MONOLITHIC LININGS & COATINGS FOR SECONDARY CONTAINMENT STRUCTURES

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ABSTRACT

In the last ten years, EPA Regulations under the Resource Conservation and Recovery Act(RCRA) for the storage and treatment of "hazardous waste" in tank systems have resulted in major changes and improvements in the design and use of concrete for vessels and other structures. Since the use of concrete for secondary containment systems is one of the key elements of the EPA's proposed strategy, this has caused a significant increase in the need for improved products and methods for the repair, sealing, and protection of concrete from an increasing number and variety of chemicals.

INTRODUCTION

This paper will provide information on the progress that has been made in developing new products and repair methods to meet the ever-increasing range of corrosive solutions, temperatures, and environmental conditions on the protection and sealing of waste containment and other concrete structures. Attention will be given to concentrated sulfuric acid, phosphoric acid, and other acids/chemicals encountered in the Central Florida phosphate CPI industry.

CONCRETE DESIGN AND REPAIR TECHNIQUES

Before we discuss the protection and sealing of concrete structures, it is pertinent to address some of the common problems encountered with concrete as a versatile building material and some of the design and repair techniques for dealing with common causes of deterioration.

CONCRETE DESIGN STANDARDS/REFERENCES

With the increase in focus on the design and use of concrete for secondary containment systems to meet EPA regulations, many owners, architects, engineers and contractors are becoming acquainted with the standard document of floors, the American Concrete Institute's "Recommended Practice for Concrete Floors and Slab Construction" (ACI 302)[1]. A voluminous collection of reprint articles that deal with problems, questions and answers covering a myriad of topics related to the use of concrete as a building material have also been published as "Problem Clinic" articles by Concrete Construction Magazine[2].

In addition to the increased awareness of good concrete floor and structures construction practice, attention is being focused on impervious linings or coatings to minimize leaks. Along with impermeable containment dikes, some engineers and owners have developed leak detection equipment or methods for below grade sumps or trench systems.

TROUBLESHOOTING - CONCRETE REPAIR PROBLEMS

It is beyond the scope of this paper to review the myriad of classifications of concrete damage or deterioration covered in the above mentioned ACI Practice and collection of reprint articles. A veritable arsenal of repair materials and techniques is available for dealing with all types of concrete damage or deterioration. The "repairability" of concrete lending itself to rehabilitation results in the unique distinction of concrete structures to rarely be "beyond repair".

Sometimes the cause of deterioration will be readily apparent. More frequently, however, it is not, and determining the cause of a particular problem might require a skilled specialist or a laboratory examination.

Some of the common problems with concrete secondary cantainment structures and neutralization basins that must be protected against aggressive chemicals that severely attack or disintegrate concrete are highlighted below.

Bug Holes and Honeycomb

These are air pockets, either visible or invisible directly under the surface. Correct preparation involves sandblasting the surface to open up those bug holes that are not completely visible and enlarging those that are visible so they later can be filled. The filler must be compatible with the lining to be installed. There are latex-modified portland cement compositions that can be used for certain light-duty linings. For heavy linings, it is preferred to use a combination of the resin normally used with the lining and a thixotropic filler, applying the compound with a trowel to fill the holes.

This filling procedure is especially necessary for two situations:

1. Where the protection is be a relatively thin film such as a 30-40 mils sprayed or rolled applied coating, and

2. When the lining has to be applied during the sunny part of the day and is exposed to sunlight. Bug holes not completely filled contain pockets of air which will expand when heated by the sun to form bubbles and pinholes in the lining.

CRACKS IN CONCRETE - ACTIVE OR DORMANT

Among causes of cracks in large concrete structures are poor structural design, overloading, excessive shrinkage, alakli-aggregate expansion or low strenteh concrete.

The pattern of the cracking, its location, the depth and width of the cracks, the presence of foreign material on the cracked surfaces and differences in elevation between two contiguous cracked-concrete masses are factors that help determine what causes the cracks to form.

In most cases, cracks must be considered active if their cause cannot be determined. Cracks that appear and continue development after the concrete has hardened are also considered active.

Cracking is called dormant when it is caused by a factor that is not expected to occur again. Under this category are plastic cracks, cracks resulting from temporary overloading, as from the movement of a piece of machinery over a slab, and random cracks caused by improper timing of concrete sawing operation. Usually a dormant crack can be permanently repaired after the full extent of cracking has occurred.

