COMMUNITY STRUCTURES
DESIGN & STRENGTHENING GUIDE

1) BUILDING SHAPE
2) FOUNDATION
3) BRACING
4) CONNECTIONS
5) COLUMN SPACING
6) RAFTER & PURLIN SPACING
7) TIE BEAM
8) OVERHANG
PURPOSE OF THIS GUIDE

THIS GUIDE IS:

This is a guide to designing, building and strengthening simple community structures.

Section 1: Designing new buildings
Section 2: Strengthening exiting building
Section 3: Strengthening CPA/TLCs & CFSs

Using this guide will increase the likelihood that buildings will survive the upcoming monsoon and cyclone season. However, it is not a guarantee that the buildings will be ‘cyclone-proof’ and these buildings should not be used as cyclone refuges.

THIS GUIDE IS NOT:

This is not a guide for building cyclone refuges. It is very unlikely that any bamboo community structure will survive a cyclone.

Community structures in the camp should not be designated as cyclone refuges, even after strengthening, unless specifically designed as such.
SECTION 1: DESIGNING NEW BUILDINGS

ESSENTIAL REQUIREMENTS:
1. Not in flood zone
2. Not in landslide zone
3. Drainage around building
4. Good access
5. Plinth
6. No bamboo embedded in ground
7. Columns anchored into ground
8. Beams tied down to columns (with dowel or through column)
9. Borak bracing in all four walls
10. Maximum 20’ between braced walls
11. Perimeter Column spacing < 5'
12. Internal Column spacing < 10'
13. Rafter spacing < 5’
14. Rafter span < 8’
15. Purlin spacing < 1'
16. Rope bracing in roof
17. Roof is tied down

PREFERABLE REQUIREMENTS:
1. Hipped roof
2. Small roof overhang (cut back if greater than 1.5’)
3. Sheltered from wind
4. Good access during rains
5. Male and Female WASH facilities

- Hipped roof reduces wind load
- Roof tied down to columns
- Columns anchored into ground
- Perimeter columns at 3-5’ spacing
- Internal columns at 6’ - 10’ spacing reduce span
BUILDING SHAPE

KEY POINTS:
1. Minimum roof pitch: 3’ rise in 10’ span (shallow roofs may collapse under weight of water)
2. Avoid monopitch roofs with large overhang at top (roof will pull off in cyclone)
3. Hipped roofs are best for cyclone

× Water will pond on roof → Collapse in monsoon
× No internal columns / internal columns too widely spaced
× Large overhang at top → roof will pull off in cyclone

✓ Pitched roof → no ponding
✓ Internal columns reduce span (max. spacing = 10’)
✓ Gable end will attract large wind loads

✓ Pitched roof → no ponding
✓ Internal columns reduce span (max. spacing = 10’)
✓ Hipped roof reduces wind load
FOUNDATIONS

KEY POINTS:
1. Raise building off ground with plinth
2. Anchor column into ground
3. **Keep bamboo out of ground**
   - Bamboo in ground or concrete will rot in ~ 6 months

- Not Anchored
- Anchored
- Bamboo will rot
- Bamboo kept out of ground using steel bracket
- Bamboo columns can be easily replaced in future
COLUMNS LAYOUT

INTERNAL COLUMNS
Min. 3.5” DIAMETER
POSITION INTERNAL COLUMNS IN EVERY OTHER BAY
RECOMMENDED: 6-10’
MAXIMUM: 12’

PERIMETER COLUMNS
Min. 3.5” DIAMETER
RECOMMENDED: 3-5’
MAXIMUM: 6’

BRACED INTERNAL WALLS / EXTERNAL BRACING
MAX DISTANCE BETWEEN BRACED WALLS = 20’
Add braced internal wall (or external bracing/props) if building is longer than 20’
KEY POINTS:
1. **Bracing in ALL 4 walls**
2. Minimum **two panels each wall**
3. 3-4” Borak Bamboo
4. **Stiff connection at both ends using dowels**
5. Add rope X-Bracing in internal walls if possible
6. **Max. distance between parallel braced walls = 20’**
   1. Add internal braced walls building is longer than 20’
ADDITIONAL BRACING

KEY POINTS:
1. Additional rope bracing can be installed quickly & easily
2. X-Bracing in ALL 4 walls and internal walls
3. 6mm rope doubled up & tightened by twisting

Note: Rope to be used as additional bracing only. Primary bracing must be borak bamboo.
CONNECTIONS

KEY POINTS:

1. **ALL ELEMENTS TIED DOWN**
   Purlins → Rafters → Beams → Columns
   Column anchored into Ground

2. **NO NAILS – Bamboo will split as it shrinks**

3. Tie beam/rafter down to column using dowel through column

4. **Holes must be oversized to avoid splitting**
   10mm bolt → 11-12mm drilled hole
   Use hand drill. Do not cut holes.

