Architectural Resilience for Disasters

presented to the

Subcommittee on Disaster Reduction
Committee on Environment and Natural Resources, Natural Science and Technology Council

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Hazard Mitigation Strategy

1. **Understand Your Risks**
2. **Community Vulnerability Assessments**
    1. Prepare a Hazard Analysis
    2. Identify Assets
    3. Vulnerability Assessment

Hazard Mitigation Strategy

3. Develop a Mitigation Strategy

A. Hazard Mitigation Goals

B. Identification and Analysis of Mitigation Measures

1. Land Use Regulations

a. Coastal Setbacks, based on erosion & inundation zones

b. Flood Regulations, based on Flood Insurance Rate Map

c. Zoning Code

d. Hazard Assessment as Part of Land Use Decisions

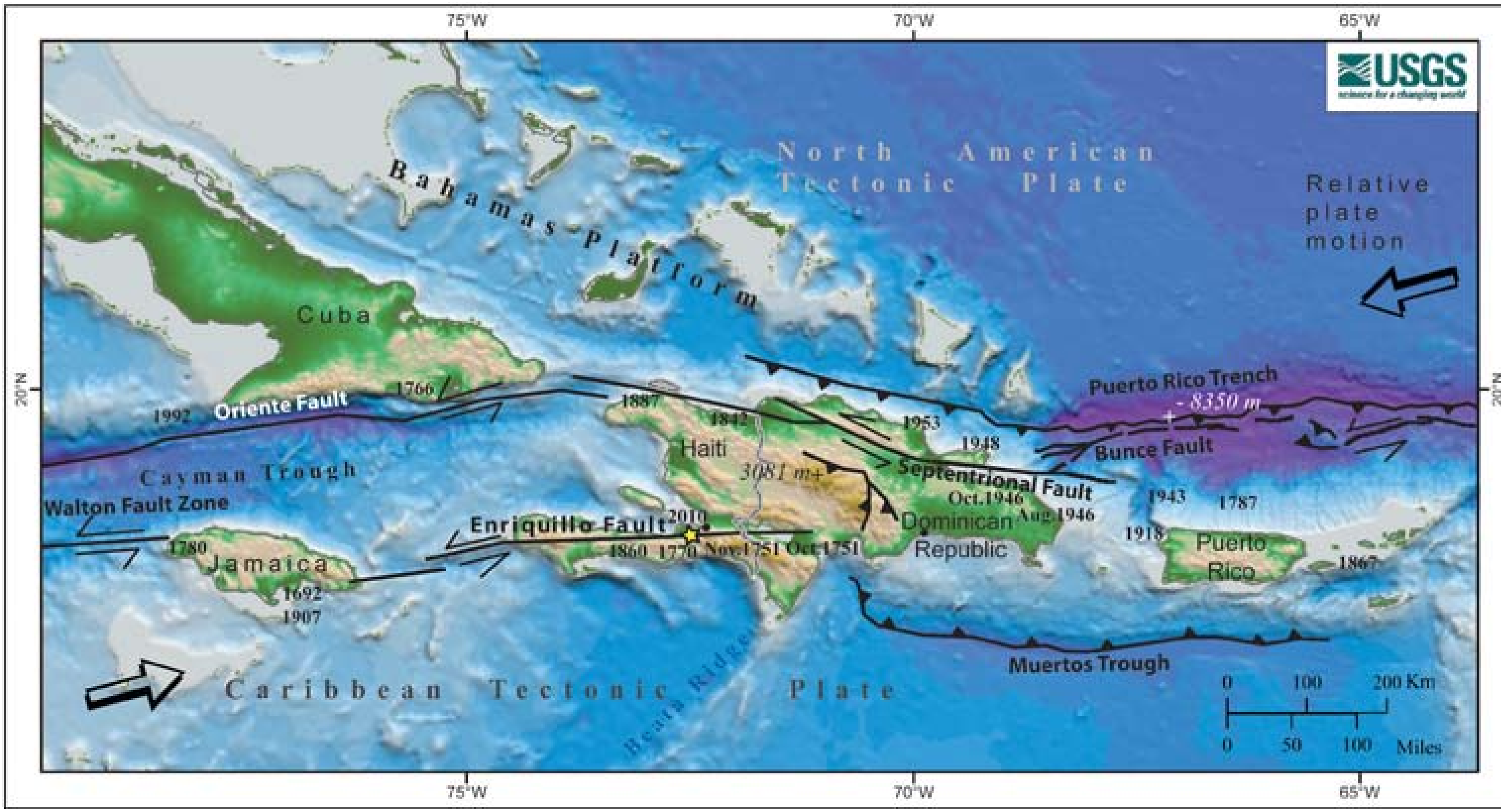
Hazard Mitigation Strategy

2. Building Standards
    a. International Building Code
    b. Vulnerability Audits and Retrofits
    c. Standards or Guidelines
    d. Training
3. Community Plans
    a. Isolated Communities
    b. Special Interest Groups
4. Public Awareness
5. Incentives – Tax Incentives, loans, grants

