SOUPAPE

Hurricane mitigation system for corrugated roofs

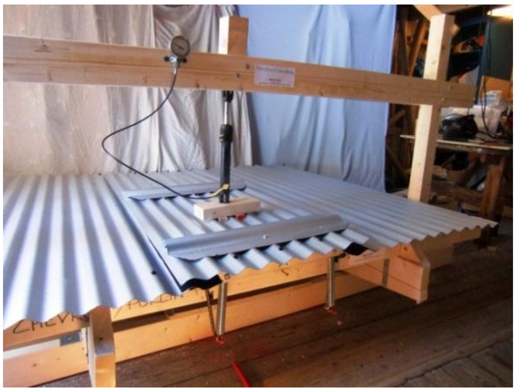
CALCULATION MANUAL ~~DRAFT~~

Ingemar Saevfors, architect, ingemar@saevfors.se
www.saevfors.se 18 Nov 2012

Mitigation Strategy

Extremely violent hurricanes happening with a frequency of less than every 50 years would require constructions with a resistance similar to military bunkers and become simply too expensive. Therefore the 50 years return period is used as an acceptable risk limit for calculating max wind loads in most building norms. What could be designed for, in case of a hurricane exceeding this threshold, is a partial loss of the roof, maybe limited to some roof sheets, but saving most of the structure.

US-norms for Port au Prince, 50 years return:	110 mph = 178 km/h = 49 m/s
US-norms for Puerto Rico, -“- :	130 mph = 209 km/h = 58 m/s
French norms for Martinique, Guadeloupe, -“- :	211 km/h = 59 m/s
Philippine norms for the most exposed typhoon prone areas :	280 km/h = 78 m/s



Wind loads

The wind velocity has a squared ($q=v^2$…) significance for the general wind pressure. Then the shape and pitch of the roof determines the resulting forces. One of the most severe problems with hurricanes is the violent uplift powers on the roof which Soupape is designed to mitigate.

Apart from this challenge, there is also the horizontal wind load, similar to an earth quake, which affects the whole structure and *must be dealt with in the general building design* by bracing, shear walls etc.

Prototype testing of Soupape when simulating the uplift suction of a 110 mph hurricane

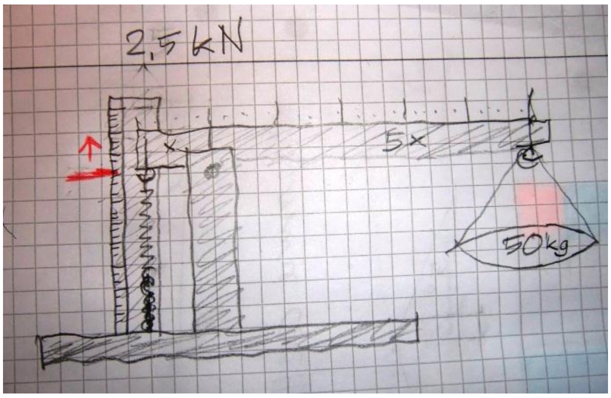
Design rationale

Soupape is based on a set of springs on a cross beam which permits the opening of a range of roof sheets so as to neutralize the suction of a peak wind gust and then closing these sheets tightly afterwards to avoid rain leaks. Every third range of sheets should be equipped with springs and open. The neighboring two sheets are fixed to the purlin as usual.

Retrofitting an existing roof is actually possible just by shifting the corrugated sheet overlaps and adding the spring system.

A gap opening of 3 cm should be enough to eliminate the suction vacuum that lifts the roof. Therefore the spring fixtures should be designed with the length allowing this extension at the anticipated hurricane wind speed. Obviously it is also important that the springs *do release* enough to provide this gap, consequently they cannot be too tight either.

These retaining springs can be sourced among industrial suppliers, metal bed manufacturers, machinery workshops etc. As they come in different qualities they must first be tested in a simple lever rig. The extension of the spring (in mm) must be measured against the tensile force applied (in kN).



In normal mode though, without wind lift, the spring should be slightly pre-stressed so as to exercise a certain rain water sealing. Bitumen felt or similar could be added for this purpose.

The aerodynamic vacuum collapse made by the gap has the same effect as when an aircraft has landed and openings in the wings force it to stop flying and reduce speed.

The airplane effect of a low pitch roof

Eurocode 1 (EN 1991-1-4:2005) prescribes form factors, or CPEs, for different zones of a roof; see below.

Traditional Swedish[1], French[2] and Spanish norms also indicate similar features. Note that wall openings on the windward side of the house will add to the internal pressure and then to the roof uplift force.

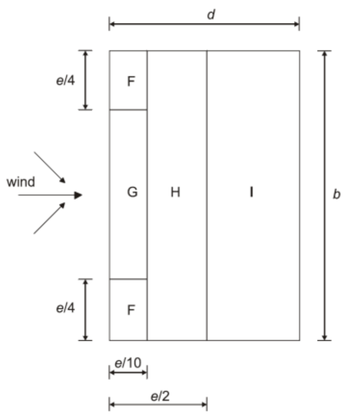


Figure 7.6 — Key for flat roofs

The CPE (external pressure coefficients) interpreted from Eurocode 1 for saddle roof with 5 degrees angle.

F	G	H	I
-2.5	-1.2 to -2.0	-0.7	-0.2

The form factor is a coefficient, normally pre-fixed with a minus when the wind surface pressure turns into aerodynamic suction. This coefficient is different across the roof; the eaves and particularly the corners of the roof must sustain much higher stress.

