CORROSION RESISTANT FENCING MATERIALS FOR NM HIGHWAY 128 SALT PLAYAS

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Special Report Prepared for Sixto Martinez
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EXECUTIVE SUMMARY

Fencing materials used along NM 128 in the salt playas of Eddy County are continuously corroding and requiring maintenance. The challenge was to identify materials that might better withstand extremes of salt, water and ultraviolet light, and keep in livestock.

Government agencies and commercial vendors were contacted to identify previous experience with this problem and any implemented solutions. Only one state government agency in Utah was found to have had any experience with salt playas fencing corrosion/degradation problems. The result was that Utah Great Salt Lake State Park has either abandoned fencing altogether or accepted a schedule of continuous maintenance.

A search was performed for materials, physical properties, performance characteristics, technical standards, and environmental impact issues. Fencing samples and sample specifications were collected from vendors. The nature of corrosion, degradation and decay was reviewed and applied to determine potentially suitable materials. The comparability of environmental contexts (marine to playas environments) was considered.

It appears that High Density Polyethylene and fiberglass products have the greatest potential for providing long-term fence post durability in the playas environment. More uncertain is whether plastic extruded mesh/nets or galvanized metal fuse-bonded PVC are viable alternatives to metal wire.

It is suggested that materials have manufacturer guarantees and/or undergo local testing.
1. INTRODUCTION

1.1 Problem

Fencing materials used along NM 128 in the salt playas of Eddy County are continuously corroding and requiring maintenance. According to the customer, the salt water in these playas is about 10 times saltier than ocean water - around 350 parts per thousand - and at various times, the fence is mostly submerged under salt water. Under these conditions, the metal posts and wire rapidly corrode and deteriorate (1). In addition, the area has some of the harshest ultraviolet (UV) radiation conditions in the world (2). NMDOT has requested that alternate fence materials be used in this area. The District needs assistance in identifying materials that will resist corrosion, decay and deterioration, be sturdy enough to keep in livestock, help motorists visually identify the roadway, and that will reduce the need for fence maintenance.

1.2 Methodology

Various government agencies and commercial vendors were contacted to identify who had previous experience with this problem, to identify previously implemented solutions, and to identify materials and approaches that might contribute to solutions. A Web based information search was performed to uncover commercially available materials, physical properties of materials, technical standards, environmental impacts, environmental effects on materials, and geographic locations where comparable environments and problems might be found. The nature of corrosion and deterioration was reviewed. Material samples were collected from vendors.

Limitations and Delimitations

For this research, fence system components were limited to posts and mesh. Change in the fence system was limited to materials that were potentially more durable. Assessment of material durability was limited by lack of environmental measurements and lack of available information on the environmental effects of salt playas on materials. As a result, knowledge based in partially equivalent environments, such as marine or costal environments, was pursued. However, it was found that these environments could not be assumed to be similar, much less comparable, to the playas. Performance characteristics of materials change across application environments and any application of this knowledge to the playas environment is based on educated guess, not on scientifically based research.

2. RESULTS

2.1 State By State Inquiries

California

Caltrans Maintenance Division Chief Steve Takigawa and Caltrans District 11 Supervisors Ray Agiar and Craig Holste reported that they had no experience with fencing in playas or comparable situations and did not know who in their organization did. They voiced doubts that environmental conditions surrounding marine fencing would be comparable to the playas (3).
Left messages for the maintenance administrators at Mojave National Preserve and Death Valley National Park but received no return calls. According to the Internet, these locations have salt playas.

**New Mexico**

Ernie Archuleta of the NMDOT products review committee said that, as far as he knows, the committee has never reviewed a plastic post for fencing or for guardrails (4).

The New Mexico Cattle Growers Association in Albuquerque offered to pose the fencing materials problem to some of their southern members (5).

In regard to concrete mixtures, Frank Kozelisky of Gallup Sand and Gravel reported that he has not heard of any problems with concrete and seawater, however, the playas may present a non-comparable situation. He said to avoid putting any chlorides into the concrete and use a low liquid to dry ratio. He suggested that there might be some advantage to pouring the concrete into a plastic bag sunk in the ground (6).

Ken Wylie of AMEC Earth & Environmental in Albuquerque recommends a high quality, low permeable concrete, something like what NMDOT specification calls a Class AA mix. NMDOT may also want to consider protective barriers for concrete. Mr. Wylie faxed the 1981 Portland Cement Association article *Effects of Substances on Concrete and Guide to Protective Treatments* that is presented in its entirety in Appendix C of this report and suggested that NMDOT take a look at the document *Guide to Durable Concrete* by the American National Concrete Institute (7).

Dr. Bob Meyers of NMDOT mentioned that concrete, by itself with no steel, has shown to be practically inert, non-reactive, in seawater. He said to make sure that plastic fencing has UV stabilizers that will not degrade under chemical attack because we have some of the harshest UV conditions in the world. In regard to drilling postholes, jetting may be preferable to auger drilling. Jetting is a process where high-pressure liquid is used to dig a hole and is useful in situations where water is close to the surface. Jetting does loosen soil and it takes time for the soil to re-compact. However, auger drilling might be a problem because wet ground may not hold the equipment. Fence posts should be “full” - that is, buried as far down under the ground as they reach above the ground because of the conditions in the playas. Fences height above ground is typically 42” for cattle and 5 to 6 feet for horses (8).

Talked to Phil Archuleta of P & M Signs Inc. in Moriarity. P&M is still in the design and testing stage of their plastic posts. They have a few set up in state parks, but the testing is not complete. The posts are 10 feet long. Mr. Archuleta says that NMDOT’s Charles Remke is involved with the testing of a couple of P&M posts, but the tests are not complete. P&M is not equipped to mass-produce these posts at this time (9).

**Nevada**

Talked to Steve Williams, District Maintenance Manager, Nevada DOT, and he did not have any experience with the fence and playas corrosion problems. He suggested that Phil Cammarata be contacted and Mr. Cammarata was left a message (10).
Texas
Jay Mitchum of South Padre Island Public Works Department has applied above water fencing to locations that are exposed to constant salt conditions but has not dealt with fences that are under ocean water. The department’s experience has been that even stainless steel rusts in above-ground applications. He has had better results with vinyl coated galvanized steel and that particular fence has held up for 10 years, but the fence is not under water. His experience is that concrete will hold up under ocean water if rebar is epoxy coated and if the concrete is not close to the surface. The Maintenance Division of this Department was contacted and left a message (11).

Joe Graff, Deputy Director of the TxDOT Maintenance Division said that TxDOT pays owners to put up fences along the right of way and TxDOT does not maintain those fences (12).

Left a message with the Naval Sea Systems Command to inquire into the material practices of the Navy.

Utah
Christopher Quick of Utah Great Salt Lake State Park said that they stopped using most fencing because nothing he has tried has lasted longer than two years. He has tried wood, galvanized, and vinyl coated fencing materials and they just get “demolished”. Stainless steel is eaten right through. He has never found anything that works for the long term. In the marina, he uses Alaskan yellow cedar for planks and Douglas Fir for pilings. The wood is treated with something, but he does not know what. He recommends using the cheapest materials and to expect a regular schedule of maintenance (13). He has not tried fiberglass or solid HDPE materials.

2.2 Deterioration and Corrosion

*The Electrochemistry of Metals Corrosion*

![Anode and Cathode Diagram](Anode_Cathode.png)

Corrosion is the transfer of electrons between metal atoms in an aqueous electrolyte solution and is a type of electric current. The sites for oxidation, anode and cathode, make up a corrosion cell. The corrosion cell can form on a singular surface or between surfaces, and the electrode ends can be adjacent or widely separated (14, pp. 1-4).

Since components of the corrosion circuit may be widely separated, it is theoretically possible that the fence and salt playas along NM 128 are acting as components of a multi-celled salt-water battery: the fence posts (anodes and cathodes) are connected by wire mesh and are set in an aqueous electrolyte solution (the salt playas) (15). This situation could complicate the structure of corrosion cells, amplify oxidizing current, and contribute to high rates of corrosion.
Corrosion cells must have four components: a) an anode, which loses metal ions, (b) a cathode, which attracts the metal ions, c) an electrolyte containing a reducible species, and d) a conducting connection between the electrodes. When any of these components are removed, electrochemical corrosion will not occur (16, p.762). It makes sense then that the three primary corrosion control methods are a) cathode removal or protection, b) anode removal or protection, and c) neutralizing the electrolyte. For the purposes of this research, both customer and researcher have focused on the removal of both anode and cathode, i.e., the replacement of conducting with non-conducting fencing materials.

**Deterioration By Non-Electrochemical Interaction**

All fencing materials realize greater or lesser degrees of deterioration or decay from a variety of abrasion, impact, structural stress, thermal, biological, chemical, and radiological (ultraviolet) causes. The exact nature and severity of this process must be assessed according to material, construction design, intended purpose, and environmental context. Degradation by ultraviolet light is covered in the section on wood and in the section on plastic.

**2.3 Materials Review**

**Wood**

There is disagreement on whether wood, treated or not, will deteriorate from the high concentrations of salts in the NM 128 playas. According to Robert Erickson, Professor Emeritus from the University of Minnesota’s Department of Wood & Paper Science, there should be no deterioration problems with using wood in salt playas because “her majesty’s ship floated in ocean water for hundreds of years without a problem.” Nevertheless, Mr. Erickson recommended that the US Forest Products Lab in Madison Wisconsin be contacted and queried (17).

Stan Lebow of the USDA Forest Service Forest Products Laboratory in Madison Wisconsin responded that there have been no studies done on the effects of high concentrations of salt on treated or untreated wood. Marine use of wood may not be comparable to the playas because of much higher concentrations of salt. The research on wood constructed salt storage sheds shows that salt destroys wood. He thinks that an oil or creosote treated wood would be best. Importantly, waterproof coatings would most likely fail (18). Also, depending on the preservative, NMDOT might need to consider the environmental impact of treated wood.

Kevin A. Flynn, et al., reports in the *Non-Biological Deterioration of Wood* that wood can be deteriorated by strong acids (pH<2) and strong alkali (pH>10). Wood is somewhat acidic and when wet, will conduct current and any attached metal will corrode. In addition, the by-products of metal corrosion can degrade the wood. Wood preserved with copper salts, such as CCA and
ACZA, can increase the metal corrosion/wood degradation process. Sodium chloride can cause defiberization of the wood surface up to an inch or so deep (19).

