
An Introduction to Tropical Engineering: Building Envelope

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1. THERMAL AND MOISTURE PROTECTION

1.1 SCOPE. This section covers various roofing systems and their performance in a hot and humid tropical environment of frequent winds, driving rain, and intense sun.

1.2 GENERAL DESIGN CONSIDERATIONS

1.2.1 ROOFING SYSTEMS. For the purpose of this discussion, roofing systems include the roof deck, insulation if used, the roof membrane, vents and drains, and any other element incorporated into the system. The following roofing types throughout the tropical humid zones are predominant because they have provided satisfactory service:

1.2.1.1 BUILT-UP (BITUMINOUS) ROOFING (BUR)

- (1) With Mineral-Surfaced Cap Sheet
- (2) Smooth Surfaced with Reflective Coating
- (3) With Gravel Surfacing

1.2.1.2 ELASTOMERIC ROOFING (SHEET-APPLIED)

1.2.1.3 ELASTOMERIC ROOFING (FLUID-APPLIED)

1.2.1.4 CORRUGATED METAL ROOFING

1.2.2 COMPARISON OF ROOFING SYSTEMS. For a comparison of roofing systems and materials, see Table 1.

1.3 BUILT-UP ROOFING (BUR)

1.3.1 GENERAL. Built-up roofing systems in tropical-humid environments have performed well, especially on roofs without insulation. Certain installations however have not performed well such as gravel surfaced roofs, roofs over insulation, and those

installed on existing dead flat roofs. The gravel surface, usually coral, blackens with algae and deteriorates, becoming a growth medium for sprouting seeds.

1.3.2 INSULATION. Insulating a BUR roofing system adds to the layers of an already labor intensive installation with a greater chance of moisture becoming entrapped in the system. The insulation provides a path for water infiltration from minor leaks which would have been only a local problem if the insulation was not under the roofing membrane. Where insulation is mandated, such as for air-conditioned buildings, carefully and properly install the roofing system to minimize these problems.

1.3.3 DESIGN GUIDELINES. Consider the following guidelines for all BUR installations:

- a) Use only glass felts. Do not use organic felts.
- b) Use Type IV asphalt.
- c) Use a reflective mineral surfaced cap sheet system or a reflective coated smooth surface system. Gravel surfacing is not recommended for use in the tropics and it is recommended that it not be used at all near airfields or in areas subject to hurricanes and typhoons. Where gravel surfacing is used, it is recommended that it be "double surfaced" (an additional surfacing of hot asphalt and aggregate placed over the original asphalt and gravel surfacing). This provides additional protection against lift-off and aggregate blowing during high winds. Note, however, that double surfacing adds both substantial weight and cost to the roofing system.
- d) Where insulation is required for a wood deck, install the insulation inside the building under the roof instead of on top, under the roofing if possible. This is not recommended for a concrete deck.
- e) Install the recommended built-up roofing system only on roofs with a minimum slope of 1/2 inch in 12 inches. In new construction, provide a slope to the structural deck of 1 inch per foot for positive drainage. For existing roofs of less than 1/2 inch per foot slope, consider another roofing system.

ROOFING TYPE	COST RANGE	WT/ 100 SF	SERV. LIFE	WAR-RANTY	UV-RESIS-TANCE	REMARKS
BUILT-UP Asphalt: Base sheet, 2 plys, mineral cap	1-2	400 lb	5-20	10-15	Good	Most prone, because of complexity, to leakage and sheet moisture entrapment in system.
FLUID-APPLIED Acrylic Elastomer w/o foam w/l in. foam Polyurthane Elastomer w/o foam w/l in. foam	2-3 4-5	23 lb 47 lb 30 lb 53 lb	7-20 7-20	1-20 1-20	Good Fair Good	Use on slopes 1/2:12 or greater. Do not use in areas with relative humidity averaging 80-85 percent annually. Recommend use of fast setting compounds. Moisture cured urethanes-use on slopes 1/4:12 or greater. Catalyzed urethanes - use on roof of any slope. Resistance to UV is good if top-coated with aliphatic urethanes.
SHEET-APPLIED Polyvinyl Chloride (PVC) Ethylene Propylene Diene (EPDM)	4-5 4-5	30 lb 35 lb	10-20 10-30+	5-10 10-25	Poor Good	Poor resistance to petroleum and solvents. Poor resistance to petroleum, most oils, and plastic roof cement.

Table 1
Roofing systems and materials

ROOFING TYPE	COST RANGE	WT/ 100 SF	SERV. LIFE	WAR-RANTY	UV-RESIS-TANCE	REMARKS
SHEET APPLIED (Cont.)						
Chlorinated Polyethylene (CPE)	4-5	30 lb	5-15	10 max.	Fair	Poor resistance to petroleum distillates, strong oxidizers, aromatic hydrocarbons.
Modified Bitumen	3-4	130 lb	5-15	5-10	Fair	Poor resistance to petroleum distillates, hydrocarbons, solvents, and some chemicals.
FIBER REINFORCED CEMENT (NON-ASBESTOS)	3-5	400-560 lb	30-50	30-50	Good	Use on slopes 4:12 (w/o waterproofing).
CORRUGATED METAL						
Aluminum	3-4	60 lb	10		Good	
Galvanized Steel	3-4	180 lb	10		Good	

Table 1 (continued)
Roofing systems and materials

1.4 SINGLE-PLY ROOFING SYSTEMS (SHEET APPLIED). Single-ply roofing systems have been in place on roofs in tropical-humid environments for many years. Failures generally have been limited to roofs of composite preformed sheets with vinyl as part of their makeup. These sheets shrink and become brittle under the intense tropical sun. On the other hand, rubber sheets of EPDM have proven to be notably successful when applied directly to concrete roof decks or over insulation by the fully adhered method.