Large concrete containment structures have been known to crack, usually before the lining has been installed, but many times after lining. The cracks open and close during temperature changes, thus straining or cracking any type of lining.

Some of the techniques and methods that have been used successfully to repair cracks in concrete structures before and after lining or coating installation are:

1. <u>EPOXY INJECTION GROUTING</u> - This method on repairing cracks by grouting with epoxy resin is described by R.W. Gaul/E.D. Smith[3]

and by William H. Kuenning.

If the cracks are from shrinkage, this method can be successful to repair cracks prior to lining or coating installation. If they are from settling or loading that can continue to stress the structure, cracks may reoccur elsewhere.

2. <u>ROUTING AND SEALING</u> - As illustrated in Figure 1, the crack is routed out to a groove ½" in to 1" deep by ½" in minimum width for the length of the crack. The lining is applied into the groove and the remaining space filled with a flexible sealant. This can be successfully only so long as the sealant resists the elements and chemicals.

3. <u>FIBERGLASS CLOTH TAPE</u> - Narrow, short cracks in areas with little temperature variation can usually be covered with a layer of fiberglass cloth tape before lining. This method is shown in Figure 2.

4. <u>ELASTOMERIC "SLIP SHEET"</u> method as illustrated in Figure 3, is used in concrete vessels and large concrete neutralization basins involving immersion service conditions. Large cracks or joints in the structure that are expected to move are bridged with fiberglass that is disbonded over a elastomeric strip one or two inches on each side of the crack, then lined. This method provides two basic functions: a) It reduces the stress-straining of the lining when cracks or joints in the concrete structure open and close during temperature changes, and b) it eliminates

exposure of joint sealant to immersion service conditions.

WATER LEAKS

Water flowing or seeping into a concrete vessel or structure is difficult to stop. One method that has been successfully used is to groove out the wet area to a depth of an inch or more and fill with a very fast hardening cement. A suitable product of this type is "Water Plug", made by Standard Dry Wall Products, New Eagle, Pennsylvania.

For stubborn leaks, it may be necessary to drill a well or excavate and pump water until the wall dries. After the lining has been properly bonded to the dry concrete, it should hold back the water pressure.

Other important factors of consideration on the design-construction and/or repair-rehabilitation of concrete containment structures that require impermeable protective linings are:

1. VAPOR BARRIERS - Although vapor barriers are not always required for slabs on grade or below grade, thick asphalt vapor barriers and other materials are effective in preventing moisture from migrating through a slab. These vapor barriers must be lapped and sealed and carried over the edge of the footings (see Figure 4). Vapor barriers installed on new construction aid the application of polyester and vinyl ester resin lining and coating systems.

   A barrier underneath an existing slab to be repaired may influence the type of repair product and lining system to be used. If much water is trapped in the concrete it could cause problems during or after application of the lining. This concern with water entrapment is why genreal industry standards call for minimum 28 days curing of new concrete prior to lining.

2. <u>DRAINAGE BED</u> - Correctly designed floors should be placed on a bed of gravel or sand, rather than directly on soil, particularly clay. This minimizes the capillary flow of water from the soil through the concrete.

3. <u>EXISTING SLAB CONDITIONS</u> - Concrete in service and exposed to caustic soda and other chemicals may be saturated and the soil underneath may also be alkaline. Moisture passing through this slab by capillary action may carry caustic with it to contaminate a prepared surface. Evaluation of previous service and core drill tests on existing contaminated slab might indicate that the concrete requires replacement.

Old concrete may present a variety of surfaces which can range from a smooth, dense finish to a rough surface with a considerable amount of exposed aggregate. The concrete may be contaminated with oils, grease, tar, or other chemicals.

Construction Practices CP-14 and CP-17[4] are recommended practices by Master Builders/Ceilcote for preparing new and old concrete for lining and coating installation.

The importance of good construction practice on the design, preparation, and repair of concrete is strongly emphasized since quality concrete and substrate condition is the starting point for successful application and performance of protective lining of secondary containment dikes, vessels, neutralization basins, and other concrete structures exposed to a variety of chemical wastes.

