Visit to
Sint Maarten and Saint Martin
following
Hurricane Irma
December 2017

Tony Gibbs FREng
Introduction

The 2017 Atlantic hurricane season was particularly active and severe, well above average, with seventeen named storms, ten hurricanes, and six major hurricanes. This compares to the long-term averages of twelve named storms, six hurricanes, and three major hurricanes. One unnamed tropical depression also formed in 2017.

One of the islands impacted was Sint Maarten / Saint Martin with hospitals on both sides of the Dutch/French border. The entire island suffered significant damage from Hurricane Irma on 6th September 2017. In previous hurricanes of the past three decades it was the Dutch side that suffered more. For example, Hurricane Luis in 1995 caused 200% of GDP total losses in Dutch Sint Maarten according to a contemporary study by the Economic Commission for Latin America and the Caribbean whereas French St Martin experienced only minor losses from that event. That disparity was not the case in 2017 with Irma.

For these reasons the Pan American Health Organisation sponsored a visit to the island by Engineer Tony Gibbs on 11-14 December to review the effects of Irma on the two hospitals and to learn about the causes of damage generally in Sint Maarten / Saint Martin. The considerable support and encouragement of Dr Dana van Alphen (Regional Advisor Disaster Management Programme of PAHO/WHO Barbados) for the mission is hereby acknowledged.

Tony Gibbs’s visit was coordinated and facilitated in the island by Dr Earl Best (Inspector General, Ministry for Public Health, Social Development and Labour).

Hurricane Irma

Hurricane Irma was an extremely powerful and catastrophic Cape Verde-type hurricane, the strongest observed in the Atlantic in terms of maximum sustained winds since Hurricane Wilma in 2005 and the strongest storm on record to exist in the open Atlantic region. It was the first Category 5 hurricane on record to strike the Leeward Islands. It was the ninth named storm, the fourth hurricane, the second major hurricane, and the first Category 5 hurricane of the 2017 Atlantic hurricane season. Irma caused widespread and colossal damage throughout its long lifetime, particularly in parts of the northeastern Caribbean and the Florida Keys.

Irma developed on 30th August 2017 near the Cape Verde Islands, from a tropical wave that had moved off the West African coast three days earlier. Under favourable conditions, Irma rapidly intensified shortly after formation, becoming a Category 2 hurricane on the Saffir-Simpson scale within a mere 24 hours. Irma became a Category 3 hurricane (and therefore a major hurricane) shortly afterward. However, the intensity fluctuated between Categories 2 and 3 for the next several days due to a series of eye-wall replacement cycles. On 4th September Irma resumed intensification, becoming a Category 5 hurricane by early the next day. On 6th September Irma had a minimum pressure of 914 hPa. Another eye-wall replacement cycle caused Irma to weaken back to a Category 4 hurricane, but the storm attained Category 5 status for a second
time, before making landfall in Cuba. After dropping to Category 3 intensity due to land interaction, the storm re-intensified to Category 4 status as it crossed warm waters between Cuba and Florida. It then began to lose strength.

The storm caused catastrophic damage in Barbuda, Saint Barthélemy, Sint Maarten / St Martin, Anguilla and the Virgin Islands.

Appendix A shows:
- the summary Tracking Chart of the 2017 Atlantic Hurricane Season;
- NOAA National Weather Service National Hurricane Center image from the GOES-16 satellite, taken on 5th September 2017 approaching the island of Sint Maarten / St Martin;
- the track of Irma in the vicinity of the island of Sint Maarten / St Martin;
- the footprints of wind speeds in the island of Sint Maarten / St Martin.

**Sint Maarten Medical Centre (SMMC)**

Dr Earl Best and Eng Tony Gibbs were welcomed on 12th December 2017 by Erika Van der Horst, the Manager Facilities at SMMC. During the visit to the hospital the following was accomplished:
- The experiences of SMMC during the past two decades of hurricane impacts, and the consequential remedial actions, were reviewed.
- A brief tour of the facility – internally and on the roof – was undertaken.
- The constraints on what could be done following Irma were outlined.
- There was an introduction to the proposed new hospital.

The SMMC had been damaged by three hurricanes prior to Irma – Luis in 1995, Georges in 1998, Lenny in 1999. In all cases the main damage was to the roof and, in particular, to the dislodging of the kentledge slabs placed on the loose-laid rubber membrane to keep it in place. Once again, it was the dislodging of the kentledge slabs that was the main problem during Irma.

