

APPENDIX A-V

DETAILED ENGINEERING

CHECK LIST FOR DESIGNING TO COUNTERACT NATURAL HAZARDS

(Earthquakes, Hurricanes and Torrential Rains)

Appendix V constitutes a comprehensive list of issues to be addressed in designing to counteract the effects of natural hazards. This is a very complex process, if done properly and thoroughly. Thus, check lists are invaluable to the exercise. For any particular project all of the items may not be relevant, but excluding item from a comprehensive list is always easier than adding relevant items to a short list.

1 Seismic, Hurricane and Rain Hazards

1.1 History

- 1.1.1 Earthquake
- 1.1.2 Hurricane
- 1.1.3 Torrential rain

1.2 Geology

1.3 Tectonics

1.4 Design characteristics

- 1.4.1 Earthquake design characteristics
- 1.4.2 Hurricane design characteristics
- 1.4.3 Design characteristics for torrential rains

2 Site Conditions

2.1 Soils

- 2.1.1 Liquefaction
- 2.1.2 Seismic characteristics

2.2 Topography

- 2.2.1 Landslide
- 2.2.2 Building on slopes
- 2.2.3 Topographic effect on wind speed
 - 2.2.3.1 Ridges
 - 2.2.3.2 Valleys
- 2.2.4 Flood prone areas
 - 2.2.4.1 Torrential rains
 - 2.2.4.2 Storm surge
 - 2.2.4.3 Tsunami

2.3 Other Factors

- 2.3.1 Corrosive Environments
 - 2.3.1.1 Coastal areas
 - 2.3.1.2 Industrial and other chemical pollutants

3 The Client's Brief

- 3.1 Function
- 3.2 Cost
- 3.3 Reliability
 - 3.3.1 Serviceability for different components of the facility
 - 3.3.2 Safety for different components of the facility

4 Design Philosophy

- 4.1 Performance in moderate and frequent hazardous events
 - 4.1.1 Protection of property
 - 4.1.1.1 Cost of repairs should be minor
- 4.2 Performance in strong, rare, hazardous events
 - 4.2.1 Saving lives
 - 4.2.2 Repairable damage (very critical facilities in earthquake events)
 - 4.2.3 Protection of all property in hurricanes and torrential rains
 - 4.2.4 Protection of all property in earthquakes (base isolation)
- 4.3 Critical areas or components of facilities
- 4.4 Post-yield behavior of structural elements
 - 4.4.1 Ductility
 - 4.4.2 Energy absorption
 - 4.4.3 Deformations
- 4.5 Building Envelope for Hurricanes
 - 4.5.1 Windows, external doors and roof cladding

5 Choice of Form or Configuration

Poor design concepts can be made safe but are unlikely to perform really well in strong earthquakes

- 5.1 Failure modes
 - 5.1.1 Redundancy
 - 5.1.2 Accidental strength
 - 5.1.3 Column capacities (and those of other vertical load-carrying elements) – New Zealand's "capacity design"
 - 5.1.4 Designing for failure
 - 5.1.4.1 Avoid failure in vertical, shear and compression elements

- 5.1.4.2 Avoid brittle failure
- 5.1.4.3 Avoid buckling failure
- 5.1.5 For hurricane forces design for repeated loads without degradation

5.2 Geometric issues

- 5.2.1 Simplicity and symmetry
- 5.2.2 Long buildings to be structurally broken (separation gaps of sufficient widths to avoid Hammering earthquakes)
- 5.2.3 Elevation shape
 - 5.2.3.1 Sudden steps and setbacks to be avoided
- 5.2.4 Uniformity
 - 5.2.4.1 Distribution of structural elements
 - 5.2.4.2 Principal members to be regular
- 5.3.4.3 Openings in principal members to be avoided
- 5.2.5 Continuity
 - 5.2.5.1 Columns and walls from roof to foundation (without offsets)
 - 5.2.5.2 Beams free of offsets
 - 5.2.5.3 Coaxial columns and beams
 - 5.2.5.4 Similar widths for columns and beams
 - 5.2.5.5 Monolithic construction
- 5.2.6 Stiffness and slenderness ($h > 4b$)
 - 5.2.6.1 Stiffness versus flexibility
 - 5.2.6.2 Maintaining the functioning of equipment
 - 5.2.6.3 Protecting structure, cladding, partitions, services
 - 5.2.6.4 Resonance
- 5.2.7 Favourable and unfavourable shapes
 - 5.2.7.1 Square
 - 5.2.7.2 Round and regular polygons
 - 5.2.7.3 Rectangular
 - 5.2.7.3.1 Aspect ratios
 - 5.2.7.4 **T** and **U** shaped buildings
 - 5.2.7.4.1 Aspect ratios
 - 5.2.7.4.2 Deep re-entrant angles
 - 5.2.7.4.3 Establish structural breaks (create rectangular plan forms – see 5.2.2)
 - 5.2.7.5 **H** and **Y** shaped buildings
 - 5.2.7.5.1 Aspect ratios
 - 5.2.7.5.2 Deep re-entrant angles
 - 5.2.7.5.3 Establish structural breaks (create rectangular plan forms – see 5.2.2)
 - 5.2.7.6 External access stairs
 - 5.2.7.7 False symmetry – regular perimeter masking irregular positioning of internal Elements
- 5.2.8 Soft storey
- 5.2.9 Cantilevers to be designed conservatively
- 5.2.10 Desirable roof shapes for hurricane resistance
 - 5.2.10.1 Steep pitched roofs (20-40 degrees)
 - 5.2.10.2 Hipped roofs are preferable
 - 5.2.10.3 Gable roofs are an acceptable compromise
 - 5.2.10.4 Mono-pitched roofs are undesirable