SELECTION OF LININGS & COATINGS FOR WASTE CONTAINMENT

It would be impossible to cover all the lining and coating systems available for the varying environments in today's industry; consequently, this discussion will be limited to products that provide protection against substances that severely attack or disintegrate concrete. Examples of these aggressive substances are: acid sulphate, sulfuric acid, hydrofluoric acid, sulfates of ammonia, and sulfurous acid.

In selecting a lining or coating system for a specific environment the most important consideration is its chemical resistance. Selection is simplified if field history reports of previous exposures in similar environments are available. If information pertaining to field service is non-existent, it is necessary to rely on field or laboratory testing. One of the most difficult tasks for any corrosion engineer or end user is the proper selection of a lining for exposure and protection against combinations of chemicals. Some examples are:

- Exposure to combinations of acids and organic solvents. The concern here is with potential organic separation phase and exposure of the lining or coating system to pure organic chemistry.

- Exposure to combinations of chemicals and other substances such as hydrofluoric acid, fluoride salts, and strong alkalies that attack glass and other silica fillers used in lining and coating products.

Field testing, or exposure to the actual environment, is most effective for applications involving exposure to combinations of chemicals because it does take into consideration all of the variances which may exist. Organic separation phase and exposure of products to pure organic chemistry is difficult to evaluate through laboratory testing. A classic example is failure of rubber sheet linings used for lining concentrated hydrochloric acid storage tanks or process vessels when the acid is contaminated or contains only a few hundred parts per million of organic solvents. Rubber sheet linings are subject to attack, softening, and swelling when exposed to organic solvents.

A very large percentage of chemical exposures in waste containment and water treating applications can be handled by polyester, vinyl ester or epoxy resins.

Table 1 provides a brief list of common definitions on thermosetting resin coating and lining systems.

An important question that must be addressed on review of these common definitions is: What is the difference between a protective lining and a protective coating?

According to the definitions in Webster's Dictionary, there isn't any difference between a protective lining and a coating. Corrosion engineers and others dealing with corrosion control have however, through experience derived meaningful definitions for us to follow.

Table II provides a listing on the types of lining and coating systems used for exposure and protection against aggressive chemicals service using polyester, vinyl ester, and epoxy resins. The protective systems are classified under types of construction and film thicknesses -- heavy duty linings, light duty linings/heavy duty coatings, and protective coatings. In selecting one protective system over another where both systems appear to be successful, consideration should be given to corrosion rate of solution, temperature, traffic or wear, other service conditions, and total cost of material. If a system looks successful at a film thickness of 15-40 mils, but the corrosion rate is excessive, the system should be a heavy duty system even through the other is more economical.

This paper will not provide a detailed review of the classification of heavy duty lining systems listed in Table II since this subject is described in detail by R.B. Washburn, M.J. Galloway, and W.R. Slama[5]. Selection of products based on cost-performance economics and new product developments related to protection of secondary containment structures in harsh environments is reviewed.

Table III compares the estimated relative costs of both materials and installatin(labor) for various floor systems that are also used as linings and coating for concrete containment structures as classified in Table II.

Product selection and costs is based on predictable performance and service life when exposed to varying chemical and physical conditions ranging from very hostile environments (A-B) to light duty service (E).

Some examples of product selections and predictable performance service based on case histories and cost-performance economics related to the protection of waste containment and other concrete structures are:

1. For years acidproof brick construction with membrane and chemical-resistant mortar was the only proven and acceptable method of protection of concrete exposed to spillage of concentrated sulfuric acid. With the increased costs of acidproof brick construction combined with the improvements in resin technology and benefits of monolithic (seamless or jointless) construction, many engineers and end-users have started to use the heavy duty glass cloth reinforced trowel linings for protection against intermittent spillage of concentrated (93-98%) sulfuric acid. The monolithic heavy duty reinforced linings also offer the benefit of resistance to concentrated sodium hydroxide(caustic). As indicated in Table III, the heavy duty reinforced systems are the next best system to acidproof brick construction at

approximately half the material and labor installation costs. Acidproof brick construction is still the best choice for chemical process areas and other applications involving high temperatures (200°F or over) and severe mechanical conditions.

Service performance histories on the monolithic heavy duty reinforced linings range from 10 to over 20 years in hostile environments and aggressive acids such as sulfuric, nitric, hydrochloric, and other chemicals that rapidly attack unprotected concrete.