5. **Fishmouth connection**
   Column diameter greater than Beam Diameter (or shape fishmouth with chisel to ensure good fit)

---

BEAM TIED DOWN TO COLUMN
HOLE DRILLED BELOW FINAL NODE

PURLINS TIED DOWN TO RAFTER
RAFTER TIED DOWN TO BEAM
BEAM TIED DOWN TO COLUMN

COLUMN ANCHORED INTO GROUND
BAMBOO LIFTED OFF GROUND
USING STEEL PLATE
BOLT HOLES NOT OVERSIZED → SPLITTING

FISHMOUTH CONNECTION WILL SPLIT
ROOF STRUCTURE

KEY POINTS:

1. RAFTERS: 4” Borak
   1. Max Spacing: 5’
   2. Max. Span: 8’
2. PURLINS: 2” Mulli
   1. Max Spacing: 1’
   2. Max. Span: 5’

Add Borak rafter at mid-span if column spacing > 5’

Mulli purlins @ 1’ c-c
Max. Span = 5’

4” Borak Rafters @ 3-5’ c-c
Max. Span = 8’
Rafter should be located above column

Beams & Rafters tied down to Column

4” Borak Columns @ 3-5’ c-c

Max. Overhang = 1.5’

4” Borak Tie Beam
Max Spacing = Every other column
Tie beam connected to edge beam with dowel
ROOF BRACING

ROPE PLAN BRACING IN ROOF
(necessary to prevent long walls collapsing sideways)

LONGITUDINAL (VERTICAL) BRACING IN ROOF – BORAK
(most important in buildings with gable ends)
CGI ROOFS

RECOMMENDED:

- **Avoid the use of CGI**
  - Expensive, Hot in the sun, Cold in winter, Noisy during rains
  - EXTREMELY DANGEROUS DURING CYCLONE
  → TAKE DOWN OR TIE DOWN IF HIGH WINDS FORECAST
  → Use tarpaulin instead if possible

- If using CGI:
  - Purlins: 2” x 2” at 2’ spacing
  - Max. Purlin span: 4’
  - Use frequent nails to hold down CGI. Every 1’ at roof edge.
  - Bend back nails (or tie CGI down to purlins)
  - Use cleats or hurricane straps to connect purlins to rafters (nail sideways, not downwards)

![Diagram of CGI roof]

- **Nail not bent back** → CGI will pull off easily
- **Purlin is too small** → split
- **Purlin nailed downwards to rafter** → use cleat instead
- **Connect purlin to rafter w. cleat**
## SUMMARY SITE IMPROVEMENTS

<table>
<thead>
<tr>
<th>RISK</th>
<th>REQUIREMENT TO MITIGATE THE RISK</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOOD RISK</td>
<td>Ensure that new facility is not in flood risk area.</td>
</tr>
<tr>
<td>LANDSLIDE RISK</td>
<td>Ensure that new facility is not in landslide risk area.</td>
</tr>
<tr>
<td>ACCESS</td>
<td>Construct pathways, stariways and bridges with handrails.</td>
</tr>
<tr>
<td>LOCAL FLOODING</td>
<td>Construct robust drainage around building connected to main drainage and alongside access routes.</td>
</tr>
<tr>
<td>MUDSLIDES</td>
<td>Add retaining walls. Terrace slope using borak posts &amp; jute bags. Plant grass or vetiver on exposed slopes.</td>
</tr>
<tr>
<td>BUILDING ON SLOPE</td>
<td>Underpin building using precast concrete (preferable) or borak posts.</td>
</tr>
</tbody>
</table>

For more guidance on Site Works please refer to the **Site Risk Mitigation Guide** and the **Site Improvement Catalogue**.

