COMPREHENSIVE SPECIFICATIONS – THE DIFFERENCE BETWEEN SUCCESS AND FAILURE IN HIGH PERFORMANCE FLOOR SURFACING SYSTEMS

Author: William, R. Hier, President
Integrated Industrial Services, Inc.
PO Box 135, Marcellus, NY 13108

Abstract: Specifier should thoroughly understand chemical reagent and thermal exposures, mechanical use and substrate movement potential, to properly specify High Performance Floor Surfacing Systems.

INTRODUCTION

High Performance Floor Surfacing Systems (HPFSS) are often used to protect concrete substrates against severe attack from chemical reagents, mechanical service and thermal cycling. System choices can range from thin film coating systems to Chemical Resistant Brick and Tile.

Monolithic systems can vary by resin and/or aggregate types and thickness. Compounding selections even further, systems can be fabric-reinforced with numerous kinds and thicknesses of textile. Final finishes of these systems can also be varied by texture.

Chemical Resistant Brick and Tile systems (CRBT) also can be varied by type, thickness and surface texture of units, as well as resin selection of setting bed and joints. Systems can be utilized with or without membranes which can also vary by resin type and optional use of textile reinforcement. Finally, brick and tile flooring systems can be installed either bricklayer's or tilesetter's method.

By virtue of the vast numbers of combinations of flooring systems available, this paper will focus only on the process of HPFSS selection and specification, as opposed to the specification of available systems. A methodical, systematic approach to understanding the service exposure, including substrate, then finding an appropriate protective system is the specifier's first challenge. The specifier's ultimate goal is to incorporate that knowledge into a comprehensive specification to ensure the installation is executed properly.

This document will explore examples of in-service specifications and discuss shortcomings and results of poor specifications. Finally, we will illustrate an example of a clearly descriptive Chemical Resistant Brick specification, discussing its purposes and goals.

IMPORTANCE OF UNDERSTANDING SERVICE EXPOSURES

Service conditions can be broken down into five basic areas:

1. Chemical reagents and their properties.
2. Thermal cycling and thermal shock conditions and exposures.
3. Mechanical abrasion and impact; type of traffic
4. Suitability of substrates
5. Structural movement and its effects

The fact-finding or discovery process is normally the most time consuming, yet most important aspect in specification development. Attaining a thorough understanding of service exposures is critical to determine the appropriate types of materials and application method. Generally, all other things being equal, the value and quality of the finished specification will be directly proportional to the quality of information derived during the discovery process.

Chemical reagents, including acids, caustics and their combinations play a vital role in ascertaining correct resins to provide chemical resistance. A particular flooring system may resist certain acids and caustics, but perhaps not in combination. Often, cleaning agents or cleaning processes are more detrimental to a flooring system than production processes.

Thermal cycling, thermal shock and elevated temperature conditions can alter a resin and/or filler choice which can withstand exposure to certain chemical reagents in lower temperatures. For example, silica or fiberglass filled novolac epoxy may easily withstand exposure to sodium hydroxide at 100°F, but will begin to drastically degrade at temperatures around 140°F. Simply knowing that caustics are in a process, for instance, is not necessarily sufficient information from which to develop a specification.

Existing concrete to be used as HPFSS flooring substrates require thorough study. Contaminants such as oils, grease, chlorides, and sulfates may inhibit bond, causing adhesive failure. If discovered, action must be taken to address contaminant removal or treatment satisfactory to the appropriate manufacturer.

Acid brick adds a load of approximately 10 to 25 pounds per square foot to the floor. Other HPFSS systems may not be that heavy, but some add significant weight. Qualified structural professionals should determine construction limitations before proceeding too far into the project. Owner involvement is very helpful in determining live loads.

Core samples taken from existing concrete slabs are very informative. Obviously thickness can be determined, as well as depth of oil and grease penetration. Samples can also be easily tested for chlorides, iron-soluble salts and sulfates. Finally, concrete can also be tested for physical strength.

Anticipated structural and substrate movement must be investigated with care. Application of even the thickest of acid bricks over expansion joints may result in cracking, breakage and major adhesion failures. Vibrating equipment, whether or not placed on pads, must be isolated with control or expansion joints within a specified flooring system. An understanding of general construction is very helpful in the discovery and HPFSS specification process.

Heavy lift truck traffic, barrel movement, point loading, degree of impact and abrasive activities will have a bearing on needed system thickness as well as filler choice. Thin quarry tile, ½" or less, will tend to crack and break under heavy loads; ¾" tile is generally a marginally functional thickness. 1-3/16" to 1-3/8" acid brick are typical thicknesses for "moderately" heavy duty mechanical use. Thicker brick may be used under unusually heavy loads.

Monolithic systems which incorporate blended steel aggregate and/or aluminum oxide as fillers suffer less from impact and abrasion than do silica-filled resins. Silica fillers tend to crush under heavy impact and point loading, Silica-filled epoxy flooring systems used under heavy metal totes or steel-wheeled carts become stressed and eventually compromised under repeated areas of attack.

Further, final finish or texture is important, especially in wet areas. Slip resistance can be achieved in a wide variety of methods and products. Monolithic surfacings can be applied in methods where the aggregate itself produces homogeneous slip resistance. More commonly, however, slip resistance is achieved by incorporating silica, aluminum oxide, garnet, or polypropylene beads into the final topcoat.

Tile and brick units are also offered in abrasive and wire cut finishes that help to make foot traffic safer over wet floors. Texture and slip resistant choices, however, are more limited than those available with monolithic surfacings. Textures in seamless flooring applications, since they are produced on-site, can be customized to an Owner's preference.

In contrast, smooth surfaces are better used in dry areas where cleanliness and sanitation are important. The better understood the type and degree of traffic, the better surface recommendation can be made to provide long term performance. Conversely, insufficient discovery effort and investigation often results in avoidable problems and client dissatisfaction.

Specifiers should exercise a great degree of caution, however, when specifying slip resistance in monolithic surfacings. Production and maintenance departments have separate ideas of ideal slip resistance. Production wants aggressive slip resistance, because of safety issues; maintenance desires smoother finishes, because of cleaning ease. Specifiers who make the decision themselves often get caught in the middle.

