile, cork tile and sheet underlayment, and rigid core luxury vinyl planks and tiles.

Foundational to RFCI's sustainable priority are six important resilient flooring industry initiatives that are relevant to specifiers of resilient flooring:

1. Support of the Vinyl Sustainability Council (VSC)
2. Support of the Green Building Initiative

3. The revision and utilization of NSF International/American National Standards Institute (NSF/ANSI) 332, *Sustainability Assessment for Resilient Floor Coverings*
4. Industry wide environmental product declarations (EPD) and product specific EPDs completed by resilient manufacturers based on International Standards Organization (ISO) 14025 and ISO 14040
5. Pilot participants for the resilient flooring category for the development of embodied carbon data for Building Transparency's Embodied Carbon Construction Calculator (EC3)
6. FloorScore certification for indoor environmental quality

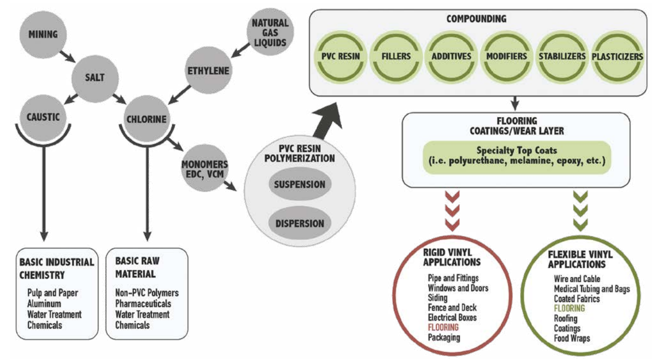
The Vinyl Sustainability Council (VSC) is supported by RFCI and plays an important role in providing information on environmental stewardship of resin producers to resilient flooring manufacturers. VSC initiatives include manufacturer compliance with the +Vantage Vinyl program, which supports supply chain transparency and sustainable corporate responsibility for resin producers that are subsequently utilized by resilient floor covering manufacturers.

The focus of the +Vantage Vinyl program is in three areas: reducing emissions to water, air, and soil; protection of the biodiversity of the ecosystem; and water conservation. Compliance with +Vantage Vinyl principles is measured voluntarily on an annual basis against impact goals of resource efficiency, emissions, and health and safety.

The Green Building Initiative (GBI) is the only ANSI-certified organization to develop green building standards that are used as the basis for green building rating systems. Green Globes includes a rating system for new construction (NC), existing buildings (EB), and sustainable interiors (SI). In addition, GBI has a federal compliance program, Guiding Principles for New Construction & Modernization that is used by various Federal Agencies and Departments, including the Veterans Administration (VA) and the Department of Defense (DoD).

NSF/ANSI 332, *Sustainability Assessment for Resilient Floor Coverings* includes compliance criteria for environmental, health and wellness, and social impacts is currently being updated from the 2015 version and is

Figure 4 **Vinyl Flow Chart**



Vinyl is an essential material for a variety of industries, including flooring.

Illustration courtesy The Vinyl Institute

anticipated to be released before the end of 2021. Certification to NSF/ANSI 332 offers specifiers of resilient flooring the highest level of confidence in sustainability and transparency. As part of the revised standard a transparency scorecard will be available so specifiers will know what criteria has been met from the standard for a specific product.

RFCI members participated in the development of industry average EPDs and many members also have development product specific EPDs as part of their sustainable initiatives for continual improvement. Life cycle assessments are required to completed EPDs, which provide usable information to the specifier as well as for the product manufacturer to evaluate processes and product design. EPDs comply with ISO 14025 Type III, third-party certified EPDs, which are recognized in green building rating systems and environmental standards, including the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design (LEED) rating systems, the Green Building Initiative's (GBI's) Green Globes rating systems, and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)/International Code Council (ICC)/USGBC/Illuminating Engineering Society (IES) Standard 189.1, *Standard for the Design of High-Performance Green Buildings* that is the content for the International Green Construction Code (IgCC).

Knowing that global warming and climate change is at the top of the list of concerns when designing buildings and specifying products, RFCI joined Building Transparency to create the pilot category for resilient flooring to develop embodied carbon information and uncertainty analysis as part of the Embodied Carbon in Construction Calculator (EC3) based upon both industry average and product specific EPD data. The category is anticipated to be public by the end of September 2021.

The sixth initiative is the development and maintenance of FloorScore certification for indoor environmental quality for resilient flooring products. It is one of the most highly recognized certifications from the designer/specifier community as well as within the consumer sector for representing the highest of standards for indoor air quality (IAQ). FloorScore certification complies with an IAQ standard for resilient flooring products that is independently certified by SCS Global Services for compliance with lower VOC emission standards, in accordance with California's *Section 01350* protocol (Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources). SCS Global Services is a provider of third-party certification, validation, and verification and is responsible for the standard used for compliance for FloorScore certifications. In addition to FloorScore certification, SCS also completed the standard used for the Assure Certified program for rigid core flooring. Assure Certified, conceived and developed by RFCI and certified by SCS Global, establishes uniform quality standards for all rigid core luxury vinyl flooring sold in the U.S. While rigid core has grown in popularity as a residential flooring solution, it is seeing more and more light commercial applications, too. Assure Certified product compliance encompasses several areas, including manufacturing quality control procedures, on-site audit, FloorScore IAQ certification, ASTM F3261-17 performance testing compliance, no intentionally added heavy metals (lead, hexavalent chromium, cadmium, and mercury) or ortho-phthalates.

Overall, the resilient floor covering industry has been proactive in initiatives that support the environment and health and wellness within the built environment. Flooring solutions that meet both sustainability and performance requirements provide designers and specifiers a broad array of products that successfully meet needs within various project types. **CS**

ADDITIONAL **INFORMATION**

Author

Jane Rohde, the principal of JSR Associates Inc., in Catonsville, Maryland, believes in a global cultural shift toward person-centered solutions for healthcare and environments for aging and sits on various healthcare and sustainability committees supporting research, advocacy, and humanistic approaches to care. Rohde provides technical consulting on sustainability and health and wellness guidelines, codes, and standards for various trade associations and standards and guidelines committees, including the Resilient Floor Covering Institute (RFCI). In 2015, she was the first Changemaker Awardee for Environments for Aging from The Center for Health Design. In 2018, she received the ASID Design for Humanity Award, was recognized as an Honorary Alumni of Clemson University's Architecture + Health program and honored as one of top 10 Women in Design for leadership in healthcare design. In 2020, she received the Pioneer Award from the Facility Guidelines Institute, and in 2021 was honored as a Green Globes Fellow from the Green Building Initiative. She can be reached via email at jane@jsrassociates.net.

Key Takeaways

When specifying flooring, one should consider both sustainability and performance. They are not mutually exclusive, but rather completely integrated. Both are affected by the material science that goes into the product: How are they constructed? Where do the materials come from that make these products? These factors not only contribute to the sustainability of the flooring, but how it performs. The materiality of different resilient flooring products may alter some perceptions regarding sustainability.

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