1.4.1 EPDM (ETHYLENE PROPYLENE DIENE MONOMER). This material is an elastomeric rubber sheet specially formulated as a flexible, stretchable roof covering. It is applied to the substrate by one or a combination of three methods:

- a) Fully-adhered with a bonding adhesive

- b) Mechanically fastened
- c) Loose-laid and ballasted with concrete pavers

Fully-adhered and mechanically fastened systems, only, are recommended for use in the tropics and especially in the areas subject to hurricanes and typhoons. EPDM sheets are manufactured in 9- to 10-foot wide sheets which are cut to length, allowed to relax, and then glued to the substrate. Laps are glued with splicing cement. The black EPDM sheets are either manufactured with a light-colored, factory-laminated reflective EPDM or Hypalon sheet, or can be coated with a reflective liquid coating after installation. In the tropics, coat the EPDM. Recoating will be necessary in 3 to 5 years to maintain high reflectivity. The type with the factory-laminated reflective surface is recommended as the life of the membrane will far outlast the field-applied coating. After the factory-applied surface has deteriorated (about 10 years in the tropics) the EPDM membrane can be field-coated for reflectivity. EPDM sheets are produced in various thicknesses; but only consider the 60 mil thickness for use. The usual insulation for EPDM roofing is a composite urethane/perlitic fiberboard which is installed with the perlite fiberboard to the roof using hot asphalt and the EPDM to the urethane side with adhesives. EPDM roofing is not resistant to grease and oil and cannot be installed near exhaust vents from food preparation areas.

1.4.2 MODIFIED BITUMEN. This sheet membrane roofing does not yet have an extensive track record for installation in a tropic humid environment. Single-ply membrane is composed of bitumen modified with plasticizers. The modified bitumen/reinforced (MB/R) membrane includes a reinforcement at mid-depth with a glass fiber or similar reinforcing mat. Total membrane thickness for MB/R is about 160 mils (slightly less for non-reinforced membranes). The membrane is bonded to the substrate in its own hot asphalt with a torch applied to the membrane as it is rolled into place. If this system is applied over urethane foam insulation, first protect the insulation with another layer of rigid perlite fiberboard insulation with joints staggered over those of the urethane board below. If insulation is required, if at all possible, place the insulation inside under the roof deck. It is recommended that the modified bitumen membrane not be installed on roofs

with a slope of less than 1/2 inch in 12 inches. Modified bitumen membrane is not tolerant of ponding water.

1.5 ELASTOMERIC ROOFING (FLUID-APPLIED).

1.5.1 ELASTOMERIC LIQUID RUBBER COATINGS. These will provide a highly reflective surface that will remain so for many years. Such a coating will greatly reduce air conditioning loads even in un-insulated buildings. Material, whether it be urethane, silicone, or acrylic has the following properties.

- a) The material has high solids liquid, 60 percent volume solids and must be resistant to ultraviolet light or greater;
- b) It must be capable of at least 150 percent elongation and recovery, and must adhere to the substrate; and
- c) The material selected must withstand ponding water, especially if the roof slope is less than 1/2 inch in 12 inches, and if the coating is protecting the topside insulation.

1.5.2 APPLICATION. Elastomeric liquids are usually applied to a clean, dry substrate with airless spray, brush, or roller. The coating is self-flashing and can be sprayed up vertical surfaces. Apply the coating to a minimum thickness of 60 mils, but 60 mils to 90 mils is recommended as a minimum if the liquid coating is over the topside insulation such as sprayed in-place polyurethane foam (PUF). Achieve the recommended thickness by applying successive coats of approximately 20 mils each. Vary each coat slightly in color (grey, tan, and white for example) so that the final coat is of the desired color and the covering of the preceding coat can be observed and measured.

1.5.3 ACRYLIC ELASTOMERS. These are usually water based, which makes them easy to apply and to clean up; and they are relatively inexpensive. Select material that has a short cure time.

1.5.4 POLYURETHANE ELASTOMERS. These materials can be either one- or two-component and are usually spray applied. Granules are often added to the final coat to provide traction (silicone can be slippery) and to harden the final coat. These coatings are prone to pin-holing when applied in thick coats (over 30 mils wet).

1.5.5 VINYL, HYPALON, AND NEOPRENE. These coatings are not recommended because of their low volume solids. Butyl coatings are not recommended because they are not resistant to high levels of ultraviolet light.