Variations in industrial flooring systems and products directly impact specific specification issues. To provide illustration, we shall focus on specifications for Chemical Resistant Brick and Tile.

Used as flooring systems to attain optimum performance where other construction methods may neither function as well nor hold up as long, CRBT applications are unique in their durability under challenging conditions. Cost of such construction is generally significantly higher than resinous monolithic alternatives, ranging from installed prices of $12 to $50 per square foot or more, depending on project size, detail, and system composition. Substrate and installation requirements, compared to resinous overlays, are more complex, requiring more application skill. In addition to the increased costs of material and labor, CRBT installation also incurs longer down-time.

Chemical Resistant Brick and Tile applications are:

1. Used in highly corrosive environments where corrosion protection is extremely important.
2. Complex and require application skill, training and experience.
3. Time consuming and require extended down-times.
4. Comparatively expensive.

Any one of the four items is sufficient reason for an Owner to exercise judicious specification control for CRBT work. When all four occur simultaneously there is added necessity to exercise even more prudent control of a project by requiring a thoroughly researched and carefully written specification.

CHEMICAL RESISTANT BRICK AND TILE FLOORING SYSTEMS

Generally, CRBT Flooring Systems can be specified as

1. Tilesetter Method, Direct-bonded
2. Tilesetter Method, Membrane
3. Bricklayer Method, Direct-bonded
4. Bricklayer Method, Membrane

Within each category, several types of grout and mortar are available for use, depending upon service exposures. For example, setting beds for direct-bonded systems include epoxy and novolac epoxy; grouts and mortars include furan, epoxy, novolac epoxy, epoxy phenolic, polyester, and vinyl esters.

Chemical Resistant Membranes include, but are not limited to, asphalt, vinyl ester, polyester, novolac epoxy and urethane. In all cases except urethane, use of fiberglass fabric or mat is generally incorporated as reinforcement. The reinforcing textile is laid into a wet matrix of any of the mentioned membrane products, then fully saturated with additional material and allowed to cure. This composite of textile and resin becomes the membrane which will be protected by brick or tile sheathing.

Direct bond refers to setting tile or brick directly to a substrate, usually concrete, without use of a membrane or lining. Membranes are used in CRBT flooring applications for increased corrosion resistance and protection from leakage in suspended slab applications. But, membranes are more commonly used in containment and vessel lining service. Direct-bonded tile and brick systems adhere to the substrate significantly better than do CRBT systems utilizing membranes.

Adhesion plays a major role in longevity and performance of chemical resistant brick and tile flooring systems. Tow motor traffic, heavy loads and impact stress any flooring system and a heavy duty CRBT system is no different. Mechanically, the direct-bonded systems will fare better than membrane systems where heavy traffic, load or impact is anticipated.

The above installation methods nor the types of grouts and mortars represent an exhaustive listing of CRBT systems. For the purposes of this work, however, they do represent the vast majority of typical flooring installations found in US plants. An understanding of these installation types will satisfy most specifiers' needs, or at least provide a basis by which the specifier may further proceed.

ASTM C 399-98, Standard Practice for Use of Chemical-Resistant Resin Mortars, distinguishes between "Tilesetter's Method" and "Bricklayer's Method" of CRBT installation. Note 1 reads:

> *"Resin mortars and grouts are differentiated as follows: resin grouts are applied to the joints, generally ¼ in. (6 mm) wide, after the brick or tile are set in place (grouting or tilesetter's method). Resin mortars are troweled onto the brick or tile in sufficient quantity to achieve a 1/8 in. (3 mm) joint after the brick are laid in place (buttering or bricklayer's method)."*

Interesting to note in the bricklayer's method description, is the fact that bricklayer's method can apply to either brick or tile. Both chemical resistant tile and brick can be applied using either method. Tile can be laid in bricklayer's method. Brick can be laid in tilesetter's method. Confusion about the terminology is common, even within the industry.

The intended application method is critical. Tilesetter's and bricklayer's methods produce different system results, with consequential different costs. Specifiers should clearly describe their intended application method so there is no question about intent. Knowledgeable CRBT contractors will probably demand clarification prior to the bid, but the specifier, more importantly, should thoroughly understand the ramifications of citing the two methods.

As a rule of thumb, bricklayer's method is more preferred for corrosive conditions. Joints are smaller, thus minimizing the exposure. Voids, air entrapment and other imperfections are less likely to occur. The entire CRBT system, using bricklayer's method, is tighter and less vulnerable to chemical attack than tilesetter's method.

The downside of bricklayer's method is the mortar or grout joints will not be as neat and precise as tilesetter's method. Costs of bricklayer's method over tilesetter's method can be significantly greater, depending upon the particular installation. Further, availability of competent contractors experienced in bricklayer's method of application is limited.

Specifiers should pay attention to aesthetics of a chemical resistant brick or tile system. Owners, especially pharmaceuticals and food and beverage processors, generally want chemical resistance AND good appearance. During the discovery or fact-finding process, a great deal of concentrated time is often spent attempting to solve the "resistance riddle." Specifers are often caught off-guard after they've specified a functionally solid and sound chemical resistant application, but the specified system cannot meet an owner's visual standard or preconceived idea of appearance.

When owners spend $12 to $50 per square foot for a flooring system, be aware, they generally want it to look good, too

CHEMICAL RESISTANT BRICK AND TILE TYPES

ASTM C-279-88 (Reapproved in 1995) – Standard Specification for Chemical-Resistant Masonry Units covers typical brick and tile subject to chemical environments. Brick and tile are considered to be three types:

- Type I – For use where low absorption and high acid resistance are not major factors.
- Type II – For use where lower absorption and higher acid resistance are required.
- Type III – For use where minimum absorption and maximum acid resistance are required.

All three types are fairly similar in thermal shock resistance. Thickness plays the determining factor in brick or tile selection. Chemical resistant tile generally are available in 3/8", ½" and ¾" thicknesses. Acid Resistant Brick are generally available in 1", 1-3/16", 1-3/8", 1-1/2", 2-1/4" and 4-1/2" thicknesses. Obviously, the greater the thickness, the greater the insulation value of the system.