Available at the Site Management Sectors: smcxb.tech@gmail.com
<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>REQUIREMENTS FOR SAFE STRUCTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUILDING SHAPE</td>
<td>Buildings with hipped roof have smaller uplift.</td>
</tr>
<tr>
<td>FOUNDATIONS</td>
<td>Install reinforced concrete footings with metal straps/steel bracket. Bamboo needs to be kept out of ground using steel bracket.</td>
</tr>
<tr>
<td>COLUMNS LAYOUT</td>
<td>External column spacing recommended 3’-5’ c-c</td>
</tr>
<tr>
<td></td>
<td>Internal column spacing recommended 6’-10’ c-c (if not possible add haunches)</td>
</tr>
<tr>
<td>BRACING</td>
<td>Add borak bracing to all four walls connected with dowels.</td>
</tr>
<tr>
<td></td>
<td>Additional rope bracing (only in combination with borak bracing).</td>
</tr>
<tr>
<td></td>
<td>Add internal braced wall if building &gt; 20’ long or prop building externally.</td>
</tr>
<tr>
<td>CONNECTIONS</td>
<td>Do not use nails with bamboo structure.</td>
</tr>
<tr>
<td></td>
<td>All elements need to be tied down and columns anchored to the ground.</td>
</tr>
<tr>
<td></td>
<td>Fishmouth connections. Holes must be oversized to avoid splitting.</td>
</tr>
<tr>
<td>ROOF STRUCTURE</td>
<td>Rafters: max spacing 5’, max span 8’</td>
</tr>
<tr>
<td></td>
<td>Purlins: max spacing 1’, max span 5’</td>
</tr>
<tr>
<td></td>
<td>Rafters need to be located above columns.</td>
</tr>
<tr>
<td></td>
<td>Ensure tie beam is connected to the edge beam using dowel to prevent slip.</td>
</tr>
<tr>
<td>ROOF BRACING</td>
<td>Plan bracing with rope.</td>
</tr>
<tr>
<td></td>
<td>Longitudinal/vertical bracing with borak.</td>
</tr>
<tr>
<td>ROOFING MATERIALS</td>
<td>Avoid use of CGI, if used:</td>
</tr>
<tr>
<td></td>
<td>Purlins 2”x2” at 2’, use hurricane straps/cleats to connect prulins to rafters, bend back nails.</td>
</tr>
</tbody>
</table>
SECTION 2: STRENGTHENING EXISTING BUILDINGS

NOTE: This section assumes the building has the following features:
- Pitched roof
- Single bamboo culm beams and columns

There is a separate section for TLCs and CFSs and other buildings characterised by:
- Monopitch/flat roofs
- Bundled 2-culm beams/rafters
- Bundled 4-culm columns
**COLUMN FOOTING**

Bamboo embedded in the ground or in concrete will rot within 6 months, leading to collapse

→ Install concrete footings with steel plate to elevate bamboo above plinth

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>ACTION</th>
<th>URGENCY</th>
<th>DIFFICULTY</th>
<th># DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns embedded in earth</td>
<td>Install concrete footing</td>
<td>HIGH</td>
<td>MODERATE</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>→ Prop building &amp; excavate around footing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>→ Install steel plates &amp; pour concrete</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>→ Cut column 1” above plinth level once concrete has set</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Columns embedded in concrete</td>
<td>Post-fix steel plates to concrete footing</td>
<td>HIGH</td>
<td>EASY BUT EXPENSIVE</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>→ Use expansion bolts or by drill into concrete and then grout</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>→ Cut column ½” above plinth level to prevent water soaking into column</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EXISTING FOOTING**

- 1” SPACER BETWEEN STEEL PLAT & BAMBOO TO ENSURE CONCRETE COVER OVER STEEL
- BENT TO PREVENT PULL-OUT
- EXCAVATE AROUND FOOTING
- 4mm THICK STEEL PLATE

**STEP 1**

- CAST CONCRETE AROUND FOOTING
- CUT BAMBOO ½” ABOVE PLINTH
- PLASTIC SHEET BELOW BAMBOO TO PREVENT WATER SOAKING INTO COLUMN

**STEP 2**

- 10mm BOLTS IN 12mm HOLES (OVERSIZD TO PREVENT BAMBOO SPLITTING)
- BOLT ABOVE FINAL NODE
- FILL BAMBOO WITH GROUT TO PREVENT WATER PONDING
**BRACING**

**KEY POINTS:**
1. Add bracing in ALL 4 walls
2. Minimum **two panels each wall**
3. 3-4” Borak Bamboo
4. **Stiff connection at both ends using dowels**
5. Add internal braced wall or external prop if building > 20’ long