In the pamphlet *Pressure Treated Wood from the Western USA for Marine, Commercial, Industrial & Residential Construction* put out by the Western Wood Preservers Institute, the claim is made that “Experience has shown that [preserved] wood is one of the best materials for construction in and around aquatic environments. It is resilient enough to withstand battering by the ocean and ships, yet naturally resistant to the destructive forces of salt water. Wood does not rust or spall and is significantly less affected by corrosion than are other materials. With its additional benefits of protection against decay-causing fungi and local wood destroying marine organisms, properly treated wood assures safe, decay-resistant, long-life performance in both fresh and saltwater installations” (20, p. 4).

Nationally standardized guide specifications for the categorical use and preservation of wood are available (21, p. 8-9, 22 pp 9-10 – also see Appendix B). These specifications detail preservative standards for wood continuously submerged under ocean water. However, these specifications address issues specifically related to conditions of biological decay but not necessarily conditions of chemical deterioration. No information was found to support the assumption that preservative treatments prevent chemical (salt) and radiological (ultraviolet) deterioration.

All treated wood has some degree of health and environmental risk (23, 24, 25, 26 p. 9, 27 p. 8-9) – and the need for environmental impact assessments must be determined. *Best Management Practices For The Use Of Treated Wood In Aquatic Environments* by the Western Wood Preservers Institute and the Canadian Institute of Treated Wood offers an overview of environmental issues for each type of preservative method (28). *Organic Alternatives to Treated Lumber* offers a whole range of alternative preservatives and materials for fence posts (29).

There are several sources that list the durability of untreated wood. Untreated wood might be a material for consideration depending on the selected cost/benefit strategy. According to *Comparative Durability of Untreated Wood in Use Above Ground* by T. L. Highley, heartwood of Douglas-fir, western white pine, redwood, Eucalyptus species, red and white oak, lodgepole pine, ponderosa pine, western red cedar, and the sapwood of redwood, white and red oak all were classified as most durable with an expected average service life of at least 20 years (30). For additional lists of wood durability ratings, see Appendix A (31, 32 p. 2).

It is uncertain whether the above-mentioned durability ratings can be applied to the environment of the salt playas. Also, durability can vary greatly within a wood species itself as described in *Surveying Wood Hulls* by David H. Pascoe: “Wood is a natural, organic material that has no consistency from one species to another, or within a species. Each tree grows differently and yields different qualities of wood. Consistency may or may not exist. There are literally hundreds of varieties of species wood used in construction, and these species also have an equally wide range of strength and other characteristics. Of all these species, only a very few have the ideal characteristics of good strength and resistance to deterioration (here deterioration means fungicidal micro-organisms and electro-chemical degradation). Woods like teak, cypress, fir, long-leaf yellow pine, mahogany and only two of hundreds of varieties of oak fit the bill. But over several thousand years of boat building, these most desirable species have been
consumed and all but disappeared, causing builders to have to utilize ever lower grades of material” (33).

While it may seem that salt saturated wood precludes the possibility of biological decay, in *Why Owens Lake Is Red*, Wayne P. Armstrong reports that there are many different kinds of salt loving algae and bacteria that thrive on the blistering heat and concentrated brine of playas. Perhaps these same agents could thrive within salt saturated wood and bring about decay (34).

Ultraviolet radiation can add somewhat to the deterioration of wood. UV deterioration can be reduced by chemical treatments and by proper cut of wood. Shang-Tzen Chang, David N. S. Hon, and William C. Feist studied the photodegradation of southern yellow pine and found that “Scanning electron micrographs showed that most of the cell walls on exposed transverse surfaces were separated at the middle lamella region after only 500 h of ultraviolet light irradiation. Fibers at the surface were degraded severely after 1,000 h of irradiation. Half-bordered pits and bordered pits on exposed radial surfaces were severely damaged by ultraviolet light. Enlargement of pit apertures as well as loss of pit domes was observed. However, wood irradiated on tangential surfaces was quite resistant to UV irradiation; only microchecks were observed. The photodegradative effect on wood surfaces can be mitigated by treating with aqueous solutions of chromic acid or ferric chloride. Only relatively small amounts of these chemicals are needed for effective protection” (35, abstract).

In summary, no information was found that considered the harsh effects of salt playas on wood. It should be remembered that Christopher Quick of Utah Great Salt Lake State Park pointed out that he stopped using wood because it just got “demolished”. Material testing is recommended.

**Concrete**

As mentioned in section 2.1 of this report, Ken Wylie of AMEC Earth & Environmental recommends a high quality, low permeable concrete, akin to what NMDOT specification calls a Class AA mix. Mr. Wylie suggested two documents for guidance (36): The 1981 Portland Cement Association article *Effects of Substances on Concrete and Guide to Protective Treatments* (Appendix C) and the *Guide to Durable Concrete* by the American National Concrete Institute. Below is an excerpt from *Guide to Durable Concrete*” (37):

2.4-Seawater exposure

2.4.1 Seawater in various locations throughout the world has a range of concentration of total salts, it is less dilute in some areas than in others. The proportions of the constituents
of seawater salts, however, are essentially constant. The concentration is lower in the colder and temperate regions than in the warm seas and is especially high in shallow coastal areas with excessive daily evaporation rates.

Where concrete structures are placed on reclaimed coastal areas with the foundations below saline groundwater levels, capillary suction and evaporation may cause supersaturation and crystallization in the concrete above ground, resulting both in chemical attack on the cement paste (sulfate) and in aggravated corrosion of steel (chlorides).

In tropical climates these combined deleterious effects may cause severe defects in concrete in the course of a very few years.

2.4.2 The reaction of mature concrete with the sulfate ion in seawater is similar to that with sulfate ion in fresh water or leached from soils, but the effects are different (Mather 1966). The concentration of sulfate ions in seawater can be increased to high levels by capillary action and evaporation under extreme climatic conditions. The presence of chloride ions, however, alters the extent and nature of the chemical reaction so that less expansion is produced by a cement of given calculated C3A content than would be expected of the same cement in a freshwater exposure where the water has the same sulfate-ion content. The performance of concretes continuously immersed in seawater made with ASTM C 150 cements having C3A contents as high as 10% have proven satisfactory, provided the permeability of the concrete is low (Browne 1980). The Corps of Engineers (1994) permits, and the Portland Cement Association recommends, up to 10% calculated C3A for concrete that will be permanently submerged in seawater if the w/c is kept below 0.45 by mass.

Verbeck (1968) and Regourd et al. (1980) showed, however, that there may be a considerable difference between the calculated and the measured clinker composition of cement, especially as far as C3A and C4AF are concerned. Therefore, the interrelation between the measured C3A content and the seawater resistance may be equally uncertain.

2.4.3 The requirement for low permeability is essential not only to delay the effects of sulfate attack but also to afford adequate protection to reinforcement with the minimum concrete cover as recommended by ACI 357.1R for exposure to seawater. The required low permeability is attained by using concrete with a low w/c, well consolidated, and adequately cured.

The permeability of concrete made with appropriate amounts of suitable ground blast-furnace slag or pozzolan can be as low as 1/10th or 1/100th that of comparable concrete of equal strength made without slag or pozzolan (Bakker 1980). The satisfactory performance of concretes containing ground slag in a marine environment has been described (Mather 1981a; Vanden Bosch 1980; and Lea 1971).

Concrete should be designed and constructed to minimize crack widths, therefore limiting seawater access to the reinforcement. Additionally, concrete should reach a maturity equivalent of not less than 5000 psi (35 MPa) at 28 days when fully exposed to seawater.
Conductive coatings applied at the time of construction as part of a cathodic-protection system can provide additional protection for concrete that is partially submerged or reaches down to saline groundwater. Silane coatings, which are water-repellent, have shown excellent protection characteristics.

Coatings that significantly restrict evaporation of free water from the interior of concrete can reduce resistance to freezing and thawing.

Marine structures often involve thick sections and rather high cement factors. Such concrete may need to be treated as mass concrete, that is, concrete in which the effect of the heat of hydration needs to be considered. When this is the case, the recommendations of ACI 207.1R, 207.2R, and 224R should be followed.

Terry Collins, Concrete Construction Engineer for the Portland Cement Association writes to the NMDOT Research Bureau in regard to concrete applications in salt playas: “I would recommend that you have a look at the sulfate tables versus cement type contained in Design and control of Concrete Mixtures, EB001, Table 9-2 or Building Code Requirements for Structural Concrete, ACI 318, Tables 4.2.2 and 4.3.1 for more information on sulfate resistance and durability of concrete. At 350 parts per thousand I calculate that to 350,000 parts per million which is a lot of sulfates, but in general a 5000 psi concrete, a minimum 0.40 water-cement ratio, and a Type V or Type HS cement should meet the requirements for this project. EB001 and ACI 318 are available at www.cement.org using the "Bookstore" function and the publication numbers for your keyword search. Please feel free to call me if you wish to discuss this issue. My office hours are 9:00 A.M. to 5:30 P.M., central time, Monday through Friday. Terry Collins Concrete Construction Engineer ph: 847-972-9170 fax: 847-972-9171” (38).

In summary, there is no specific research data on the suitability of using concrete in salt playas. Nevertheless, it appears that there are concrete formulae that may be suitable. Material testing is recommended.

**Fiberglass**

Fiberglass comes in a variety of resin/fiber formulae and types: E-Glass is all purpose fiber and is resistant to water; C-Glass is acid resistant, used for its chemical stability in corrosive environments, and is not generally used as a reinforcement; S-Glass has the highest strength and stiffness; and AR –Glass is alkali resistant and used for strengthening cements. Different types and formulae may be used together in one product.

Fiberglass can be adversely affected by exposure to ultraviolet light, resulting in loss of physical properties. No specific information was found on UV degradation processes or on stabilization techniques. According to Susie Seely of F & F Composite, UV protection is provided through product coatings or within the product resin. Coatings can be delicate and may not survive the wind driven particulates of the playas environment. Depending on design, construction and fiber/resin mixture, posts made from this material can be extremely strong and can last a life-
time. Good quality fiberglass posts can be installed using conventional post/pile driving equipment. Fiberglass’ environmental and human/animal health impacts are negligible (39).

No research data exists on fiberglass durability in the playas environment, but the application of this material looks promising. Material testing and manufacturer’s guarantee is recommended. It is assumed that there are technical standards for fiberglass regarding chemical and ultraviolet protection, but none could be found. It appears that porosity is a degradation issue for fiberglass.