- 5.2.10.5 Boxed eaves recommended for overhangs exceeding 450mm
- 5.2.10.6 Parapets reduce wind uplift
- 5.2.10.7 Ridge ventilators reduce internal pressures

5.3 Distribution of horizontal load-carrying functions in proportion to vertical load- carrying functions (avoid the overturning problem)

5.4 Structural system to be agreed by design team

- 5.4.1 Moment-resisting frames
- 5.4.2 Framed tubes
- 5.4.3 Shear walls and braced frames
- 5.4.4 Mixed systems

6 **Choice of Materials**

6.1 Local availability

6.2 Local construction skills

6.3 Costs

6.4 Politics

6.5 Ideal properties

- 6.5.1 High ductility
- 6.5.2 High strength-to-weight ratio
- 6.5.3 Homogeneous
- 6.5.4 Ease of making connections
- 6.5.5 Durable

6.6 Order of preference for low-rise buildings

- 6.6.1 In-situ reinforced concrete
- 6.6.2 Steel
- 6.6.3 Reinforced masonry
- 6.6.4 Timber
- 6.6.5 Prestressed concrete
- 6.6.6 Precast concrete
- 6.6.7 Unreinforced masonry not recommended

6.7 Light- weight roof cladding of pitched roofs

- 6.7.1 Method of fixing critical to roof performance

7 **Construction Considerations**

7.1 Supervision

7.2 Workmanship

7.3 Ease of construction

8 **Components**

8.1 Base isolators and energy-absorbing devices (to be given consideration)

8.2 Foundations

8.2.1 Continuous

8.2.2 Isolated (to be avoided)

8.2.3 Piled

8.3 Movement and separation joints

8.4 Diaphragms

8.5 Precast concrete

8.6 Welded beam-column joints for moment-resisting steel frames (to be avoided)

8.7 Shear walls and cross bracing

8.8 Hurricane straps, wall plates and connections

8.9 Joint details for roof trusses

8.10 Asbestos-cement cladding (unfavourable in hurricane situations)

9 **Elements**

9.1 Structure

9.2 Architecture

9.3 Equipment

9.3.1 Electrical feed to be kept clear of roof structure

9.3.2 Electrical feed to be routed underground within the property

9.4 Contents

10 **Cost Considerations**

10.1 Capital costs ignoring natural hazards (hypothetical, academic)

10.2 Capital costs including natural hazards

10.3 Maintenance costs

11 **Analysis**

11.1 Understanding the structural model

11.2 Torsional effects

11.3 Geometric changes
 11.3.1 The P-delta effect

11.4 3-D analysis (required only for irregular structures)

11.5 Dynamic analysis (required only for complex structures)

11.6 Stress concentrations

11.7 Complexity of earthquake effects and inadequacies of sophisticated analytical method

11.8 Effects of non-structural elements
 11.8.1 Change in the natural period of the overall structure
 11.8.2 Redistribution of lateral stiffness and, therefore, forces and stresses (this could lead to premature shear or pounding failures of the main structures and also excessive damage to the said non-structural elements due to shear or pounding)

11.9 Soil-structure interaction
 11.9.1 Critical but usually ignored or played down

12 **Detailing**

12.1 Compression members

12.2 Beam-column joints
 12.2.1 Reinforced concrete
 12.2.2 Structural steel: - all-welded construction

12.3 Reinforced-concrete frames

12.4 Non-structural walls and partitions

12.5 Shelving

12.6 Mechanical and electrical plant and equipment
 12.6.1 Securely fastened to the structure
 12.6.2 Pipework

13 **Construction Quality**

14 **Maintenance**

14.1 Refer to Appendix A-XI – “Maintenance as a Tool for Mitigation”