Major Natural Disaster

2010 Haiti Earthquake
catastrophic magnitude 7.0Mw
12 January 2010

Haiti Tectonics, Major Faults



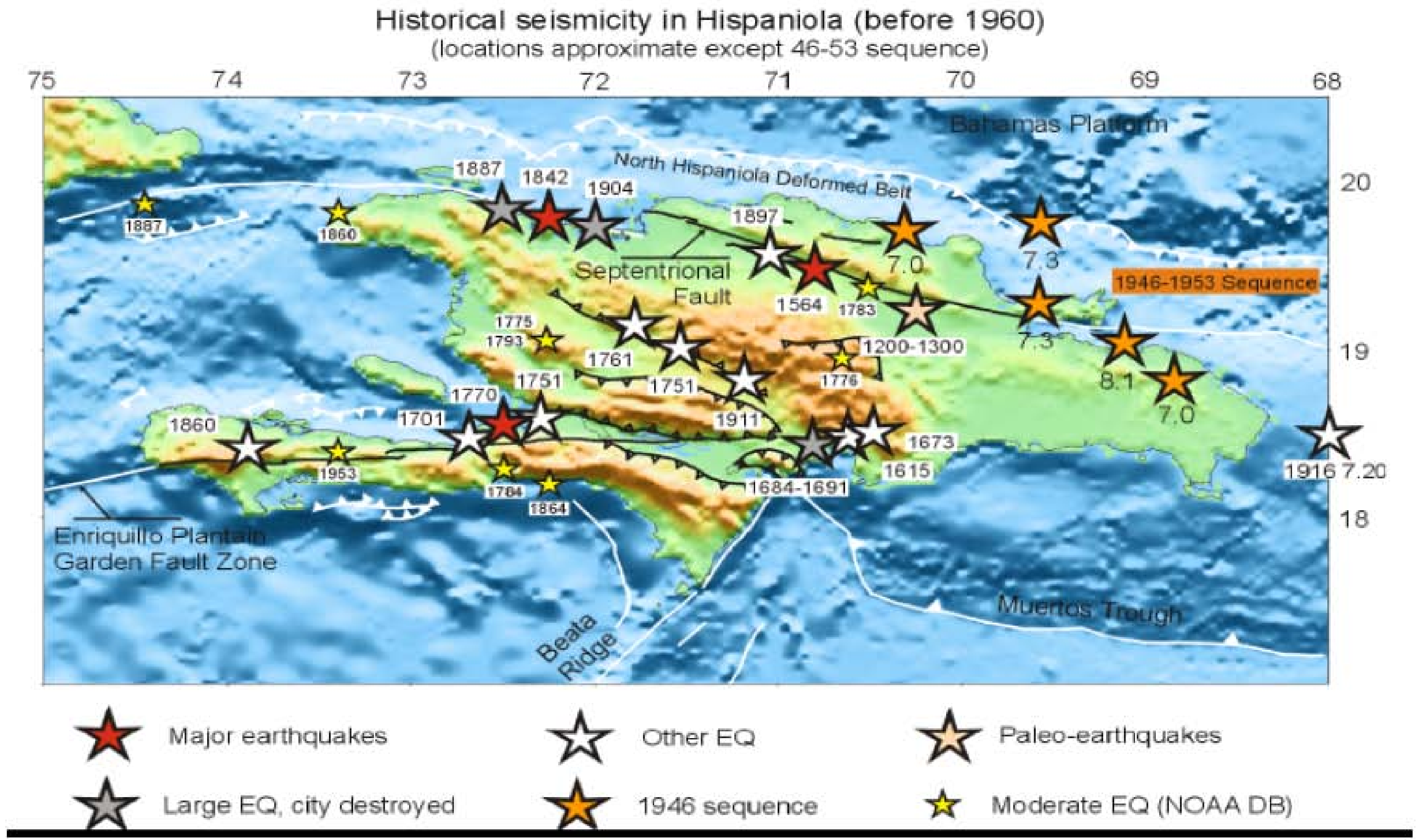


Figure 1: Historical Seismicity in Hispaniola prior to 1960. Last major earthquake near Port-au-Prince was in 1770.

Source: USGS

Haiti Damage Summary

- 20,000 Commercial Buildings – collapsed or damaged beyond repair
- 225,000 Residences– collapsed or damaged beyond repair
- Estimated 75% of city's combined commercial and residential structures will need to be torn down (Gerard-Emile Brun, President Rene Preval's Commission to evaluate damage and recommend ways to solve housing crisis, WSJ, 1/23/10)
- Government Buildings
  - National Presidential Palace
  - National Assembly
  - Supreme Court
  - Prison Civil de Port-au Prince
  - Ministry of Finance, Education, Communication and Culture
- Port-au-Prince Cathedral

Design and construction practices Haiti

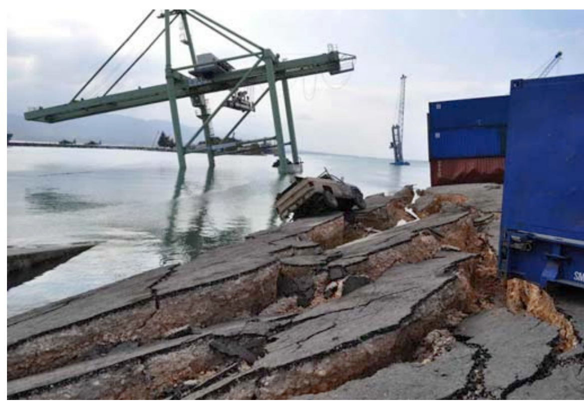
- Critical facilities/Engineered buildings –
  - Type –
    - Reinforced concrete (RC),
    - RC with infill walls,
    - Masonry block,
  - Design
    - No seismic design,
    - Substandard material

- Single family dwellings –
  - Type
    - Unreinforced masonry
    - Adobe
    - Concrete block or RC
    - No seismic design
    - Poor materials
    - High concentration
- Infrastructure – no seismic design
    - Lifelines
    - Transportation systems

