Guidelines for Buildings at Risk from Natural Disasters

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Drafting Committee

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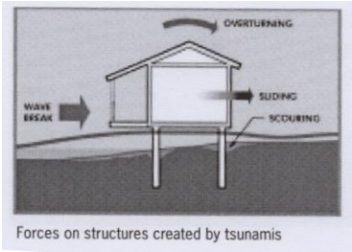
Sources & Resources

- Design of Buildings for High Winds, Ministry of Local Government and Housing, 1980
- Guidelines for Reconstruction of Houses affected by tsunami in Tamil Nadu, www.tn.gov.in/tsunami
- Coastal Construction Manual (3 vols.) Federal Emergency Management Agency, www.fema.gov/pdf/hazards/nhp_fema55.pdf

Post-tsunami Damage Surveys

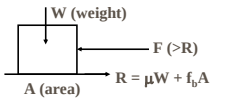
Forces induced by tsunamis



Forces on structures created by tsunamis

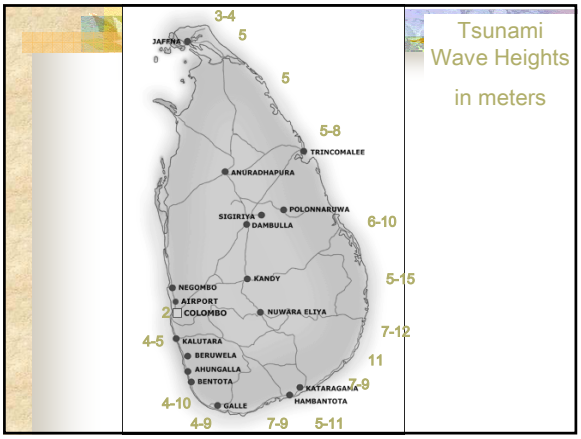
Overturning

Sliding Failure



Scouring - Partial collapse

Disaster Resistance in General



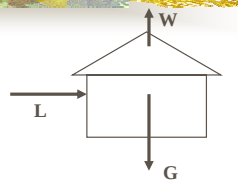
Design wind speeds (m/s)

Zone 1	49.0	(53.5)
Zone 2	42.5	(47.0)
Zone 3	33.5	(38.0)

Natural Hazards

- Cyclones (wind)
  - Northern & Eastern Provinces
- Waves (flooding, tsunamis)
  - Coastal Zone
    - Elevation < 3 m from MSL (5 m in N & E)
    - Distance < 500m from shore (1 km in N & E)
- Earthquakes (lateral motion)
  - All over country
  - Low intensity; hence moderate provision

Hazard Loads



- Loads:
  - Gravity loads – vertically down
  - Wind loads – vertically up (often); roofs
  - Wave loads; earthquakes – lateral; walls

Building to resist hazards

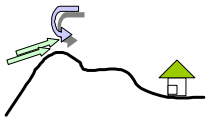
- Increase of weight
  - Additional material
- Introduction of steel reinforcement
  - Additional technology
  - Risk of corrosion
  - Increase in cost

