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PRELIMINARY DESIGN AND CONSTRUCTION GUIDELINES FOR VERTICAL CON--ETC(U)
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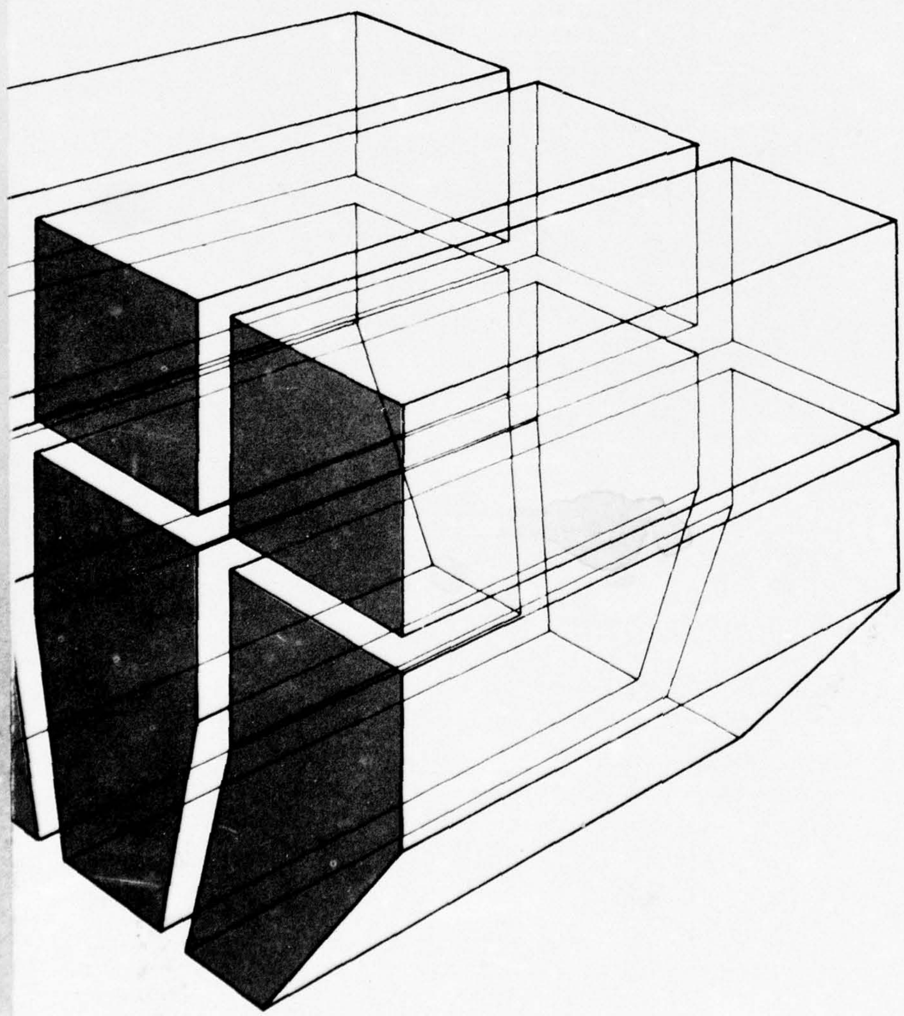
INTERIM REPORT C-74
October 1976
Vertical Construction in Desert and Tropic Regions

PRELIMINARY DESIGN AND CONSTRUCTION GUIDELINES FOR VERTICAL CONSTRUCTION IN DESERT AND TROPICAL THEATERS OF OPERATIONS



by
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(14) CERL-IR-C-74

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER INTERIM REPORT C-74	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) PRELIMINARY DESIGN AND CONSTRUCTION GUIDELINES FOR VERTICAL CONSTRUCTION IN DESERT AND TROPICAL THEATERS OF OPERATIONS		5. TYPE OF REPORT & PERIOD COVERED (9) INTERIM rept.,
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) A. Kao (10) Anthony Kao J. Cook Jere Cook		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS CONSTRUCTION ENGINEERING RESEARCH LABORATORY P.O. Box 4005 Champaign, Illinois 61820		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (16) (17) 4A762719AT41-T5-004
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE (11) October 1976
		13. NUMBER OF PAGES 36 (12) 37p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service, Springfield, VA 22151.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

vertical construction
desert climate
tropical climate

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study provides a simple description of the basic principles and guidelines that should be observed in designing and planning shelters in desert and tropical climates. The study identifies preferred materials, design, and construction details for use in the theater of operations (TO). Findings are based on actual Army field experience and research of existing literature pertinent to construction in desert and tropical regions.

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FOREWORD

This study was performed for the Directorate of Facilities Engineering, Office of the Chief of Engineers (OCE), under Project 4A762719AT41, "Design, Construction, and Operations and Maintenance Technology for Military Facilities"; Task T5, "Research for Base Development in Theater of Operations"; Work Unit 004, "Vertical Construction in Desert and Tropic Regions." The QCR number is 1.07.002. The OCE Technical Monitor is Mr. R. Barnard.

The work was conducted by the Military and Base Engineering Branch (FOM) of the Facility Operations Division (FO), U.S. Army Construction Engineering Research Laboratory (CERL). The Principal Investigator is Dr. A. M. Kao.

COL J. E. Hays is Commander and Director of CERL and Dr. L. R. Shaffer is Deputy Director. Mr. R. B. Blackmon is Chief of FO and Dr. E. L. Marvin is Chief of FOM.

CONTENTS

FIGURES

TABLES

PRELIMINARY DESIGN AND CONSTRUCTION GUIDELINES FOR VERTICAL CONSTRUCTION IN DESERT AND TROPICAL THEATERS OF OPERATIONS

1 INTRODUCTION

Background

In the past, building materials and systems used by the U.S. Army in tropical and desert regions have seldom differed greatly from those used in the temperate zone in the continental United States (CONUS). Although some building materials and systems may be found that could function with equal effectiveness in all climatic zones, such systems would undoubtedly be uneconomical and impractical for military applications. The use of improper building materials, construction details, or building systems which could result would not only adversely affect the working effectiveness or living comfort of the occupants due to inferior or unsatisfactory environments, but would also cause unnecessary maintenance problems for facility engineers. Consequently, information on the performance of various building materials, construction details, and building systems in the tropics and desert is needed.

Purpose

The purpose of this report is to provide design and construction criteria or guidelines for use by the Corps of Engineers (CE) in the field. The guidance will help in selecting the materials, construction details, and systems for use in theaters of operations (TO) located in desert and tropical regions that will result in the best human environment consistent with military objectives and economy.

Approach and Scope

Findings in this report were based on actual Army field experiences and research of existing literature pertinent to construction in desert and tropical regions.

Although the findings relate primarily to facilities in the TO, which are assumed to have a maximum life expectancy of 5 years, some of the recommendations are also applicable to permanent conventional construction.

Technology Transfer

The final technology transfer from this study will be through field demonstrations, reports, and Army Training Literature Programs (ATLP).

The findings can also be used to update existing documents, such as NAVFAC's *Materials Criteria for Construction in Tropical Environments.*[1]

[1] *Materials Criteria for Construction in Tropical Environments*, NAVFAC INST-11012.98A (Department of the Navy).

2 CLIMATIC CONDITIONS

The Army Facilities Component System (AFCS)[2] uses four climatic zones to describe the climates of the world: (1) temperate zone, (2) frigid zone, (3) tropical zone, and (4) desert zone.

Deserts are characterized by a season of very high temperatures (85 to 125°F [29 to 52°C]), with generally moderate night temperatures (60 to 80°F [16 to 27°C]. They have short winters with low rainfall and moderate temperatures during the day and cold temperatures at night (30 to 50°F [-1 to 10°C]). Tropics differ from the deserts in having high humidity throughout the year, even in dry seasons, and a smaller variation in day and night temperatures (75 to 95°F [24 to 35°C] in the hot season, 50 to 70°F [10 to 21°C] in the cold season).

The tropical and desert zones are each further divided into two categories: wet-warm and wet-hot for tropical and humid-hot and hot-dry for desert. Table 1 summarizes the temperature, relative humidity, and solar radiation values defined by the AFCS for each category in the two zones.