1.6 SHINGLE AND TILE ROOFING. Wood shingles and shakes, clay tile, and similar roofing materials are not recommended for consideration in tropical humid environments for various reasons, including high initial cost and short life due to rapid deterioration. Asphalt shingles, with lower initial cost, can require frequent maintenance and repair in high-wind areas.

1.7 FIBER-REINFORCED CEMENT ROOFING. Cement-asbestos roofing and siding has been a long-life, maintenance-free material which has been used successfully throughout the tropics and elsewhere. However, because of the health and environmental problems with asbestos, it is no longer available. Non-asbestos similar products are now being manufactured in shingle and corrugated sheet forms, and they perform well in a tropical or humid environment.

1.8 CORRUGATED METAL. Corrugated metal roofing, as used herein, includes galvanized metal and aluminum. The material may be factory coated or unfinished. This material is generally utilized as roofing and siding for prefabricated warehouse type structures but also have been used on commercial and residential structures. Provide adequate fastenings and building tie-downs in hurricane and typhoon areas.

1.8.1 GALVANIZED STEEL. Use 24 gauge minimum and coat on both sides to provide an acceptable long life. Factory finishing is recommended. The coating must be of adequate thickness and be ultraviolet resistant.

1.8.2 ALUMINUM. Aluminum roofing is 18 gauge minimum and anodized (0.7 mil) or otherwise factory coated on both sides. Separate the aluminum from the steel framework by applying a bituminous coating to either the aluminum or the steel at the bearing points. Use stainless steel fasteners.

1.9 INSULATION AND VAPOR BARRIER. Give special consideration to particularly high humidity locales such as Guam, Philippines and Diego Garcia where the 1 percent outdoor ambient dewpoint temperatures in excess of 70 degrees F may be higher than the design indoor dry bulb temperature. Where this situation exists, select the insulation to maintain its exterior surface temperatures above the ambient dewpoint temperature. Install a continuous vapor barrier at a location where its temperature will be above the ambient dew-point temperature to prevent water vapor from infiltrating and condensing within the walls. (See Figures 1 and 2.)

1.9.1 FOAM GLASS. Foam glass rigid insulation board is a good insulating material with a high heat resistance (R) value, is dense enough for foot traffic, and will not absorb water. However, foam glass is expensive and, therefore, is not often used as a roof insulation.

1.9.2 FIBERGLASS. Fiberglass insulation is often used as a topside insulation under built-up roofing membrane. This insulation will readily absorb, conduct and hold water and is, therefore, often the cause of a roofing failure. On the other hand, fiberglass is a very good insulating material when placed inside the building on top of a suspended ceiling. Fiberglass is not recommended as a topside insulation.

