CLADDING AND FIXING CONFERENCE
Luxembourg, 3 & 4 of September 2014

Cecilia Braedt (SRU) - Development of Manual on CGI Roofing
CGI Roofing Manual

1. Objective:

To develop a technical resource that can support the Shelter Cluster and shelter actors in the field, to give recommendations and make informed choices about roofing solutions using CGI.
1. 1. Introduction

2. Materials

3. Material Quality Control

4. Effects of wind

5. Roof types

6. Guiding principles

7. Maintenance

8. Annexes: conversion table, cyclone categories, pitch of roof (° and %), results case study calculations
2. Materials

a. Corrugated galvanized Iron or steel (CGI) sheets,

- general specifications
- The most common coatings
2. Materials

- **Durability/service life:** The performance of galvanized steel exposed to open air depends on five main factors: Temperature, Humidity, Rainfall, Sulfur dioxide concentration in the air (pollution) and Air salinity.

  - Example using the online “Zinc Coating Life Predictor” (ZCLP): for a **service life of 10 years**, in Tacloban region (Philippines), the zinc coating should be:
    - 15.2 μm thick in a rural area (107 g/m²)
    - 20 μm thick in a urban area (140 g/m²)
    - 26 μm thick in a coastal area (181 g/m²)

  - 250 g/m² zinc coating (recommended by IFRC) corresponds to app. 13.8 years service life in coastal area.
2. Materials

b. Support

- Coconut lumber and pine as reference;
  basic info for bamboo and metal

- fixings, hurricane straps and accessories
3. Material Quality Control (CGI)

a. storage, transportation and safety measures

b. How to verify the specs

c. Devices to check the quality of galvanized steel. E.g. “zinc coating gauge” - can measure the thickness of the zinc coating (cost app. 500€)
2. Effects of Wind

Peak velocity pressure (in N/m²) in function of wind speed and exposure situation

**Windspeed:**

- **Tropical Storm Cat 1:** <100km/h - 150km/h
- **Tropical Storm/Hurricane Cat 2-3 (major):** 150km/h - 208km/h
- **Hurricane Cat 4 (major):** 209km/h - 251km/h

**Exposure Situations:**

- Urban area
- Suburban area / rural area protected by trees
- Rural area with low vegetation
- Coastal area
5. Roof Shapes and Pitches

a. Roof shapes

- Shed roof / single-pitch roof / monopitch roof
- Gable roof / pitched roof / duopitch roof
- Hip-roof / hipped roof
- Gambrel roof

b. Roof pitches

- 5° pitch / 9% pitch
- 15° pitch / 27% pitch
- 26° pitch / 52% pitch
- 45° pitch / 100% pitch
6. Case Study calculations

a. Windload calculations based on a generic 3x6m shelter with
   - CGI roof
   - 45cm eaves
   - Roof structure 45x70mm laths/battens,
   - CGI sheets as of EIC specs (width 914 mm, 11 corrugations, 76.2 mm between corrugations)
   - Roofing nails: twisted shank, length: 63 m

→ Calculations for four roof shapes, each shape with the four pitches, in the four exposure scenarios and for three wind-speeds.
6. Case Study example

- hipped roof, **pitch = 5 °**
- Basic wind velocity < 150 km/h (cat.1)
- with peak wind velocity at 208 km/h
- coastal area exposed to the open sea
- distance between laths = 0,60 m (2ft)
- distance between rafters = 1,20 m (4ft)