Lifeline Damage, Haiti

- Downed Power Lines
- Road Blockage
- Failed Bridges
- Failed Water/Sewer System
- Port Facilities, etc.






Source: Anne Kiremidijian, PhD

OAS study on existing buidlings, Haiti, completed 12/09

- **Study detailed many flaws** and concluded far less serious disaster would destroy many of Haiti's buildings :
  - **Weak or missing reinforcement**
  - **Structures on steep slopes with unstable foundations**
  - **Inadequate or nonexistant inspections**
  - **Poor designs, materials and techniques**

OAS study not yet released
Miami Herald, 01/24/10

Downtown Port-au-Prince Ravaged by Quake, Haiti

Salesian Mission School collapsed by Quake in Slum of Cite Soleil, Haiti

CC UN Photo/Logan Abassi

Hotel Montana, Haiti
4-star hotel

originally built in 1946
Expanded to include shops, a swimming pool and conference facility.


CC Elena Heredero (wikimedia)

Before


CC UN Photo/Logan Abassi

After

Hotel Christopher, Haiti –
United Nation Stabilization Mission Headquarters
3-star hotel

No image

CC UN Photo/Logan Abassi

Before

After

UN Employees:
83 deaths, 23 missing

Sydney Morning Herald,
Jan 28, 2010

The Cathedral of Our Lady of the Assumption, Haiti

Built between 1884 and 1914, and was dedicated on December 13, 1928

CC Garrett Crawford (www.Flickr.com)

Before

CC UN Photo/Logan Abassi

After

Market / Commercial, Haiti

Existing Conditions Before Earthquake

Wood

CC JoseJose (www.Flickr.com)