The three types of brick and tile are distinguished by rates of water absorption and sulfuric acid (H_2SO_4) solubility, with minimum strengths of modulus of rupture being the same for all three (1,250 psi as an average of 5 brick or tile, with no individual tile or brick less than 1,000 psi). Type I units (most common for flooring installations) require properties of no less than 6% average water absorption as tested with 5 units (no individual more than 7%) and H_2SO_4 solubility maximum 20% weight loss in an average of 5 units.

Type III units are significantly denser than Type I's: water absorption 1% average, 1.5% high individual; sulfuric acid solubility 8% max. Type III units, although denser and more chemical resistant, are not practical for use in most flooring applications. Though meeting "Tolerances for Warpage" in Table 2 of the Standard, the maximum permissible warpage dimensions render the overall aesthetic value and surface planarity wanting.

For example, in face dimensions of 8" and under, maximum allowable warpage is 3/32". Note, that 3/32" is plus or minus. That means if a brick is laid and the thickness is –3/32" and one next to it is +3/32", we have a potential 3/16" "lipper" in 8" (the width of 2 bricks). At least two problems immediately result: first, the floor has a 3/16" deep pond to trap liquids, thus exacerbating a corrosive situation. Second, the situation has created a potential tripping or safety hazard.

UNDERSTANDING REFERENCED STANDARDS

Considerable difficulty and confusion can easily arise in the writing of a CRBT specification if the specifier does not totally understand the reference he or she inserts. Unfortunately most, if not all, chemical resistant brick and tile standards are not easy to instate. The previous example bears out this statement.

Note 3 of ASTM C-279, in fact, typifies the ambiguity:

> *"The above tolerances may not be consistent with the recommended mortar joint sizes contained in Practices C-397 and C-723. If the brick or tile with tighter tolerances than those described in 3.3 (Sizes) and 3.4 (Warpage) (of this Standard) are required, the purchaser shall negotiate such requirements with the manufacturer."*

Very few Owners will accept chemical resistant brick floors that meet only minimum unit size requirements of ASTM C-279. Disputes in appearance generally result from deficient specifications failing to properly address or describe acceptable workmanship or appearance, often relying solely upon C-279. As seen in the example above, reliance on C-279 alone can result in a 3/16" surface elevation difference within a CRBT system—over a span as small as an 8". Simply specifying tile or brick to meet ASTM C-279 will not guarantee a good CRBT flooring system.

Several other ASTM standards are pertinent for use in CRBT specifications:

- *ASTM C-904-98 Standard Terminology Relating to Chemical-Resistant Nonmetallic Materials.*
- *ASTM C-395-95 Standard Specification for Chemical-Resistant Resin Mortars.*
- *ASTM C-397-00 Standard Practice for Use of Chemically Setting Chemical-Resistant Silicate and Silica Mortars*
- *ASTM C-399-98 Standard Practice for Use of Chemical-Resistant Resin Mortars.*
- *ASTM C-658-98 Standard Specification for Chemical-Resistant Resin Grouts for Brick or Tile.*
- *ASTM C-723-98 Standard Practice for Chemical-Resistant Resin Grouts for Brick or* Tile

Also indicated within these listed standards are other referenced ASTM standards that could be appropriate for specific use. Specifiers should investigate and become familiar with them as well.

Physical properties of grouts and mortars discussed in these standards represent minimum or maximum allowable properties. It is incumbent upon the specifier, however, to understand application requirements in detail to properly specify a mortar or grout.

ASTM C-395, for example, stipulates that carbon-filled vinyl ester mortar have a maximum initial setting time of 6 hours at 73°F ± 4°F. If a hypothetical area to be treated must be turned around in 4 hours, because of process requirements, then simple specification of this standard will not work. The specifier must find a mortar meeting the requirements of *ASTM C-395* plus having an initial setting time of less than 4 hours.

EXAMPLES OF SHORTCUTS TO FAILURE

Readers who have engaged in specification writing understand the temptation to take shortcuts. Research, discovery, investigation, double-checking assumptions, plus all the rest of energy that is dedicated to the effort of writing a sound specification, can be challenging. If difficult time constraints are added to the burden, the task can be arduous.

Two particular specification shortcuts probably account for most failures:

- Using manufacturer's guideline specifications as project specifications.
- Simply changing pertinent information in a "canned" or previously written specification to make it fit a new project.

Manufacturer's guideline specifications should be understood only to be guidelines. Some specifiers use guideline specifications as near finished or finished products. Very often, when specifications are not written to take into account actual project needs or requirements, conflict and claims result.

Following are some actual examples of specification problems written around manufacturer's guideline specifications:

Requiring a chemical resistant brick surfacing on a truck unloading area, an electronics company engaged a firm to design the project. Sales representatives provided the project manager with information and guideline specifications written around epoxy phenolic mortar.

Apparently without further investigation, the designer specified a CRBT system using epoxy phenolic mortar. The wording was written nearly verbatim with the manufacturer's specification. Sodium hydroxide, a caustic, was a primary exposure in one of the truck unloading areas.

Epoxy phenolics are known to resist a wide variety of acids. Unfortunately, as resistant as they may be to acids, they are extremely vulnerable to caustic attack.

In addition to the resin recommendation problem, the designer specified a brick manufacturer who does not manufacture trim pieces. The successful bidder presented the potential problems to the design firm and owner immediately after award.

The design firm, realizing their specification inadequacies, wanted to re-design the unloading area to accommodate use of the phenolic resin. Intercession by the owner negated re-design, and in fact, resulted in changing the system to epoxy novolac joints and a different brick manufacturer who could supply correct trim pieces.

Budget estimates from the design firm were derived from information provided by the original sales representative. Specification correction resulted in significant cost overrun compared to budgets submitted to the owner. Explanations given by concerned parties in this type of situation often results in political discomfort. This situation was no different.

In another instance, a specifier was utilized by a Fortune 500 food processing plant to design a protective flooring system. Drawings showed ¼" thick vinylester novolac, fiberglass reinforced, with a flake-filled vinylester novolac finish. Contrarily, the specifications called for a standard, aggregated-filled ¼" troweled epoxy, applied over a flexible epoxy membrane..