In tropical areas, wet-warm conditions are generally found under the canopy of heavily forested areas, whereas wet-hot conditions are found in the open. The main differences are that wet-hot regions are characterized by a relatively higher temperature, much higher wind, and intense solar radiation. In wet-hot regions AFCS design wind speeds for facilities with a life expectancy of less than 5 years, such as those located in the TO, are a wind of 45 knots for a 5-minute period with gusts to 65 knots. Designs with a life expectancy of 5 years or more may be subjected to winds of 55 knots for a 5-minute period with gusts to 85 knots, except at exposed coastal and mountain locations where stronger winds may be experienced. Wind in wet-warm regions is generally light, seldom exceeding 5 knots. Since most facilities are located in the open areas (wet-hot condition), this report is concerned primarily with wet-hot conditions.

Humid-hot conditions in desert zones are limited to the immediate coast of bodies of water having high surface temperatures, such as the Persian Gulf, the Red Sea, and a small region above the Gulf of California in the southwestern United States. Hot-dry conditions are found in the deserts of northern Africa, the Middle East, west Pakistan and India, the southwestern United States, western Mexico, and central and western Australia. Hot-dry regions have much lower humidity and slightly higher temperatures than humid-hot areas. Design wind speeds specified by the AFCS for desert zones are the same as those specified for tropical zones (wet-hot).

[2] *Army Facilities Components System*, TM 5-301 Series (Department of the Army, 1970).

Table 1

Summary of Temperature, Solar Radiation, and Relative Humidity Extremes

	Climatic Zones and Categories			
	Tropical Zone		Desert Zone	
	Wet-Warm	Wet-Hot	Humid-Hot (Coastal-Des)	Hot-Dry
Operational Conditions				
Ambient Air Temperature °F (°C)	75 (24)	78-95 (26-35)	85-100 (29-38)	90-125 (32-52)
Reverse Season Air Temperature °F (°C)	40 (4)	40 (4)	32 (0)	25 (-4)
Solar Radiation Btu/sq ft/hr (W/m^2)	Negligible	0-360 (0-1136)	0-360 (0-1136)	0-360 (0-1136)
Ambient Relative Humidity %	95-100	74-100	63-90	5-20
Storage and Transit Conditions				
Induced Air Temperature °F (°C)	80 (27)	90-160 (32-71)	90-160 (32-71)	90-160 (32-71)
Induced Relative Humidity %	95-100	10-85	10-85	2-50

3 DESIGN AND CONSTRUCTION GUIDE FOR FACILITIES IN TROPICAL REGIONS

Introduction

The combination of high humidity and high heat in hot-wet tropics causes some construction materials to deteriorate at an accelerated rate and also adversely affects human comfort. Nevertheless, most construction materials provide satisfactory service if properly installed and maintained under severe climatic conditions. Appropriate care in planning and detailing facilities can greatly improve human comfort. CE personnel in the field can use the following findings and suggestions for each building element to plan and construct satisfactory TO facilities.

Siting

General

Factors such as solar radiation, breeze or tradewind, view, entrance and approach, ground contours, and drainage are all important considerations in laying out a satisfactory facility. However, among these factors, solar radiation and breeze are most important for hot-wet (tropic) climates. The sun overheats all surfaces it strikes directly--roof, walls, windows, and surrounding grounds. These surfaces either transmit heat and light into the building or reflect it. Therefore, the problem is how to reduce the amount of heat the sun projects into the building or how to keep sunlight off the walls. The breeze is helpful in evaporating perspiration from the skin in high humidity areas.

Findings and Suggestions

1. Oblong buildings should be oriented so that the long axis is in an east-west direction to minimize solar radiation through walls.

2. Overhanging eaves should be used to stop or reduce solar radiation on walls and through windows.

3. Trees and vegetation can be used to shade buildings from the sun, but must be situated so they do not obstruct natural breezes.

4. Buildings must be laid out and oriented to receive prevailing winds and breezes. (Note: Since solar radiation is comparatively simple to deal with, the direction of the prevailing wind may become the deciding factor in laying out a building.)

5. A staggered layout (Figure 1) permits breeze distribution to adjacent structures.

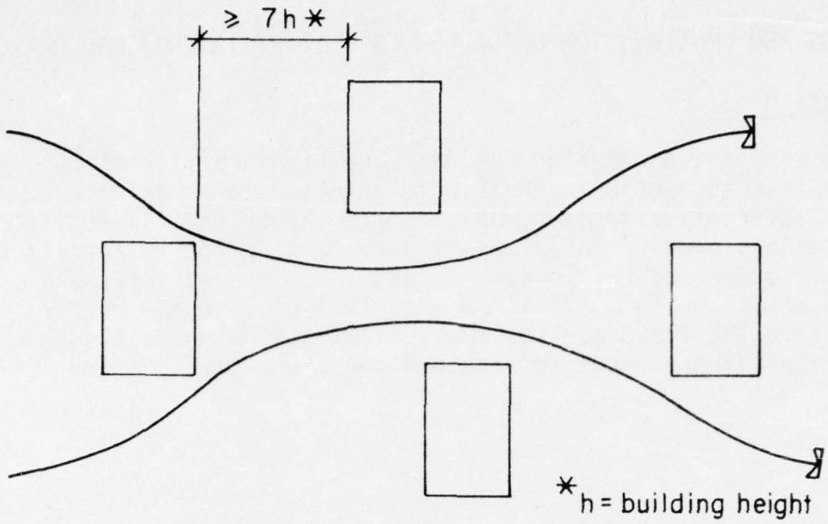


Figure 1. Staggered layout.

Roof

General

The roof of a building has the greatest exposure to solar radiation. Intense heats are generated during the day. The roofing material and system used should be able to reduce the penetration of heat to the interior during the day and effectively disperse the accumulated heat to prevent further radiation at night. The latter is particularly important in the tropics, since the temperature differs little from day to night.

Findings and Suggestions

1. Adequate air gap must be provided between ceiling and roof. Hot air in attics must be moved either mechanically or nonmechanically. Roofing systems shown in Figure 2 are satisfactory.

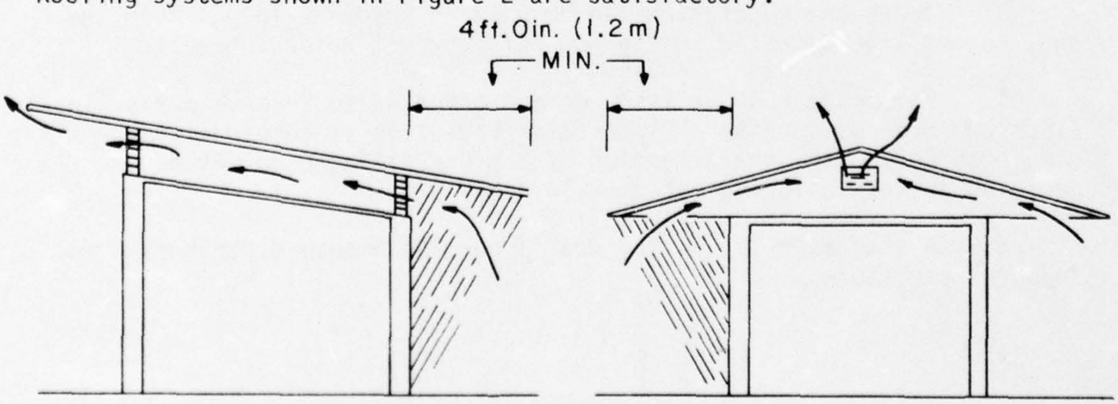


Figure 2. Suggested roofing systems.

2. Eaves should project at least 4 ft (1.2 m) (Figure 2) beyond the wall to keep rain off windows and walls and provide additional shade.

3. Fine mesh screen must be used at ventilation openings to prevent dry-wood termites from entering the attic through the openings.

4. For air-conditioned buildings, ceilings should be adequately insulated to reduce cooling load and prevent condensation above ceiling.

5. Types of roofing materials that have been used successfully in the past are:

a. Corrugated aluminum sheet

b. Corrugated galvanized metal sheet

c. Baked enamel corrugated metal sheet

d. Asbestos-cement shingles

e. Good quality asphalt shingles

To prevent corrosion of aluminum or galvanized metal sheets due to galvanic action, fastening materials must be the same as the parent material. Experience in the Panama Canal Zone indicates that without proper coating and a good maintenance program, the service life of corrugated galvanized sheet metal is quite short. At locations where the influence of seawater is severe, some sheet metal has lasted less than 2 years.