General Guidelines

Location issues - elevation

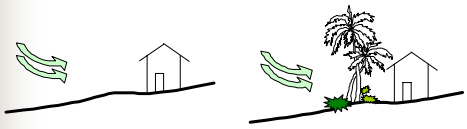
Bad

Good



Location Issues - shielding

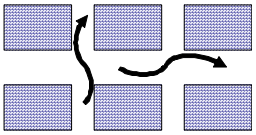
Bad Good



Planning Issues - clustering

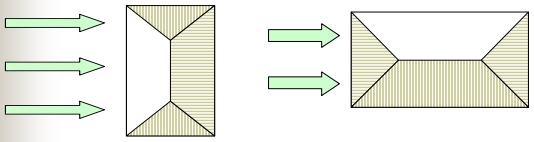
Tunnel Effect

Bad for wind Good for floods



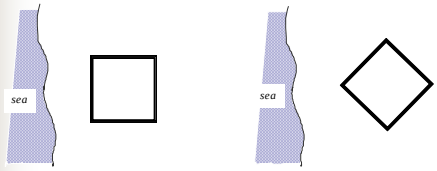
Planning Issues – orientation I

Bad Good



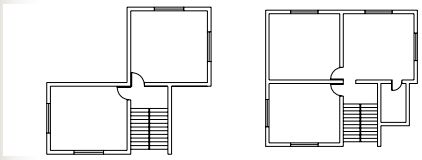
Planning Issues – orientation II

Bad Good



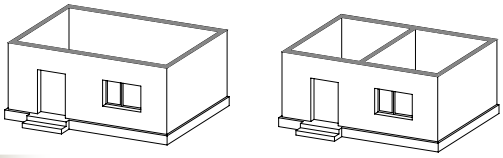
Layout issues – robust form

Bad Good



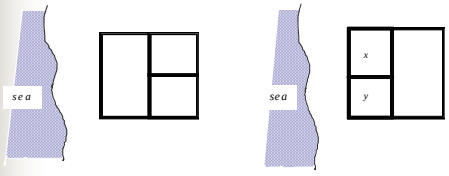
Layout issues – wall support 1

Bad Good



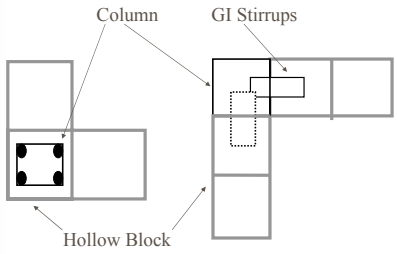
Layout issues – wall support 2

Bad Good

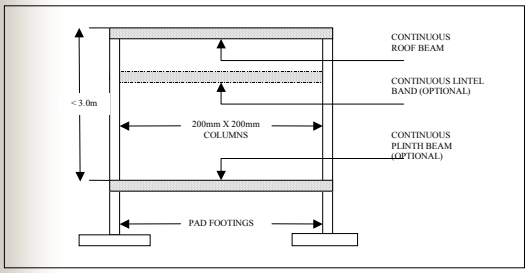


Specific Guidelines

Columns – connected to walls
(for *flooding*; also *cyclone & earthquake*)

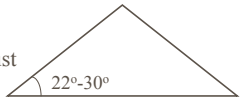


Horizontal beams/bands
(for *flooding*, *cyclone & earthquake*)



Roof – Reducing Uplift
(for *cyclone*)

- Increase Slope
  - Uplift → Downthrust



- Concrete Roofs
  - Weight > Uplift

Roof - Tying Down
(for *cyclone*)

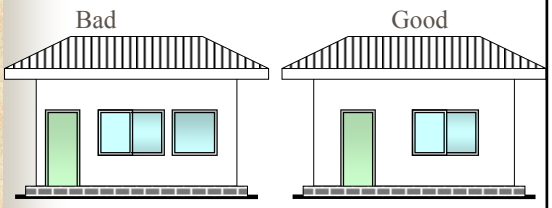
- Roofing material → Roofing frame → Walls or columns → Foundations
- Sufficient weight to mobilize
- Deterioration of tensile materials:
  - Fibres – UV
  - Steel / metal – sea spray

Walls
(for *flooding*, *cyclone*)

- Increase weight; thickness
- External walls
  - Preferably 200 mm min
  - If 100-150 mm, should be solid
- All walls tied at roof / lintel level

Wall Openings – restrict sizes

Aggregate width < 50% of wall width;
space > 600 mm, 50% of shorter opening ht (25% at corners)



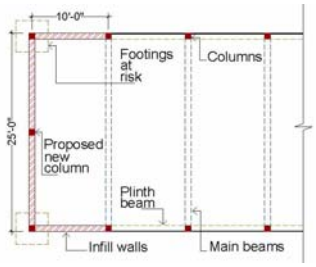
Multi-storey buildings - general

- Use multi- storey concrete frame structures in near shore areas (Vertical evacuation)
- Loadbearing wall structures are not the most desirable
- "Stilt" structures are probably the best, if properly designed (e.g. moment resisting frames, soft storey effect dealt with) and if the lower floor space can be utilized

Multi-storey buildings - scouring

- Shallow foundations must be founded well below scour level
- Aprons can be useful; and soil improvement
- Infill walls are required for bracing
- Long buildings can tolerate local damage
- Plinth beams are essential

Recommended Practice - example



Features of Booklet

- Essential requirements & Desirable features
- Flooding (**F**), Cyclone (C), Earthquake (E) (Boldface for importance)
- Figures for good & bad practice
- "Pre-engineered" buildings

New Systems and Materials

Performance based specifications

- Strength, Stability
- Deformation, Vibration
- Changes in properties (UV, water, salt)
- Fire suppression, Fire egress
- Thermal insulation, Ventilation, Lighting
- Rain penetration
- Economy, Maintenance & Repair, Employment potential
- Local raw materials, environmental impact

Agremént Board Concept:

- Not covered in codes of practice
- New materials and systems
- Sufficient calculations and testing
- Satisfying performance specifications
- Demonstration house is not enough!

Building Materials & Debris – An environmental issue

- Approx. no. of destroyed houses requiring reconstruction = 100,000
- Debris, per house (typical 500 sq. ft) = 17 cu.m.
- Hence total volume of debris = 1.7 mill. cu. m.
- Sand demand per house (typical 500 sq. ft) = 10 cu.m.
- Hence total sand demand = 1 mill cu. m.

(4" unplastered blockwork or 4" plastered brickwork)

Sand Supply and Demand – pre Tsunami - c. 2001

- Total Sand use/demand – 7.3 mill m^3
- Sand mining from Deduru Oya to Nilwala Ganga (major rivers in SW quadrant; unsustainable) – 4.1 mill m^3
- Note: river sand mining may be even more adverse for the coastline after the tsunami

Sand shortfalls and solutions? (post Tsunami)

- Commence Offshore sand project (Western province)
- Explore utilization of inland dune sand (Tsunami reconstruction only)
- Start major quarries in Southern and Eastern provinces
- Crushing, re-cycling technology for post-disaster situations

Conclusions

- Note that most disaster loads act laterally and upwards (rather than downwards)
- Hence tying down/together is important – most often done with RC elements
- Ensure connectivity and ductility (because disasters will create post-yield conditions)
- Robustness in form is also important
- Address environmental issues w.r.t. materials

Acknowledgements

- Mr Ron Watermeyer
- Dr Asoka Perera
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- Holcim (Lanka) Ltd
- Society of Structural Engineers, Sri Lanka

(Note: consult us thro' an engineer)