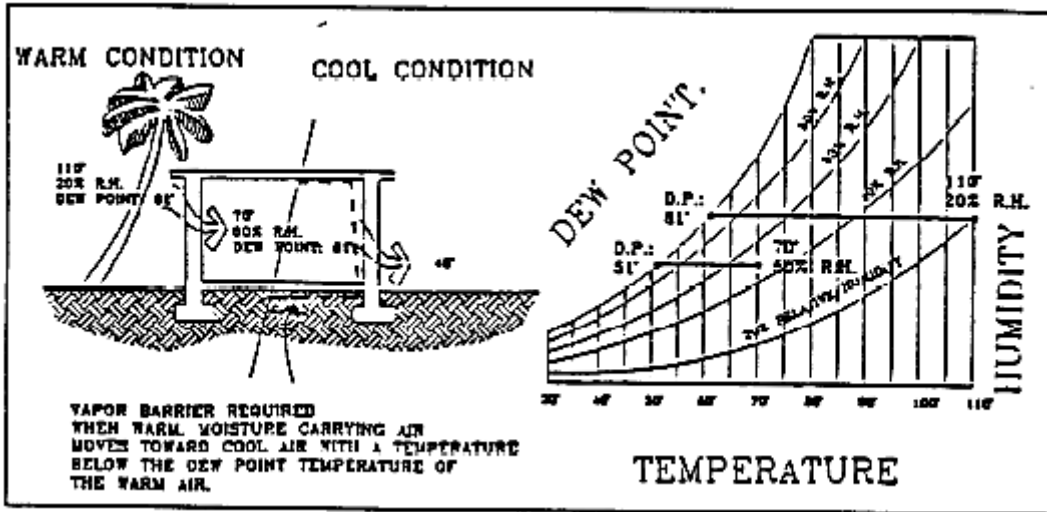


Figure 1
Moisture migration and dew point

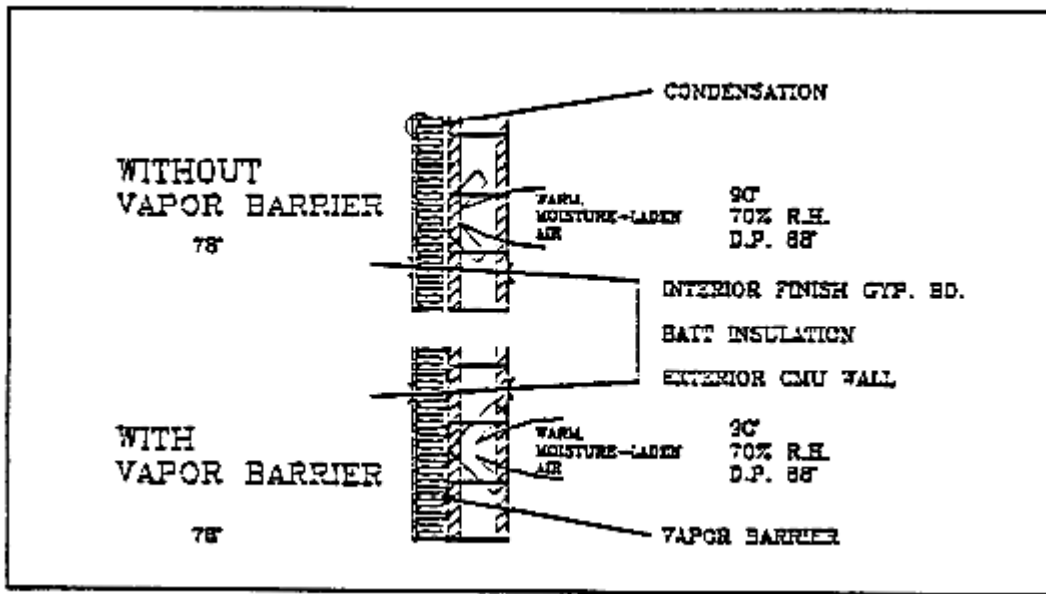


Figure 2
Moisture migration and vapor barrier

1.9.3 SPRAYED IN PLACE POLYURETHANE FOAM (PUF). PUF has been used as roof insulation. However, Polyurethane foam has the difficulty of obtaining skilled applicators, and the impracticability of applying it in windy conditions limit its use in the tropics.

1.9.4 POLYURETHANE BOARD. Rigid polyurethane board insulation is manufactured faced and unfaced. Facings include foil and perlitic fiberboard. The boards are secured to the deck with mechanical fasteners or with hot asphalt. In the latter case, the urethane is faced on one or both sides with perlitic fiberboard. Rigid polyurethane insulation board is recommended for use under EPDM single-ply roofing. In this case, use board that is faced on the bottom side with fiberboard and top side with foil. When used with a BUR system, add a second layer of fiberboard with joints staggered over those of the urethane board below.

1.9.5 FIBERBOARD. Fiberboard is not recommended as a roof insulation in the tropics. It will absorb, conduct and hold water. It swells when wet and deteriorates. As a result, the roofing system may blow off when subjected to high winds.

1.9.6 FLASHING AND SHEET METAL. Many roofing systems are self-flashing or flashing materials are provided by the roofing material manufacturer.

1.9.6.1 FLASHING, GUTTERS, AND DOWNSPOUTS. In an atmosphere laden with salt spray, stainless steel is recommended. Where salt spray is not severe, flashings, gutters, and downspouts may be of stainless steel, aluminum alloy (3003-N14), or copper. Where aluminum is specified, ensure thickness is not less than 0.032 inches. In hurricane and typhoon areas, ensure aluminum thickness is not less than 0.065 inches where exposed to the direct wind. Aluminum may be used over concrete construction, provided that required reglets are of stainless steel, and aluminum surface in contact with concrete or masonry is coated with bituminous paint or zinc chromate primer. Use stainless steel nails, screws, bolts, and fasteners. Also, secure flashing at one-half the normal interval

to ensure a wind-resistant installation. Galvanized steel sheet is not recommended for flashing or for gutters and downspouts.

1.9.7 VENT FLASHING. Lead sheet is recommended for plumbing vents.

1.10 SEALANTS

1.10.1 GENERAL. Because of the constant threat to structures in the tropics caused by the intrusion of moisture and salt-laden air, incorporate adequate control joints in the structure design, and properly detail joints to be sealed on the drawings.

1.10.2 SELECTION. There are only three unique considerations for selection of sealants and seals (preformed tapes, foams, and extrusions) for use in the tropics. They are resistant to ultra-violet light, resistant to immersion in or prolonged exposure to water, and resistant to extreme high temperatures.

1.10.2.1 UV RESISTANCE. Rubberized bituminous material, polysulfide and polyurethane sealants, and styrene butadiene rubber closure strips all show only fair to poor UV resistance. Do not consider these materials for exterior applications where they are exposed to direct sunlight.

1.10.2.2 WATER IMMERSION. Bituminous, butyl, polybutene, polyvinyl acetate latex, polyurethane, poly mercaptan, and polyisobutylene sealants all show poor service characteristics when immersed in water. Consider this in joints which might be subjected to periodic flooding, or which might be exposed to constant, prolonged rainfall or wind-driven spray.

1.10.2.3 HIGH TEMPERATURES. Although ambient temperatures may seldom exceed 110 to 120 degrees F in tropic regions, portions of structures in these areas may well reach 180 degrees F, or greater depending upon the material, when exposed to direct sunlight. Polybutene, bituminous, acrylic-latex, polyvinyl acetate latex sealants,

polychloroprene (neoprene), polyvinyl chloride (PVC), and polyurethane foams, and neoprene, PVC, and styrene butadiene rubber extruded seals and closure strips have maximum recommended service temperature ranges from 130 to 180 degrees F. Do not use these materials where structural elements exposed to sunlight may exceed these temperatures.