- **BORAK BAMBOO BRACING NODE-TO-NODE**
- **STIFF CONNECTIONS USING DOWELS**
- **HALF PIECE OF BORAK BELOW BRACING TO SUPPORT BRACE VERTICALLY**
- **BRACE CONNECTED TO COLUMN USING DOWEL**
- **BRACING CONNECTS RIGHT INTO COLUMN-BEAM CONNECTION USING FISHMOUTH**
ADDITIONAL ROPE BRACING

KEY POINTS:
1. Additional rope bracing can be installed quickly & easily in walls
2. Add rope bracing to roof
3. 6mm rope doubled up & tightened by twisting

Note: Primary wall bracing must be borak bamboo. Rope to be used as *additional* bracing only.
CONNECTIONS

KEY POINTS:

1. **ALL ELEMENTS TIED DOWN**
   - Purlins → Rafters → Beams → Columns
   - Column anchored into Ground

2. **NO NAILS – Bamboo will split as it shrinks**

3. Tie beam/rafter down to column using dowel through column

4. **Holes must be oversized to avoid splitting**
   - 10mm bolt → 11-12mm drilled hole

5. **Fishmouth connection**
   - Column diameter greater than Beam Diameter (or shape fishmouth with chisel to ensure good fit)

BEAM TIED DOWN TO COLUMN
HOLE DRILLED BELOW FINAL NODE

PURLINS TIED DOWN TO RAFTER
RAFTER TIED DOWN TO BEAM
BEAM TIED DOWN TO COLUMN

COLUMN ANCHORED INTO GROUND
BAMBOO LIFTED OFF GROUND

FISHMOUTH CONNECTION WILL SPLIT

BOLT HOLES NOT OVERSIZED → SPLITTING
### Strengthening the Roof

There is a range of possible ways in which the roof may require strengthening. The table below indicates which action to take in each circumstance:

<table>
<thead>
<tr>
<th>Risk</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rafters are too widely spaced. Spacing &gt; 5’</td>
<td>Add extra rafters between existing</td>
</tr>
<tr>
<td>Purlins are too widely spaced. Spacing &gt; 1.5’</td>
<td>Add extra purlins between existing</td>
</tr>
<tr>
<td>Tie beam not fixed to edge beam</td>
<td>Connect tie beam to edge beam using dowel to prevent slip</td>
</tr>
<tr>
<td>Low quality polythene used</td>
<td>Remove grass → Add tarpaulin over polythene → Replace grass</td>
</tr>
<tr>
<td>Large overhang → Large uplift force from wind</td>
<td>Cut back roof overhang. &amp;/or: Add tie-down blocks</td>
</tr>
</tbody>
</table>

![Diagram showing roof strengthening measures](image)

- Add Borak rafter at mid-span if rafter spacing > 5’
- Add mulli purlins at mid-span if purlin spacing > 1’
- Cut back overhang if > 2’
- Connect tie beam to edge beam using dowel to prevent slip (dowel before final node!)
SUMMARY: RISKS & MITIGATION

Rain ponding on flat roof
→ Remove roof, trim columns to increase roof pitch then rebuild roof

Large overhang → Large uplift force
→ Cut back roof or tie down
→ Install tie-down blocks around building

Columns embedded in ground will rot
→ Replace with concrete footings

No bracing (or poorly connected bracing)
→ Install borak bracing
→ Connect using dowels & fishmouth
→ Add internal braced wall if building > 20’ long

Tie beam poorly connected against slip
→ Connect tie beam to edge beam using dowel to prevent slip

Old/damaged materials
→ Replace damaged elements
→ Add tarpaulin over polythene in roof

Widely spaced rafters (>5’) and purlins (>1’)
→ Add rafters and purlins at mid-point between existing

Widely spaced columns
→ Add columns at mid-span
→ Add internal columns every other bay (max 10’ c-c)