<table>
<thead>
<tr>
<th>exposure situation</th>
<th>Peak velocity pressure qp (N/m²)</th>
<th>Corrugated galvanized sheet</th>
<th>Fixings main part</th>
<th>Fixings eaves overhang / hip / ridge</th>
<th>Type of hurricane straps connection between lath and rafter</th>
<th>Type of hurricane straps connection between rafter and top plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat 0 (coastal area)</td>
<td>1985</td>
<td>Minimum thickness = 0,40 mm (gauge 30)</td>
<td>2 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td><strong>6 roofing nails per lath per CGS</strong> (penetration length = 45 mm)</td>
<td>Maximum support reaction = 5827 (1307 lb) → possible choice: CS18</td>
<td><strong>Necessity to reduce the distance between rafters (0,90 m)</strong> → Maximum support reaction = 5449 N (1222 lb) + Maximum horizontal support reaction = 270 N (61 lb) → possible choice: H14</td>
</tr>
<tr>
<td>Cat II (rural)</td>
<td>1429</td>
<td>Minimum thickness = 0,40 mm (gauge 30)</td>
<td>2 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>4 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>Maximum support reaction = 5594 N (1254 lb) → possible choice: CS18</td>
<td>Maximum support reaction = 5231 N (1173 lb) + Maximum horizontal support reaction = 259 N (58 lb) → possible choice: H14</td>
</tr>
<tr>
<td>Cat III (sub-urban)</td>
<td>1016</td>
<td>Minimum thickness = 0,40 mm (gauge 30)</td>
<td>1 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>3 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>Maximum support reaction = 3978 N (892 lb) → possible choice: CS20</td>
<td>Maximum support reaction = 3720 N (834 lb) + Maximum horizontal support reaction = 184 N (41 lb) → possible choice: 2x H3 or H10A</td>
</tr>
<tr>
<td>Cat IV (urban)</td>
<td>953</td>
<td>Minimum thickness = 0,40 mm (gauge 30)</td>
<td>1 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>3 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>Maximum support reaction = 3729 N (836 lb) → possible choice: CS22</td>
<td>Maximum support reaction = 3488 N (782 lb) + Maximum horizontal support reaction = 173 N (39 lb) → possible choice: 2x H3 or H10A</td>
</tr>
</tbody>
</table>
6. Case Study example

- hipped roof, pitch = 30°
- Basic wind velocity < 150 km/h (cat.1) with peak wind velocity at 208 km/h
- coastal area exposed to the open sea
- distance between laths = 0.60 m (2ft)
- distance between rafters = 1.2 m (4ft)

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<th>exposure situation</th>
<th>Peak velocity pressure qp (N/m²)</th>
<th>Corrugated galvanized sheet</th>
<th>Fixings main part</th>
<th>Fixings eaves overhang / hip / ridge</th>
<th>Type of hurricane straps connection between lath and rafter</th>
<th>Type of hurricane straps connection between rafter and top plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat 0 (coastal area)</td>
<td>1985</td>
<td>Minimum thickness = 0.4 mm (30 gauge)</td>
<td>2 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>5 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>Maximum support reaction = 3483 N (781 lb) → possible choice: CS22</td>
<td>Necessity to reduce the distance between rafters (0.60 m) → Maximum vertical support reaction = 4329 N (971 lb) + Maximum horizontal support reaction = 121 N (27 lb) → possible choice: H10A</td>
</tr>
<tr>
<td>Cat II (rural)</td>
<td>1429</td>
<td>Minimum thickness = 0.4 mm (30 gauge)</td>
<td>2 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>4 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>Maximum support reaction = 3761 N (844 lb) → possible choice: CS22</td>
<td>Necessity to reduce the distance between rafters (0.90 m) → Maximum vertical support reaction = 4676 N (1049 lb) + Maximum horizontal support reaction = 130 N (29 lb) → possible choice: H10A</td>
</tr>
<tr>
<td>Cat III (sub-urban)</td>
<td>1016</td>
<td>Minimum thickness = 0.4 mm (30 gauge)</td>
<td>1 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>3 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>Maximum support reaction = 3566 N (800 lb) → possible choice: CS22 / H6</td>
<td>Maximum vertical support reaction = 4433 N (994 lb) + Maximum horizontal support reaction = 124 N (28 lb) → possible choice: H10A</td>
</tr>
<tr>
<td>Cat IV (urban)</td>
<td>953</td>
<td>Minimum thickness = 0.4 mm (30 gauge)</td>
<td>1 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>3 roofing nails per lath per CGS (penetration length = 45 mm)</td>
<td>Maximum support reaction = 3343 N (750 lb) → possible choice: CS22 / H6</td>
<td>Maximum vertical support reaction = 4156 N (932 lb) + Maximum horizontal support reaction = 116 N (26 lb) → possible choice: H10A</td>
</tr>
</tbody>
</table>
7. Guiding Principles