Later in the specification, under "inspection," the specifier indicated the work to be approved by a <company> engineer. The named company, however, was the company's most fervent competitor. That previous flooring specification written was for the rival company.

The design firm was immediately dismissed by the food processing plant and another firm retained to complete the specification and the project.

Pages can be filled with these kinds of examples. Unusual or very specialized applications and systems, such as HPFSS, suffer often from these types of shortcuts. Many specifiers charged with writing a specialized flooring specification have limited experience in such applications. High Performance Flooring Systems first must be understood, then the discovery process must take place. Properly effecting such a task requires effort and focus.

Shortcuts are often taken at the plant engineering level. We have seen sketches of an area with a note, "install acid brick." When asked about brick size, texture, setting and grouting materials during a pre-bid meeting, a plant representative directed bidders to use their best judgments.

Many plant engineering departments that spend time on new projects, seem to spend most of their time on drawings. Their drawings and plans are often very thorough, but tend to stand alone in many cases. Following is an example of a corresponding CRBT "specification" that accompanied four pages of full scale plans:

"Install 1-3/8" abrasive acid brick. Set and grout with chemical resistant epoxy. Workmanship shall be of the best quality available."

Previous examples of actual specifications leave the owner in a very vulnerable position and the burden of interpretation on the installer. Unfortunately, definition of quality often becomes an after-the-fact issue, resulting in conflict or contention. Better projects are obtained from detailed and accurate specifications, which are enforced.

With costs ranging from $12 to $50 per square foot, it would seem that chemical resistant brick and tile projects deserve commensurate specification effort.

WORKABLE CRBT SPECIFICATIONS

"Sample Chemical Resistant Brick Flooring Specification," found in Appendix A, describes a floor surfacing application. ABC Cheese Company is converting a storage area to a cheese packaging area. Our specification takes into account the full range of service exposures discussed earlier in this document.

Lactic and other organic acids are common in dairy operations. Cleaning-In-Place (CIP) operations contain aggressive chemical reagents which are often overlooked during specification development.

Prior to evolution of novolac epoxy mortars, furan and vinyl ester mortars were and continue to be dairy industry standards in chemical brick and tile construction. Certain novolac epoxy mortar formulations, however, provide broad range chemical protection without high odors during application. Further, some novolac formulations are resistant to thermal shock from steam cleaning as well as being fairly moisture tolerant during application.

Research, investigation and discovery generally leads the specifier to derive at least a general idea about product and system requirements. Written requests to manufacturers, such as that shown in Appendix B, and the resulting written response provide a valid recommendation technique and project record. Manufacturer's generally can give viable recommendations if they are given sufficient data.

Specified resinous products and systems in the Sample Specification resulted from this process.

Several US manufacturers are able to produce chemical resistant brick that meet ASTM C-279-88 in dimension, however, most owners will reject the warpage deviation accepted by the standard. Food plants and pharmaceuticals, especially, demand acid brick installations to be chemically resistant, in plane with no puddling or ponding and aesthetically pleasing.

Currently, only one chemical resistant brick manufacturer in the US produces Type I dimensionally stable brick with precision ends and a full line of trim pieces to meet these requirements. CRBT specifiers often list three acceptable manufacturers to provide acid brick meeting only ASTM C-279. If aesthetics and full trim are required in a project, specifying brick in this manner can create difficult project problems.

Inexperienced contractors usually choose one of the two lesser expensive units meeting the specification, but will be unable to please the Owner, because of consequential difficulty or inability to achieve satisfactory appearance. Since the two other brick manufacturers cannot provide proper trim pieces and their brick only meet dimensional stability per ASTM C-279, installations usually result in irregular joint lines and elevation differences.

No US manufacturer produces a Type II or Type III brick with full trim availability. Further, the Type III brick that is available marginally meets ASTM C-279 dimensional requirements, if at all. Design consultants who specify Type III brick in food and beverage and the pharmaceutical industries, where aesthetics are an issue, will continue to propagate project confusion and delay, as well as suffer from professional embarrassment.

Our Sample Specification bypasses the potential problem and sole-sources the chemical resistant brick manufacturer. Showing the client actual pieces of brick and the trim pieces available (or not available) from each manufacturer is generally all that is needed to prove the point. If the Owner still chooses to consider the other two manufacturers, then the Owner will own the potential problem.

Bricklayer's method produces a tighter, more chemical and thermal resistant joint than tilesetter's method. Unfortunately, as discussed in the body of the document, not many CRBT contractors are adept at this method of brick installation. Much effort, therefore, has been spent in addressing contractor requirements.

Quality Assurance requirements are specific and should leave no question in the bidders' minds that application expertise and experience as well as supervisory capabilities are required to be awarded the work.

ICRI Guideline No. 03732 and the accompanying visual standards make specification of anchor profile in concrete simple. Plastic replicas of various degrees of profile and preparation methods give project participants an actual idea of anchor pattern. Disputes are drastically reduced.

Sloping and drainage are normally important issues in chemical resistant brick flooring. Corrosion is reduced if reagents are not allowed to settle on the floor. Further, many industries cannot tolerate liquids to pond on their floors. Our specification addresses identification of problems, treatment and inspection of these critical areas.

"Illumination" in Project Conditions will reduce the chance for error and expedite the project by making the work more visible. Both applicators and inspectors will be able to see the work more clearly with good lighting.

Shutdown time constraints are severe in this project. Contractor is therefore required to submit two schedules: that which the Contractor expects to do and that which the Contractor anticipates to be "worst case scenario." Industrial contractors involved in shutdown work usually attempt to execute most work at the front end of a project to ensure timely completion, or "anticipated schedule." If additional work develops during the project, comparison of the two schedules to actual work completed will provide the Owner's Representative with a good idea about feasibility of successful execution.

Delivery of materials and equipment prior to actual job start allows the Contractor to begin work immediately on the first day of Shutdown. If the Contractor didn't think of that opportunity, the specification served to offer it, with the purpose of expediting the work at no additional cost.