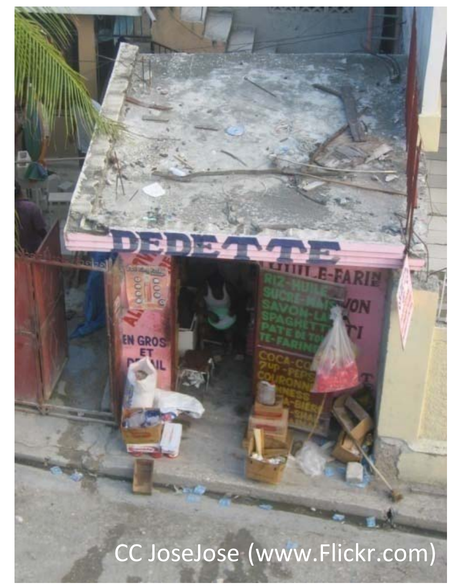
Market near Marche de Fer
Port-au-Prince, Haiti

Concrete

CC Vanberto (www.Flickr.com)

Iron Market
Port-au-Prince, Haiti

Masonry & Concrete



CC JoseJose (www.Flickr.com)

Store: Dedette
Port-au-Prince, Haiti

Residential, Haiti

Existing Conditions Before Earthquake

Masonry

Residential Neighborhood
Port-au-Prince, Haiti

Wood

Cite Militaire
Port-au-Prince, Haiti

Miscellaneous Materials: Corrugated Steel, Plywood & Plastic

Slum of Le Saline
Port-au-Prince, Haiti

Buildings that Survived

Reinforced Concrete Construction , Haiti

Built to International Building Code Requirements

Digicel 12-story Tower (tallest bldg in Port Au Prince)
Port-au-Prince, Haiti

US Embassy
Port-au-Prince, Haiti

Buildings that Survived, Residential Sandbag Construction, Haiti

Image used with permission from www.earthbagbuilding.com

Image used with permission from www.earthbagbuilding.com

Earthbag Sun House, Les Cayes, Haiti

Approximately 90 miles from Port-Au-Prince, the Sun House survived undamaged during Haiti's 7.0 earthquake. Neighboring buildings were destroyed.

Cal-Earth earthbag construction meets requirements for California Earthquake Building Codes

Optional Designs for future:
Earthquake and Hurricane Resistant Systems
Bamboo- Residential