2. New spray applied high build coating systems have been developed in the past 5-10 years that provide good resistance to fairly strong chemicals in mild immersion or spillage conditions. These products provide benefits of lower installed costs and ease of repair. As indicated in Table II, they are often times used for protection of walls in conjunction with lining of trench and collection sump in concrete containment structures with heavy duty reinforced lining systems.

NEW PRODUCT DEVELOPMENT

One of the most interesting and promising new product developments in the past 5-7 years is the use of new multi-functional epoxy formulations using NOVOLAC clycloaliphatic amine adduct curing agent. The development and resistance of this new epoxy resin/curing system to concentrated sulfuric acid is described V. Brytus and J.S. Puglisi[6].

Poly Plus 2000, a spray applied flake filled high build (40 mils DFT) protective coating system developed by Master Builders using the high cross-link density multi-functional Novolac resin/curing technology offers resistance to full range of sulfuric acid from 5.3% (5 Degrees Baume) to 93.2%+ (66 Degrees Baume) in both immersion and spillage service. The resistance of this product to hydrochloric acid, phosphoric acid, and concentrated sodium hydroxide (caustic) is excellent.

Poly Plus 2000 is finding wide acceptance as a high performance coating system for protection of tank farm chemical storage containment and other secondary containment structures exposed to spillage of concentrated sulfuric acid and caustic that are widely used for water treatment and chemical processing applications by the CPI, Pulp & Paper, Power, and other industries. Field applications and service performance histories on Master Builders Poly Plus 2000 high performance protective coating system for secondary containment structures exposed to concentrated sulfuric acid, caustic and other chemicals range from 2-5 years.

SUMMARY

The monolithic linings and coatings that exhibit the most versatile chemical resistance also require the strongest concrete and best surface preparation. Successful coating of concrete requires attention to many details of design, surface preparation, repair, application, and inspection.

With the variety of monolithic linings and coating systems available, there are very few environments in secondary containment and chemical waste disposal that cannot be contained. All of the systems discussed have excellent performance histories in a host of waste containment and chemical processing applications.