The original kentledge slabs were square on plan with the dimensions 500mm x 500mm x 50mm and of precast concrete acting as ballast (the thickness of the slabs was not constant as some of them measured a bit less than 50mm. Also, the newer tiles which were imported from Holland for post-Luis repairs were a bit thicker than 50mm. Lastly, the tiles on which the solar collector panels rested were substantially thicker than 50mm.)

After Lenny, in about 2003, new precast slabs were provided with different geometries. The critical change was the provision of short, upstand ridges along parallel edges of the slabs. These ridges would produce turbulence over the roof surface and thus reduce the uplift (or negative) pressures from the wind. This was a sound aerodynamic idea to reduce vulnerability. Also, the new slabs were mainly rectangular rather than square on plan. However, this was not enough to prevent dislodgement during the unusually severe Hurricane Irma.
Following Hurricane Irma Sint Maarten Medical Center asked Royal Haskoning DHV to carry out the technical assessment of the building structure, building construction and all building systems of all buildings on the site of the hospital. The report on the assessment is dated 26th October 2017.

In addition to the dislodging of the roof slabs there was debris-impact damage to fascias and a few windows and to some balustrades in the atrium space. Settlement cracks were observed in some internal walls. These may not be attributable to the hurricane.

Erika Van der Horst provided a set of photographs taken soon after Hurricane Irma. They are in Appendix B. A few photographs taken during the December visit are in Appendix C.

An important problem faced by those responsible for repairing the damage to SMMC is the imminent plan to replace the existing facility with a completely new hospital. Therefore the reasonable intention is to assume a further five years only for the operation of the existing SMMC.

The slabs around the perimeter of the roof are those experiencing the highest uplift pressures. One possible solution may be to anchor them with steel beams which would themselves be anchored to the parapet structures. This scheme needs to be more thoroughly thought through.

In 1998, following the damage caused by Hurricane Georges, the original designers of the facility (PPDnv of Curaçao) proposed the following:
- removing the upper four layers of the roof construction;
- casting a light-weight concrete slab on top of the profiled steel sheet (which would also provide temperature insulation);
- applying waterproofing to the top surface of the concrete slab.

At that time the cost estimate for implementing that proposal was a total of US$712,000 to cover approximately 6,000 square metres of roof.

Tony Gibbs in 1998 recommended the following steps to be carried out if this proposal was to be implemented:
- Determine the wind forces on the roof.
- Analyse the roof structures and the overall building structures for the new gravity loads, the new wind loads and the new earthquake loads.
- If the analyses should identify weaknesses, the substandard components of the structures should be strengthened.
- Ensure that the fastening of the existing profiled sheets to the steel beams is satisfactory for resisting the wind forces as determined above.
- Ensure that there is positive anchorage of the lightweight concrete to the profiled sheets.
- Ensure that the method of securing the waterproof layer to the lightweight concrete deck is satisfactory for resisting the wind forces as determined above.

The proposed new hospital has already been designed and funding for construction is awaited.
Erika Van der Horst shared the design criteria for the new hospital with Tony Gibbs. It is also understood that the new building will be base isolated, which is very good news indeed. According to the designers, Royal Haskoning DHV, the building has been designed according to the Eurocode using the hazard level of “Seismic Zone 3 according to the Uniform Building Code 1997”. The latest, comprehensive study of the seismic hazard for structural design purposes in the Eastern Caribbean was done in 2009-2010. It would be useful to review the design using the following information which Tony Gibbs provided to Erika Van der Horst:

<table>
<thead>
<tr>
<th>Period in seconds</th>
<th>0</th>
<th>0.2</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sint Maarten (475-year)</td>
<td>0.314</td>
<td>0.792</td>
<td>0.220</td>
<td>0.096</td>
<td>0.057</td>
</tr>
<tr>
<td>Sint Maarten (2475-year)</td>
<td>0.574</td>
<td>1.485</td>
<td>0.451</td>
<td>0.209</td>
<td>0.129</td>
</tr>
</tbody>
</table>

More detailed information is available if it is required to plot the full spectrum from 0 seconds to 3 seconds.

According to the designers, Royal Haskoning DHV, the building has been designed according to the “Miami standards for hurricanes” and “based on a Category 5 hurricane.... with a maximum wind speed of 160 mph.” The latest, comprehensive study of the wind hazard for structural design purposes in the Caribbean was done in 2007-2008. It would be useful to review the design using the following information which Tony Gibbs provided to Erika Van der Horst:

<table>
<thead>
<tr>
<th>Location</th>
<th>Return Period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50  100  700  1700</td>
</tr>
<tr>
<td>miles per hour – 3-second gusts</td>
<td></td>
</tr>
<tr>
<td>Saint Martin / Sint Maarten</td>
<td>127  140  167  175</td>
</tr>
</tbody>
</table>

**Sint Maarten – The General Impact**

The early reports after Hurricane Irma stated that there was significant damage in Sint Maarten. The impact on hotels, shops and the general infrastructure in the capital, Philipsburg, meant that tourism was seriously impacted. More particularly, the damage to the relatively new terminal building at Princess Juliana International Airport was rendered completely out of use pending major repairs.