**Fiberglass Vendors**

- **F & F Composite** makes the product called Fiberfence. Fiberfence is a fiberglass fencing system that the company is extremely confident will meet the needs of NMDOT. The company says that it had a previous contract with us to supply fiberglass signposts. The company is willing to tailor its production process, in terms of formula, sizing and design, to meet the needs of the NMDOT. The company is in the process of sending a product sample and a set of specifications. Contact information is:
  
  Susie Seely  
  F & F Composite Group, Inc.  
  715 Katy Road  
  Keller, Texas 76248  
  Voice Office: (817) 379-4411  
  Voice Cell: (817) 793-3560  
  E-mail: suzanneseely@yahoo.com

- **Designovations Inc.** makes TUFF’n Lite, a fiberglass composite post that has an UV inhibitor. The product is used for off shore drilling applications and will not be affected by salt water. The product’s torsional strength is stronger than steel and it is 75% lighter than steel posts. The company sent product specifications and samples. Contact information is:
  
  Jim Anderson  
  Designovations, Inc.  
  Voice Office: (888) 868-6588  
  E-mail: jim@designovations.com  
  Web: http://designovations.com

**Mesh**

Extruded mesh and nets could be alternatives to metal wire mesh or wire. Permanent extruded plastic fencing may be durable enough to survive the playas for a few years, but its ability to survive livestock stressors is unknown. Heavy-duty commercial fishing net may be a solution to both playas and cattle. It is unknown if livestock would chew through plastic mesh or nets and the materials do stretch to a certain extent. Stiff, rigid polyethylene mesh is another possible alternative. No research data exists on net durability in
the playas environment and materials testing and manufacturer’s guarantee is recommended.

While PVC coated triple galvanized wire/mesh/chainlink may be a product worthy of consideration, Christopher Quick of Utah Great Salt Lake State Park mentioned that none of the plastic/polymer coated fencing material that he tried lasted for long, and others have expressed doubt about the ability of any coatings to survive the wind driven particulates of the playas.

Mesh Vendors

- According to Ski Mountain Supply, their net/pop fence is UV stabilized polypropylene fishing net, the kind of heavy-duty netting used for commercial fishing. Ski Mountain Supply predicts that this netting will last for at least four years in the playas and the company can supply the netting in any size. Contact information is:
  
  Ski Mountain Supply, Inc.
  PO Box 5225
  Laconia, New Hampshire 03247
  Voice Office:  (800) 695-7142
  Web:  http://www.skimountainsupply.com

- According to Absolute Ponds.com, their high-quality heavy-duty plastic netting has many aquaculture uses. Because it will not rust or rot, it is the perfect choice for water use. The black polyethylene mesh is UV resistant for long life. These nets are very stiff and rigid and could stand up on their side by themselves (almost like a plastic coated fencing material). They are the heaviest plastic netting available. Contact information is:
  
  Web:  http://www.absoluteponds.com/pond-nets.htm

- According to the Blair Corporation, their product Sports Net is made out of polyethylene (HDPE) and is the strongest netting on the face of the Earth. It is a molecularly aligned HDPE and is 2 to 3 times stronger than nylon. Recognizable trade names for this product are Spectra in the USA and Dynema in Europe. Commercial fisherman around the world currently use polyethylene netting in the most abused portions of their trawls where abrasion is a particular concern. The oceans of the world have been the testing grounds for our sports netting products. Their products have mastered the most extreme conditions in which all of the elements that are detrimental to the life span of our netting exist on a constant basis. All netting is Sea Strong High Density Polyethylene certified, is impregnated with 2 % UV inhibitor, no net coating is ever required, nets are permanently black and protected, and all netting is guaranteed for 5 years against UV degradation. Contact information is:
  
  Jack Blair
  Blair Corporation
  Voice Office:  (832) 928-9655
  E-mail:  jack_o_blair@yahoo.com
  Web:  http://www.blairwirerope.com/sportsnet.html
C. E. Shepherd Company offers a fuse-bonded PVC coated galvanized wire mesh and claims that it is extremely corrosion resistant. The wire is welded after galvanization. The company’s specifications include a chemical resistance chart that is included in the paper binder version of this report. The company sent a sample of their PVC coated mesh. Contact information is:

C. E. Shepherd Company
2221 Canada Dry Street
Huston, TX 77023
Voice Office: (713) 924-4300

**Plastic**

High Density Polyethylene (HDPE) appears to have the best combination of chemical resistance and rigidity of all the plastics that could be considered for application in the salt plays (40, 41, 42, 43). HDPE comes in different kinds of formulae. Good quality HDPE is exceptionally resistant to corrosive substances, oil and fuels, insects, fungi, salt, weathering and other environmental stresses, and will not rot, splinter, or crack. HDPE requires no waterproofing, painting, or other coatings. The life of standard HDPE can reach up to 50 years. Good quality HDPE can be installed using conventional post/pile driving equipment. Environmental and human/animal health impacts are negligible (44). No research data exists on HDPE durability in the playas environment. Material testing and/or manufactures guarantee is recommended.

Plastics can be adversely affected by exposure to ultraviolet light, resulting in loss of physical properties. In *Light Stability of Plastics*, Dr. Phil Jacoby, Vice President of Technology at the Mayzo Corporation writes: “...When a polyolefin part is exposed to the sun, the ultraviolet (UV) photons, which contain the most energy, can be absorbed by the polymer chain causing the carbon-hydrogen bond to break. This leaves the carbon atom on the chain with an unpaired electron and also releases a hydrogen atom with an unpaired electron. These two species are referred to as free radicals, and they are very unstable. These free radicals can go on to attack other polymer molecules producing even more free radicals, or they can react with oxygen in the air to produce peroxides and hydroperoxides, which are also unstable...

"In order to minimize this degradation and extend the lifetime of the part, two approaches can be used. The first is to incorporate additives into the part that screen out or block the UV radiation, much like the sunscreens that we use on our skin. One class of screeners are opaque pigments such as titanium dioxide (TiO2) and carbon black. Carbon black is particularly effective in absorbing UV and visible light, and can be used at levels as low as 1-2.5 % depending on the required lifetime and exposure conditions. If one needs to produce a part that is not going to be white or black, there are certain UV screening compounds that primarily absorb only in the UV portion of the spectrum…

“The other way of stabilizing plastics against UV degradation is to incorporate additives that act as free radical scavengers. These are compounds that neutralize the free radicals which lead to the polymer degradation. The most common of these are the hindered
amine light stabilizers (HALS). There are many different types of HALS…The choice of which HALS to use is important since it can also interact with other additives in the formulation…

(45)”

In *Long Term Performance of Plastics and Accelerated Aging Tests*, Dr. Jacoby writes:
“…Predicting service lifetimes has been a major challenge for the plastics industry. Not only do we need methods to predict these lifetimes, but we also need ways to compare and evaluate new materials or formulations that are in the development stages (46).”

In a phone conversation, Dr Jacoby said that each plastic formulation has a different lifetime depending on formula and end use - a period that the manufacturer should have tested for. While HDPE automatically exhibits moderate resistance to UV degradation, stabilizers increase its lifetime. Currently, there is “no gold standard” for evaluating and predicting HDPE UV resistance. There are several approaches to evaluation and prediction, and the manufacturer should be able to provide that information (47).

According to *UV Light Resistance* by Layfield Group Limited, laboratory UV tests such as ASTM G53 do not provide enough information to allow a “reasonable correlation to exposed life”, and “the best source of information is to look at actual exposure data collected from outdoor exposure tests.” Layfield’s HDPE 80, a plastic liner, has a UV lifetime of approximately 20 years (48).

An introduction to benzophenone stabilizers can be found at:
http://www.norquaytech.com/uvstabilizers.htm

**Plastic Vendors**

● Aeolian Enterprises, Inc., provides HDPE plastic lumber and fences. The company offers hollow profile and solid profile boards. The 6x6 and 4x4 hollow posts appear to be ideal for filling with concrete or sand. The company sent a sample of their lumber and promotional information can be found in the paper binder version of this report. Contact information is:
  Aeolian Enterprises, Inc.
  P.O. Box 888
  Latrobe, PA  15650
  Voice: (800) 269-4672
  E-mail:  aeolian@aeo1.com
  Web:  http://www.aeo1.com

● United States Plastic Lumber provides HDPE, HDPE/Fiberglass and HDPE/Composite plastic lumber. The product of greatest interest is the HDPE fiberglass reinforced structural lumber, which is utilized in heavy-duty construction scenarios, including piers, docks and bridges. The lumber comes in sizes suitable for fencing. Trimax is guaranteed for 50 years and comes with multitudinous and in-depth specification documentation. The company sent a sample of Trimax along with its specifications. The specifications are on a CD titled *Architectural Binder* that
can be found in the paper binder version of this report.

Contact information is:
Nathan S. Kalenich, Applications Engineer
U.S. Plastic Lumber
620B East Oregon Road
Lititz, PA  17543
Voice Office:  (609) 517-6308
Alternate Voice:  (717) 735-8775
E-mail: KalenichN@uspl.net
Web: http://www.usplasticlumber.com

Other Options

Scott’s Fencing Company in Albuquerque has a design for a low maintenance fencing system for use in the playas. This researcher was told that NMDOT did not have any way to protect such proprietary designs. As a result, this option cannot be described in this report. For more information, contact the company at 821-1114 and ask for Chris.

CONCLUSIONS

No formalized testing of fencing materials in playas has been performed. Consequently, any application of an untried material could be considered an experimental application. The NMDOT may want to acquire vendor statements of material performance, specifications, and guarantees for any material considered. Playas could be analyzed for constituent chemicals, pH, and average UV exposure with this analysis provided to vendors to help determine material durability/suitability. The Department may want to do its own testing on candidate materials.

It appears that certain High Density Polyethylene (HDPE) and fiberglass products have the potential for providing long-term fence post durability in the playas environment. It is uncertain whether plastic extruded mesh/net or galvanized metal fuse-bonded PVC mesh/wire is a viable alternative to metal mesh/wire.

The mode of UV stabilization should be specified for each material. Some approaches to UV stabilization do not last.

A cost benefit analysis should be done for each material. Significant short-term benefits, significant long-term benefits, lifecycle costs, initial material and construction costs and Department budgetary parameters should be considered. For example, material A requires no maintenance for fifty years, lasts for fifty years, has higher initial cost, and provides the lowest lifecycle cost of all materials. Material B requires frequent maintenance, lasts for only three years, has the lowest initial cost of all materials, and provides the highest lifecycle cost of all materials. Budgets may only allow the purchase of material B, though at the cost of long-term burden.