© 2009 Bamboo Technologies

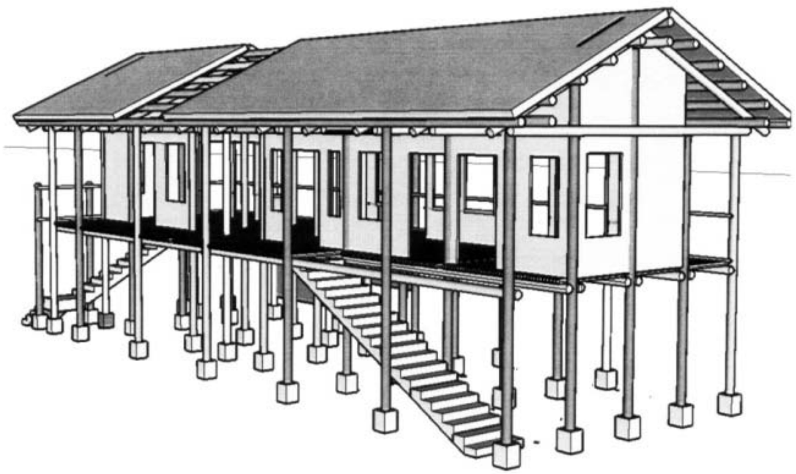
Bamboo system

© International Network for Bamboo & Rattan, 1997-2009

Bamboo House, India

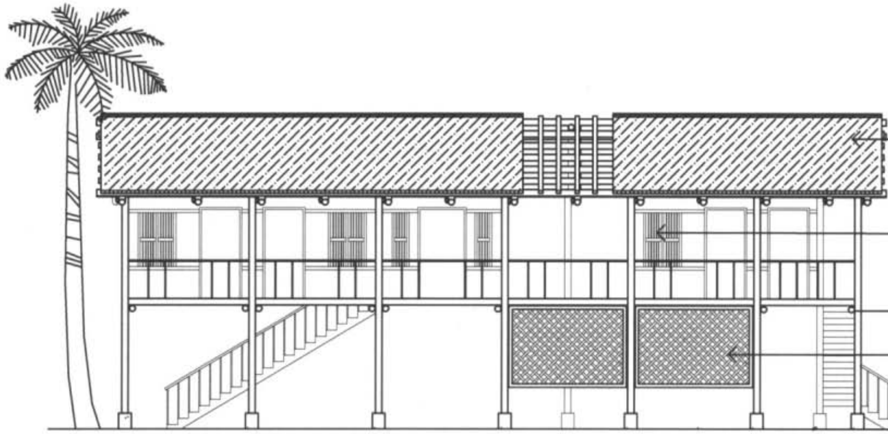
Can be engineered to meet earthquake and hurricane conditions.

Bamboo Building Methods



Resilient Bamboo Housing, Concept Sketch
Sri Lanka

Bamboo House - India



Steel Frame-
Residential & Commercial

Image w permission Steel Frame Housing USA

Steel Frame on Concrete Slab

Image w permission Steel Frame Housing USA

Completed Steel Frame House, 400 sf

System can be engineered to comply with CA Seismic Building Code and Miami Dade Hurricane Code

Image w permission Reid-Steel, British

4-story steel frame, Mauritus

Structural Concrete Insulated Panel, SCIP
Residential & Commercial

Ministry of Housing, Colombo, Sri Lanka. Example Housing

Can be engineered to meet seismic and hurricane requirements.

Photos taken after Hurricane Andrew in Homestead, FL. See roof picture below.

Images with permission from Advanced Structural Panel Industries, LLC

Structural Concrete Insulated Panel, SCIP

Image courtesy Goggle Maps

Before Hurricane Ike

Image courtesy NOAA, Satellite photo taken 9.14.2008

Post Hurricane Ike

Crystal Beach House,
Bolivar Island, Texas
Post Hurricane Ike

Building Configuration

Audubon Houses, Bolivar Penninsula, Texas

Building Configuration

School, Bolivar Penninsula, Texas

Building Configuration Recommendations- Flood

Blue Water Hotel: Open Piazza at Ground level allows the wave energy to pass through the structure and minimize damage

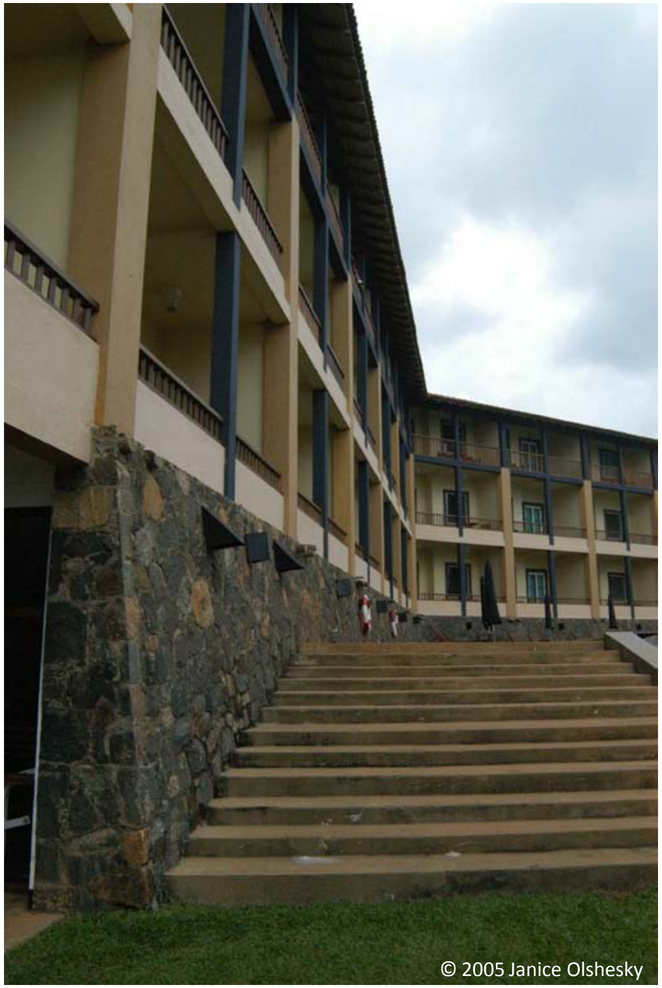
Reinforced Concrete
Blue Water Hotel, Wadduwa, Sri Lanka

