Risk and vulnerability assessment of health facilities: focus on structural and non-structural elements

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Sources of Information, Photographs and Sketches used in presentation:

1. Seismic Safety of non structural elements and contents in Hospital Buildings - GoI, UNDP
2. A homeowner’s guide to hurricane retrofitting - Institute for business and home safety
3. Improving wind/ cyclone resistance of buildings - Guideline by Prof A S Arya, GoI
5. Tool kit for Safe Hospitals - UNISDR
6. Field manual on capacity assessment of health facilities responding in emergencies, WHO
7. Training Manual on earthquake, cyclone, flood and tsunami safe construction in Fiji by Mr. Robert Pole and Josefani Bola
Who/What are Vulnerable?

- Buildings
- Patients
- Hospital Beds
- Medical and Support Staff
- Equipments and facilities
- Basic Lifelines and services
Structural elements

The “structure” is the part of the building that is designed to carry the weight of the building (dead load), its contents and people (live load), and the impact of wind and ground-shaking (dynamic load).
Non structural Elements

• The non-structural building elements include the stairways, doors, windows, chimney, lighting fixtures, heating ducts and pipes, wall cladding, and false ceilings.

• “building contents” includes all of those items that users bring into a building; furniture, appliances, electronics, equipment, coolers and air-conditioners, stored items, and so forth.
Non Structural elements for vulnerability assessment

<table>
<thead>
<tr>
<th>Architectural</th>
<th>Equipments &amp; Furnishings</th>
<th>Basic Installations and Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divisions and partitions</td>
<td>Medical equipment</td>
<td>Medical gases</td>
</tr>
<tr>
<td>Interiors</td>
<td>Industrial equipment</td>
<td>Industrial fuel</td>
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<tr>
<td>Facades</td>
<td>Office Equipment</td>
<td>Electricity</td>
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<td>False Ceilings</td>
<td>Furnishings</td>
<td>Telecommunications</td>
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<tr>
<td>Covering elements</td>
<td>Supplies</td>
<td>Vacuum network</td>
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<td>Cornices</td>
<td>Clinical Files</td>
<td>Drinking water</td>
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<tr>
<td>Terraces</td>
<td>Pharmacy shelving</td>
<td>Industrial water</td>
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<td>Chimneys</td>
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<td>Air conditioning</td>
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<tr>
<td>Surfacing</td>
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<td>Steam</td>
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<td>Glass</td>
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<td>Piping</td>
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<tr>
<td>Attachments (Signs, etc.)</td>
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<td>Waste disposal</td>
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<tr>
<td>Ceilings</td>
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<tr>
<td>Antennas</td>
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Vulnerability Assessment

- Vulnerability assessment of nonstructural elements should be carried out after the assessment of structural vulnerability, has been made, since the results of the latter are very valuable for judging the susceptibility to damage of non-structural elements.
Check list for structural assessment

- Location
- Shape/ Symmetry
- Height/ Storeys
- Roof type/ Angle
- Material of construction
- Alterations in original design
- Ramp
Check list for non structural elements

- Presence/ Number
- Location of equipments
- Anchorage
- Material of anchorage
- Location of chemical, hazardous material storage
- Training on handing

<table>
<thead>
<tr>
<th>Equipment</th>
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<tr>
<td>Central Air-conditioning Unit</td>
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<tr>
<td>Electric Generators</td>
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<tr>
<td>X-ray Equipment</td>
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<tr>
<td>Boiler</td>
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<tr>
<td>CT-Scan Machine</td>
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<tr>
<td>Hydrotherapy Pool</td>
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<tr>
<td>MRI Machine</td>
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<tr>
<td>Respirators</td>
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<tr>
<td>Anesthesia Machine</td>
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</tbody>
</table>
Location and orientation

Orientation/ direction of building

Turbulent flow of wind on longitudinal and transverse sides of high-rise buildings
Location and Orientation

*fig 4*
Shielding of house by hillock

*fig 5*
No shielding from high wind due to absence of barriers

Shielding from high wind by permeable barriers such as strong trees

Wind shielding of buildings
Location and orientation

- Buildings in valleys protected from high wind velocities
- Buildings in ridge attracting high wind velocities
- Construction at ground level - risk of inundation
- If natural elevation not available construction on stilts or artificially raised earth mounds
Total destruction of Princess Margaret Hospital in Jamaica