See, the paper binder version of this report for supporting information.
REFERENCES

1. Sixto Martinez, New Mexico Department of Transportation (personal communication, May 27, 2004).

2. Dr. Bob Meyers, New Mexico Department of Transportation (personal communication, June 22, 2004).


4. Ernie Archuleta, New Mexico Department of Transportation (personal communication, June 24, 2004).


8. Dr. Bob Meyers, New Mexico Department of Transportation (personal communication, June 22, 2004).


10. Steve Williams, Nevada Department of Transportation (personal communication, August 10, 2004).


12. Joe Graph, Texas Department of Transportation, (personal communication, June 9, 2004).

13. Christopher Quick, Utah Great Salt Lake State Park, (personal communication, June 7, 2004)


47. Dr. Phil Jacoby, Vice President of Technology, Mayzo Corporation (personal communication, August 20, 2004).

APPENDIX A

Durability of Tree Species

<table>
<thead>
<tr>
<th>Groupings of domestic wood species according to approximate relative decay resistance of heartwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistant or very resistant</td>
</tr>
<tr>
<td>Bald cypress (old growth)</td>
</tr>
<tr>
<td>Catalpa</td>
</tr>
<tr>
<td>Cedar</td>
</tr>
<tr>
<td>Cherry, black</td>
</tr>
<tr>
<td>Chestnut</td>
</tr>
<tr>
<td>Cypress, Arizona</td>
</tr>
<tr>
<td>Juniper</td>
</tr>
<tr>
<td>Locust, black&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mesquite</td>
</tr>
<tr>
<td>Mulberry, red&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Oak</td>
</tr>
<tr>
<td>Bur</td>
</tr>
<tr>
<td>Bambel</td>
</tr>
<tr>
<td>Oregon white</td>
</tr>
<tr>
<td>Post</td>
</tr>
<tr>
<td>White</td>
</tr>
<tr>
<td>Osage orange&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Redwood</td>
</tr>
<tr>
<td>Yew, Pacific&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> These woods have exceptionally high decay resistance - <sup>b</sup> Other than longleaf, slash and eastern white pine


<table>
<thead>
<tr>
<th>Decay Resistance of Untreated Selected Native Nebraska Trees Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
</tr>
<tr>
<td>Osage-orange (hedge)</td>
</tr>
<tr>
<td>Black Locust</td>
</tr>
<tr>
<td>Eastern Red cedar and Juniper</td>
</tr>
<tr>
<td>Honey locust</td>
</tr>
<tr>
<td>Hickory</td>
</tr>
<tr>
<td>Catalpa</td>
</tr>
<tr>
<td>Mulberry</td>
</tr>
<tr>
<td>Bur Oak</td>
</tr>
<tr>
<td>Black Walnut</td>
</tr>
<tr>
<td>Hackberry</td>
</tr>
<tr>
<td>Ponderosa Pine</td>
</tr>
<tr>
<td>Cottonwood</td>
</tr>
</tbody>
</table>

Source: Schmidt, Thomas L. and Kuhns, Michael R. Native Wood Fence Posts. Electronic version issued October 1996. Published in NebGuide, Published by Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln [http://ianpubs.unl.edu/forestry/g314.htm#wpfd](http://ianpubs.unl.edu/forestry/g314.htm#wpfd)
APPENDIX B
Specification Guide to Treated Wood

### Specification Guide to Treated Wood End Uses

<table>
<thead>
<tr>
<th>USE</th>
<th>AWP STANDARD</th>
<th>DOW-TYPE PRESERVATIVES</th>
<th>MINIMUM RESISTANCE - POUNDS PER SQUARE FOOT</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Use Category</td>
<td>C Standard</td>
<td>Copper Naphthenate</td>
</tr>
<tr>
<td>BEAMS &amp; TIMBERS, glue laminated before or after treatment</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Damp environment, above ground</td>
<td>3B</td>
<td>C20</td>
<td>0.040</td>
</tr>
<tr>
<td>Dry environment, above ground</td>
<td>1, 2</td>
<td>C20</td>
<td>0.040</td>
</tr>
<tr>
<td>Ground contact</td>
<td>4A</td>
<td>C20</td>
<td>0.010</td>
</tr>
<tr>
<td>Highway construction</td>
<td>4B, 4C</td>
<td>C14, C20</td>
<td>0.040 – 0.060</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highway bridge</td>
<td>4B</td>
<td>C2, C14</td>
<td>0.05</td>
</tr>
<tr>
<td>Above ground</td>
<td>3B</td>
<td>C2, C15</td>
<td>0.06</td>
</tr>
<tr>
<td>Ground contact</td>
<td>4A</td>
<td>C2, C15</td>
<td>0.06</td>
</tr>
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<td>HIGHWAY MATERIAL</td>
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<tr>
<td>Lumber and timbers for bridges, structural members, decking, catwalks and curbs</td>
<td>4B</td>
<td>C2, C14</td>
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<tr>
<td>Structural lumber and timbers</td>
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<td></td>
<td></td>
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<tr>
<td>– In saltwater use and subject to marine borer attack</td>
<td>5A, 5B, 5C</td>
<td>C3, C14</td>
<td>NL</td>
</tr>
<tr>
<td>– Piles, foundations, land and freshwater use</td>
<td>4C</td>
<td>C3, C14</td>
<td>0.10 – 0.14</td>
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<tr>
<td>– Piling, in saltwater use and subject to marine borer attack</td>
<td>5A, 5B, 5C</td>
<td>C3, C14</td>
<td>NL</td>
</tr>
<tr>
<td>– Posts: Round, half-round, square-round</td>
<td>4A</td>
<td>C5, C14</td>
<td>0.055</td>
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<tr>
<td>– Post: Sawn</td>
<td>4A</td>
<td>C2, C14</td>
<td>0.06</td>
</tr>
<tr>
<td>– Handrails and guardrails</td>
<td>3B</td>
<td>C2, C14</td>
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<tr>
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<td>3B</td>
<td>C2</td>
<td>0.04</td>
</tr>
<tr>
<td>Ground contact and freshwater use</td>
<td>4A</td>
<td>C2</td>
<td>0.06</td>
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<tr>
<td>MARINE LUMBER AND TIMBERS</td>
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<td></td>
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<tr>
<td>Fresh water</td>
<td>4A</td>
<td>C2</td>
<td>0.09</td>
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<tr>
<td>Members out of water but subject to saltwater splash or ground contact</td>
<td>4B</td>
<td>C2, C18</td>
<td>NL</td>
</tr>
<tr>
<td>In saltwater or saltwater use and subject to marine borer attack</td>
<td>5A, 5B, 5C</td>
<td>C2, C18</td>
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</tr>
<tr>
<td>PILES</td>
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</tr>
<tr>
<td>Foundation (round)</td>
<td>4C</td>
<td>C3</td>
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<tr>
<td>Land and freshwater use (round)</td>
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<td>C3</td>
<td>0.10 – 0.14</td>
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<td>C3, C18</td>
<td>NL</td>
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<td>Marine, dual treatment (round)</td>
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<td>C3, C18</td>
<td>NL</td>
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<tr>
<td>Sawn timber piles</td>
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<td>C2</td>
<td>NL</td>
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<tr>
<td>PLYWOOD</td>
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<tr>
<td>Sub-floor, damp above ground</td>
<td>2</td>
<td>C9</td>
<td>NL</td>
</tr>
<tr>
<td>Exterior, above ground</td>
<td>3B</td>
<td>C9</td>
<td>NL</td>
</tr>
<tr>
<td>Soil contact</td>
<td>4A</td>
<td>C9</td>
<td>NL</td>
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**NOTE:** This is a summary document only for complete information, see AWP Book of Standards.
### Specification Guide to Treated Wood End Uses

<table>
<thead>
<tr>
<th>USE</th>
<th>C2 Standard C5 Standard</th>
<th>ACQ²</th>
<th>ACQ²</th>
<th>CA-B³</th>
<th>CBEM²</th>
<th>DEC³</th>
<th>CECA²³</th>
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<td>NL</td>
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<td>5A, 5B, 5C</td>
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<td>2.5</td>
<td>NL</td>
<td>NL</td>
<td>2.5</td>
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<td>C3, C14</td>
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<td>NL</td>
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<td>- Piling in saltwater use and subject to marine boron attack</td>
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<td>C3, C14</td>
<td>NL</td>
<td>1.5 – 2.5³</td>
<td>NL</td>
<td>NL</td>
<td>1.5 – 2.5³</td>
</tr>
<tr>
<td>- Posts, Round, half-round, quarter-round</td>
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<td>C5, C14</td>
<td>0.40</td>
<td>0.40</td>
<td>NL</td>
<td>NL</td>
<td>0.40</td>
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<tr>
<td>- Posts, Sawn</td>
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<td>C2, C14</td>
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<td>0.40</td>
<td>NL</td>
<td>NL</td>
<td>0.40</td>
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<td>- Handrails and guardrails</td>
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<td>C2, C14</td>
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<td>C2</td>
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<td>0.25</td>
<td>0.10</td>
<td>0.20</td>
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<td>C2</td>
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<td>0.40</td>
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<td>Fresh water</td>
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<td>C2</td>
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<td>0.21</td>
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<td>Members out of water but subject to saltwater splash or ground contact</td>
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<td>C2, C18</td>
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<td>2.5</td>
<td>NR</td>
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<td>2.5</td>
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<td>PILES</td>
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</tr>
<tr>
<td>Foundation (round)</td>
<td>4C</td>
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<td>NL</td>
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<td>0.80 – 1.0</td>
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<td>NL</td>
<td>0.80</td>
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<td>Marine (round) in salt or brackish and subject to marine boron attack</td>
<td>5A, 5B, 5C</td>
<td>C3, C18</td>
<td>NL</td>
<td>1.5 – 2.5³</td>
<td>NL</td>
<td>NL</td>
<td>1.5 – 2.5³</td>
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<tr>
<td>Marine, dual treatment (round)</td>
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<td>C3, C18</td>
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<td>NL</td>
<td>NL</td>
<td>1.0</td>
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<td>Seven timber piles</td>
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<td>C2</td>
<td>0.60</td>
<td>0.60 – 0.80</td>
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<td>NL</td>
<td>0.60 – 0.80</td>
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<tr>
<td>PLYWOOD</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Sub-floor, damp, above ground</td>
<td>2</td>
<td>C9</td>
<td>0.25</td>
<td>0.25</td>
<td>0.10</td>
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<td>Exterior, above ground</td>
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<td>0.40</td>
<td>0.21</td>
<td>0.41</td>
<td>0.40</td>
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</tbody>
</table>

APPENDIX C

Effects of Substances on Concrete and Guide to Protective Treatments

Effects of Substances on Concrete and Guide to Protective Treatments

Quality concrete must be assumed in any discussion on how various substances affect concrete. In general, achievement of adequate strength and sufficiently low permeability to withstand many exposures requires proper proportioning, placing, and curing. Certain fundamental principles by which the quality of concrete can be controlled are well established:

- Low water-cement ratio—nor to exceed 0.49 by weight.
- Minimum cement content—584 lb per cubic yard (335 kg/m³).
- Suitable cement type—such as portland cement low in tricalcium aluminate, C₃A, to reduce or prevent attack by some chemicals that react with C₃A, notably sulfates.
- Adequate air entrainment—the amount dependent on maximum aggregate size.
- Suitable workability—avoiding mixes so harsh and stiff that honeycomb occurs, and those so fluid that water rises to the surface. Slump should be 2-4 in. (50-100 mm).
- Thorough mixing—until all concrete is uniform in appearance, with all materials evenly distributed.
- Proper placing and consolidation—filling all corners and angles of forms without segregation of materials. Where possible, construction joints should be avoided.
- Adequate curing—supplying additional moisture to the concrete during the early hardening period or covering concrete with water-retaining materials. (Rapid evaporation of moisture from the concrete surface soon after it is placed may cause plastic shrinkage cracking.) Curing compounds must not be used on surfaces that are to receive protective treatment. Concrete should be kept moist and above 50°F (10°C) for at least the first week, but longer curing periods usually increase resistance to corrosive substances. Concrete should not be subjected to hydrostatic pressure during this period.