6. The color of roofing materials should be as light as possible to promote heat reflection.

7. Experience in the Panama Canal Zone has indicated that built-up roofing is not a good system for use in hot-wet climates. Built-up roofing has a slower runoff rate than roofs with smoother surfaces; dirt and seeds can easily become lodged between small stones on the roof. Since seeds germinate rapidly in hot-wet environments, grass and weeds grow thickly on the roofs (Figure 3). The roots eventually force their way through the roofing materials and cause the roofs to leak. Another problem with this type of roof is blistering due to expansion of moisture trapped between layers of roofing material. Although this phenomenon can be prevented by taking special care to preclude moisture between layers during construction, this is very difficult, especially in tropical regions where it rains frequently.

8. Flat concrete roofs with or without false ceilings below are undesirable and should not be used because of heat storage and the possibility of cracking due to contraction and expansion.

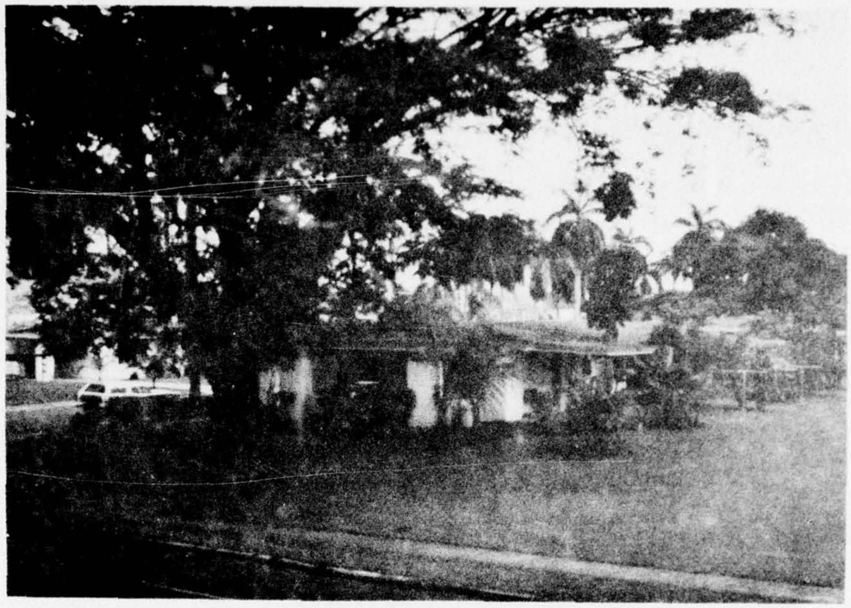


Figure 3. Grass growing on built-up roofing (Panama Canal Zone).

9. Roof systems in very high wind (hurricane, cyclone, or typhoon) areas should be securely anchored using "cyclone bolts" (Figure 4). "Cyclone bolts" tie all structural components--roof, walls, floor, foundation--together. Battens placed over the roof cladding are effective in resisting fluctuating wind loads.

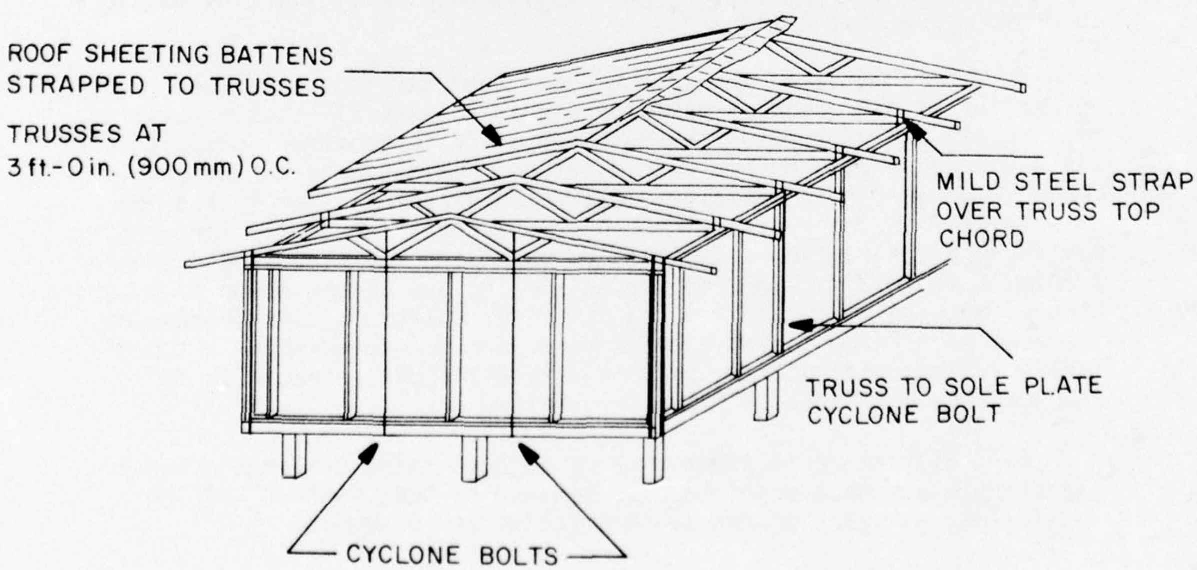


Figure 4. Suggested roofing details for buildings in high wind areas.

10. Adequate overlappings should be provided for corrugated sheet metal to prevent leaks due to capillary action and suction effect.

11. Wood used for roof construction should be pressure-treated and kiln-dried. Preservative used for treatment should be pentachlorophenol conforming to appropriate Federal Specifications.

12. Gutters should be used only where absolutely necessary. Due to high runoff rates, gutters do not function as intended. In addition, if not aligned and sloped properly, gutters collect dirt and seeds, which germinate and grow rapidly (Figure 5). They also provide a breeding ground for mosquitoes. To prevent splashing and erosion of the foundation, concrete aprons or gutters must be built to catch drips from the eaves.

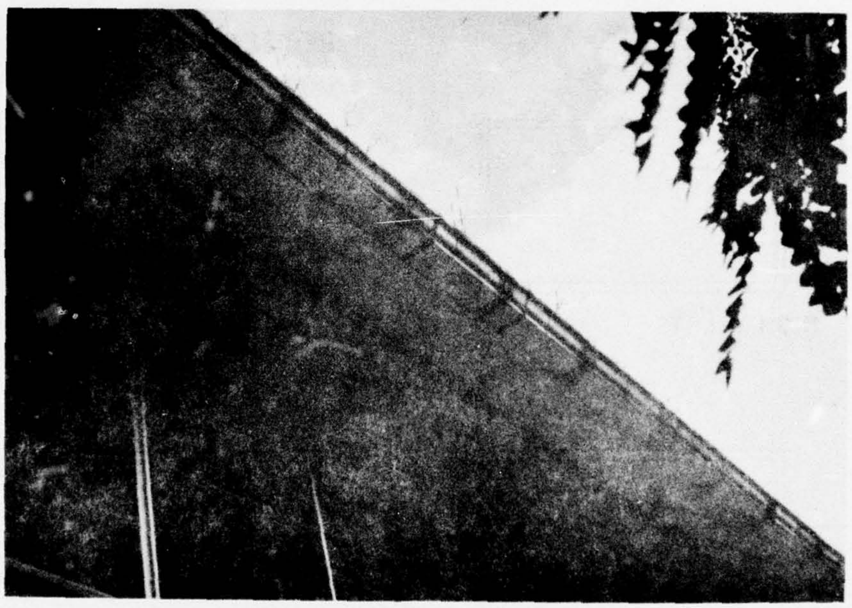


Figure 5. Grass and weeds growing in gutter (Panama Canal Zone).

Exterior Walls and Wall Openings

General

The combination of high humidity and high heat is very oppressive to building occupants. Proper orientation of the building and roof construction can reduce heat. Moving air, although it does not lower humidity, refreshes occupants by evaporating perspiration. Walls must be properly constructed and openings properly located to allow movement of air where needed.

Findings and Suggestions

1. Buildings should be oriented so they receive maximum breeze and minimum solar radiation through walls.

2. For non-air-conditioned building, as many openings as possible should be provided in all exterior walls.

3. Openings should be located at middle and lower parts of the walls, since breezes are desirable at body and floor height (Figure 6).