→ Based on the case study calculations and analysis of the field tests derive some basic guiding principles to support decision making on the choice of roof shape, and amounts and quality of materials to use

<table>
<thead>
<tr>
<th>Roof Shapes</th>
<th>Category 0: Wind Speed ≤ 100 km/h (Peak at 150 km/h)</th>
<th>Category 1: Wind Speed ≤ 150 km/h (Peak at 209 km/h)</th>
<th>Category 3: Wind Speed ≤ 209 km/h (Peak at 250 km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5°</td>
<td>15°</td>
<td>30°</td>
</tr>
<tr>
<td>Hipped</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Gable</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Single-Pitch</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

- Distance laths
- Distance rafters
- Hurricane straps Rafter / top plate
- # roofing nails for the edges/m
- Replace by # roofing screws
- # roofing screws for the edges/m
- # roofing nails for the edges/m
- Replace by # roofing screws
### 7. Guiding Principles

<table>
<thead>
<tr>
<th></th>
<th>Urban area</th>
<th>Suburban area / rural area protected by trees</th>
<th>Rural area with low vegetation</th>
<th>Coastal area</th>
</tr>
</thead>
</table>
| **Single-pitch roof** | $5^\circ < \text{Pitch} < 15^\circ$
Very easy to build
Require a lot of material $\rightarrow$ very costly
Roofing screws recommended | $5^\circ < \text{Pitch} < 15^\circ$
Very easy to build
Require a lot of material $\rightarrow$ very costly
Roofing screws recommended | Pitch $= 5^\circ$
Very easy to build
Require a lot of material $\rightarrow$ very costly
Roofing screws recommended | Pitch $= 5^\circ$
Very easy to build
Require more material $\rightarrow$ extremely costly
Roofing screws recommended |
| **Gable roof**     | $5^\circ < \text{Pitch} < 45^\circ$
Easy to build
Average cost
Roofing nails | $5^\circ < \text{Pitch} < 30^\circ$
Easy to build
Require more material $\rightarrow$ extremely costly
Roofing screws recommended | Pitch $= 5^\circ$
Easy to build
Require more material $\rightarrow$ extremely costly
Roofing screws necessary | Pitch $= 5^\circ$
Easy to build
Require even more material $\rightarrow$ extremely costly
Roofing screws necessary | Pitch $= 5^\circ$
Easy to build
Require more material $\rightarrow$ extremely costly
Roofing screws recommended |
### 7. Guiding Principles

“rating” from 0 = not feasible/recommendable to 5= best performance/cost ratio of the different roof types taking into account the criteria:

- resistance to wind
- amount of material needed (implication on logistics/cost )
- complexity of construction (implication on cost & time)

( Distance between laths and rafters, number of nails/screws, types of hurricane straps)

<table>
<thead>
<tr>
<th>Exposure Situation</th>
<th>Pitch</th>
<th>5°</th>
<th>15°</th>
<th>30°</th>
<th>45°</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - Coastal Area</td>
<td>hipped roof</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>gable roof</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>single-pitch</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>gambrel</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II - Rural Area</td>
<td>hipped roof</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>gable roof</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<tr>
<td></td>
<td>single-pitch</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td></td>
<td>gambrel</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III - Rural Area</td>
<td>hipped roof</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>gable roof</td>
<td>4</td>
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<td>0</td>
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<td></td>
<td>gambrel</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV - Urban Area</td>
<td>hipped roof</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>gable roof</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<tr>
<td></td>
<td>single-pitch</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>gambrel</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Field-Test

Verify and complete the calculations with complementary field tests of different CGI and fixings, to identify the weakest elements.
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