Many buildings suffered little or only moderate damage. Nevertheless Irma’s impact on the built environment in Sint Maarten was significant.

The common losses to be observed were the usual suspects:
• light-weight roofs (except those with hipped roof geometries);
• exterior wall cladding;
• windows and exterior doors.

Appendix D shows examples of damage and destruction and also of successes.

**Sint Maarten Standards**

Building control in Sint Maarten is governed by:
• Landsverordering (National Ordinance)
• Landsbesluit (National Decree)
The main contents of these documents are dated 1935.

For reinforced concrete construction the regulations are G.B.V. 1930 Gewapend Beton Voorschriften. The number 1930 represents the year of publication. The document was prepared by Koninklijk Instituut van Ingenieurs (K.I.V.I.) ([www.kivi.nl/English](http://www.kivi.nl/English)). That is The Royal Netherlands Society of Engineers.

The official standards in the above-listed documents make no mention of:
• wind;
• torrential rain;
• earthquake.
Therefore, it is not a requirement for development approval to design for these phenomena. In practice, many buildings in Sint Maarten are designed and constructed for these phenomena. However, the severity levels are left up to the designers.

In 1997 Dr C P W “Chris” Geurts of TNO Building & Construction Research and his colleagues conducted a study of wind speeds in the Netherlands Antilles. The graph summarising the results of the study is in Appendix E. This information is known to some of the engineers working in Sint Maarten and has been used in the design of some structures.

A meeting was held at the office of Independent Consulting Engineers NV (ICE). Present were:
• Ronald A M Daal – President (ICE)
• Yuri P Daal – Structural Engineer (ICE)
• Dr Earl Best
• Erika Van der Horst
• Tony Gibbs

---

1Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research) – TNO was founded by law in 1932 to enable business and government to apply knowledge. As an organisation regulated by public law, it is independent and not part of any government, university or company. TNO contributes to the design, construction and maintenance of safe structures.
The ICE Vice President, Jan J M Vanden Eynde, was not in office at the time. Tony Gibbs had met him and Ronald Daal during a visit to Sint Maarten in 1996 following Hurricane Luis.

ICE have been providing services on both the Dutch and French sides of the island for decades and are in a good position to provide an insight on practices in Sint Maarten / St Martin. They confirmed that they routinely used much more up-to-date information than what was required by the 1935 standards. They used the information on wind from the 1997 TNO study for Sint Maarten.

Studies have been carried out during the past decade for wind and earthquake forces for structural design in the Eastern Caribbean, including Sint Maarten. They include:

- “Probabilistic Seismic Hazard Assessment for The Eastern Caribbean Region” by EUCENTRE and SRC – The maps for PGA 475-year return period and SA-0.2 second and SA-1.0 second 2475-year return period are in Appendix E. The values for Sint Maarten are given in the section on SMMC earlier in this report.

### The Hôpital Louis-Constant Fleming in St Martin

Dr Earl Best, Lawyer Dana Kweekel and Eng Tony Gibbs were welcomed on 13th December 2017 by a delegation including:
- Francisco Moreno – Director
- Louis Jeffrey – Chairman of the Medical Board
- Alain Putzeys – Engineer, Technical Services

The group toured the hospital, including the damaged internal areas and the roof. A summary of the observations is provided below:
- There were some windows broken by flying debris,

---

2 The Eucentre Foundation, European Centre for Training and Research in Earthquake Engineering, based in Pavia (Italy), is a non-profit organisation that promotes, supports and sustains training and research in the field of seismic risk mitigation. The Eucentre was founded in 2003 by the following institutions: Italian National Department of Civil Protection, University of Pavia (Italy), Italian Institute of Geophysics and Volcanology (INGV), Institute of Advanced Study (IUSS) of Pavia (Italy).