4. Screens and louvers should be used to prevent insects and driving rains, respectively, from entering the building.

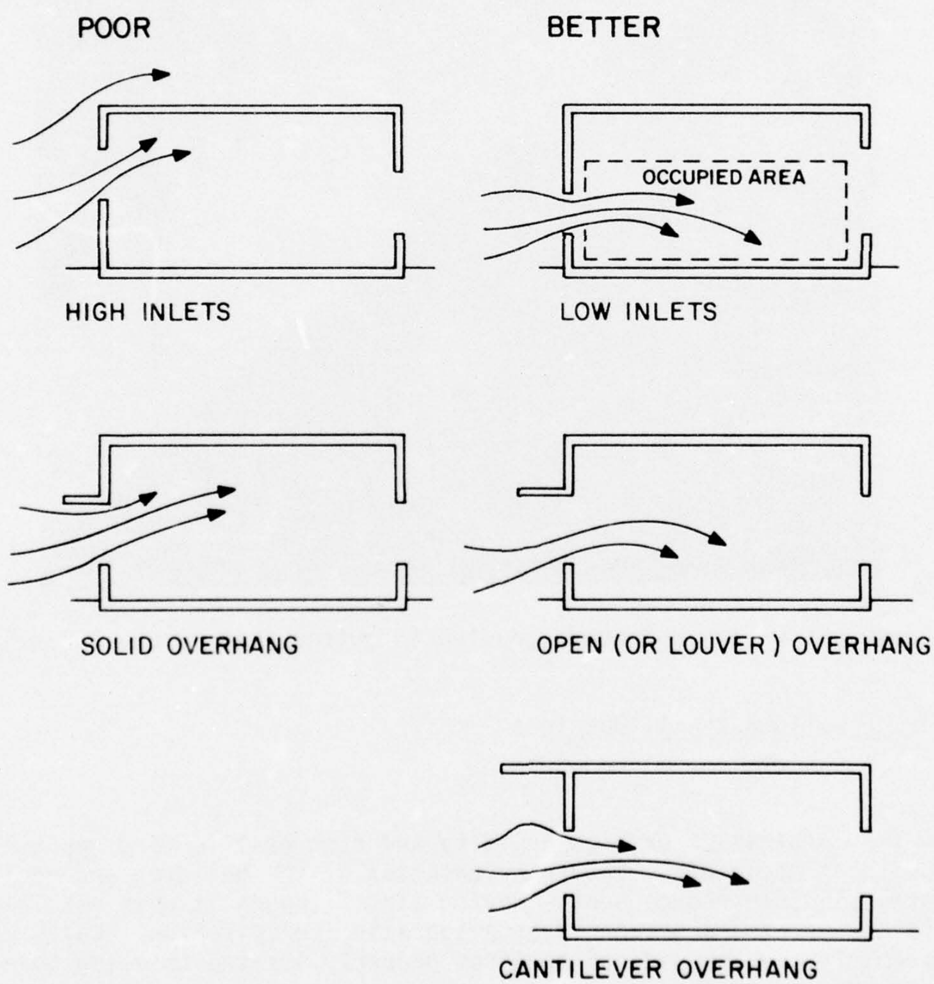


Figure 6. Effect of wall opening location on air motion.

5. Lumber used for wall construction should be toxic-treated by pressure-treating and kiln-drying. Preservative used for treatment should be pentachlorophenol conforming to appropriate Federal Specifications.

6. For a building with an expected life span of 5 years or less, treated wood is satisfactory for walls and sidings. Because the treatment wears off after a period of time, leaving the wood susceptible to attack by fungi and termites, wood is not considered suitable for permanent construction. For permanent construction, reinforced concrete and concrete blocks appear to be most suitable.

7. Galvanized corrugated steel sheets may be satisfactory for some locations. However, for locations where the influence of seawater is severe, maintenance costs are high.

8. Stucco-finished walls are satisfactory but are more suitable for permanent construction.

9. Fiberglass, which is known to be very durable under various weather conditions, can be used for sidings.

10. Asbestos cement shingles are too brittle and fragile to be used as siding material for barracks where strength and durability are required (Figure 7).

11. Adequate insulation must be provided on the ceiling and in the walls if the building is to be air conditioned. Insulation will not only cut down the cooling load, but also prevent condensation around the exterior surfaces of the building caused by surrounding humid air; such condensation accelerates the rate of deterioration of the material.

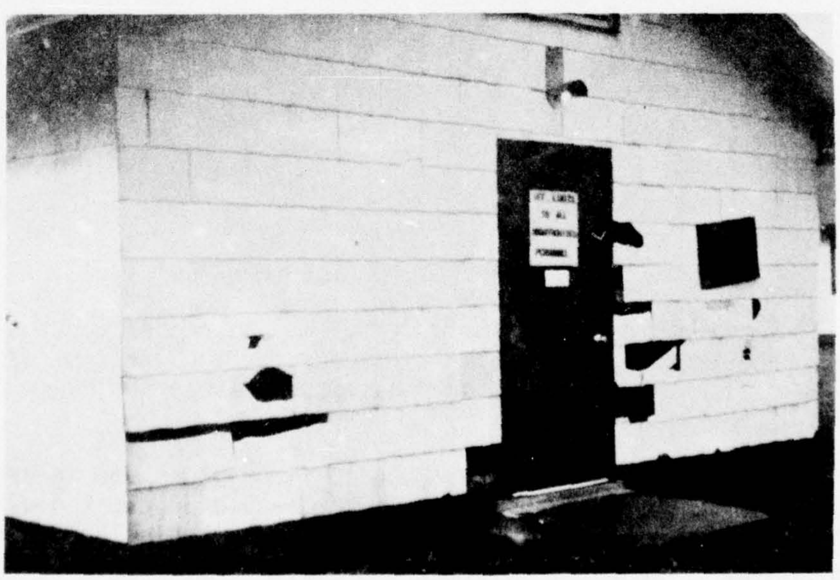


Figure 7. Typical breakages on asbestos cement shingle sidings (Fort Stewart, GA).

Foundation

General

Concrete slabs on concrete footings have been generally used and are performing satisfactorily in the Panama Canal Zone. Footings should be placed deep enough to avoid any differential settlement of the foundation due to shrinkage of subsoil during the dry season that may occur in tropical areas. Buildings on stilts appear to be particularly suitable, since they have less heat reflected from the ground, lower night temperature all around the building, and space between the floor slab and wet ground.

Findings and Suggestions

1. Buildings, especially wood buildings, should be built on stilts or a raised foundation if possible (Figure 8). Wood used for the foundation should be treated with creosote.

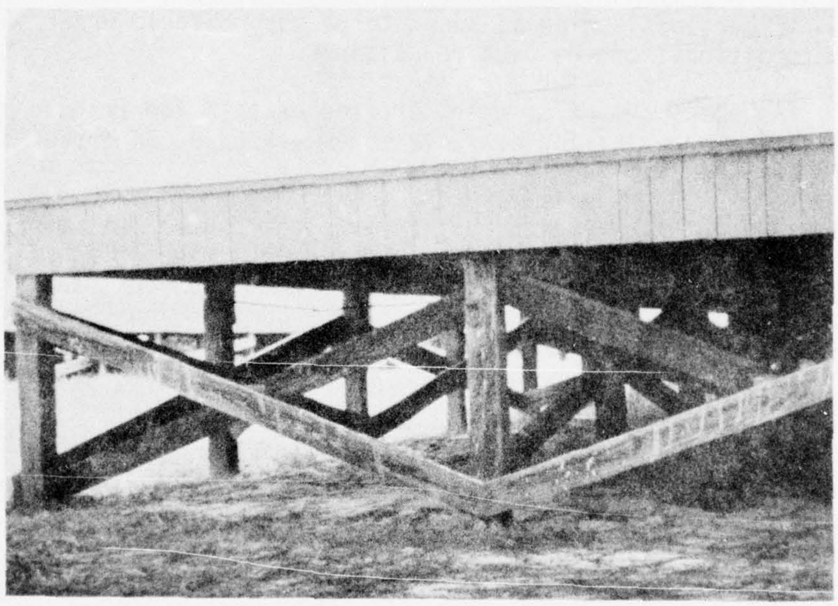


Figure 8. Raised wood foundation (Fort Polk, LA).