Beams not properly tied down to columns
→ Connect beams to columns using dowels

Community Structures - Design & Strengthening Guide. v1 | 05.04.2018
<table>
<thead>
<tr>
<th>PRIORITY</th>
<th>PROBLEM</th>
<th>STRENGTHENING ITEM</th>
<th>DIFFICULTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 FLOOD RISK</td>
<td>Building in Flood zone</td>
<td>Close facility</td>
<td>Easy</td>
</tr>
<tr>
<td>2 LANDSLIDE RISK</td>
<td>Building in Landslide zone</td>
<td>Deconstruct facility</td>
<td>Moderate</td>
</tr>
<tr>
<td>3 ACCESS</td>
<td>Difficult to access during rains (steep slopes, flooded paths, etc.)</td>
<td>Improve pathways &amp; stairways, raise bridges, add handrails to bridges and stairways</td>
<td>Difficult</td>
</tr>
<tr>
<td>4 LOCAL FLOODING</td>
<td>Poor drainage → local flooding around building &amp; pathways</td>
<td>Add robust drainage around building connected to main drainage and alongside access routes</td>
<td>Difficult</td>
</tr>
<tr>
<td>5 MUDSLIDES</td>
<td>Exposed slopes above facility + rain → Mudsides (small landslide)</td>
<td>Add retaining walls, terrace slope using borak posts &amp; jute bags, plant grass or vetiver on exposed slopes</td>
<td>Difficult</td>
</tr>
<tr>
<td>6 BUILDING ON SLOPE</td>
<td>Ground below foundation at risk of collapse</td>
<td>Underpin building using precast concrete (preferable) or borak posts</td>
<td>Difficult</td>
</tr>
</tbody>
</table>

For more guidance on Site Works please refer to the Site Risk Mitigation Guide and the Site Improvement Catalogue

Available from the Shelter or Site Management Sectors: sheltercxb.tech1@gmail.com

Community Structures - Design & Strengthening Guide. v1 | 05.04.2018
<table>
<thead>
<tr>
<th>PRIORITY</th>
<th>PROBLEM</th>
<th>STRENGTHENING ITEM</th>
<th>DIFFICULTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 FOUNDATIONS</td>
<td>Bamboo columns embedded in ground/concrete will rot</td>
<td>Install concrete footings and lift bamboo out of ground</td>
<td>Moderate</td>
</tr>
<tr>
<td>2 STABILITY</td>
<td>No Bracing (or bracing is poorly connected) → collapse</td>
<td>Add borak bracing to all four walls connected w. dowels</td>
<td>Easy</td>
</tr>
<tr>
<td>3 CONNECTIONS</td>
<td>Loose/weak connections → building will fall apart</td>
<td>Tighten connections</td>
<td>Easy</td>
</tr>
<tr>
<td>4 COLUMN SPACING</td>
<td>Columns are too far apart → beams will fail in high winds</td>
<td>Add columns at mid-point between existing and in the centre of building.(or add haunches)</td>
<td>Moderate</td>
</tr>
<tr>
<td>5 RAFTER SPACING</td>
<td>Mulli bamboo cannot span more than 5’</td>
<td>Add rafters at mid-point between existing</td>
<td>Easy</td>
</tr>
<tr>
<td>6 PURLIN SPACING</td>
<td>Widely spaced purlins → Roof will collapse in high wind/rain</td>
<td>Add purlins at mid-point between existing</td>
<td>Easy</td>
</tr>
<tr>
<td>7 OLD/DAMAGED MATERIAL</td>
<td>Mite damage to bamboo or split bamboo Polythene (not tarpaulin) in roof</td>
<td>Replace damaged elements</td>
<td>Moderate</td>
</tr>
<tr>
<td>8 TIE BEAM (PITCHED ROOF)</td>
<td>Tie beam free to slide horizontally over edge beam → Collapse</td>
<td>Connect tie beam to edge beam using dowel to prevent slip</td>
<td>Easy</td>
</tr>
<tr>
<td>9 OVERHANG / EAVES</td>
<td>Large overhang → Large uplift force from wind</td>
<td>Cut back roof or tie down Install tie-down blocks around building</td>
<td>Easy</td>
</tr>
</tbody>
</table>
SECTION 3: STRENGTHENING CPA/TLCs & CFSs

This is a guide to strengthening the standard TLC/CPAs and CFSs in the camp, characterised by the following features:

- Monopitch/flat roofs
- Bundled 4-culm columns
- Bundled 2-culm beams/rafters

The design used in this section was developed by CODEC. Design was modified prior to construction.
KEY ELEMENTS REQUIRING STRENGTHENING

BEAM-COLUMN CONNECTION

SHALLOW ROOF PRONE TO PONDING
POLYTHENE USED, NOT TARPALIN

WIDELY SPACED RAFTERS & LONG SPANS

LARGE OVERHANG

WIDELY SPACED COLUMNS

NO BRACING

COLUMN FOOTING
BEAM-COLUMN CONNECTION

- Nothing to stop roof pulling off column
- No fishmouth connection → Beam can slip sideways off column
- Beam has fallen off column
- Beam not securely fixed on column