FIGURE 1 - ROUTING & SEALING

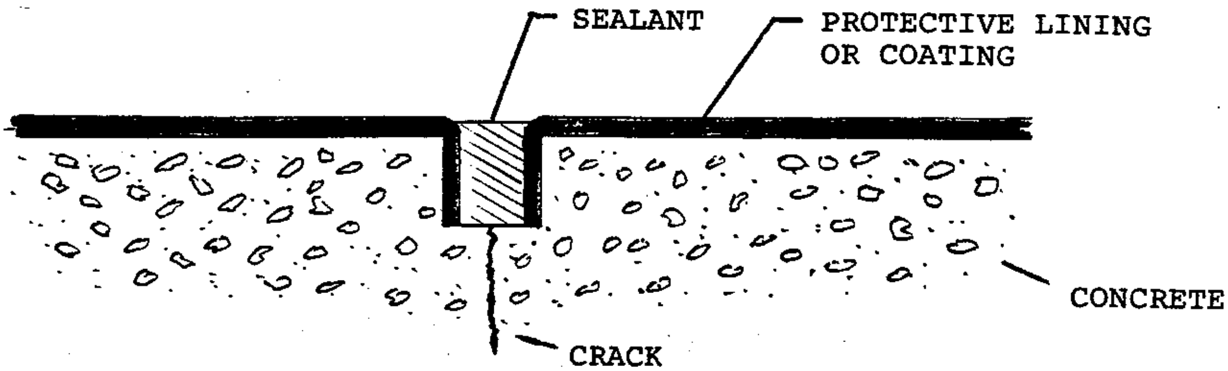


FIGURE 2 - FIBERGLASS CLOTH TAPE

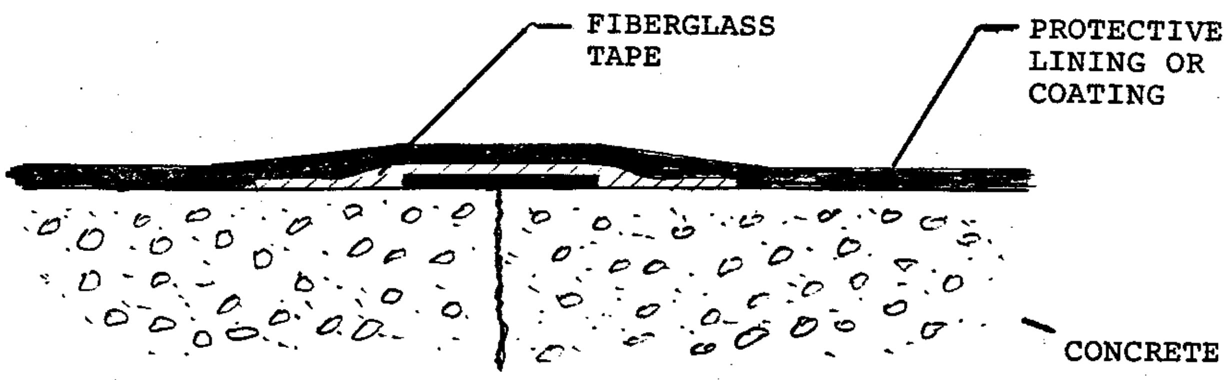
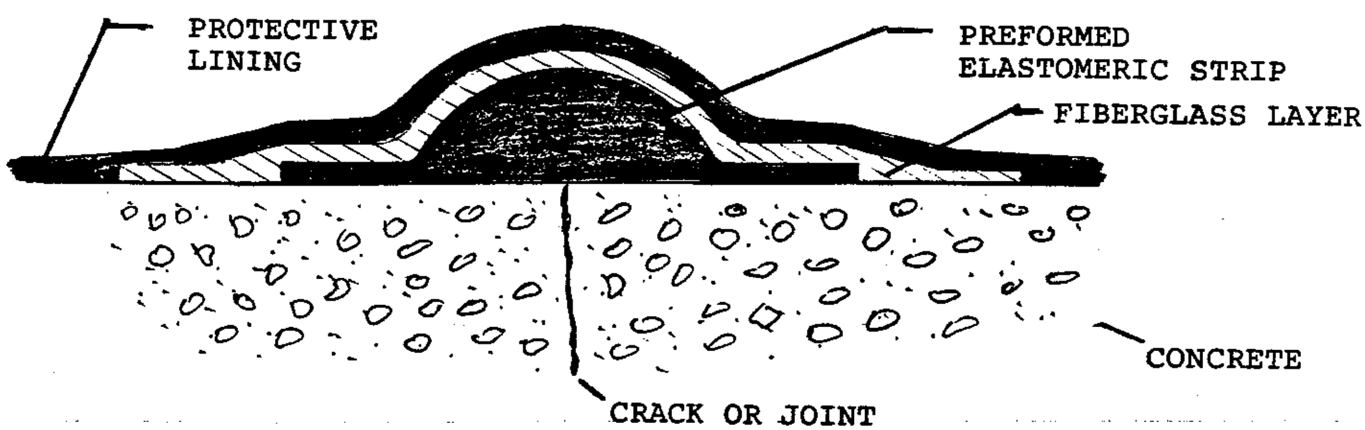


FIGURE 3 - ELASTOMERIC "SLIPSHEET"