2. DOORS AND WINDOWS

2.1 SCOPE. This section covers exterior and interior type wood, metal, and glass doors and windows; glazing; and finish hardware.

2.2 GENERAL DESIGN CONSIDERATIONS

2.2.1 DOOR AND WINDOW SYSTEMS. To minimize the destructive corrosive tropical elements that generally cause door and window assemblies to fail, select pre-manufactured systems combined with quality control during installation. Exterior doors may be composed of metal, aluminum and glass, all wood and all glass. Window systems that utilize factory fabrication for all components including weather-stripping are highly recommended.

2.2.2 MAINTENANCE. A regular maintenance program is essential in the tropics to reduce the impact of the destructive elements. Weather damaged finish of wood or metal doors will expose the doors to rapid deterioration and costly replacement unless corrected promptly and properly. Design doors and frames against rain infiltration using weather-stripping, interlocking thresholds and other weather-sealing devices.

2.2.3 HARDWARE AND LOUVERS. Provide all metal exterior and interior doors with template hardware. Avoid louvered doors on exterior entrances; they are very susceptible to weather deterioration. Consider other means to provide the venting function. Ensure that louvers in doors are drainable, weatherproof and factory-primed. Doors with factory-installed louvers are also recommended.

2.3 WOOD DOORS. Treat all wood elements of exterior and interior doors.

2.3.1 EXTERIOR WOOD DOORS. These types of doors are flush solid core block with type one waterproof glue, face assembly, medium density overlay (MDO) on both faces. Prior to assembly, treat all woods used with a water repellent. In addition, treat all edges

with two coats of water repellent after fabrication, with all surfaces being factory sealed with spar varnish or other approved sealer prior to shipment. Do not use doors subjected to weather conditions with no protection from elements. Historically, failure of wood doors can be traced to lack of proper priming and finishing on all surfaces, including edges and sides of doors.

2.3.2 INTERIOR WOOD DOORS. These doors may be hollow, mineral or solid core doors with wood face veneers.

2.4 METAL DOORS

2.4.1 HOLLOW METAL DOORS. These are generally used for utility rooms, service rooms, exit doors, in areas subjected to above-normal physical abuse, and where required by local codes and ordinances. Under these conditions, all metal doors and frames are completely factory finished as well as salt spray, humidity, and weathering tested. Metal covered wood core doors are less desirable than hollow metal doors since the sheet metal cladding is lighter and subject to faster deterioration. Where sound transmission qualities are required, specify composite construction steel doors with a Sound Transmission Coefficient (STC) rating.

2.4.2 FIRE-RATED DOORS AND FRAMES. Strict requirements for fire doors and frames (i.e., labeled doors) preclude changes or modifications except when approved by the fire protection engineer. However, to assure maximum protection for fire doors with ferrous metal components, ensure all such metals are hot-dip galvanized; and, in addition, frames are shop primed.

2.4.3 GLASS DOORS. Where design or the aesthetics dictate solid glass or metal framed glass doors, frames are stainless steel, type 304 or 316 in 12, 14, or 16 gauge, polished and finished except where the exterior doors are in a well-protected area in which case aluminum (clear anodized after fabrication) may be considered.

2.4.4 PLASTIC LAMINATE FACED DOORS. Use plastic laminate covered doors primarily for interiors; however, under given design parameters, they could be used as an exterior door where weather protection is maximized (such as where door is on the lee side of the building or where the building overhang is sufficient to protect the door from wind-driven rain). These doors are also of hollow, mineral or solid cores, with high pressure decorative laminate facings on all exposed edges. Ensure exposed edges (top and bottom) are weatherproof treated against moisture and water penetration if door is to be used for exterior purposes.

2.5 WINDOWS

2.5.1 WINDOW SELECTION. Base the selection of window types on the standard building design criteria including wind conditions and frequency of tropical storms. Operable windows of the awning or projected type are the recommended options. Jalousie type windows are less desirable for air conditioned areas because of their high air and water infiltration factors.

2.5.2 ALUMINUM WINDOWS. Aluminum windows, whether fixed or operable, are the designer's only choice. Aluminum does oxidize readily and the finish specified should be anodic (clear or colored). Alternatively, factory-applied fluorocarbon or electro-deposited epoxy finishes provide excellent corrosion resistance and color retention. For added protection to anodized finishes, select a clear aliphatic urethane finish factory-applied over the anodic coating. Use stainless steel hardware for operable parts.

2.5.3 OTHER WINDOWS. Do not use steel, wood, and plastic-clad wood windows in tropic regions.

2.6 GLASS AND GLAZING. There are few unique requirements for glass and glazing in tropical areas except for the increased use of tinted glass. Size and thickness of glass may vary from non-tropical applications because of increased wind pressure. Plastic and rubber-glazing elements, including weather-stripping, must be UV-resistant.