2. A minimum depth of 18 in. (45.7 cm) is needed for footings. However, the exact minimum depth is governed by the greatest depth at which seasonal changes in moisture cause appreciable shrinkage and swelling of the soil.

3. All fill or backfill soil, under floor slabs and in areas about the perimeter of the building using timber should be treated with poison to provide a lethal barrier to subterranean termites. The appendix provides a specification for application of soil poisoning.

4. Termite seals or caps should be used where wood comes in contact with footings (Figure 9).

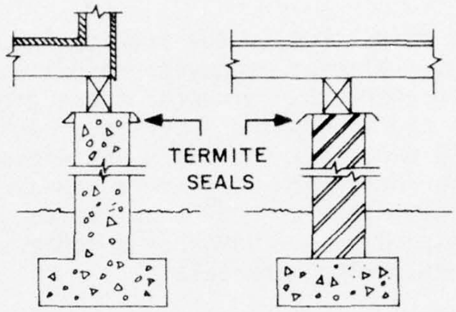


Figure 9. Termite seals between wood and concrete footing.

Interior Walls

In non-air-conditioned buildings where interior comfort is provided by moving air, no interior walls should be used, since they obstruct the movement of air. If partitions are absolutely necessary, they should be placed so that they do not affect air movement. Figure 10 shows the effects of partitions on air movement.

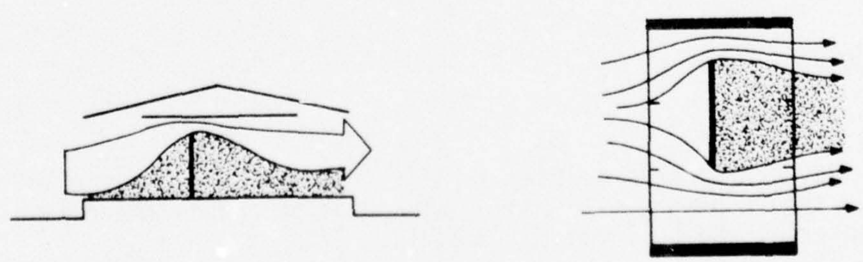


Figure 10. Effects of partitions on air movement.

Gypsum board (or dry wall) is too fragile to be used as covering material for interior walls, especially in barracks and should therefore not be used. Particle board should be used instead.

Doors and Windows

General

Frequent, heavy rainstorms in the tropics are another critical problem for buildings. Without adequate protection, such as roof overhangs or awnings over openings, rainwater seeps through along the edges of doors and windows and floods the interior of buildings during heavy rainstorms. Glass is necessary for doors and windows in air-conditioned buildings, but not for doors and windows in non-air-conditioned buildings. Unguarded glass transmits heat completely; therefore, if glass is used, it should be shaded by overhangs or awnings or coated with whitewash or other heat-reflecting materials.

Findings and Suggestions

1. Overhangs or awnings should be used over doors and windows to reduce solar radiation and protect them from rain.

2. For non-air-conditioned buildings, as many openings as possible should be provided around the buildings for breeze.

3. No glass should be used for windows and doors in non-air-conditioned buildings; openings should be covered with screens and louvers to prevent insects and rain, respectively, from entering the buildings.

4. If glass is used for windows and doors and cannot be shaded effectively, it should be whitewashed or coated with heat-reflecting materials.

Miscellaneous

Ground Treatment

1. Pavement should be used as little as possible; more grass and vegetation should be grown to reduce glare and to reduce the temperature of the air entering the building (Figure 11).

2. Seeding has not worked well in tropical environments because of the intensity of rain. Either sprigging or erosion control fabric is required to protect the ground for seeding.

Painting

Paints applied to exterior building surfaces in wet-hot and wet-warm areas (Panama Canal Zone and Southeastern CONUS) following current

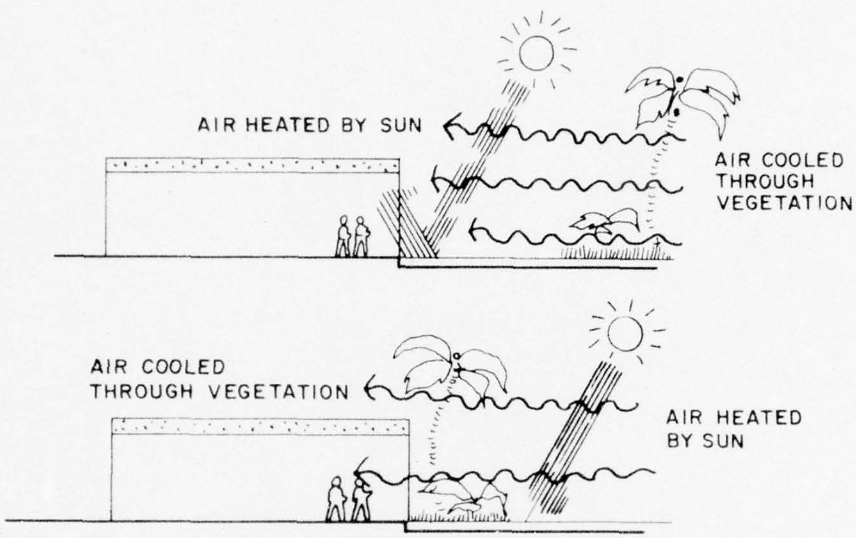


Figure 11. Effect of vegetation.

specifications have not performed satisfactorily. Additional investigation is required to correct the deficiencies.

Mechanical

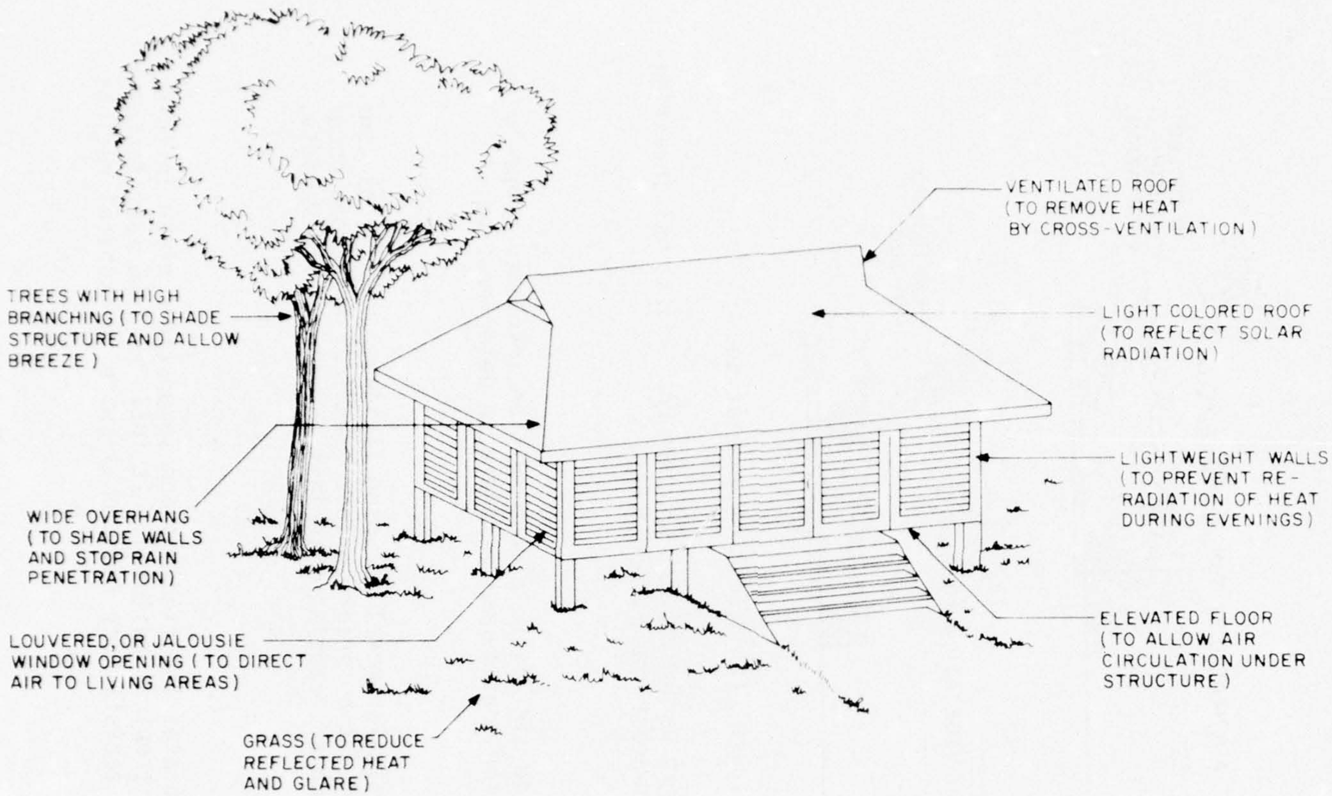
Return air/outside air mixing plenum must be insulated properly to prevent any condensation that causes accelerated deterioration.