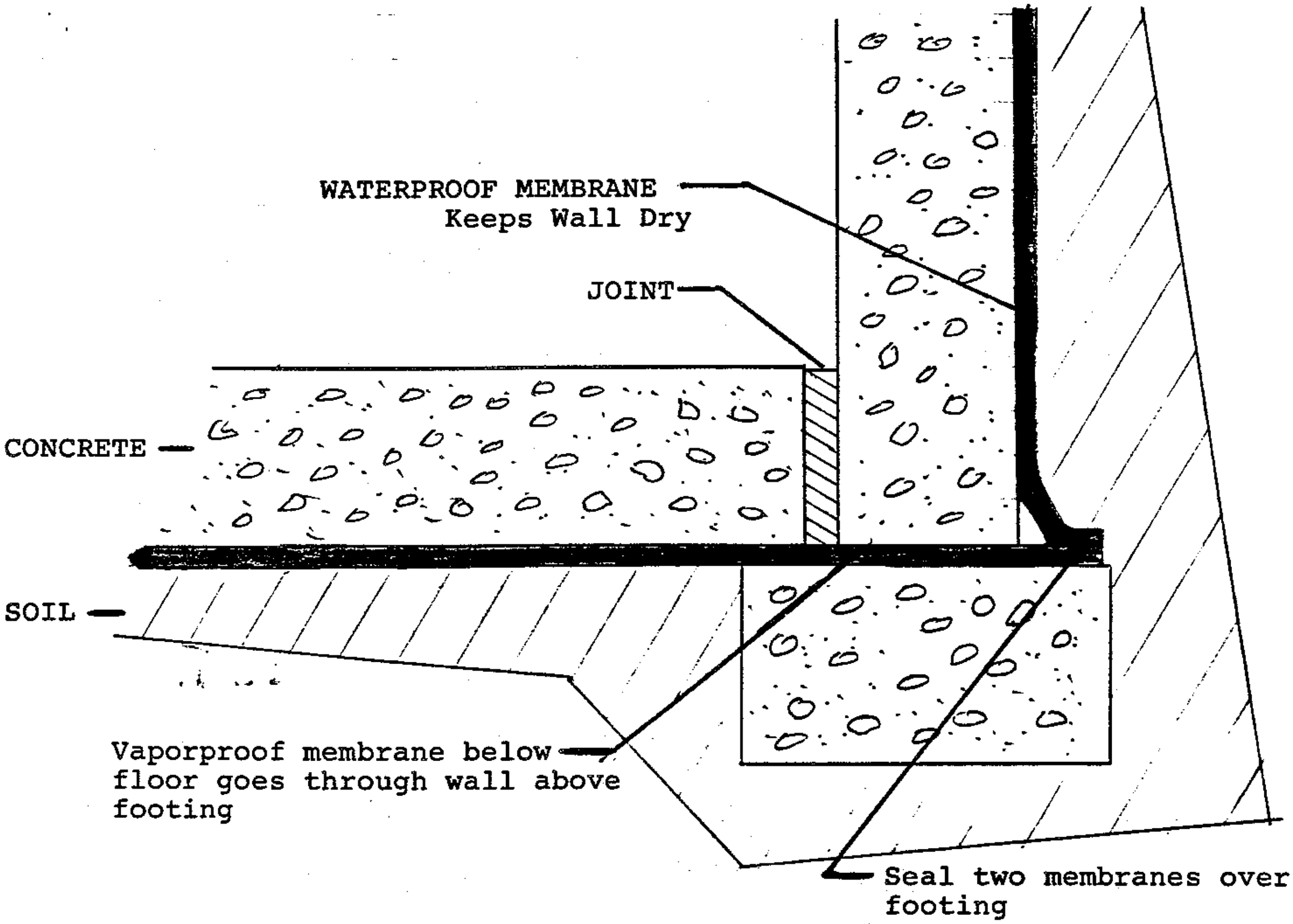


FIGURE 4

The greatest effectiveness in vaporproofing the slab is obtained by completely isolating it from the surrounding soil by sealed membranes.

TABLE 1

DEFINITIONS

FILM THICKNESS

Thin Film	5-15 Mils
Thick Film	40-60 Mils
Heavy Duty	125-160+ Mils

LINING

Briefly stated, linings for immersion service are mixtures of liquid thermosetting resins and inert fillers, usually reinforced with glass flakes and glass or synthetic fibers. The mixtures are applied by trowel or spray to a vessel or concrete tank at a thickness of 30 mils or more to protect the vessel or tank from corrosion or the contents from contamination.

THERMOSETTING RESIN

A synthetic resin used for these purposes in liquid form which hardens at nlrmal temperatures, after addition of a catalyst or curing agent.

REINFORCEMENT

Materials used to lend strength to the resin of the lining system.

FILLER

Materials used in powder form which are chemically stable or inert. These materials are added to the resin to reduce thermal expansion, stress concentration, permeability, build thickness and aid in application.

CURING AGENT

A chemical which either initiates the polymerization of a thermosetting resin or enters into a cross-linking reaction with the resin to solidify it.