Warranty is an issue that can be handled within the specification, as does our sample. A separate document can also be written addressing terms and conditions in far greater detail. Owners, depending on size and legal staff, often have proprietary requirements for warranties or guarantees. Further, each state has specific laws which the specifier should be consider.

Overall, the specification is written in a sincere attempt to make the Contractor fully aware of degree of quality required, with no surprises. All parties, including the Owner's Representative and Inspector have very clear methods by which to judge quality and workmanship. Finally, the specification is written with the distinct goal to ensure the Owner receives a high performing, long-lasting floor installation, in a short amount of time.

CONCLUSION

Determination of appropriate chemical resistant brick and tile systems is challenging. Discovery and research must be carried out methodically and thoroughly to assemble and organize relevant information. Quality and usefulness of a floor surfacing specification is often commensurate with the quality of preliminary investigation and confirmation of results.

Manufacturers' current guideline specifications, specifications from other projects, and most other "resources" used for writing floor surfacing specifications contain industry references. Blind usage of references can lead to project delays, added costs, claims and professional embarrassment. References first must be read and understood before incorporation into a specification.

REFERENCES

(1) SSPC, "The Inspection of Coatings and Linings – A Handbook of Basic Practice for Inspectors, Owners and Specifiers" – Chapter 5.2 Chemical-Resistant Brick and Tile Linings. (1997).

(2) ICRI-ACI, "1999 Concrete Repair Manual" (1999)

(3) Tile Council of America (TCA), "1999 Handbook for Ceramic Tile Installation" (1999)

(4) Rosen, Harold J., "Construction Specifications Writing – Principles and Procedures" Fourth Edition, John Wiley & Sons, Inc., New York (1998)

(5) Stitt, Fred A., "Construction Specifications Portable Handbook" McGraw Hill, New York (1999)

APPENDIX A

SAMPLE CHEMICAL RESISTANT BRICK FLOORING SPECIFICATION

1.0 General

1.1 Scope

Provide supervision, labor, incidental materials, sundries, and equipment necessary to safely complete chemical resistant brick flooring installation at ABC Cheese Company, 100 Main Street, Middle City, IA 11111 – Building 200, Cheese Packaging Room. Intent of this specification is to provide a chemical resistant brick flooring system resistant to cheese-making and associated exposures. Work will be performed and completed during ABC Cheese Company's scheduled shutdown, from June 28, 2000 through July 9, 2000.

1.2 References

Publications listed below form a part of this specification, and may be referred to in the text by the basic designation only.

1.2.1 Society for Protective Coatings (SSPC) and NACE International (NACE) Joint Standards

SSPC-SP13/NACE 6	Surface Preparation of Concrete
SSPC-TU 2/NACE 6G197	Design, Installation, and Maintenance of Coating Systems for Concrete Used in Secondary Containment

1.2.2 Society for Protective Coatings (SSPC)

SSPC-Guide 12	Guide for Illumination of Industrial Painting Project

1.2.3 American Concrete Institute (ACI)

ACI 503.4-92) (Reapproved 1997)	Standard Specification for Repairing Concrete with Epoxy Mortars

1.2.4 International Concrete Repair Institute (ICRI) Standards

Guideline No. 03732	Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings and Polymer Overlays

1.2.5 American Society for Testing and Materials (ASTM) Standards

ASTM C-279-88	Specification for Chemical-Resistant Masonry Units
ASTM C-395-95	Standard Specification for Chemical-Resistant Resin Mortars
ASTM C-397-00	Standard Practice for Use of Chemically Setting Chemical-Resistant silicate and Silica Mortars
ASTM C-399-98	Practice for Use of Chemical-Resistant Resin Mortars
ASTM C-723-98	Standard Practice for Chemical Resin Grouts for Brick or Tile
ASTM C-904-98	Terminology Relating to Chemical-Resistant Non-metallic Materials

1.2.6 Code of Federal Regulations (CFR)

29 CFR 1910.134	Occupational Safety and Health (OSHA) Standards – Respiratory Protection.
29 CFR 1910.1200	Hazard Communications
29 CFR 1926.405	Electrical Safety Requirements

1.3 Definitions

1.3.1 Bricklayer's method. As opposed to grouting or tilesetter's method, bricklayer's method is buttering or troweling of resin mortar onto sides of chemical resistant brick just prior to laying brick into place.

1.3.2 Acid brick. For the purposes of this specification, “acid brick” or “brick” shall mean field pieces of specified chemical resistant brick, Type I, 3-7/8” x 8” x 1-3/8”, single abrasive.

1.3.3 Trim pieces. For the purposes of this specification, “trim pieces” are 1-3/8” thick, pre-fabricated accessory chemical resistant brick shapes.

1.3.4 Owner’s Representative. A. J. Kay, DEF Engineering Group, 222 Main Street, Middle City, IA 11111. Phone: 222-111-2222. Fax: 222-111-2223.

1.3.5 Contractor’s Representative. Contractor’s project contact who is authorized to make monetary, scheduling or any other binding decision on behalf of the Contractor related to this project.

1.3.6 Project Complete. For purposes of this specification, “project complete” shall mean all materials, products and systems will be cured and hard, ready for traffic. All Contractor personnel, materials, equipment and tools shall be removed from project area. Project area shall be swept clean, hosed down and all errant spatter cleaned and removed. The site shall be ready for Owner’s use and occupancy.

1.4 Submittals

Contractor shall submit to the Owner’s Representative no later than two weeks prior to the scheduled Pre-Job Conference:

1.4.1 Manufacturer’s product data sheets for specified materials.

1.4.2 Manufacturer’s material safety data sheets (MSDS) for specified products.

1.4.3 Chemical Resistant Brick and Tile Projects detailing all chemical resistant brick and tile applications completed by contractor in the past 5 years. Specifically note chemical resistant brick applications using bricklayer’s method.

1.4.3.1 Provide name, address and phone number of individuals familiar with work performed.

1.4.4 Resume of construction experience of Contractor’s Representative, addressing in particular, the requirements of 1.5.2 below.

1.4.5 Resume of construction experience of the on-site foreman who will be working and/or constantly supervising the project, from beginning to end. Address in particular the requirements of §1.5.3 below.