Other

Materials of dissimilar metal for pipe fittings, electrical connections, etc., should not be intermingled. Chemical reactions occur much faster in the tropics, causing materials to deteriorate rapidly.

Summary

Figure 12 incorporates the findings and suggestions given in this chapter into an ideal tropical building. It includes important features required to provide a satisfactory functional space in tropical regions.



This structure, for a wet-hot region, follows six design objectives: 1) Long axis set in East-West direction, 2) Solar radiation penetration is reduced, 3) Heat from inside is removed to outside, 4) Evaporative cooling is aided by ample natural ventilation, 5) The building is set to receive the prevailing summer winds, and 6) Attic ventilation is aided by vents in the soffits.

Figure 12. Ideal tropical building.

4 DESIGN AND CONSTRUCTION GUIDE FOR FACILITIES IN DESERT REGIONS

Introduction

High daytime temperatures with severe aridity are major characteristics of the hot-dry desert region. Unlike tropical regions, the temperature variation between day and night in the desert is great. Due to the absence of cloud cover and vegetation, the sun heats the earth's unshaded barren surface to more than 150°F (65°C) at midday; at night the rapid loss of heat to the ambient air can lower the temperature to 60°F (15°C).

Due to the convection currents caused by the intense heating of the air near the ground, winds usually occur during the afternoon. Without much vegetation, the winds and dust (dust storms) are a design problem. Expansion and cracking of building materials are also problems in desert regions. Rains are generally nonexistent; however, some accommodation must be made for the potential flash floods that occur suddenly and last only a few hours, but leave up to 6 in. (15.2 cm) of water.

Although the requirements for buildings in hot-humid coastal deserts differ somewhat from those in hot-dry deserts, the general recommendations for hot-dry deserts also apply to hot-humid regions.

Siting

General

When laying out a facility in a desert environment, certain factors must be generally considered--solar radiation, dust storms, breezes, views, entrances, ground contour, and site drainage. Among these, solar radiation is a particularly important design consideration. Every attempt must be made to shade, baffle, or intercept the sun's rays from striking the buildings. The best design will keep as much of the building as possible in shade, including walls, roof, and windows.

Breezes are also a factor to be considered when designing in desert climates. The building must be designed to maximize benefit from any breeze. Although the breeze is not desirable during the day, it may be required at night to remove hot air from the buildings.

Findings and Suggestions

1. Oblong buildings should be oriented so that the long axis is in an east/west direction; i.e., the sun follows the length of the roof top.

2. Buildings should be oriented to use overhanging eaves to stop or reduce solar radiation on walls and through windows.

3. Although trees and vegetation are hard to grow in desert regions, use of trees and vegetation to shade the building from the sun should be considered whenever possible.

4. Consolidation of buildings into long rows, thus minimizing surface exposure to the sun should be considered rather than exposing several surfaces of each building.

5. Buildings should be sited with entrances on the leeward side to minimize penetration of wind and dust during dust storms.

6. Accessibility of natural services such as water, waste removal, etc., should be considered in the absence of these supplied services.

Roofing

General

In hot-dry climates the roof is generally the primary source of heat gain into the building due to incorrect design. High-density, heavyweight construction heats slowly; it cools just as slowly. In so doing, it dumps some of the lost heat into a cooler zone, usually the interior of the structure. This phenomenon occurs more intensely for dark-colored roofs than light-colored roofs. The particular environment dictates the roof system that must be designed to reflect and/or absorb as required.

Findings and Suggestions

1. An adequate air gap must be provided between the ceiling and roof. The hot air which builds up in the attic space must be vented to the ambient air mechanically or nonmechanically.

2. The roof should extend beyond the walls to provide shade for walls and windows.

3. When heat is to be kept from penetrating to the interior of the structure from the roof, roof materials exposed to the sun must be as nearly white as possible.

4. All roofing, regardless of type, must be securely attached to the structural system to resist being torn off by strong winds. At Fort Irwin, CA, only fiberglass-asbestos roll roofing has performed satisfactorily. Unsatisfactory performance of other materials occurred when inadequately nailed shingles were blown from the roof. The corners and edges of corrugated sheet metal roofing must also be securely tied down. The corrugated metal sheets must be strapped directly to the purlins or the tresses to keep them from being blown apart by the winds.

5. Wind and heat are the primary factors which make built-up roofing unsuitable for desert use (Figures 13 and 14). If this type of roofing is used, only high-melt (190°F [87°C]) asphalt can be used.

6. If concrete is used for roofing, expansion joints must be provided at not more than 20 to 30 ft (6.1 to 9.1 m) intervals in the slab. Expansion joints must also be provided between the roof slab and walls to allow free movement of walls and roofs.

7. To prevent corrosion of aluminum or galvanized metal sheets due to galvanic action, fastening materials must be the same as the parent material.

8. Air-conditioned buildings must have adequate insulation in the ceiling. Insulation, when applied, must be applied above the structural deck and below the waterproof cover.

9. Gutters are not necessary and should not be used.

Exterior Walls and Wall Openings

General

Traditionally, the walls of buildings in hot desert climates have been constructed of dense heavyweight materials--earth, adobe, concrete--and the size and number of window openings have been minimized. Both these techniques have reduced interior daytime temperatures, but have caused interior night temperatures to remain elevated due to insufficient ventilation from windows and high thermal capacity of the walls.

Findings and Suggestions

1. Ventilation from daytime ambient air is undesirable. Therefore, the number and size of window openings should be minimized, or large openings should be equipped with a cover that can be kept over the window during the day and opened in the evening.

2. Concrete blocks, slump blocks, and adobe are suitable for walls. However, expansion joints must be provided at proper intervals (usually at 20 to 30 ft [6.1 to 9.1 m]) and the surface must be whitewashed to reflect radiation. These building materials are more suitable for permanent construction which can be restructured and air conditioned.

3. Stucco has not performed satisfactorily because it cracks in hot-dry climates.

4. Galvanized corrugated metal sheets and aluminum sheets are satisfactory for exterior siding if installed properly. The metal sheets must be lapped toward the prevailing wind and strapped securely in place. Galvanized metal sheets must be painted with aluminum paint to

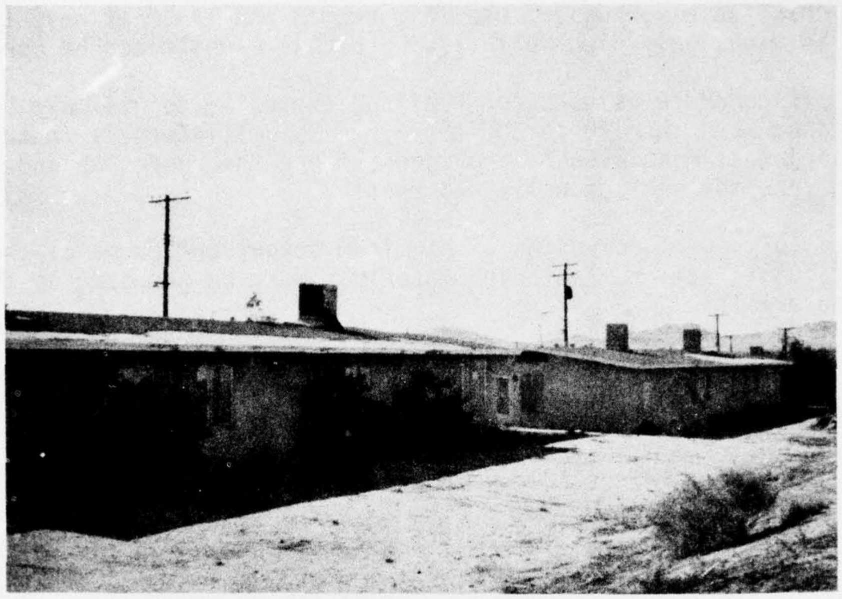


Figure 13. Typical built-up roofing torn apart by wind (Fort Irwin, CA).