TABLE II

MAJOR LINING & COATING CLASSIFICATIONS

	HEAVY DUTY LININGS	LT DUTY LININGS/ HEAVY DUTY COATNGS	PROTECTIVE COATINGS
TYPE OF CONSTRUCTION: REINFORCEMENT AND RESIN	Glass Cloth or Mat Reinforced Polyester, Vinyl Ester or Epoxy Resin	Glass Flake Filled Thick Film Coatings With or Without Mat Reinf. Polyester, Vinyl Ester, Epoxy	Small Flake Filled Polyester Or CTE Coating Systems
METHODS OF APPLICATION	Trowel	Spray, Brush, Roller	Spray, Brush, Roller
THICKNESS RANGE	1/8"-3/16"	30-40 Mils DFT Without MR Layer	15-18 Mils DFT
REASON FOR SELECTION	1. Chemistry 2. Abrasion or 3. Temperature	1. Light Chemistry 2. Temperature	1. Very Mild Chemistry 2. Atmospheric -Fumes
TYPICAL USES	1. Interior Vessel Lining 2. Harsh Spillage 3. Heavy Duty Traffic or Abrasion	1. Interior Coating Of Vessels- Mild Immersion 2. Mild to Aggressive Spillage 3. Light Duty Floor Traffic	1. Exterior Of Tanks/ Vessels 2. Wall Protection Above Splash/ Spillage Zone 3. Structural Steel Coatng in Corrosive Fume Service

NOTES ON ABOVE:

1. Carbon filled and graphite flake filled formulations are available in the above Heavy Duty and Lt Duty systems for applications requiring resistance to hydrofluoric acid, fluoride salts, and strong alkalies.

2. The above category of products is characterized by resistance to hostile environments and the capacity to withstand varying physical impositions.

3. Combinations of the above products/systems can be utilized for protection of secondary containment structures, i.e., use of heavy duty reinforced systems for lining floor, trench, collection sump, and splash zone of walls and use of heavy duty coating for upper walls.

TABLE III

RELATIVE INSTALLED UNIT COSTS (LABOR & MATERIALS) OF FLOOR SYSTEMS

This chart compares the relative costs of both materials and installation (labor) for various floor systems. This chart will aid the engineer or customer in the selection of higher service life performance products for critical process or aggressive chemicals service areas.

Product selection should be based on floor service conditions and expected service life. This is expressed as: "Dollars Per Square Foot Per Year" of service performance ($/ft²/year)

Zone	Cost per FT^2	Floor System
A.	$18.00 To 25.00	Acidproof Brick Floors With Membrane And Chemical-Resistant Mortars
B.	$ 8.00 To 10.00	Reinforced 1/8" Floor Systems Trowel Application
C.	$ 4.00 To 6.00	Unreinforced ¼" Floor Toppings Trowel Application
D.	$ 3.00 To 4.00	High Build Floor Toppings, Broadcast Seed Application 60-100 Mils
E.	$ 1.50 To 2.50	High Build Floor Coatings, Brush, Roll, or Squeegee Application 15 to 40 Mils

FLOOR SERVICE CONDITIONS ZONES

A-B - represent heavy duty or critical process floor service zones.

C-D - represent moderate floor service zones.

E - represent light floor service zones.

For list of MBT Floor Systems for the above service zones see the attached information.

B I B L I O G R A P H Y

1. AMERICAN CONCRETE INSTITUTE'S
"Recommended Practice for Concrete Floors and Slab Construction" (ACI 302)

2. Collection of articles (reprints) from <u>Concrete Construction</u> Magazine in the following books:

   - "Concrete Floor Construction"
   - "Troubleshooting Concrete Flatwork and Paving Problems"
   - "Repair of Concrete"
   - "Concrete Repair Techniques"

3. R.W. Gaul and E.D. Smith,
"Effective and Practical Structural Repair of Cracked Concrete"
American Concrete Institute Publctn. SP-21 "Epoxies with Concrete"

4. R.B. Washburn, M.J. Galloway, and W.R. Slama, "Reinforced, Chemical-Resistant, Thermoset Linings", October 1985 issue of the SSPC <u>Journal of Protective Coatings & Linings</u>

5. V. Brytus and J.S. Puglisi, "Epoxy Resin Systems for FGD Units", Paper Number 307, NACE CORROSION/84, New Orleans, La.

6. W.A. Severance, "Monolithic Linings for Chemical Waste Disposal", Paper Number 227, NACE CORROSION/80, Chicago, Ill.