Design Considerations

Whenever concrete is to be coated for corrosion protection, the forms should be coated with materials that will not impregnate or bond to the concrete after they have been stripped. Hence, forms coated with form oils or waxes should not be used against surfaces to be coated. Curing membranes that are weakly bonded to the concrete may develop little or no bond to coatings applied over them. If form oils, waxes, or curing membranes are present, they should be removed by acid washing, sandblasting, sandblasting, or other such processes.

Where spillage of corrosive substances is likely to occur, a floor should have a slope to drains of at least 2% to facilitate washing.

Many solutions that have no chemical effect on concrete such as brines and salts, may crystallize upon drying. It is especially important that concrete subject to alternate wetting and drying of such solutions be impervious to them. When free water in concrete is saturated with salts, the salts crystallize in the concrete near the surface during the drying process, sometimes exerting sufficient pressure to cause scaling. Structures exposed to brine solutions and having a free surface of evaporation should therefore be provided with a protective treatment on the side exposed to the solution.

In addition, movement of salts into the concrete may result in corrosion of reinforcing steel. The corrosion reactions form compounds that cause expansion and disruption of the concrete. Significant corrosion of steel in reinforced concrete will occur if (1) sufficient oxygen is available, and (2) the normally passive state of steel in concrete is impaired. Porous concrete or surface cracks permit the penetration of oxygen to the reinforcement. The steel is normally passive because a protective oxide film is formed and maintained on it by the high concentration of hydroxide ions (high pH) in the water solution in concrete. This protective film may be impaired by (1) sufficient lowering of the pH value, as by reaction of carbon dioxide from the air or other sources, or (2) a sufficient concentration of chloride ions in solution. High cement content in high-quality impermeable concrete provides protection against corrosion of reinforcement by producing a high pH value and limiting exposure to air.

It is important that sufficient concrete coverage be provided for reinforcement where the surface is to be exposed to corrosive substances. Carbon steel bar...
supports for reinforcement should not extend to the concrete surface. Deep recesses in the concrete should be provided for form ties, and they should be carefully filled and pointed with mortar. Acids attack concrete by dissolving both hydrated and unhydrated cement compounds as well as calcareous aggregate. In certain acids and acid solutions it may be impossible to apply an adequate protective treatment to the concrete, and the use of a “sacrificial” calcareous aggregate should be considered. Replacement of siliceous aggregate by limestone or dolomite having a minimum calcium oxide concentration of 50% will aid in neutralizing the acid. The acid will attack the entire exposed surface more uniformly, reducing the rate of attack on the paste and preventing loss of aggregate particles at the surface. The use of calcareous aggregate will also retard expansion resulting from sulfate attack caused by some acid solutions.

The rate of attack on concrete may be directly related to the activity of the aggressive chemical. Solutions of high concentration are generally more corrosive than those of low concentration—although in some cases, the reverse is true. The rate of attack may be altered by the solubility of the reaction products of the particular concrete. Lowering the hydroxide concentration generally causes more rapid attack in the concrete. Also, since high temperatures usually accelerate any attack, better protection is required than for normal temperatures.

Surface Preparation
Proper preparation of the concrete surface and good workmanship are essential for successful application of any protective treatment. Concrete should normally be well-cured (28 days to six months, depending on service conditions and coatings used) and dry before the protective coatings are applied. Moisture in the concrete may cause excessive internal vapor pressure that can result in the treatment’s blistering and peeling. Precautions should be taken to eliminate objectionable voids in the surface that might cause pinholes in the coating. Good vibration and placing techniques will reduce the number of these surface imperfections. The concrete surface should be smoothed immediately after removal of forms by applying grout or mortar, or by grinding the surface and then working grout into it. Other surface treatments that have good adhesion to cured concrete, such as latex-modified grouts or mortars, epoxy, or other synthetic resin formulations, can also be used to produce a smooth surface.

It is important to have a firm base free of grease, oil, efflorescence, laitance, dirt, and loose particles. The best method of cleaning the concrete surface depends on job conditions. Dry removal of accumulated dirt and dust is best achieved by scarifying, grinding, or sandblasting, but the dust and dirt produced by these methods may be undesirable. When such dust cannot be tolerated, a liquid-based cleaning technique can be used. There are three stages of wet cleaning: (1) degreasing, (2) acid treatment, and (3) neutralizing to clean and etch thoroughly. Cleaning operations should be performed only under conditions where appropriate safety precautions have been taken.

Degreasing is accomplished by applying a mixture of a cleaner/curing-compound remover (a chlorinated, emulsifiable solvent), an industrial grease remover (a highly alkaline, low-phosphate, biodegradable detergent), and liberal amounts of water. The mixture is used to scrub the concrete surface, repeatedly, if necessary. The surface finally is rinsed and scrubbed with clear water, vacuumed to a damp condition, and then allowed to air-dry.

Acid treatment of the surface involves scrubbing the dry floor with an etching solution (a mild organic acid combined with detergents, emulsifiers, and solvent). After a vacuuming machine picks up any residual material, the concrete surface is then rinsed, scrubbed clean of the acid solution, and dried.

Neutralization of any acid left on the surface is then accomplished by wetting the surface with clear water, sprinkling on a detergent cleaner (highly alkaline, high-phosphate, non-residue-forming detergent), scrubbing, rinsing with water, and vacuuming to a damp condition. The concrete is then rinsed again with clear water, vacuumed damp dry, and allowed to air-dry before the new surface finish is applied.

Acid treatment is recommended only for cleaning floor surfaces that are to receive a new surface finish. Other wet-cleaning methods include high-pressure water-jetting and steam cleaning. Selection of method depends on the type and severity of contamination.

Grinders can be used to remove weak, friable laitance, high spots, and trowel and other marks. Grinding can improve the smoothness and wear-resistance of the floor.

Scalakers and concrete sanders can remove laitance, paint marks, pitch adhesives, thermoplastic adhesives, smooth the concrete, and produce non-skid surfaces. The machines have hardened-steel cutting wheels that hammer off the surface.

Shotblasting or abrasive blasting removes surface contaminants. Machines with vacuum bags make the operation almost dust-free.

After a concrete surface is cleaned and dried, all residue must be removed. Various industrial vacuum machines are used to remove microdust particles from a prepared surface.

Concrete cast against forms is sometimes so smooth that adhesion of protective coatings becomes difficult. Such surfaces should be acid-etched, sandblasted lightly, or ground with silicon carbide stones to obtain a slightly roughened surface.

Choosing the Treatment
Protective treatments for concrete are available for almost any degree of protection required. Coatings vary widely in composition and performance, and some of the generic classifications given here are so broad that
they can serve only as a guide. The reader is advised to seek further, more detailed recommendations from the manufacturer, formulator, producer, or material supplier.*

Every coating is formulated to render a certain performance under specified conditions. Its quality should not be determined solely by the merits of any of its components since it is the proportioning of ingredients that determines performance. Coating performance also depends upon the quality of surface preparation, method and quality of coating application, air conditions during application, and film thickness. Any general discussion of chemical resistance and other properties of coatings must assume optimum formulation and proper use. The producers of the various coatings can provide valuable information on the merits of their products for a particular use and on the proper and safe procedure for application. Many coatings contain solvents that are fire, explosion, or toxic hazards.

Certain materials (thermosetting) soften at elevated temperatures and may even melt or become ineffective. Various grades of coatings are available for use over a fairly wide temperature range. Where flavor or odor is important, the U.S. Food and Drug Administration or the Food Directorate of Health and Welfare Canada should be consulted regarding materials for use with food ingredients.

The coating thickness required depends on (1) the exposure, whether continuous or intermittent; (2) the resistance of the material to the chemicals involved; and (3) the ability to form a continuous, pinhole-free surface. As a rule, thin coatings are not as durable as heavier coatings and hence are less suitable where there is considerable abrasion.

The more common protective treatments are indicated in the tables (starting on page 7), the numbers and letters corresponding to the descriptions given here. For most substances, several treatments are suggested. They will provide sufficient protection in most cases. When choosing a type of protection, consider the chemical environment, service condition (i.e., splash and spindrift), and any mechanical requirements, keeping in mind the consequences of failure and ease of repair.

The information in the tables is only a guide for determining when to consider various coatings for chemical resistance. Where more specific information is required, particularly to determine whether protection is required for large installations, small mortar prisms representative of the concrete to be used can be immersed in the corrosive liquid and evaluated for resistance.* Where continuous service over long periods is desirable, it may be more economical to use the higher-quality means of protection rather than a lower-first-coat treatment that may be less permanent.

**Protective Treatments**

1. Magnesium fluosilicate or zinc fluosilicate. The treatment consists generally of three applications. Either of the fluosilicates may be used separately, but a mixture of 20% zinc fluosilicate and 80% magnesium fluosilicate appears to give the best results. For the first application, 1 lb (0.45 kg) of the fluosilicate crystals should be dissolved in 1 gal (3.78 L) of water; about 2 lb (0.91 kg) of crystals per gallon of water are used for subsequent applications.

The solution may be applied efficiently with large brushes for vertical surfaces and mops for horizontal surfaces. The surfaces should be allowed to dry between applications (about three or four hours are generally required for absorption, reaction, and drying). Brush and wash the surface with water shortly after the last application has dried to remove incrusted salts that can cause white stains.

Treatment with fluosilicates reduces dusting and hardens the surface by chemical action. It increases resistance to attack from some substances but does not prevent such attack. With poor-quality concrete, the treatment is not effective.

Concrete surfaces to be treated with fluosilicates should not contain integral water-repellent agents because these compounds will prevent penetration of the solution. Hardeners should not be used when paints are to be applied because they result in poor adhesion of many coatings. Also, hardened surfaces are difficult to etch properly.

2. Sodium silicate (commonly called water glass). Commercial sodium silicate is about a 40% solution. It is quite viscous and must be diluted with water to secure penetration. The amount of dilution depends on the quality of the silicate and permeability of the concrete. Silicate of about 42.5 degrees Baumé diluted in proportions of one-quarter part per part of water by volume makes a good solution. Two or three coats should be used. For tanks and similar structures, progressively stronger solutions are often used for the succeeding coats.