2.7 FINISH HARDWARE. Do not use copper alloy screws or bolts to secure or connect aluminum items, even if the copper alloy item is plated. Use stainless steel or aluminum screws. Use stainless steel Type 302 or 304 screws and bolts on items exposed to the weather. Where 6061-T5 aluminum for threshold is secured to concrete floors, protect the contact surfaces of the threshold and concrete against galvanic or corrosive action. The use of galvanized bolts and screws exposed to the weather is discouraged. Use galvanized screws and bolts to secure or connect copper alloy items.

2.7.1 LOCKSETS. In a heavy salt spray environment, the entire lockset used on the exterior is stainless steel Type 302 or 304 including screws, bolts, and nuts. Standard commercial grade hardware is recommended for use when conditions are not as severe as direct salt spray. Interior lock and latch sets are either bronze or stainless steel Type 302 or 304, including fronts, strike, escutcheons, knobs, bolts and all interior working parts. In an air conditioned building commercial grade I locksets are acceptable. In a non-air conditioned building, use the same locksets recommended for exterior doors, marine grade I, fully non-ferrous.

2.7.2 HINGES. Hinges on exterior doors, whether exposed on the interior or exterior side of the door, are stainless steel Type 302 or 304 with stainless steel screws, bolts and pins. Hinges on interior doors are either cast or cold forged bronze or stainless steel Type 302 or 304. Screws, pins and bolts are bronze or stainless steel. Nylon or Teflon bearings may be provided; however, use ball bearing type hinges on large heavy doors and frequently used entrance/exit doors. Except for stainless steel, do not use ferrous metal as base metal for hinges. Fire-rated doors must have a base metal of either steel or stainless steel. Do not use bronze hinges on fire-rated doors. Use steel hinges with stainless steel pins. Do not use paint-grade hinges.

2.7.3 CLOSERS. Use stainless steel inside bracketed or door mounted closures on exterior doors. Non-ferrous closures, such as aluminum or cast bronze, are permissible where door utilization is minimal. Use Type 302 or 304 stainless steel or non-ferrous

closures on interior doors. On surface-mounted closers use a special rust inhibiting finish on all ferrous parts. This is also recommended for concealed closers.

2.7.4 EMERGENCY DEVICES. Use stainless steel or bronze base metal with plated finish.

2.7.5 CABINET HARDWARE. Cabinet hardware should be brass, bronze, or chrome plated. Do not use ferrous metal items.

2.7.6 MISCELLANEOUS HARDWARE. For all miscellaneous hardware for exterior doors use stainless steel, Type 302 or 304, or bronze except where aluminum doors and frames are permitted. Aluminum thresholds may be provided with the standard precautions for installation of aluminum items. Bathroom and toilet finish hardware are bronze or stainless steel. Do not use ferrous metal items.

3. FINISHES

3.1 SCOPE. This section covers gypsum wallboard, plastering systems, acoustic tile, and metal ceiling suspension systems; flooring materials; and paints and stains, including protective coatings.

3.2 GENERAL DESIGN CONSIDERATIONS. The general problems encountered after the design selection and installation of most finish materials are moisture infiltration, condensation and salt spray buildup, ultraviolet ray deterioration (of exterior finishes), and under certain design conditions, interior materials being subjected to wind penetration through exterior walls. As an example, in certain tropical areas, the primary cause of the impairment of a metal suspension system for ceilings is the high humidity level. All metal items are susceptible to "sweating" under this condition. The slightest difference in the temperature of the metal and the surrounding air temperature and dewpoint will condense moisture on the metal. If the metal is a ferrous metal, the subsequent rust and stain create a maintenance problem with the materials. Therefore, it is imperative that continual awareness of the above addressed problems be maintained during the design stage.

3.3 GYPSUM WALLBOARD. Gypsum wallboard is an economical wall finishing material if installed and used according to manufacturer's instructions. It is also an ideal material to provide adequate fire-rated protection for interior areas. Nevertheless, gypsum board is susceptible to damage in some facilities. Also, in a tropical environment, deterioration through absorption of moisture and termites attacking the paper facing may be a problem. Although 1/2-inch thick board may be used in some areas, minimum thickness of 5/8-inch is recommended. The use of polyvinyl chloride (PVC) trim, stops, screens, vents and expansion joints is recommended in lieu of zinc-coated ferrous metal in the tropics.

3.4 CEMENT-FIBER BOARD

3.4.1 GENERAL. Cement-fiber board is fire-rated, asbestos-free, and highly resistant to impact, rot, and moisture. Installation materials and methodology are similar to gypsum

wallboard. Its high impact resistance makes it an excellent economical alternative to plaster where the potential for damage precludes gypsum wallboard in high use/traffic areas such as living quarters and corridors, and high humidity areas such as kitchens and showers. Cement-fiber board is also suitable for exterior soffits.

3.4.2 SPECIAL BOARD TYPES. Many manufacturers produce prefinished, decorative cement-fiber panels providing concrete, plaster, and fine aggregate surface appearance for exterior siding. The board may also be used as a backer board for ceramic tiles and for exterior synthetic plaster finishes.