REMEDIAL ACTION:

CONNECT BEAM TO COLUMN WITH DOWELS & TIE DOWN
(DOWEL MUST BE BELOW BAMBOO NODE)
If it is possible to rebuild the roof, it is recommended that the beam-column connection is redesigned so that the double beams sit side-by-side instead of being stacked vertically – see section on Beam-Column Connection.
KEY POINTS:
1. Add bracing in ALL 4 walls
2. Minimum two panels each wall
3. 3-4” Borak Bamboo
4. Stiff connection at both ends using dowels
ADDITIONAL ROPE BRACING

KEY POINTS:
1. Additional rope bracing can be installed quickly & easily in walls
2. Add rope bracing to roof
3. 6mm rope doubled up & tightened by twisting

Note: Primary wall bracing must be borak bamboo. Rope to be used as additional bracing only.
There is a range of possible ways in which the roof may require strengthening. The table below indicates which action to take in each circumstance:

<table>
<thead>
<tr>
<th>RISK</th>
<th>MITIGATION</th>
<th>IMPORTANCE</th>
<th>DIFFICULTY</th>
<th># DAYS LABOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rafters are too widely spaced</td>
<td>Add extra rafters between existing</td>
<td>HIGH</td>
<td>MODERATE</td>
<td>1-2</td>
</tr>
<tr>
<td>Spacing &gt; 5’</td>
<td>Or: Take down &amp; <strong>rebuild roof</strong></td>
<td></td>
<td>DIFFICULT</td>
<td>3</td>
</tr>
<tr>
<td>Purlins are too widely spaced</td>
<td>Add extra purlins between existing</td>
<td>HIGH</td>
<td>MODERATE</td>
<td>1-2</td>
</tr>
<tr>
<td>Spacing &gt; 1.5’</td>
<td>Or: Take down &amp; <strong>rebuild roof</strong></td>
<td></td>
<td>DIFFICULT</td>
<td>3</td>
</tr>
<tr>
<td>Roof is too flat → Ponding</td>
<td>Take down roof → Trim columns → <strong>Rebuild roof</strong></td>
<td>HIGH</td>
<td>DIFFICULT</td>
<td>3</td>
</tr>
<tr>
<td>Low quality polythene used</td>
<td>Remove grass → Add tarpaulin over polythene → Replace grass</td>
<td>Moderate</td>
<td>MODERATE</td>
<td>1</td>
</tr>
<tr>
<td>Large overhang → Large uplift force from wind</td>
<td>Cut back roof overhang &amp;/or: Add tie-down blocks</td>
<td>Moderate</td>
<td><strong>EASY</strong></td>
<td>1</td>
</tr>
</tbody>
</table>

*If the roof is rebuilt, it is recommended that the beam-column connection is redesigned so that the double beams sit side-by-side instead of being stacked vertically – see section on Beam-Column Connection*
STRENGTHENING THE ROOF cont.

RAFTER & PURLIN SPACING

Add Borak rafter at mid-span if column spacing > 5’

Mulli purlins @ 1’ c-c
Max. Span = 5’

4” Borak Rafters @ 3-5’ c-c
Max. Span = 8’

Beams & Rafters tied down to Column

PONDING ON ROOF

Water will pond on flat roof \(\rightarrow\) roof collapse
Min slope = 1’ rise / 5’ length
COLUMN FOOTING

Bamboo embedded in the ground or in concrete will rot within 6 months, leading to collapse
→ Install concrete footings with steel plate to elevate bamboo above plinth

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>ACTION</th>
<th>URGENCY</th>
<th>DIFFICULTY</th>
<th># DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns embedded in earth</td>
<td>Install concrete footing → Prop building &amp; excavate around footing → Install steel plates &amp; pour concrete → Cut column 1” above plinth level once concrete has set</td>
<td>HIGH</td>
<td>MODERATE</td>
<td>2</td>
</tr>
<tr>
<td>Columns embedded in concrete</td>
<td>Post-fix steel plates to concrete footing → Use expansion bolts or by drill into concrete and then grout → Cut column ½” above plinth level to prevent water soaking into column</td>
<td>HIGH</td>
<td>EASY BUT EXPENSIVE</td>
<td>1</td>
</tr>
</tbody>
</table>