Each coat should be allowed to dry thoroughly before the next one is applied. On horizontal surfaces the solution may be liberally poured on and then spread evenly with mops, brooms, or brushes. Scrubbing each coat with stiff fiber brushes or with scrubbing machines and water after it has hardened will assist penetration of the succeeding application. The treatment increases resistance to attack from some substances but does not prevent such attack.

3. Drying oils. Two or three coats of linseed oil may be used as a protective treatment; boiled linseed oil dries faster than raw oil and is used more commonly. Linoleic acid, oleic acid, or straight tallow oil also can be used. Soybean oil and tung (China wood) oil can be used, but coats of these oils fluctuate widely with the commodities market.

The concrete should be well cured and at least 14 days old before the first application of a drying oil. If this

*These four terms are used interchangeably in this publication.

is not possible, the concrete should be neutralized by applying a solution consisting of 3 oz of zinc chloride and 5 oz of orthophosphoric acid (85% phosphoric acid) per gallon of water (24:40:1000). After it is brushed on the concrete, the solution should be allowed to dry for 48 hours. Any crystals that have formed on the surface should then be removed by light brushing. This solution should not be used on prestressed concrete. Sometimes a magnesium fluoride treatment is also applied to harden the surface before the oil treatment. The oil treatment may be applied with mops, brushes, or spray and the excess removed with a squeegee before the oil gets tacky. It is not wise to build up a heavy surface coat of oil because the oil from the surface is desirable. Diluting the oil with turpentine or kerosene to obtain a mixture of equal parts gives better penetration for the first coat; subsequent coatings may be diluted less. Careful heating of the oil to about 150°F (65°C) and hot application to a warm surface also help achieve better penetration. Each coat must dry thoroughly for at least 24 hours before the next application. Drying oils tend to darken concrete.

4. Courmarone-indene. Available in grades from dark brown to colorless, this synthetic resin is soluble in xylene and similar hydrocarbon solvents and should be powdered to aid dissolving. A solution consisting of about 6 lb of courmarone-indene per gallon of xylene with 1/2 pt of boiled linseed oil (3 kg courmarone-indene per liter xylene plus 0.2 L boiled linseed oil) makes a good coating. Two or more coats should be applied to fairly dry concrete. The coatings have a tendency to yellow with exposure to sunlight but the yellowing does not seem to affect the protective properties.

Courmarone-indene availability has been decreasing for many years and current substitutes include hydrocarbon resin polymers (hydrocarbon resins) and rosin-based resins.

5. Styrene-butadiene. Styrene-butadiene copolymer resins are available in various medium-strength solvents, some faster drying than others. Three coats are generally recommended, with the first coat thinned for better penetration. Twenty-four hours should elapse between coats, and a delay of 7 days is necessary for thorough drying before the coated surface is placed in service. These coatings tend to yellow with exposure to sunlight.

Decorative butadiene coatings are widely marketed as latex paints. They are usually not satisfactory for protection against chemical attack because latex paints generally do not form sufficiently impermeable films.

6. Chlorinated rubber. This treatment consists of a trowel-applied mixture of heavy consistency up to 3/8 in. (3 mm) thick, or multiple coats of specially formulated lower-viscosity types can be brushed or sprayed on to a maximum thickness of 10 mils (0.25 mm). An absolute minimum of 5 mils (0.12 mm) (applied in two coats) is recommended for chemical exposure. In general, concrete should age for two months before this treatment. The concrete may be damp but not wet, as excessive moisture may prevent adequate bonding. It is advisable to thin the first coat, using only the producer’s recommended thinner (other thinners may be incompatible). A coating dries tack-free in an hour, but a 24-hour interval is recommended between coats.

The applied coating is odorless, tasteless, and non-toxic after it dries. Its strong solvents, however, may lift and destroy previously painted and aged coatings of oil or alkyd base.

7. Chlorosulfonated polyethylene (Hyposion). Four coats of about 2 mils (0.05 mm) each and an appropriate primer are normally recommended to eliminate pinholes. Thinning is not usually required, but to reduce viscosity for spray application, the producer’s recommended thinner should be used up to a limit of 10% of the amount of coating used. Each coat dries dust-free within 10 to 20 minutes and the treatment cures completely in 30 days at 70°F (21°C) and 50% relative humidity. A fill coat of grout or mortar is required since the paint film will not bridge voids in the concrete surface. Moisture on the surface may prevent good adhesion. These coatings are expensive and must be applied by trained personnel. They are not used where less costly coatings are adequate.

8. Vinyls. Of the vinyls available, polyvinyl chloride, polyvinyl chloride-acetate, and polyvinylidene chloride are the ones used extensively in corrosion control. The resins are soluble only in strong solvents. Due to the high viscosity of the resins, only solutions of low solids content can be made. Multiple coats are therefore required for adequate film thickness. Vinyls should generally be sprayed onto dry surfaces as their fast drying (30 minutes) makes brush application difficult.

Vinyl chloride coatings make good top coatings for vinyl chloride-acetate and others, but do not themselves adhere well directly to concrete.

Polyvinyl acetate latex (waterborne) copolymers are widely available as decorative coatings but, like other latexes, they are usually inferior to solvent-system coatings for chemical resistance. In addition, the vinyl acetate latexes (waterborne emulsions) are sensitive to the free alkalinity of concrete and eventually break down.

9. Bituminous paints, mastics, and enamels. Asphalt or coal tar coatings may be applied cold (paints and mastics in cutback or emulsion form) or hot (mastics and enamels). Two coats are usually applied to surface-dry concrete; a thin priming coat to ensure bond and a thicker finish coat. The priming solution is of thin brushing consistency and should be applied to cover the surface completely; any uncoated spots should be touched up. When the primer has dried to a tacky state, it is ready for the finish coat. Multiple coats should be applied at right angles to each other to ensure continuity and avoid pinholes.

Emulsions are slower drying, more permeable, and less protective than the other coatings. Cutbacks and emulsions, if not completely cured, can impart odor or flavor to materials with which they are in contact. The producer’s recommendations on service and application temperatures should be strictly observed.

Bituminous mastics may be applied cold or heated until fluid. Cold mastics are cutbacks or emulsions con-
taining finely powdered siliceous mineral fillers, asbestos fibers, or bitumen-coated fabrics to form a very thick, pasty, fibrous mass. This mass increases the coating's resistance to seeping and at elevated temperatures and to abrasion. Thin mastic layers, about 1/16 in. (1 mm) thick, are applied on and allowed to dry until the required thickness has been obtained. Hot mastics usually consist of about 15% asphaltic binder, 20% powdered filler, and the remainder sand, graded up to 4 in. (5 mm) maximum size. They should be poured and troweled into place in 1/4-in.-thick (25-mm) layers.

Enamels should be thinned, stirred, and carefully heated until they reach the required temperature. If an enamel is heated above the producer's recommended temperature, it should be discarded. If application is delayed, the pot temperature should not be allowed to exceed 375°F (190°C). When fluid, the enamel should be applied quickly over tacky cutback primer since it sets and hardens rapidly.

Polyester. These resin coatings are two- or three-part systems consisting of polyester, peroxide catalyst, and sometimes a promoter. The amount of catalyst mix should be carefully controlled because it affects the rate of hardening. The catalyst and promoter are mixed separately into the polyester. Fillers, glass fabrics, or fibers used to reduce shrinkage and coefficient of expansion compensate for the brittleness of resin and increase strength.

Coatings with a 2- to 4-hour pot life generally cure in 24 to 36 hours at 75°F (24°C). Shorter curing periods require reduced pot life because of high heat of reaction. Coatings are sensitive to changes in temperature and humidity during the curing period. Some coatings can be applied to damp surfaces at temperatures as low as 50°F (10°C). The alkali resistance of some polyesters is limited. It is recommended that trained personnel apply the coatings.

Urethane. These coatings may be one- or two-part systems. A one-part system may be moisture cured or oil modified. The coatings cure by reacting with moisture in the air. They can be applied on dry surfaces to prevent hardness during the curing period. Oil-modified coatings dry by air oxidation and generally have the lowest chemical resistance of the urethane coatings. Two types of the two-part system are also available: catalyzed and polyure. Catalyzed coatings have limited pot life after mixing and curing rapidly. For polyure-cured coatings, the mixture is stirred well and allowed to stand for about one-half hour before use; it should have a pot life of about 6 hours. Polyester-cured coatings are the most chemically resistant of the urethane coatings but require the greatest care in application. All urethane coatings are easily applied by brush, spray, or roller. For immersion service in water and aqueous solutions, it may be necessary to use a primer and the urethane producer should be consulted. Satisfactory cure rates may be attained at relative humidities of 30% to 90% and temperatures between 50°F and 100°F (10°C and 38°C). Lower temperatures will retard the rate of cure.

The principal disadvantages of urethane coatings are the very careful surface preparation needed to ensure adhesion and the difficulty in recoating unless the coating is sanded. Multiple coats should be used and an inert filler added if voids are present on the concrete surface (the coatings are unable to span air voids).

12. Epoxy. These coatings are generally a two-package system consisting of epoxy resin—which may be formulated with flexibilizers, extenders, diluents, and fillers—and a curing agent. The coating properties are dependent on the type and amount of curing agent used. The common curing agents suitable for room-temperature curing are amines, polyamines, amine adducts, polyamines, and tertiary amines. The single-package coatings are epoxy esters that are generally inferior to the two-package epoxies in chemical resistance. They require an alkali-resistant primer and are not recommended for immersion service. Some epoxy formulations are 100% solids and others are solution coatings. The formulator's recommendations should be followed in selecting the right system for the protection needed.

It is also desirable to follow the formulator's recommendations for the best application procedures, temperatures, and allowable working life. Generally, three coats must be applied to eliminate pinholes; glass flake may also be used to bridge pinholes. Contact with epoxy resins or hardeners can cause skin irritation or allergic reactions, and proper protection, as recommended by the manufacturer, is necessary.

Epoxy linings may be formed with reinforcement such as woven fabrics, mats, or chopped glass fiber. For example, on concrete that may expand or contract significantly due to temperature or moisture changes, an isolation layer of two-component polysulfide joint sealant of the self-leveling type is troweled over the surface to form a 1/32-in.-thick (1-mm) layer of synthetic rubber. As soon as the rubber has cured, the epoxy coating is applied with a roller to a film thickness of 1 mil (0.25 mm). Then fiberglass cloth is spread over the wet epoxy coating and pressed into it. A second epoxy coating is applied immediately to embed the fiberglass. There are epoxy systems that cure at temperatures of 40°F (5°C) or less, bond to damp surfaces, and will cure even if flooded with water immediately after application.