View from the Sea, Indian Ocean

Blue Water Hotel, Wadduwa, Sri Lanka elevated structure on columns

View to Indian Ocean beyond

Building Configuration Recommendations- Flood
Lighthouse Hotel, Galle, Sri Lanka



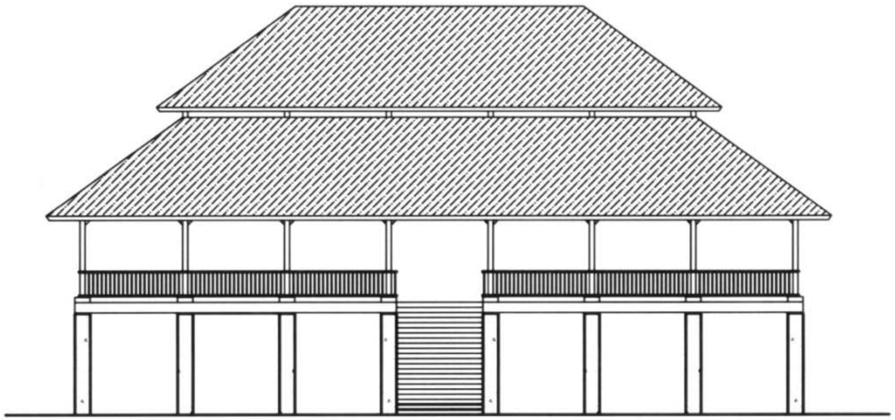
- Built along oceanfront on rock outcropping, buttressed base

Building Configuration- Flood Structure with many openings Lighthouse Hotel, Bath House

Damage was minor to this structure as water could move through it.

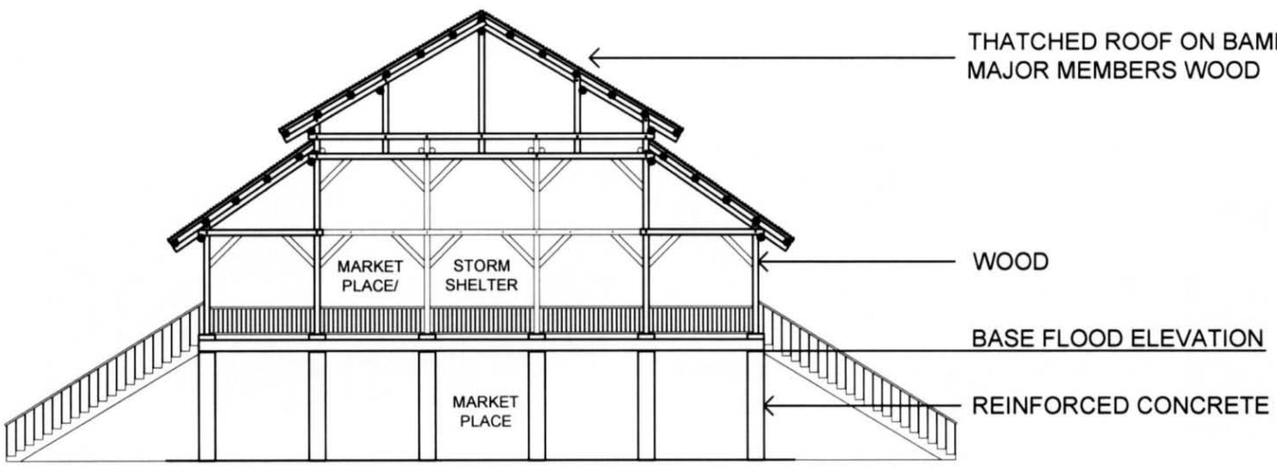
Design and Construction Guidelines

Reinforced concrete and bamboo roof: Civic Pavillion - Sri Lanka



Elevation

Elevated Structure, Colombo, Sri Lanka



Section – Civic Pavilion with Marketplace at Ground level, and first floor provides extended shelter during floods. Allows wave energy to pass through the structure.

