Introduction

This training package describes how poor design and construction practices contribute to the catastrophic collapse of South-east Asia and South Pacific village buildings, under the action of cyclones, earthquakes and tsunamis.

Construction Problems Under Cyclone, Earthquake & Tsunami

Let us pause for a moment,
and remember those killed in natural disasters
(just ordinary people like you and me)
in the wrong place at the wrong time.

The following pages are just a few examples of the devastating power of cyclonic winds, earthquakes and tsunamis in our region.

Cyclone Damage

Cook Islands, February 2010

Photos: Cyclone Damage on Aitutaki in the Cook Islands
Courtesy of D Kaunitz (Emergency Architects Australia)

Earthquake Damage

Aceh Indonesia, December, 2004

Tsunami Damage

Indonesia, Thailand, India, Sri Lanka – December 2004

Earthquake and Tsunami Damage

Solomon Islands, April 2007

Some buildings are less prone to damage than others

Although subjected to the same cyclone, earthquake or tsunami, some houses remain virtually unscathed while others are destroyed or rendered unusable.

The following two houses, side by side, were both subjected to the 2007 Solomon Islands earthquake and tsunami. The more substantial green “timber and concrete house” includes adequate horizontal load resistance (in the form of a strong lower storey room), while the adjacent brown “leaf house” (without any bracing) is now unserviceable and requires temporary props to prevent collapse.

The common feature is that **all surviving houses are well-built and braced** (in some cases by braced lower storey walls, in other cases by diagonal bracing).

Poor design and construction contributes to failures

The following pages show various examples of both good and bad design or construction.

Lack of bracing

Compaction under Piers, Footings, Ring Beams and Slab-on-Ground

The foundations under concrete piers, footings, ring beams and slab-on-ground must be properly compacted. Weak soils should be excavated and replaced.

Pad Footings and Column Reinforcement Thailand

Pad Footings and Column Reinforcement India (Villupurum)

Unreinforced concrete slab-on-ground Sri Lanka (Trincomalee)

Reinforcement in Footings & Ring Beam

There must be sufficient reinforcement in ring beams, columns and footings
Aceh (Tibang)

Too much reinforcement in ring beams, columns and footings wastes money and makes it difficult to compact concrete
Aceh (Lam Kruet)

Too Much Water in Concrete

Reference: *Beware of excess water*, Cement Concrete & Aggregates Australia, March 2006:

Strength – The strength of concrete, and its ability to support loads, can be severely reduced by too much water in the mix.

Cracking – As water evaporates from concrete during hardening, there is a tendency for "early-age cracking" and "drying shrinkage cracking". The width and extent of cracks will increase as the amount of water is increased.

Delamination – If concrete is too wet when finished, it could dry and shrink at the surface, while remaining moist underneath, thus causing delamination.

Abrasion / Surface Dusting - Excessive moisture in concrete can lead to reduced abrasion resistance of the surface, 'dusting' and exposure of the coarse aggregate.

Durability – Concrete with excess water will be more prone to penetration by water and salts, and may exhibit reinforcement corrosion and surface spalling (concrete cancer).

Reinforcement Cover in Concrete

Steel reinforcement must be surrounded with sufficient thickness of well-compacted concrete, to prevent corrosion of the steel and spalling of the concrete, commonly known as “concrete cancer”.

Suspended concrete roof corrosion (India)

Concrete wall corrosion (Australia)

Concrete lintel reinforcement corrosion (India)

Sub-floor Bracing

Buildings must include adequate sub-floor bracing, that is adequately fixed into the structure.

Inadequate Bracing
(Solomon Islands)

Bolts too close to the end of timber brace
Papua New Guinea (Mt Hagen)

Wall Framing & Bracing

Buildings must also include adequate wall bracing.

Improvised Connectors – PNG

Inappropriate Joint in Top Plate – PNG

Wall Bracing – PNG (Mt Hagen)

Inadequate Wall Bracing – Australia

Anchorage of Roof Tiles or Roof Sheeting

The roof framing and cladding (including tiled or steel sheet roofing) must be adequately tied down to the structural frame.

Tiles tied down – Thailand

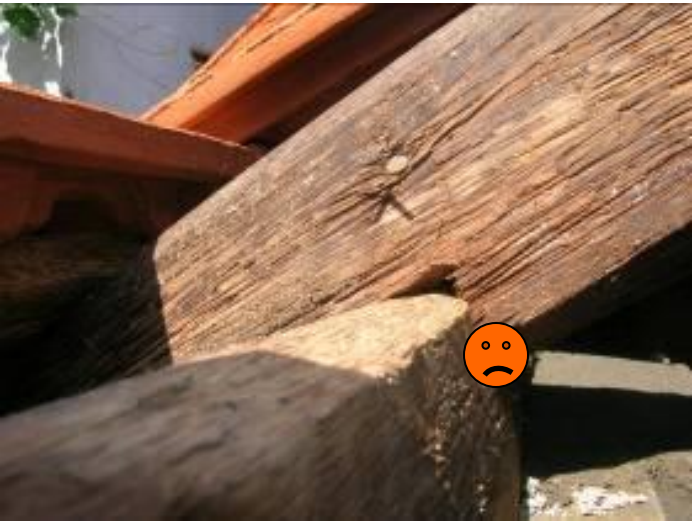
Roof sheeting tied down – Indonesia

Tiles not tied down – India

Tiles not tied down – Sri Lanka

Anchorage of Roof Framing

Roof anchorages must be designed and constructed to resist wind uplift.



Skew Nail - India

Welded Reinforcement - Thailand

Bent reinforcement – Aceh

Framed Roof - Aceh

Fixing Masonry Walls Into the Structure

Masonry walls must be properly fixed into the structure.

Brick to Concrete Columns
Indonesia (Aceh)

Bonded Masonry - Sri Lanka (Trincomalee & Batticoloa)

No ties between columns and masonry – Sri Lanka (Galle)

Quality of Bricks, Blocks & Mortar

Bricks, blocks and mortar must be of the specified quality to ensure that they remain durable.

Concrete Blocks & Mortar
Sri Lanka (Batticoloa)

Clay Bricks & Mortar
India (Villupuram)

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This training package covers broad engineering principles and building practices, with particular emphasis on affordable housing and associated village infrastructure in the Asia-Pacific region. These broad principles and practices must be translated into specific requirements for particular projects by professional architects, engineers or builders with the requisite qualifications and experience. Associated sample specifications and drawings are available in electronic format, with the express intention that architects, engineers and builders will edit them to suit the particular requirements of specific projects. The design, construction and costing of structures must be carried out by qualified and experienced architects, engineers and builders, who must make themselves aware of any changes to the applicable standards, building regulations and other relevant regulations. The authors, publishers and distributors of these documents, specifications and associated drawings do not accept any responsibility for incorrect, inappropriate or incomplete use of this information.

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