3.5 PLASTERING SYSTEMS

3.5.1 GENERAL. A portland cement-lime mix is corrosive to metal lath in tropical environments. To reduce plaster and stucco cracking which contributes to moisture and condensation infiltration, delete the lime base and substitute a liquid plasticizing agent with the principal ingredient of a resin compound. The result produces a material with greater resistance to most climatic effects in the tropical zone to minimize structure-related cracking. Include sufficient control joints.

3.5.2 EXTERIOR INSULATION AND FINISH SYSTEMS. These systems, consisting of an insulation board with integral scrim and synthetic plaster finish, are sold as a "complete system" by numerous firms. They have the advantage of providing a "plaster" exterior with integral insulation and can be applied to existing concrete and masonry surfaces as well as to wood or metal stud systems in new construction. Their disadvantage is that they can be installed only by manufacturer-approved installers. This may be an impossible criteria to meet in the tropics, particularly in remote areas. Additionally, damage to a large area of the surface, say in an accident involving a forklift or motor vehicle, will require repair using original materials and by an approved installer to maintain the manufacturer's warranty on thermal and moisture protection. Use these materials as a combined exterior finish with built-in layered insulation board, thereby achieving two separate functions: providing the finish plus insulating, which contribute to an energy-

efficient building. Their application can be over any substrate, both new and existing surfaces.

3.5.3 SPECIAL CONSIDERATIONS. If the surface is to be painted, do not use coral aggregate in the plaster system. If no option is available, use a sodium silicate system for stabilization.

3.6 ACOUSTICAL TILE AND METAL CEILING SUSPENSION SYSTEMS. Ceiling suspension main runners and cross runners, including wall channels, miscellaneous moldings and accessories, are an aluminum alloy and finished as applicable, except where fire-rated installation is a requirement. In fire-rated areas, a concealed grid system with galvanized steel, factory finished with baked enamel, is recommended.

3.6.1 HANGAR WIRE. Where the hanger wires are located in attic areas vented to the outside in a salt spray environment, use stainless steel or copper-bearing alloy wires. Do not vent attic areas above air-conditioned spaces where cold water lines or A/C ducts are located. Ensure that these areas are air conditioned to preclude condensation problems.

3.6.2 INSTALLATION. Dissimilar metal installation must include standard preventive measures against electrolytic corrosion. Ensure that all aluminum material has a minimum paint coil coating of 0.7 mil thickness. Where aluminum is in contact with concrete or masonry, coat the aluminum contact surface with bituminous paint or, where appearance is a requirement, a paint system consisting of a chromate primer and two-coat enamel finish. All nails, screws, bolts and fasteners are stainless steel or aluminum; except where galvanized steel is used (in concealed areas), galvanized screws and bolts may be used in lieu of stainless steel. Do not use aluminum for securing suspended ceiling systems onto concrete or masonry walls.

3.6.3 SPECIAL PANELS. In high-humidity areas, select acoustical lay-in panels in food service and bath areas and in areas with no air conditioning based on humidity resistance. These include scrubbable mineral composition panels, mineral-fiber/cement panels, and

aluminum pans. If regular cellulose composition panels are used, use them only in 2-foot by 2-foot grid systems.

3.6.4 MAINTENANCE CONSIDERATIONS. Ensure that ceiling systems, including acoustical tile and concealed suspension systems, are employed in air conditioned facilities, are under a continual maintenance program.

3.7 FLOORING MATERIAL. Do not use coral aggregate, dolomites, or limestone as a setting bed for tile or terrazzo. Wood flooring requires termite treated wood. Carpeting is a secondary-backed type installed with a rubber-coated pad.

3.8 PAINTS AND STAINS. Because of the severity of many tropical environments (high solar radiation, high temperatures, high rainfall and salt spray), paints frequently will not perform well at tropical locations. Mildew defacement and deterioration of paints may occur rapidly if preventive measures are not taken. Procurement delays, inadequate storage facilities, application equipment failures and general remoteness from more populated locations with available technical help may add further problems to the painting program.

3.8.1 MATERIAL SELECTION. The selection of paint materials and systems is frequently determined by a list of substrates and materials. The materials or systems listed for a given substrate perform suitably in the tropics if the substrate is properly prepared and the paint material is properly stored, handled, and applied. Where the guide specification gives one or more options, it is recommended that the superior option (i.e., an alkyd over a latex or an epoxy over an alkyd, for example) be selected.

3.8.2 SPECIAL CONSIDERATIONS. In cavity or double wall construction, apply a low permeable coating to exterior walls to help minimize the amount of moisture transfer through the wall. Apply a high permeable coating to interior wall surfaces to ensure that any water vapor that passes through the exterior coating and vapor barrier enters the air

conditioned space and does not remain trapped within the insulation and wall material. Use vinyl wall covering in air conditioned buildings when a vapor barrier is installed.