1.4.6 Schedule. Show two (2) schedules:

1.4.6.1 “Expected Schedule” shall show anticipated daily completion targets of work components.

1.4.6.2 “Must Do Schedule” shall show required daily completion targets of work components to ensure Project Complete by 12 Noon, July 9, 2000.

1.4.7 Contractor’s Health and Safety Program, including Hazardous Communications Program.

1.4.8 Submit setting and mortar materials and chemical brick certification, as described in §2.4.1 and §2.4.2, within three (3) days of delivery.

1.5 Quality Assurance

1.5.1 Contractor shall have completed at least five chemical resistant brick projects, using bricklayer’s method.

1.5.1.1 Per 1.4.3 above, submit CRBT installation history.

1.5.2 Contractor’s Representative or Project Manager shall have had supervisory responsibility in at least two chemical resistant brick projects of similar magnitude of this specified project.

1.5.2.1 Provide training history and seminars relating to CRBT applications and theory.

1.5.2.2 Provide copies of certificates of related course completions or industry recognition.

1.5.3 Contractor’s Project Foreman shall be experienced and competent in chemical resistant brick application, having had hand’s on involvement in at least five chemical resistant brick projects, at least three of which having been bricklayer’s method. Foreman shall be assigned full time to this project, from beginning to end.

1.5.3.1 Provide training history and seminars relating to CRBT applications and theory.

1.5.3.2 Provide copies of certificates of related course completions or industry recognition.

1.5.4 Install a 5’ x 5’ Job Mock Up of the specified flooring system in an area designated by Owner’s Representative.

1.5.4.1 Following approval by Owner’s Representative, mock-up shall be used as the standard by which the quality of materials and workmanship will be measured.

1.5.5. Prior to start of the project, at a time and date designated by Owner, a Pre-Job Meeting will be held by the Owner. Specification requirements and any clarifications will be discussed. Attendees shall include, but not be limited to:

- 1.5.5.1 Owner's Representative.
- 1.5.5.2 Specifier
- 1.5.4.1 Owner's Third Party Inspector
- 1.5.4.2 Contractor's Representative
- 1.5.4.3 Contractor's Foreman who will be working/and or supervising the work throughout the entirety of this project.
- 1.5.4.4 Schedule shall be finalized at this meeting.
- 1.5.4.5 Owner's Representative, or his or her designee shall take notes and distribute minutes to attendees.

1.5.6 Flood Test

- 1.5.6.1 Upon completion of project, flood floor ensuring water runs to drains and does not puddle or pond in any area.
- 1.5.6.1 Correct deficient areas by removal of deficient construction and proper replacement.

1.6 Delivery, Storage and Handling

Deliver materials in properly sealed and labeled containers, bags and boxes, bearing manufacturer's name and product identification, batch number, and date of manufacture.

1.6.5 Resin manufacturer's packaging shall also comply with ASTM C-395-95, Section 10.

1.6.6 Store and handle materials per manufacturer's written instructions.

1.6.7 Store materials and equipment in area designated by Owner.

- 1.6.7.1 Storage area shall be kept clean and neat at all times.

1.7 Project Conditions

1.7.1 During installation maintain the temperature so the slab temperature ranges between 60°F to 85°F and air temperature not exceeding 85°F.

- 1.7.1.1 ABC Cheese Co. shall utilize in-plant HVAC resources to control air temperature. Contact E. F. Gee, Plant Engineer at Extension 123 for coordination.

1.7.2 Project area shall be maintained in a dry condition.

- 1.7.2.1 Immediately report any leaks to E. F. Gee, Plant Engineer for repairs.

1.7.3 Illuminate project area per SSPC-Guide 12.

- 1.7.3.1 Minimum illumination in Table 1 for Task Specific – surface preparation and application areas shall be 50 Foot Candles, in lieu of 20 as specified. All other conditions remain the same.

1.8 Sequencing and Scheduling

All CRBT work shall be performed and completed from 7:00 am, June 28, 2000 to 12:00 Noon, July 9, 2000.

1.8.1 Contractor may deliver and store materials on site after June 23, 2000, if desired.

- 1.8.1.1 Contact E. F. Gee, Plant Engineer to coordinate early deliveries.

1.8.2 Project site is available to Contractor, 24 hours per day during the shutdown period. Any and all overtime required to be worked by Contractor to be Project Complete is the Contractor's responsibility.

1.8.3 Contractor's work shall be Project Complete by 12:00 Noon, July 9, 2000.

1.8.4 Contractor shall provide sufficient and effective supervision to ensure smooth and efficient work flow and attaining specified quality.

1.8.5 Inspector shall be on-site at all times with Contractor.

- 1.8.5.1 Inspections shall be made in a timely manner, considering time to be of the essence.
  - 1.8.5.1.1 Contractor's work shall be inspected as soon as practical.
  - 1.8.5.1.2 Work shall be accepted or rejected to allow the work and/or repairs to proceed promptly.

1.9 Environmental Compliance

Comply with all applicable federal, state, local and plant environmental regulations, regarding air and water quality, and hazardous waste.

1.10 Safety Compliance

Comply with all federal, state, local and plant safety regulations, in particular those standards referenced in Section 1.2.6 above.

1.11 Warranty

Contractor hereby warrants that all work conforms to this specification, and is free of any defect in material or workmanship, and will remain so for a period of two (2) years after final acceptance of the work.

1.11.1 CRBT system shall protect against chemical reagents as follows:
- 1.11.1.1 10% Lactic Acid – ambient temperature
- 1.11.1.2 37% Hydrochloric Acid - 110°F
- 1.11.1.3 25% Sodium Hydroxide - 110°F
- 1.11.1.4 20% Nitric Acid - 110°F

1.11.2 Contractor shall remedy to Owner's satisfaction, at Contractor's expense, any failure or defect in the CRBT system, as shown below, but not limited to:
- 1.11.2.1 Disbonding of brick from substrate.
- 1.11.2.2 Disbonding of mortar joints from brick.
- 1.11.2.3 Development of pinholes in mortar joints.
- 1.11.2.4 Erosion of mortar joints.
- 1.11.2.5 Erosion of brick.
- 1.11.2.6 Disbonding of control and expansion joint sealants from brick.