Historic Structure design, Colombo, Sri Lanka

Framing Construction and Connections

- Recommended connections from foundation to roof

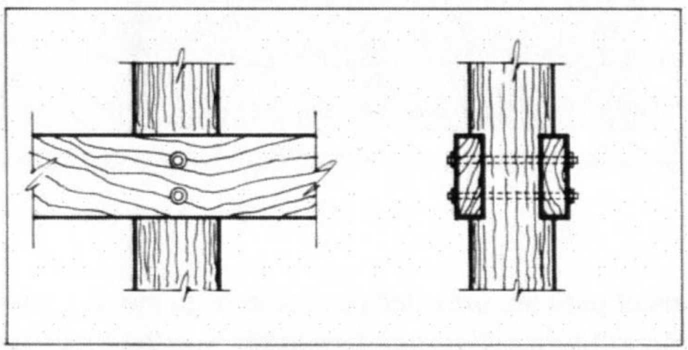


Figure 4.33. Dapped Pole Connection

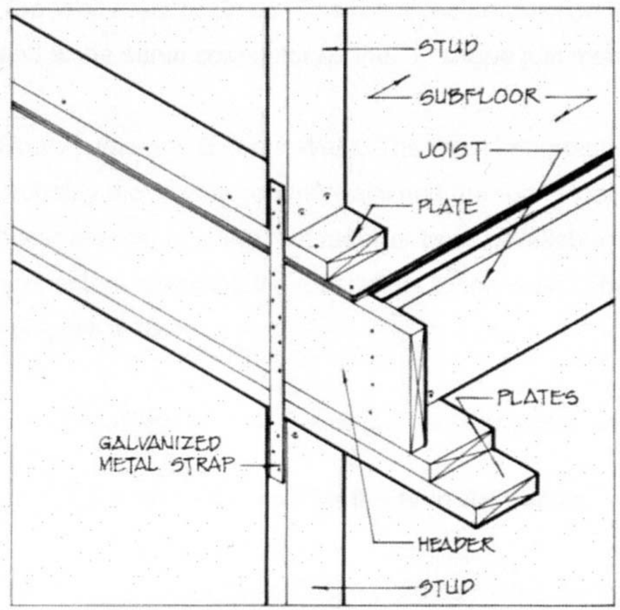


Figure 4.44. Stud-to-Stud Connections

Source: FEMA

Site and Ecosystem
Yala Safari Hotel

Photo Source: USGS

Before

After

Yala Safari Hotel

Before the Hotel was constructed, the natural sand dunes were removed for the guest's view of the Ocean

The Yala Safari Hotel was completely destroyed by the Tsunami.

Site and Ecosystem
Yala Safari Cabins

Ecosystem was undisturbed during construction

Cabin Roofs amongst trees

This is a view to the Ocean from the Dining Hall.

Ecosystem was undisturbed at Yala Safari Cabins. The sand dunes and mangrove trees were left intact. The Manager told us the water in the lagoon rose up but not too high. He explained the cabins sustained only minor damage, roof shingles had to be replaced.

Yala Safari Cabins

View from Dining Hall looking away from the Ocean from the same vantage point as the previous slide.

Existing Haiti Building Codes- OAS report

- There is no national Building Code in Haiti.
- When **technical standards are used, choice is by engineer responsible** for design of projects. Determined by the education background of the engineers.
- Most common norms are:
  - ASCE 7-02
  - French Norms
  - Canadian Norms

  (Source: Organization of American States)
- **Lack of enforcement**

Recommendations
Multi-Hazard Approach

- Address the multi-hazard problem
  - Earthquakes
  - Hurricanes
  - Mud/landslides
- Develop earthquake hazard maps (Kiremidijan PhD)
  - Ground shaking
  - Liquefaction potential
  - Landslide potential
- Develop hurricane hazard maps
- Develop maps for other hazards
- Design a country-wide land use map that takes into consideration these hazards

Recommendations Haiti Design/Construction Requirements

- Develop/adopt Building Codes and other infrastructure codes
    - Work with Caribbean Building Code (CUBIC), which does exist.
  - Seismic
  - Hurricane
  - Everyday loads
- Adopt FEMA enhancements
- Consider geological hazards – landslides, liquefaction, coastal erosion (Anne Kiremidijan, PhD)
- Consider environmental impact
- Include ideas of sustainability
- Use indigenous materials whenever possible/ prudent and cost effective

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