Figure 14. Built-up roofing failure caused by heat. Asbestos cement sheets used for siding are satisfactory (Fort Irwin, CA).

reflect solar radiation. Insulation must also be provided in all buildings which are to be air-conditioned.

5. Asbestos cement sheets are suitable for exterior siding in desert regions (Figure 14). Asbestos shingles, however, are too fragile for exterior sidings due to poor support provided behind the shingles (Figure 7).

6. All openings, windows, doors, and exhaust vents must be secured against winds and sand penetration.

7. Openings should be located in approximately the middle of the wall or nearest to body height to let the breeze cool the body most directly (Figure 6).

8. Due to its poor weathering characteristics, wood is not recommended for use as exterior siding for permanent construction in deserts.

9. Galvanized corrugated sheet steel is satisfactory for hot-dry desert areas but not for coastal (humid-hot) areas because maintenance to retard the effects of seawater is too costly.

10. Fiberglass is very durable and may be considered satisfactory for all desert areas.

11. Due to occasional dust storms, windows that require the least maintenance and provide the best seal against dust penetration should be used. Both sliding and double-hung windows have performed unsatisfactorily. Sliding windows have been especially troublesome because sand accumulates in their tracks and necessitates cleaning (Figure 15). It is believed that louvered or pivoted windows may perform well under desert weather conditions.

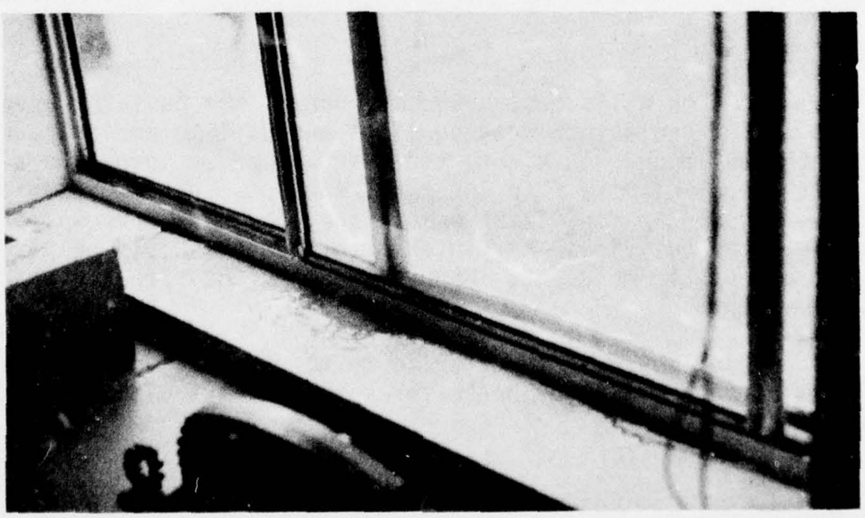


Figure 15. Typical problem with sliding window accumulating sand in its tracks (Fort Irwin, CA).

12. Since glass transmits heat completely, glass used for windows or openings must be shaded with an overhang, whitewashed, shielded with heat-reflecting material, or covered with a removable cover during daylight hours.

Foundation

General

Unlike tropical regions where raised foundations are considered desirable, raised foundations are undesirable in desert regions. On-grade concrete slabs and concrete footings are generally suitable for buildings in desert regions. The foundations must be set deep enough to distribute the load and avoid differential settlement. Although rains are generally nonexistent, some accommodation must be made to protect building foundations from flash floods.

Findings and Suggestions

1. Wood foundations are to be avoided for permanent buildings; however, they may prove feasible for temporary construction. More testing of wood foundations in desert climates is necessary.

2. On-grade concrete slabs and concrete footings are generally suitable for buildings in desert regions. However, soil conditions in some desert areas are susceptible to large volume changes which require special foundation systems. For permanent construction, detailed sub-soil investigations must be conducted prior to designing the foundation system.

Interior Walls

1. Exterior walls must cover as much of the building envelope as possible during the day to keep sunlight and daytime ambient air outside the building. At night, the windows can be opened to allow as much of the cool night air to enter as required. Use of interior partitions should be minimized because they obstruct movement of evening air through the building. Any interior partition should be placed so it does not affect air movement. Figure 10 shows the effect of partitions on air movement.

2. Gypsum board is too fragile to be used for interior partitions; some form of fiberglass may be better suited. Particle board is a good alternative.

Miscellaneous

Ground Treatment

Pavements should be used as little as possible. Whenever possible, grass should be grown or some nonreflective substance should be placed around the building.

Painting

Based on past experience at Fort Irwin, CA, Fort Huachuca, AZ, and Yuma Proving Ground, AZ, paints applied to buildings (stucco, masonry, and woods) following present federal specifications do not last well. Additional investigation is required to obtain new data to correct the deficiencies.

Mechanical

Refrigeration cooling should not be used in hot-dry deserts, but is required for humid-hot (coastal) deserts. In hot-dry regions, two-stage evaporated cooling is sufficient.

Other

Materials of dissimilar metal for pipe fittings, electrical connections, etc., should not be intermingled. Galvanic action between dissimilar metals causes the materials to deteriorate. The high alkali content of water which is normal in desert regions causes corrosion problems in water distribution systems and air cooling units (Figure 16). Water pipes must have proper linings, and water must be treated to remove the undesirable mineral before being used in the air-cooling units.

Summary

Figure 17 shows an ideal desert building incorporating most of the important features required to provide a suitable functional space in hot-dry desert regions. Some design features advocated for hot-dry conditions need modification in humid-hot (coastal) desert regions. The modifications should include more definite provision for securing free- or forced-air movement when desired and minimizing any interference to air movement. The refrigeration devices selected should dehumidify as well as cool.

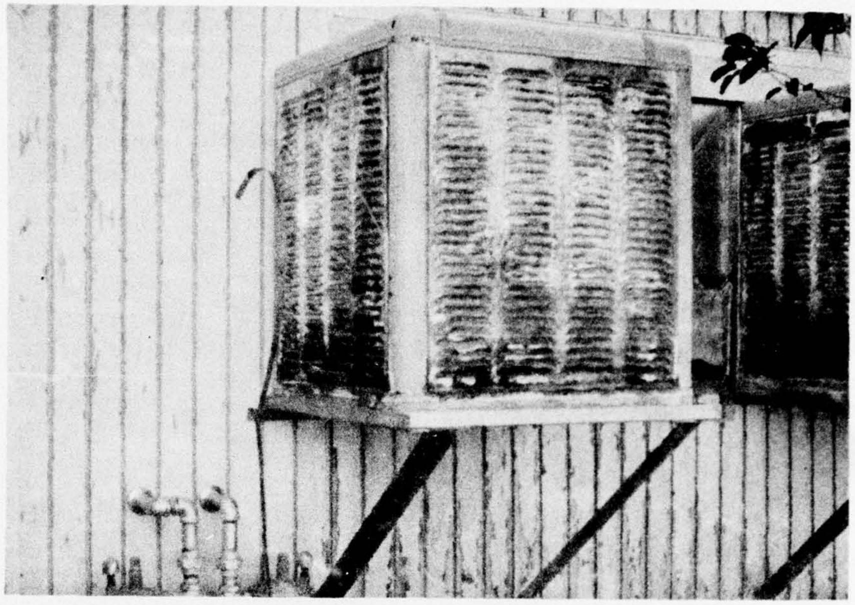
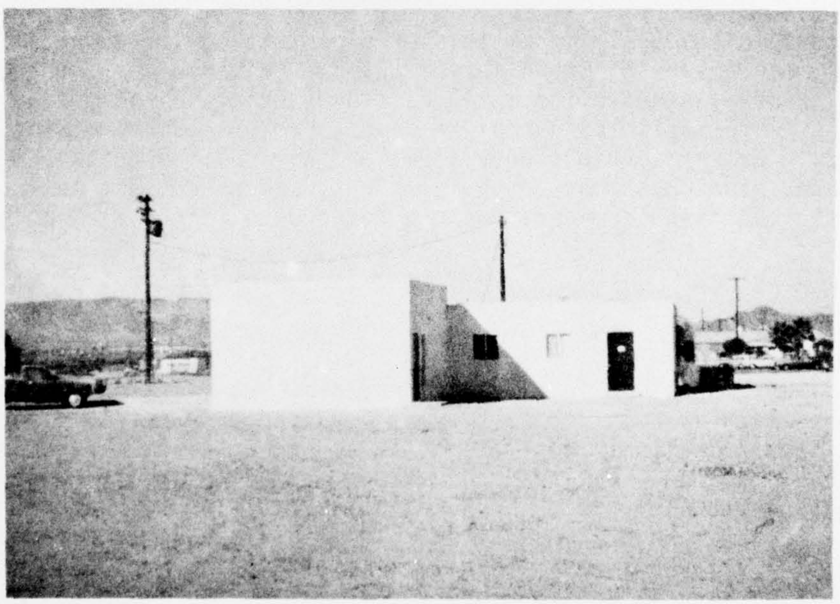