1.11.3 Contractor shall not be responsible for warranty repairs due to failure from unusual conditions such as:
- 1.11.3.1 Chemical attack from reagents other than those shown in §1.11.1.
- 1.11.3.2 Extraordinary impact and physical abuse.
- 1.11.3.3 Unusual building movement.
- 1.11.3.4 Undetected hydrostatic or vapor pressure.

1.11.4 Owner shall notify contractor in writing within seven (7) days of discovery of defects.
- 1.11.4.1 Contractor shall make proper repairs in a timely manner, preferably within 14 days of notice.

2.0 Products

Products and systems shall be installed according to manufacturer's recommendations and instructions, except as modified in this specification.

2.1 Acceptable Manufacturers.

2.1.1 Chemical Resistant Brick
- 2.1.1.1 STU Tile and Brick Co., Canton, OH, (456) 789-0123

2.1.2 Chemical Resistant Resin and Mortar Products
- 2.1.2.1 XYZ Resin Products Co., San Francisco, CA., (123) 456-7890
- 2.1.2.2 RST Resins and Mortars, New York, NY, (234) 678-9012

2.1.3 Expansion Joint Materials
- 2.1.3.1 XYZ Resin Products Co.
- 2.1.3.2 RST Resins and Mortars

2.2 Materials

Chemical Resistant Brick shall be sole-sourced, as specified. Novolac setting , mortar and expansion joint materials shall be product systems, all from either XYZ Resin Products Co. or RST Resins and Mortars.

2.2.1 Chemical Resistant Brick shall be STU Tile and Brick Co Type I, Red Shale, Single Abrasive, 3-7/8" x 8" x 1-3/8". Brick shall comply with ASTM C 279-88, except maximum permissible warpage shall be 1/32" in lieu of 3/32" as shown in Table 2 Tolerances on Warpage. All other conditions remain the same.

2.2.1.1 Brick shall be Premium Quality, with scored sides and bottoms.

2.2.1.2 Brick shall be double-waxed.

2.2.1.2.1 Do not stack or ship brick with waxed surface to unwaxed surface.

2.2.1.2.2 Wax shall not be applied to edges or ends of brick units.

2.2.1.3 Brick shall have "Precision Ends," square and true.

2.2.1.4 Trim Pieces shall be 1-3/8" thick.

2.2.1.4.1 Vertical trim shall be smooth

2.2.1.4.2 Horizontal trim shall be single abrasive

2.2.1.3.3 All appropriate Trim Pieces shall be used as intended.

2.2.2 Novolac setting materials shall be novolac epoxy, complying with ASTM C 395-95, except Initial Setting Time in Table 1 Physical Requirements shall be 4 hours or less . All other terms and conditions remain the same. Novolac setting materials shall be either

2.2.2.1 XYZ Novolac Setting Resin System, or

2.2.2.2 RST Novolac Setting Bed

2.2.3 Mortar materials shall be novolac epoxy, complying with ASTM C 395-95, except Initial Setting Time in Table 1 Physical Requirements shall be 4 hours or less. All other terms and conditions remain the same. Novolac mortar materials shall be either

2.2.3.1 XYZ Novolac Resin Mortar System, or

2.2.3.2 RST Novolac Brick and Tile Mortar

2.2.4 Expansion and Joint Sealant materials shall be either

2.2.4.1 XYZ Traffic Joint Sealant CR, or

2.2.4.2 RST Expansion Joint Sealant

2.3 Equipment

Tools and equipment, including trowels, mix pans, mixers, and straight edges, shall be maintained in a clean, efficient operating condition, with no resins or mortars allowed to harden on the surfaces.

2.3.1 Brick shall be cut with a "brick saw." No hammer cuts shall be allowed.

2.3.2 Power mixing of setting and/or mortar materials, if used, shall be accomplished with a "Kol-type" mixer per ASTM C-723-98.

2.3.2.1 Mixer shall rotate at speeds between 60 – 100 RPM to minimize air entrapment.

2.3.3 Setting racks shall not allowed on the project site.

2.4 Source Quality Control

2.4.1 Chemical resistant brick manufacturer shall certify that shipped units meet requirements of §2.2.1.
2.4.1 Submit per §1.4.8.

2.4.2 Manufacturer of setting and mortar materials shall certify by batch number that products meet requirements of §2.2.2 and §2.2.3.

2.4.2.1 Submit per §1.4.8

3.0 Execution

3.1 Existing Conditions

3.1.1 Inspect project site for conditions which could adversely affect quality and schedule.

3.1.1.1 Measure concrete slab and ambient air temperatures.

3.1.2 Comply with § 1.7.

3.1.3 Immediately advise Owner's Representative of adverse conditions.

3.1.3.1 Any installation of CRBT materials shall constitute Contractor's acceptance of conditions.

3.1.4 Ensure all furniture and equipment has been removed from project site.

3.1.5 Verify planarity of concrete substrate does not deviate more than 1/8" in 10 feet.

3.1.6 Hose down floor to verify positive drainage and slope to drains of concrete.

3.1.7 Test for moisture using calcium chloride test per SSPC13/NACE 6, §5.6.3.

3.2 Preparation – General

3.2.1 Place warning ribbon, cones and sawhorse barriers at doorways and openings of Bottle Filler Room.

3.2.2 Sweep concrete substrate.

3.3 Surface Preparation

3.3.1 Drainage correction and planarity remediation shall be accomplished by use of epoxy mortar system approved by setting and mortar resins manufacturer.