13. Neoprene. These coatings may be one- or two-part systems. The one-part system is used as a thinner film than the two-part and generally has a lower chemical resistance. It cures slowly at room temperature and some curing agents may limit its shelf life. The two-part system may require a holding period between mixing and application.

To allow evaporation of water from the concrete, application of either system should not begin for at least 10 days after removal of the forms. Some coatings require primers, while others are self-priming. Adhesion is often improved by application of a diluted first coat to increase penetration of the surface. Each coat should be sufficiently solvent-dry before the next application; however, if it becomes too fully cured, it may swell and lose adhesion. Three coats, 2 to 3 mils (0.025 to 0.038 mm) each, are normally recommended to eliminate the
possibility of pinholes. For immersion service, minimum dry thickness should be 20 mils (0.5 mm).

14. Polyurethanes. These coatings may be one- or two-part systems. They do not harden with age and they remain rubbery over a broad temperature range. Thick coats of 20 to 50 mils (0.5 to 1.25 mm) can be applied at one time. For the two-part systems, atmospheric moisture serves as the curing agent; when humidities are low, curing can be hastened by spraying with a fine water mist. The two-part system usually has a pot life of 30 to 60 minutes and becomes tack-free overnight.

15. Coal tar-epoxy coatings are classified in three main types according to epoxy resin content: high-resin coatings for dry thicknesses of 15 mils (0.38 mm), medium-resin coatings for integral linings of concrete pipe; and low-resin coatings for building nonsagging barriers up to 40 mils (1 mm) thick. The first type requires a special primer and its thickness is achieved in two coats. The other types do not require primers and may be applied in a single coat, but they require a relatively long cure time. Some coal tar-epoxy resin coatings are catalytically cured with a hardener or with both hardener and catalyst.

Coal tar-epoxy coatings are a two-package system. A combination of coal tar, filler, solvent, and epoxy resin may be in one package and the curing agent (commonly amine, polyanine, amine adduct, polyamide, or tertiary amine) in the other. These two packages are usually mixed in a ratio of 2:1 to 1:0.5, but the ratio may be lower. The coal tar, filler, solvent, and curing agent may also be blended together to make up one package and the epoxy resins in separate for the other package. These two packages are generally mixed in a ratio of 3:1. The packages must be proportioned correctly to secure proper cure and chemical resistance. Storage life of the blenders can vary from six months to two years, depending on formulation.

It is important that the two packages be thoroughly mixed and power agitation is strongly recommended. Mixing small quantities is not advisable. Insufficient mixing will be revealed only after the coating has cured. For some coatings, a one-half-hour waiting period between mixing and application is desired. Pot life is generally 3 to 4 hours at 70°F (21°C), but it may vary from several minutes to 6 hours, depending on solvent content and formulation.

Some coal tar-epoxy coatings should not be applied at temperatures below 50°F (10°C) or when there is danger of their becoming wet within 24 hours of application. However, there is a coal tar epoxy that can be applied at temperatures lower than 40°F (5°C) that will not be harmed by becoming wet immediately after application and can be recoated even after several weeks. Spray applications generally result in better coverage. However, the sides of a short, stiff bristle brush or a long-nap roller may be used. The second coat should be applied within 48 hours to prevent adhesion problems between coats. The first coat dries at air temperatures above 75°F (24°C), the producer's maximum recommended time between coats must be observed. These coatings should not be put into service until a minimum of 5 days' curing time has elapsed.

16. Chemical-resistant masonry units and mortars. Three basic types of chemical-resistant masonry units are available: Type H brick, generally fire clay; Type L brick, generally shale; and carbon and graphite brick, intended for use where additional chemical resistance is required. Types H and L brick should conform to Standard Specifications for Chemical-Resistant Masonry Units (ASTM C279).

brick thickness generally varies from 1% to 3% in. (30 to 100 mm), depending upon severity of service conditions. Brick surfaces should be scored or wire cut (matte texture). The brick must, of course, be laid in mortar that is also chemical resistant.

The chemical resistance of mortars may be evaluated by the Standard Test Method for Chemical Resistance of Mortars (ASTM C267). The more commonly used chemical-resistant mortars may also be used alone, without masonry units, to form thick coatings, usually applied by trowel. These mortars are:

a. Asphactic and bituminous mortars—for use over a limited range of low temperatures. Some are sand- filled, others are not. They may be applied either as mastics that depend upon evaporation of solvent or as hot-melt compounds.

b. Epoxy resin mortars—two- or three-part systems with either amine or polyamide curing agents. They should conform to Standard Specifications for Chemical-Resistant Mortars (ASTM C395) or Standard Specification for Resin Chemical-Resistant GROUTS (ASTM C658). For instructions on their use, see the Standard Recommended Practice for Use of Chemical-Resistant Mortars (ASTM C399).

c. Epoxy mortar—should conform to ASTM C399 or C658. They require a primer to ensure satisfactory adhesion to concrete. For their use, see ASTM C399.


e. Phenolic resin mortars—should conform to ASTM C399. For instructions on their use, see ASTM C399.

f. Polyester resin mortars—should conform to ASTM C398. Their resistance to strong chemicals is limited, but they will withstand mildly oxidizing solutions such as bleach. For instructions on their use, see ASTM C398.

g. Silicate mortars—should conform to Standard Specifications for Chemically Setting Silicate and Silica Chemical-Resistant Mortars (ASTM C486). For instructions on their use, see the Standard Practice for Use of Chemically Setting Chemical-Resistant Silicate and Silica Mortars (ASTM C387).

h. Sulfur mortars—should conform to Standard Specifications for Chemical-Resistant Sulfur Mortar (ASTM C267). For instructions on their use, see the Standard Recommended Practice for Use of Chemical-Resistant Sulfur Mortars (ASTM C386).

A bed of mortar or an impervious membrane lining is usually placed between the masonry lining and the concrete. Rubber and vinyl sheets or properly primed
and hot-applied ¾-in-thick (10-mm) asphaltic materials, both plain and glass-cloth reinforced, are preferred for the membrane lining, depending on the corrosive substance. The primer should conform to Standard Specifications for Primer for Use with Asphalt in Damproofing and Waterproofing (ASTM D-2411), except that the asphalt content should not be less than 35% by weight. Floor slabs that are to receive a masonry lining should have a smooth wood-fibral finish. A slab having a steel-trowel finish may be too smooth for adhesion of the asphaltic membrane.

17. Sheet rubbers. Soft natural and synthetic rubber sheets ¼ to ½ in. (3 to 12 mm) thick may be cemented to concrete with special adhesives. Sometimes two layers of soft rubber are used as a base, with a single layer of hard rubber over them.

Chemical-resistant synthetics available as sheeting are neoprene, polyvinylidene chloride-acrylonitrile, plasticized polyvinyl chloride, polyisobutylene, butyl, nitrile, polysulfide, and chlorosulfonated polyethylene rubbers.

18. Resin sheets. Synthetic resins, particularly polyester, epoxy, and polyvinyl chloride, are available as sheet materials. These sheets are not referred to in the tables but may be used wherever comparable resin coatings are recommended. They are often glass fiber reinforced and may be cemented to concrete with special adhesives.

19. Lead sheet. In the United States, lead sheet used for chemical resistance is called lead chemical lead. The sheets should be as soft as possible (to minimize the number of joints) but not too heavy to handle—the thinnest sheet may be as large as 9 x 20 ft (2.7 x 6.0 m). Thicknesses range from 1/84 to ½ in. (0.4 to 12 mm). Lead may be cemented to concrete with an asphaltic cement. Each sheet should be overlapped and the seam welded by conventional lead-burning techniques. If the lead is to be subjected to high temperatures, it may be covered with chemical-resistant masonry to reduce thermal stresses.

20. Glass. Two types have been used for corrosion resistance: high-silica glass and borosilicate glass. Borosilicate glass, the more alkali-resistant material, is recommended because alkalis in concrete may cause glass etching. Glass may be cemented to the concrete. Thermal shock is often a cause of failure in glass-lined structures.

References
4. ACI Committee 201, Guide to Durable Concrete, American Concrete Institute, Detroit, 1977.
### CORROSION RESISTANT FENCING MATERIALS FOR NM 128 SALT PLAYAS

<table>
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<tr>
<th>Material</th>
<th>Effect on concrete</th>
<th>Protective treatments</th>
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</tbody>
</table>

### SALT AND ALKALIES (SOLUTIONS)*

<table>
<thead>
<tr>
<th>Material</th>
<th>Effect on concrete</th>
<th>Protective treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicate</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sulfate</td>
<td>Disintegration</td>
<td>None</td>
</tr>
<tr>
<td>Phosphate</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Chloride</td>
<td>Slow dissolution</td>
<td>None</td>
</tr>
<tr>
<td>Sulfate</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sulfite</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Chloride</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sulfite</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Carbonate</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sulfate</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Chloride</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sulfite</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

*In porous or cracked concrete, chloride may cause cracking.

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8

**Notes:**
- Corrosion resistant materials are recommended for NM 128 salt playas.
- Use of concrete aggregate lessens corrosion.

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**Conclusion:**
- Corrosion resistant materials are recommended for NM 128 salt playas.
- Use of concrete aggregate lessens corrosion.
SOLVENTS AND ALCOHOLS

<table>
<thead>
<tr>
<th>Material</th>
<th>Effect on concrete</th>
<th>Protective treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon tetrachloride</td>
<td>None*</td>
<td>1, 2, 10, 12, 16 (b, c, e)</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>None* (see de-icers under &quot;miscellaneous&quot;)</td>
<td>1, 2, 5, 7, 10, 12, 13, 14, 16 (b, c, e, f, h), 17, 19</td>
</tr>
<tr>
<td>Ethyl ether</td>
<td>None*</td>
<td>11, 12, 16 (c, d, e)</td>
</tr>
<tr>
<td>Methyl alcohol</td>
<td>None*</td>
<td>1, 2, 5, 7, 10, 12, 13, 14, 16 (b, c, e, f, h), 17, 19</td>
</tr>
<tr>
<td>Methyl isobutyl</td>
<td>None*</td>
<td>10 (c, e), 17, 19</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>None*</td>
<td>10 (c, e), 17, 19</td>
</tr>
<tr>
<td>Toluene</td>
<td>None*</td>
<td>10 (c, e), 17</td>
</tr>
<tr>
<td>Triorthocresol</td>
<td>None*</td>
<td>12, 16 (b, c, e)</td>
</tr>
<tr>
<td>Triethylamine</td>
<td>None*</td>
<td>1, 2, 5, 7, 10, 12, 13, 14, 16 (b, c, e, f, h), 17, 19</td>
</tr>
<tr>
<td>Triorthocresol</td>
<td>None*</td>
<td>1, 2, 5, 7, 10, 12, 13, 14, 16 (b, c, e, f, h), 17, 19</td>
</tr>
</tbody>
</table>

*Triorthocresol is required to prevent loss from penetration, and surface treatments are generally used. **Frequently used as de-icer for airplanes. Heavily spalled concrete containing inefficient entrained air may cause surface scaling.