Refer to http://www.civil.ist.utl.pt/~cristina/EBAP/FolhasEdifAltos/EN_1991_1-4_Wind%20actions.pdf for other types of roofs, mono-pitch etc.

See below for spreadsheet calculations of wind uplift and Soupape response

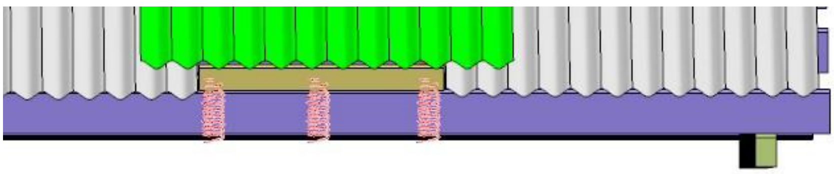
---

[1] SBN80

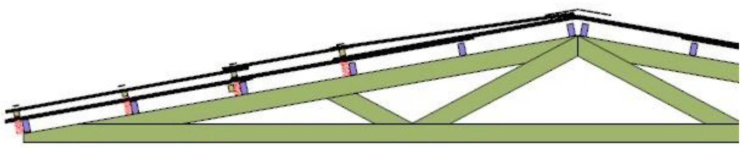
[2] NV65

Eaves and ridge design

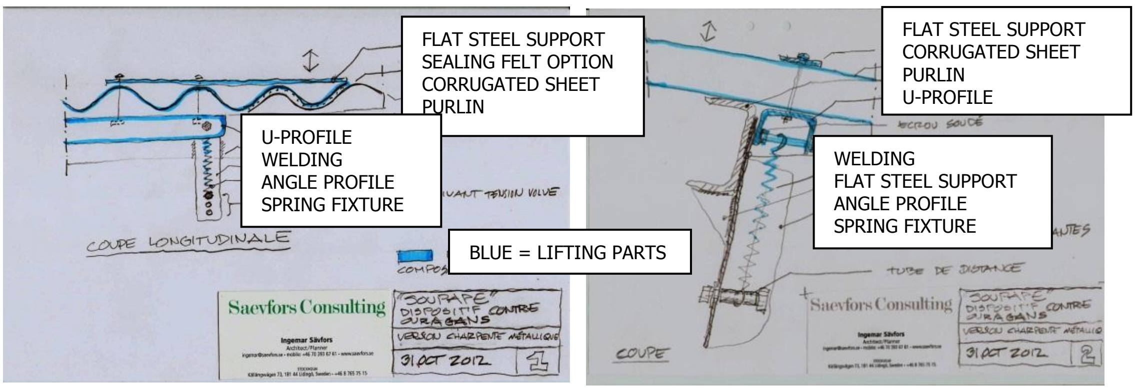
As seen above, at the eaves and roof corners the hurricane rip-off risk is much higher. If the spring response capacity is questionable to cope with that, simply put an extra spring in between the normal two on the same lifting cross beam. When built in you can test the response with a hydraulic jack simulating the uplift.



At the ridge fix the ridge plate on top of the roof sheets as normally to the last purlin and without springs. In this way the sheet will act as a hinge, but there is much flexibility in corrugated roof sheets to perform like this. The wind lift effect is not so high at the very ridge.

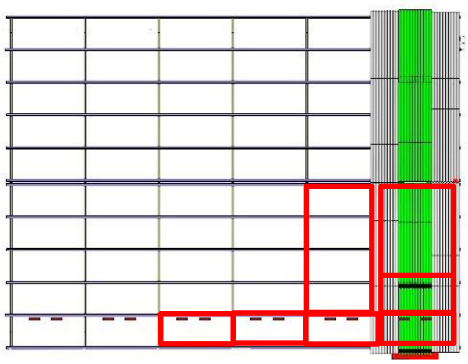


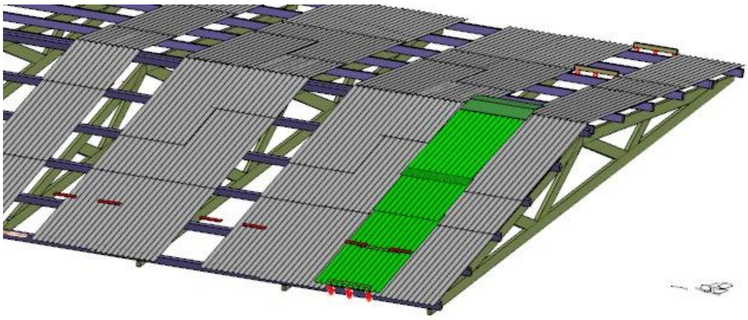
Below: Spring fixture for metal roof structure



Calculation method

For calculation purposes the roof is divided into Response Units (RU). Such a unit is a roof sheet *area* retained by 2 springs attached to a purlin. Divide the roof plan into zones according to the relevant form factor and the expected stress. Depending on the parameters below, the number of RUs needed and the resulting numbers of springs are determined.





The Soupape calculations refer only to the hurricane uplift. For the normal wind pressure *downwards* and other load combinations like earth quakes, live loads etc the structural integrity of the roof must be calculated as usual.

Soupape system partly mounted between regularly fixed roof sheets.

Refer to the attached spreadsheet ***Soupape.xlsx*** for the actual mathematic operation.
You will be required to feed in these parameters:

- The design wind speed, probably from norms you find relevant.
- The form factor, CPE as explained above. If you want to save on springs you can set up less RUs at the inner parts of the roof.
- RU length and width
- The allowable stress for a spring, having been tested as described above.