**CUT BAMBOO ½” ABOVE PLINTH**

**CAST CONCRETE AROUND FOOTING**

**FILL BAMBOO WITH GROUT TO PREVENT WATER PONDING**

**EXCAVATE AROUND FOOTING**

**BENT TO PREVENT PULL-OUT**

**CAST 4MM THICK STEEL PLATE**

**4 CULM BAMBOO COLUMN**

**EXISTING FOOTING**

**STEP 1**

**STEP 2**

10mm BOLTS IN 12mm HOLES (OVERSIZED TO PREVENT BAMBOO SPLITTING)
## ROOF OVERHANG & UPLIFT LOADS

Large roof overhangs will experience large uplift loads in the event of a cyclone.

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>ACTION</th>
<th>DIFFICULTY</th>
<th># DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof overhang &gt; 2’</td>
<td>Cut back overhang to 2’</td>
<td>EASY</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>Cast concrete tie-down blocks around building and connect to roof structure with rope</td>
<td>MODERATE</td>
<td>1</td>
</tr>
</tbody>
</table>

### Diagram

- Cut back large overhang
- Tie down roof using concrete block & rope
- Concrete block or buried sandbags
Beams tied down to columns using dowels or holes through columns

Cut back large overhang

Perimeter and internal columns added to reduce span

Borak bracing added to all four walls → Connect using dowels

Concrete footings added

Bamboo columns lifted out of ground

Roof strengthened:
• Angle of roof increased
• Rafters added at mid-span
• Polythene replaced with tarpaulin

Tie down roof using concrete block (or sandbags) & rope
SUMMARY: RISKS & MITIGATION

- **Roof is too flat and polythene used instead of tarpaulin** (water will pond & roof will fail)
  - Replace roof & trim columns to increase angle

- **Large uplift forces from wind**
  - Tie down roof using sandbags & rope

- **Large overhang**
  - Cut back

- **Beams not properly tied down to columns**
  - Connect beams to columns using dowels

- **Columns are too widely spaced**
  - Add columns at mid-span
  - Add internal column

- **Rafters too widely spaced**
  - Add rafters at mid-span

- **No bracing (or poorly connected bracing)**
  - Install borak bracing
  - Connect using dowels

- **Columns embedded in ground will rot**
  - Replace with concrete footings

---

Community Structures - Design & Strengthening Guide. v1 | 05.04.2018
## SUMMARY: RISKS & MITIGATION

<table>
<thead>
<tr>
<th>RISK</th>
<th>MITIGATION</th>
<th>IMPORTANCE</th>
<th>DIFFICULTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bamboo columns embedded in ground/concrete will rot</td>
<td>Install concrete footings and lift bamboo out of ground</td>
<td>HIGH</td>
<td>Moderate</td>
</tr>
<tr>
<td>No Bracing (or bracing is poorly connected)</td>
<td>Add borak bracing connected w. dowels</td>
<td>HIGH</td>
<td>Easy</td>
</tr>
<tr>
<td>Rafters span too far</td>
<td>Add columns at mid-span Or: Add haunches</td>
<td>HIGH</td>
<td>Moderate</td>
</tr>
<tr>
<td>Rafters are too widely spaced</td>
<td>Add columns at mid-span</td>
<td>HIGH</td>
<td>Moderate</td>
</tr>
<tr>
<td>Beam-Column connection is poor</td>
<td>Tie beams down to columns using dowels or holes drilled through columns</td>
<td>HIGH</td>
<td>Easy</td>
</tr>
<tr>
<td>Flat roof → Ponding</td>
<td>Prop roof → trim columns → lower roof and reconnect</td>
<td>Moderate</td>
<td>Difficult</td>
</tr>
<tr>
<td>Low quality polythene used</td>
<td>Replace roofing material</td>
<td>Moderate</td>
<td>Difficult</td>
</tr>
<tr>
<td>Large overhang Large uplift force from wind</td>
<td>Cut back Add tie-down blocks</td>
<td>Moderate</td>
<td>Easy</td>
</tr>
</tbody>
</table>

### RECOMMENDATION – BEST CASE
- Add borak bracing / improve connection
- Add haunches to support rafters
- Take down roof and rebuild
- Insert concrete footings and lift bamboo out of ground

### RECOMMENDATION - MINIMUM
- Add columns at mid-span
- Add borak bracing / improve connection
- Add extra rafters within existing roof structure
- Improve beam-column connection