VEGETABLE OILS

<table>
<thead>
<tr>
<th>Material</th>
<th>Effect on concrete</th>
<th>Protective treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peppermint</td>
<td>Mild attack and considerable penetration</td>
<td>1, 2, 10, 11, 12, 14, 16 (b, c, e)</td>
</tr>
<tr>
<td>Almond</td>
<td>None*</td>
<td>1, 2, 6, 10, 11, 12, 14, 16 (b, c, e, f, h), 17, 19</td>
</tr>
<tr>
<td>Olive</td>
<td>None*</td>
<td>14, 18 (b, c, e, f)</td>
</tr>
<tr>
<td>Poppy seed</td>
<td>None*</td>
<td>14, 18 (b, c, e, f)</td>
</tr>
<tr>
<td>Walnut</td>
<td>None*</td>
<td>14, 18 (b, c, e, f)</td>
</tr>
<tr>
<td>Mergueine</td>
<td>Slow disintegration—faster with melted margarina</td>
<td>1, 2, 8, 10, 11, 12, 13, 18 (b, c, e, f)</td>
</tr>
<tr>
<td>Caper</td>
<td>None*</td>
<td>1, 2, 8, 10, 11, 12, 14, 16 (b, c, e, f)</td>
</tr>
<tr>
<td>Cocoa bean</td>
<td>None*</td>
<td>1, 2, 8, 10, 11, 12, 14, 16 (b, c, e, f)</td>
</tr>
<tr>
<td>Coconut</td>
<td>None*</td>
<td>1, 2, 8, 10, 11, 12, 14, 16 (b, c, e, f)</td>
</tr>
<tr>
<td>Cottonseed</td>
<td>None*</td>
<td>1, 2, 8, 10, 11, 12, 14, 16 (b, c, e, f)</td>
</tr>
<tr>
<td>Mustard</td>
<td>None*</td>
<td>1, 2, 8, 10, 11, 12, 14, 16 (b, c, e, f)</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>None*</td>
<td>1, 2, 8, 10, 11, 12, 14, 16 (b, c, e, f)</td>
</tr>
</tbody>
</table>

*Applied in thin coats, the material quickly saturates and has no effect. The effect indicated above is for sustained exposure to the material in liquid form.
### FATS AND FATTY ACIDS (ANIMAL)

<table>
<thead>
<tr>
<th>Material</th>
<th>Effect on concrete</th>
<th>Protective treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish liver</td>
<td>Disintegration</td>
<td>2, 9, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Fish oil</td>
<td>Slow disintegration with moist fish oil</td>
<td>2, 9, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Whale oil</td>
<td>Slow disintegration</td>
<td>1, 2, 3, 8, 9, 10, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Neatfoot oil</td>
<td>Slow disintegration</td>
<td>1, 2, 3, 8, 9, 10, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Tallow and tallow oil</td>
<td>Slow disintegration</td>
<td>1, 2, 3, 8, 9, 10, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Beef fat</td>
<td>Slow disintegration with solid tetraethanol with metal</td>
<td>1, 2, 3, 8, 9, 10, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Lard and lard oil</td>
<td>Slow disintegration</td>
<td>1, 2, 3, 8, 9, 10, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Slaughterhouse waste</td>
<td>Disintegration due to organic acids</td>
<td>8, 10, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
</tbody>
</table>

### MISCELLANEOUS

<table>
<thead>
<tr>
<th>Material</th>
<th>Effect on concrete</th>
<th>Protective treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia Liquid</td>
<td>None, unless crude harmfull ammonia acts on concrete</td>
<td>6, 8, 9, 10, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Vapors</td>
<td>Possible slow disintegration of moist concrete and steel attached to paper or cracked mass concrete</td>
<td>6, 8, 9, 10, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Asbestos</td>
<td>Harmful if wet, when sulfide and sulfinates leach out into water. Acidized, under “Salt and Alkalies”</td>
<td>1, 2, 3, 8, 9, 10, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Hot</td>
<td>Thermal expansion</td>
<td>96 (sodium alginate cement, fly ash) and refractory-silicate-clay mortars</td>
</tr>
<tr>
<td>Automobile and diesel exhaust gases</td>
<td>Possible disintegration of moist concrete by action of carbon monoxide or sulfide acid gases und “Asbestos”</td>
<td>1, 2, 3, 8, 9, 10, 12, 13, 16 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Baking soda</td>
<td>None</td>
<td>1, 2, 3, 8, 9, 10, 11, 12, 10 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Beer</td>
<td>No progressive disintegration, but in beer storage and fermentation tanks a special coating is used to protect against beer contamination. Beer may support the growth of yeasts, yeasts, bacteria, insects, or animals (see under “Acid”).</td>
<td>1, 2, 3, 8, 9, 10, 11, 12, 10 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Baking solution</td>
<td>See the specific chemical, such as hydrofluoric acid in concrete</td>
<td>1, 2, 3, 8, 9, 10, 11, 12, 10 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Borax crystals</td>
<td>See anhydrous, sodium, under “Salt and Alkalies”</td>
<td>1, 2, 3, 8, 9, 10, 11, 12, 10 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Borax</td>
<td>See chlorides, sodium, or other salts under “Salt and Alkalies”</td>
<td>1, 2, 3, 8, 9, 10, 11, 12, 10 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Boraxite</td>
<td>Disintegration if borax is used, or if a liquid containing hydrochloric acid and water is used</td>
<td>1, 2, 3, 8, 9, 10, 11, 12, 10 (b, c, d, e, f, i, 17)</td>
</tr>
<tr>
<td>Buttermilk</td>
<td>Disintegration due to lactic acid</td>
<td>1, 2, 3, 8, 9, 10, 11, 12, 10 (b, c, d, e, f, i, 17)</td>
</tr>
</tbody>
</table>

**Common Acids and Solvents**

- Butyl mercaptan: Slow distillation
- Carbon disulfide: Gas may cause permanent shrinkage. See paraffinic acid under “Acid”.
- Caustic soda: See hydroxide sodium, under “Salt and Alkalies”.
- Chole sulfate: See nitrite sodium, under “Salt and Alkalies”.
- Choline gas: Slow distillation of moist concrete
- Chrome plating solutions: Slow distillation
- Cider: Slow distillation, see acetic acid under “Acid”.
- Chlorides: See chelate above
- Coal: None, unless coal is high in pyrite, sulfuric acid and sulfur. Sulfinates leaching from damp coal may oxidize to sulfuric or sulfuric acid, or ferrous sulfite (see under “Acids” and “Bacteria and Alkalies”). Reseal is greatly retarded by deposit of an insoluble film.
- Coke: Sulfinates leaching from damp coke may oxidize to sulfuric or sulfuric acid, or ferrous sulfite (see under “Acid”).
- Copper plating solutions: None
- Corn syrup: Slow distillation
- De-icers: Chlorides (calcium and sodium, urea, and ethyl alcohol cause scaling of non-ferrous metals).
- Distiller’s wash: Slow distillation due to tolerant solid
- Faroingating: Slow distillation. Industrial fermentation processes produce lactic acid in sea water under “Acid”.
- Flavorings: Flavoring gas (400-1100° F.) causes thermal erosion. Cured, conditioned sulfuric acid hydrochloric acids disintegrate concrete slowly.
- Formulated fertilizers: 37% (fertile) slow distillation due to ferrous acid formed in solution
- Fruit juices: Lignite if any effect on moist fruit juices as arsenic and acidic acid do not appreciably affect concrete. Sugar and hydrochloric acid and other acids cause disintegration.
- Gas water: Ammonium sulfide, present in sufficient quantity to cause concrete disintegration.
- Glass: None
- Glyceryl triacetate: None
- Hydrogen sulfide: Slow distillation in moist soil or water. Hydrogen sulfide converts to sulfuric acid
- Isopropyl alcohol: Slow distillation
- Lead refining solution: Slow distillation
- Lactic acid: Slow disintegration
- Lignin: Slow disintegration
CORROSION RESISTANT FENCING MATERIALS FOR NM 128 SALT PLAYAS

**Lignite oils**
Slow disintegration if fatty oils present

**Lye**
See hydrates, sodium and potassium under "Salt and Alkalies"

**Munition**
Slow disintegration

**Mash, fermenting**
Slow disintegration due to acetic and lactic acids and sugar

**Milk**
None unless milk is sour. Then lactic acid disintegrates concrete slowly.

**Mine water, waste**
Sulfates, sulfides, or acids present disintegrate concrete and attack steel in porous or cracked concrete

**Molasses**
Slow disintegration at temperatures 127°F

**Nickel plating solutions**
Slow disintegration due to nickel ammonium sulfide

**Nitric**
See nitrate, potassium, under "Salt and Alkalies"

**Graze**
Sulfides leaching from damp zones may oxidize to sulfuric acid or ferrous sulfate (see under "Acid" and "Salt and Alkalies")

**Pickling brine**
Steel attacked in porous or cracked concrete. See stains, bronze, oil, or klinger.

**Salt ammonium**
See chloride, ammonium, under "Salt and Alkalies"

**Salt water**
See chlorine, sodium, under "Salt and Alkalies"

**Sulfuric acid**
Corrosion possible due to lactic acid. Flavor impaired by cement.

**Sea water**
Disintegration of concrete with inadequate surface resistance and steel attacked in porous or cracked concrete

**Sewage and sludge**
Usually not harmful. See hydroper sulfide above

**Slag**
Slow disintegration due to acetic, butyric, and lactic acids, and sometimes fermenting agents of hydrochloric or sulfuric acids

**Sodium hydrochloride**
Slow disintegration

**Sugar (sucrose)**
None with dry sugar on thoroughly cured concrete. Sugar solutions may disintegrate concrete slowly.

**Sulfite liquor**
Disintegration

**Sulfur dioxide**
None if dry. With moisture, sulfur dioxide forms sulfuric acid.

**Tannin bark**
Slow disintegration postulated if damp. See tannic liquor below

**Tannin liquor**
None with most tannins, including chromium. If liquor is acid, it disintegrates concrete.

**Tobacco**
Slow disintegration if organic salts present

**Trichloroethylene**
None

**Urea**
None (see decolor

**Urine**
None, but steel attacked in porous or cracked concrete

**Vinegar**
Slow disintegration due to acetic acid

**Washing soda**
None