Figure 16. Corrosion of air-cooling unit (Fort Irwin, CA).



Massive material (concrete) used for roof and wall construction delays impact of solar radiation and provides warmth during cold evenings. Walls are whitewashed to reflect solar radiation. Few and small openings minimize direct transmission of solar radiation and penetration of dust during dust storms. Building is elongated in an east-west direction.

Figure 17. Ideal desert building (Yuma Proving Ground, AZ).

5 UTILITY OF VARIOUS CONSTRUCTION MATERIALS IN TROPICS AND DESERT

Ferrous Metals and Zinc

Ferrous metals corrode rapidly in tropics unless exposed and free of ground. Zinc is unsuitable in the tropics due to corrosion.

Aluminum and Its Alloys

Aluminum alloys last well in both tropical and desert climates. They have high reflectivity to solar radiation and are little affected by aging. In addition, they are light and transportable.

Copper, Copper Alloys, and Lead

Copper, brass, and bronze generally perform well in tropical environments. However, lead suffers through "fatigue cracking" due to thermal expansion and contraction.

Concrete and Other Cement Products

Concrete products generally perform well under tropical climates. However, exposed surfaces are susceptible to blackening in warm-wet tropics. Unless adequate expansion joints are provided to allow free movement between building members, thermal expansion and contraction causes cracking of building members.

Steel Reinforcement

The chances of corrosion are high for steel reinforcement in tropical regions due to the high rainfall and atmospheric humidity.

Asbestos Cement

Asbestos cement becomes brittle in hot-dry climates. The breakage rates of asbestos shingles used without proper backing are high; flat sheets with proper backing are satisfactory, however. Generally, asbestos cement sheets used with proper backing such as fiberboard, gypsum, or plywood sheathing are a good material for exterior sidings because they are economical and easy to handle.

Earth and Stabilized Earth

Earth walls (or adobe blocks) are highly susceptible to termite depredation unless stabilized. However, certain earths such as laterite are quite durable in tropics and very durable in deserts. Earth has the advantage of being largely a site material, thus reducing transport costs. Adobe blocks can be made with relatively unskilled labor.

Gypsum Products

Gypsum products have been used successfully externally in desert climates.

Building Boards

Hardboard and plywood must be treated to prevent termite attack. Treated hardboard and resin-bonded plywood have been used satisfactorily in warm-wet climates, but painting is considered desirable. Since the maintenance cost is high due to frequent painting, the use of these materials may not be cost effective for permanent construction.

Timber

Unless treated, timber performs very poorly in tropics because of attacks by fungi and termites. Even with treatment, timber is still susceptible to attack, since the treatment wears off after a certain period of time. Therefore, timber is not a good construction material for permanent facilities. Some of the native woods, such as Cedro Espino (Bombacopsis quineta), Mora (chlorophor tinctoria), and Corotu (Enterolobium cyclocarpum) have good resistance to termite attack; using these wood species for construction may be feasible. In desert climates, timber deteriorates because of continual expansion and contraction. In addition, the continual expansion and contraction reduces paint-holding qualities, as does sand blasting (Figures 18 and 19).

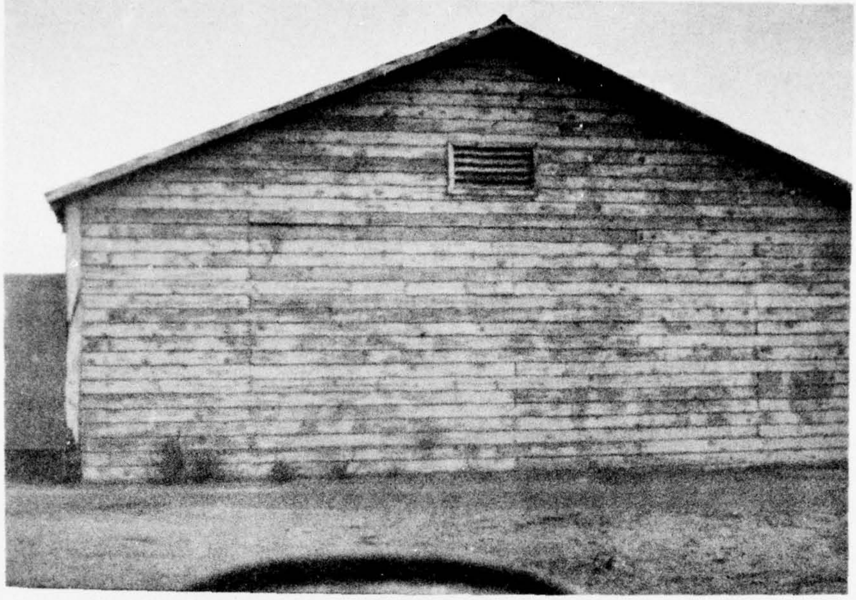


Figure 18. Poor paint-holding quality of wood siding (Fort Irwin, CA).

Figure 19. Failure of paints on wood siding due to poor paint-holding quality and sand blasting (Fort Irwin, CA).

APPENDIX:

TERMITE CONTROL BY SOIL POISONING[3]

General

Soil poisoning shall be applied as hereinafter specified. All soil, fill or backfill under floor slabs, patios, carports, utility closets, walks and all areas about the perimeter of each building as hereinafter described shall receive poison treatment to provide a lethal barrier to subterranean termites. All treated areas disturbed after treatment shall be treated again.

Material

Soil poisoning for 2 percent chlordane shall conform to Federal Specification O-I-515. Technical chlordane shall be 72 percent by weight, approximately 8 lb of chlordane per gal (959 kg/m^3).

Application

Soil poisoning treatment shall be applied in accordance with the precautions on the label. At the time of application, the soil shall be in a friable condition with sufficiently low moisture content to allow uniform distribution of the chemical throughout the soil. Soil shall be treated immediately prior to placing waterproof membrane where concrete is to be placed on waterproof membrane.

a. Under Footings. Immediately prior to pouring footings, treat soil which will lie under and adjacent to footings by applying chemical at a rate of 2 quarters per square foot. Apply as a coarse spray.

b. Foundation Walls. Two gal per 5 lin ft (0.005 m^3/m) in a strip 1 ft (0.3 m) wide in trench on exterior, with one-half of the application near level of top of footings before any backfill is placed, and the remainder when the trench is virtually filled. Two gal per 5 lin ft (0.005 m^3/m) in a strip 1 ft (0.3 m) wide shall be applied to a shallow trench adjacent to the interior side of the foundation or buildings.

c. Under Slabs on Ground. Just prior to placing concrete floor slabs, treat soil with 1 1/2 gal of chemical per 10 sq ft (0.06 m^3/m^2) as overall treatment. In critical areas such as around utility openings

[3] *Specifications for Construction of 48 U.S. Quarters at Various Locations in the Canal Zone* (Panama Canal Company, 1974).

for pipes, conduits, and ducts, 0.5 gal per square foot (0.02 m^3/m^2) shall be applied. Along the junction of the slab with the wall, 2 gal per 5 lin ft (0.005 m^3/m) in a strip 1 ft (0.3 m) wide next to the wall.

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