3.8.3 SUBSTRATE PREPARATION. In the tropics water infiltration and mildew growth are both problems where concrete masonry units are used. Include explicit instructions for surface preparation for both new and existing concrete and masonry surfaces. On new masonry surfaces, specify a latex block filler. The filler coat must be thoroughly brushed in, otherwise leaking will occur. Two finish coats of acrylic emulsion paint with mildewicide is recommended for both masonry and concrete surfaces. In tropical areas, take care to assure that wood, concrete and masonry surfaces are dry before painting. Latex paints may be more tolerant of damp surfaces but they are also slow drying where the humidity is high. Efflorescence (white to gray powdery products) may occur on concrete surfaces, especially on interior walls of air conditioned buildings. Include the appropriate requirements for efflorescence removal. Where moisture migration through concrete or masonry walls from the outside to the inside presents a problem, seal the outside with a surface conditioner or concrete primer to correct the problem. If interior concrete walls are continuously damp, cracks in roofs that allow the entrance of rainwater must be suspected. Repair these cracks as well as any cracks around the windows before painting. Do not paint interior steel that will be fireproofed.

3.8.4 REPAINTING. Localized repairs to a coated surface are ordinarily best made by cleaning exposed substrate, spot priming and topcoating with the same type of material existing on the surface. Topcoating of a weathered paint is generally done with a similar type of topcoat. In tropical areas, paints must be mildew-resistant. Microorganisms may utilize the oils in oleoresinous or alkyd paints as a source of food. Dirt, pollen or other surface contamination may also accelerate the growth of microorganisms. Softgel coatings and textured coatings permit more rapid pick-up of mildew. Thus, it is desirable to obtain hard, smooth, inert paint films and keep them free of contamination. Because of the high temperatures and rainfalls in tropical areas, store all materials indoors or out of direct sunlight. Procure no more paint at one time than can be used in one year. In topcoating weathered paint, remove all mildew, dirt, grease, chalk or other contaminants

that might deter good bonding along with loose paint. Dirt, mildew and other airborne contaminants collect rapidly in protected areas such as under the overhangs of roofs; remove them by appropriate cleaning prior to repainting.

4. SPECIALTIES

4.1 SCOPE. This section covers louvers and vents for exterior conditions, identifying devices, sun control, toilet compartment cubicles, and toilet room accessories.

4.2 LOUVERS AND VENTS FOR EXTERIOR CONDITIONS. It is recommended that all louvers and vents be aluminum, 6063-TS or 3003 alloy, welded or fusewelded frames, with an anodized coating of not less than 0.7 mil. Blades should be drainable and stormproof type. Design structural framework for wind loads occurring within the various areas of the tropical zone.

4.3 SIGNAGE

4.3.1 FIBERGLASS. These materials are fiber-reinforced, internally colored resinous plastics and will withstand most of the aggressive elements when used for exterior purposes. However, bright colors tend to fade when exposed to constant sunlight. Direct sun also causes delamination over the long run but this is not a problem for fiberglass used as signs. Fiberglass, unlike most other plastics used in signage, can be readily painted.

4.3.2 ACRYLIC PLASTIC AND PHENOLIC. Use these for interior purposes only.

4.3.3 PORCELAIN ENAMEL. Porcelain enamel can be factory baked on to either steel or aluminum. Use aluminum backing since damage to porcelain enamel over steel can be extensive (often causing the enamel frit to separate from the steel backing in an area 2 to 10 times the size of the point of impact). Use aluminum backing, specifying that the porcelain enamel be applied to both sides of the substrate, and that mounting holes be made before baking to adequately protect the substrate.

4.3.4 INSTALLATION. For exterior applications and interior use in heavy traffic areas, firmly attach signage to structure walls with tamper-proof fasteners. Mount large exterior

signs on two posts set in concrete. Adhere interior signage on doors to the door surface with waterproof silicone adhesive.

4.3.5 COLORS. Coordinate choice of colors with manufacturer's information with regards to color fastness when signs are subject to exterior environment.

4.4 SUN CONTROL. Interior and exterior sun control devices are categorized as interior blinds, both metal and woven fabrics, and woven fiberglass screens. Limit metals for sun control devices to prefinished aluminum with a minimum thickness of 0.032 inch for recommended spans. Fiberglass woven fabric should be rot- and weather-resistant, colorfast, dimensionally and thermally stable, and fire retardant where and when required.

4.5 TOILET COMPARTMENTS

4.5.1 MATERIAL SELECTION. In consideration of the severe salt-laden air and potential rust conditions, it is recommended that only noncorrosive materials be used in toilet compartments. Recommendation includes plastic laminate covering for wood core doors, division panels and urinal screens. Cast alloy, nonferrous chrome-plated hardware with stainless steel floor and ceiling panel fittings are also recommended.

4.5.2 PHENOLICS. An acceptable alternate to plastic laminate-covered doors and partitions is a plastic covered solid plastic phenolic resin core for compartment divisions. This material is waterproof, steam-proof, rust-proof and corrosion free. Galvanized steel with a bonderized enamel finish is not recommended, especially for urinal screens.

4.6 TOILET ROOM ACCESSORIES. For toilet and washroom equipment, construct all units from stainless steel (with all stainless steel moving parts), using welded connections where required, and with concealed mountings for vandal-proof installation. Where color is included as a requirement, specify vinyl vacuum bonded to stainless steel only, as cold-rolled steel will corrode in the tropical environment.