Construction close to the sea shore might result in great losses
Location and orientation

Straight line layout generates wind tunnel effect

Adopt non linear layout
Design

Wind velocity increase due to large openings at lower floors
Design

- Outer hang over of the roof less than 0.5 meters
- If the outer hangover is more, the roof undergoes more uplift force due to cyclonic winds
Design

Orientation of openings is parallel

- Any other arrangement of openings other than parallel, adds to the wind load and uplift load experienced by roof
Timber roof split due to strong hurricane winds
Design

Asymmetric building with empty pockets are more vulnerable to damage.

Symmetric buildings are more stable.
Mitigation Measures

- Having RCC roof
- Lateral and cross bracings for non RCC roofs
- Lateral bracings to walls
  Adds to strength of elements against lateral loads of wind
- Proper Anchorage of roofing elements
  It is very important for preventing roof from blowing away
- Safety net for country tile roofs
  To avoid falling of broken tiles from the roof in case of cyclone and earthquake
Mitigation Measures

Hatched area indicates where more frequent fixings are required

Hipped roof
Mitigation Measures

- Metal sheet fixings and purlin-to-rafter connection
  - Spacer block
  - Self-tapping screw
  - Metal sheeting
  - Rafter
  - Purlin
  - Galvanized hurricane strap fixed to rafter and purlin

Ridge connection

Valley connection
Wind can induce torsional effects on structural steel

Failure of an unreinforced masonry wall without an adequate base anchorage
Impact of windborne debris against louvre windows

A roof from a structure located 100 m away was violently thrown by the strong winds of a hurricane.
Structural Mitigation Measures

Detail of stud to concrete footing connection
Stud and top plate connection

Double top plate
Galvanized plate
Stud & top plate connection

Stud and top plate connection
Rafters and top plates should be anchored with galvanized straps.
Use of galvanized hurricane straps is recommended

Timber rafter connection to concrete

Structural Mitigation Measures
Mitigation Measures
Mitigation Measures

- Smaller glass panes
- Plastic film on glass
- Metal screen, grill in windows
Flood Mitigation Measures

- Protected Water Sources
- Dewatering arrangements
- Drainage design
- Height of plinth and HFL
- Pavement in surrounding
Effects

TSUNAMI - INUNDATED WARD AT NAGAPATTINAM HOSPITAL

Bhuj Hospital- Gujarat Earthquake 2001
For a hospital it is essential to have protection against penetration of windborne debris and water.

Anchorage of protective shutters on outside walls.

Anchorage system of shutters on interior columns.
Risk from Non Structural Elements

Shelves containing medicines etc. without anchorage
Risk from Non Structural Elements

- Storage cabinets next to sitting space without anchorage
- Unanchored storage cabinets in the corridor can cause obstruction during evacuation.
- Unanchored furniture and accessories
- Picture frames resting on furniture fall down
Risk from Non Structural Elements
Mitigation Measures

- **Removal** - hazardous material
- **Relocation** - heavy object on a top shelf
- **Restricting the mobility** - gas cylinders and power generators
- **Anchorage** - water heater
- **Flexible couplings** - between separate parts
- **Supports** - ceilings
- **Substitution** - heavy tiles
- **Modification** - rigid glass with adhesive plastic
- **Isolation** - loose objects.
- **Reinforcement** - chimney
- **Stock piling and tools on hand**
Non Structural Mitigation Measures

Tall or narrow furniture can fall!

Items on wheels or smooth surfaces can roll or slide!

Roller mounted eq
Mitigation Measures

A good example of strapping external equipments
Mitigation Measures

Pipes crossing expansion joint of the building

External oxygen and gas tanks should not be loose

Unanchored oxygen cylinders
Risk from Non structural elements

Restraints and fasteners for larger external elements like tanks
Mitigation Measures

SECURE WATER TANKS

Secure Signage, Satellite Dishes, Architectural Cladding an Glass
THANK YOU