3.3.1.1 Repair per ACI 503.4-92 and manufacturer's recommendations.

3.3.1.2 Cured epoxy mortar shall exhibit no porosity.

3.3.1.2.1 Apply additional mixed epoxy liquids over cured mortar to satisfy porosity or "openness."

3.3.2 Remove oil and grease per ICRI Guideline No. 03732, Detergent Scrubbing.

3.3.3 Shotblast substrate per ICRI Guideline No. 03732, Steel Shotblasting.

3.3.3.1 Minimum surface profile shall be CSP-7, Heavy Abrasive Blast.

3.3.4 Difficult access areas, may be scarified per ICRI Guideline No. 03732, Scarifying.

3.3.4.1 Minimum surface profile shall be CSP-9, Heavy Scarification.

3.3.5 Vacuum prepared substrate, ensuring dust, errant shot, dirt and debris are removed from the surface.

3.4 Layout

3.4.1 Square up and layout floor with brick to be installed in running bond pattern, longitudinally east to west.

3.4.1.1 Layout floor so edge cuts shall be no less than half the full brick dimension.

3.4.1.2 Control and expansion joints shall be laid out so no less than half the length of a brick shall be laid along the edge of the joint.

3.4.1.2.1 If a lesser dimension is required to maintain proper joint placement, such adjustment shall be made in the brick course one course back from the joint edge.

3.5 Chemical Resistant Brick Selection

3.5.1 Carefully cull chemical resistant brick units that do not meet §2.2.1.

3.5.1.1 Discard stock which are chipped, warped or inappropriately sized to lay 1/16" above or below adjoining units.

3.6 Mixing of Setting and Mortar Materials

3.6.1 Materials shall be mixed per manufacturer's instructions and as modified or clarified by this specification.

3.6.1.1 Discard mix after it has passed its working life and becomes stiff. Do not attempt to retemper or reclaim.

3.6.2 Mixing areas shall be protected by cardboard laid over polyethylene to prevent contamination.

3.6.2.1 Keep area clean and organized, with discarded materials and empty packaging removed from mix area at lunch break and at the end of the work day.

3.7 Cutting and Laying Chemical Resistant Brick

3.7.1 Set up brick saw and cutting area in a location sufficiently removed from installation site to ensure dust, slivers, chips and debris are not errantly dispersed into the project area.
3.7.2 All cuts shall be made with a brick or tile saw, expressly made for such purpose.
3.7.3 Where possible, place cut-side of brick unit as an interior joint.
3.7.4 Do not use cut side of brick as part of a control or expansion joint.

3.8 Trowel setting material over concrete which will result in a minimum 1/8” setting bed after chemical resistant brick are set home.

3.9 Brick shall be set bricklayer’s method, joint widths ranging from 1/16” minimum to 1/8” maximum.

3.9.1 Apply mortar to two sides of each brick unit to form a “V,” then shove brick home.
3.9.1.1 Press brick down and smoothly slide it into position against adjacent bricks.
3.9.1.2 Once in place, lightly tap into final position.
3.9.1.3 Maximum elevation difference between any two adjacent brick shall be no greater than ±1/32”.
3.9.2 All joints shall be full.
3.9.2.1 Cut with trowel fresh excess mortar squeezed from joint, leaving brick surface smooth.
3.9.2.2 Remove and replace mortar where voids or holes develop.
3.9.2.2.1 Do not attempt to “point-in” voids with additional material.

3.10 Control and Expansion Joints

3.10.1 Joints shall be continuous, ending in another expansion joint or control joint.
3.10.1.1 Joints shall be laid out and maintained at a continuous 3/8” width.
3.10.1.2 No cut-side portion of any brick shall be part of the joint construction.
3.10.2 Control and expansion joints shall mirror those in substrate.
3.10.2.1 Column lines and door openings
3.10.3 Place joints at additional locations.
3.10.3.1 Around equipment pads
3.10.3.2 Around trench drains
3.10.3.3 Along perimeter of room, between toe of coved base and first course of brick.
3.10.4 Press ½ diameter foam backer rod into joint maintaining the top of the backer rod 3/16” below the top plane of the joint.
3.10.4.1 Fill joint with sealant material, leaving no voids or holes.
3.10.4.2 Finished joint shall be straight, smooth and in plane with the adjacent brick surfaces.
3.10.4.3 Edges shall not be rounded or chipped.

3.11 Chemical Resistant Brick Floor Cleaning

After mortar joints have cured, remove excess mortar and errant materials by use of steam and/or hot water washing.
3.11.1 Screen off floor drain baskets and covers to prevent melted wax, debris and contaminants from plugging drain system.
3.11.2 Clean any remaining stains from brick surfaces.

3.12 Quality Control and Inspection

Inspection shall be performed to assist in specification compliance, and does not preclude Contractor’s ultimate responsibility to provide completed work according to specification.
3.12.1 Inspection shall be accomplished by an independent third party inspector and shall report to the Owner’s Representative.
3.12.2 Contractor shall not proceed to the next activity until Inspector has observed and approved the following hold points:
3.12.2.1 Drainage condition of substrate per §3.1.6.

3.12.2.2 Final preparation of substrate per §3.3.5.
3.12.2.3 Drainage testing of floor system per §1.5.6
3.12.2.4 Final inspection of flooring installation.

3.13 Site Clean Up

Following completion of the work, remove any remaining debris, equipment, materials and tools from site. Restore all existing facilities affected by the work to their original condition.

APPENDIX B

ACID BRICK ENGINEERING
1000 Main Street
Capital City, IA 22222

April 1, 2000

Raymond Jones, Technical Services Manager
XYZ Resin Products Co.
100 Bay Street
San Francisco, CA 99999

Dear Mr. Jones:

Our client, ABC Cheese Co., will be installing a 1-3/8” acid brick floor over a two year old concrete substrate.

Please advise your recommendations for setting and mortar joint materials (bricklayer’s method) for a direct-bonded floor and expansion/control joint materials, given the following conditions:

<u>Chemical exposure – Process and CIP</u>

10% Lactic acid – ambient temperature
37% Hydrochloric acid - 110°F
25% Sodium Hydroxide - 110°F
20% Nitric Acid - 110°F

Floors are hosed down every hour with 180°F hot water and steam cleaned with detergent (MSDS attached) at the end of each shift.

8,000 lb, rubber-wheeled lift trucks drive across the floor, moving 2,000 lb pallets of cheese.

Setting and mortar materials must meet ASTM C-395-95 and C-399-98. This project, however, has rapid-turnaround requirements, so escalated setting times are preferred.

Please fax your response as soon as possible, followed by a mailed hard copy.

Thank you for your assistance.

Sincerely,

Edward G. Engineer
Project Manager