3 The Seismic Research Centre of the University of the West Indies was established in 1952 with the objective of monitoring volcanic activity in the Lesser Antilles. The work of the Centre was extended to include the monitoring of tectonic (non-volcanic) earthquakes and the non-volcanic islands of Trinidad, Tobago, Barbados and Antigua were included in the system. Jamaica joined in 1957 but withdrew in 1985 to form its own unit.
• Part of the roof sheeting was damaged by a 40-foot container which flew over the roof and landed on part of it.
• Over most of the hospital the roof performed well. It consisted of fairly thick, stainless steel (SS315), deep-trapezoidal sheets. The only damage was by flying debris.
• There was some damage to the perimeter fence.
• Part of the roof of the psychiatric wing was damaged.
• The main hospital was built in 2002 and the psychiatric wing was added in 2013.
• There is evidence that the main building was consciously designed for earthquakes.
• Of the 92 beds before Irma, 70 were in use at the time of the visit.
• There was no clear statement about the use of higher standards for the repairs of the facility.

Photographs taken during the visit are in Appendix F.

**St Martin – The General Impact**

The early reports after Hurricane Irma stated that there was catastrophic damage in St Martin with most of the buildings severely damaged or destroyed. This was an exaggeration of the situation. Many buildings suffered little or only moderate damage. Nevertheless Irma’s impact on the built environment in St Martin was significant.

The common losses to be observed were to the light-weight roofs and to exterior wall cladding. Windows and exterior doors were dislodged or breached by flying debris. Coastal construction was also impacted severely by wave action. There was also evidence of failures due to poor maintenance leading to corroded steel and rotted timber.

There were several spectacular failures of large, industrial-type, steel structures. Such structures are sensitive to any increase in wind forces above what they may have been designed to resist. Also, they often lack a high degree of redundancy and “accidental” resistance. Consequently, they have little spare capacity to deal with overloads.

Appendix G shows examples of damage and destruction and also of successes.

**St Martin Standards**

The significant failures in French St Martin was a bit of a surprise.

The French Antilles have the most effective enforcement systems for building standards in the Caribbean. The system uses *bureaux de contrôle* to check designs and to check quality control methods during construction.

The standards are prescribed. ICE were able to provide information for St Martin. They stated
that the standard for wind is a basic wind speed of 36 metres per second (10-minute average) at 10-metre height. This equates to 51.5 metres per second or 115 miles per hour (3-second gust). The wind speeds in St Martin ranged from 165 to 182 miles per hour (3-second gust). Thus the wind forces were 2 to 2.5 times the basic St Martin standard. Clearly, the bureaux de contrôle were enforcing (however effectively) an inadequate standard.

It is understood that this is being reviewed.

**Conclusions**

Here is a summary of the main observations and suggestions from the visit:

- Hurricane Irma was an unusually strong wind event and it is not surprising that the damage and destruction in Sint Maarten and St Martin were severe.
- Many buildings weathered the hurricane with little or no damage, indicating that success is within reach if the aim is to prevent disasters.
- In the case of light-weight roofs, those with hipped geometries performed demonstrably well.
- There is a serious communication gap between the Commonwealth Caribbean and the French and Dutch islands. Well researched and documented information developed in the past decade by internationally-acclaimed experts in the fields of wind and seismic hazards for the Eastern Caribbean focussing principally on an English-speaking audience is not well known in either Sint Maarten or St Martin. There needs to be much better sharing of such scientific information among all Caribbean communities.
- There is an urgent need for Sint Maarten to adopt up-to-date standards, replacing its 1935 code, for all new buildings.
- It is understood that the Netherlands will be granting €550 million to Sint Maarten to assist with post-Irma reconstruction. It is understood that the grant is contingent on two conditions – the adopting of anti-corruption legislation and the strengthening of border controls. Shouldn’t there be a third condition requiring the use of contemporary technical standards for the reconstruction?
- French St Martin needs an urgent review of its wind-load standards.
Appendix A

Hurricane Irma
NOAA National Weather Service National Hurricane Center image from the GOES-16 satellite, taken on September 5, 2017 near the island of Sint Maarten / St Martin
Appendix B

Sint Maarten Medical Centre
(immediately after Irma)
Photos by Erika Van der Horst
Appendix C

Sint Maarten Medical Centre
(12th December 2017)
SMMC roof under repairs

SMMC window damaged by flying debris
SMMC settlement crack in wall

SMMC – The containers used for stores were stable.
Appendix D

Sint Maarten after Irma
The loss of metal roof sheets was commonplace.

Most hipped roofs survived Hurricane Irma.

Point Blanche – roof sheeting lost from flat roof.

Most of these roofs survived Hurricane Irma.
Photovoltaic panels fared better than expected.

Princess Juliana air terminal was out of use.

Casino Royale was out of action

Complete destruction of walls, partitions and much else

Yachts were severely impacted

Urban destruction
Sint Maarten complete destruction of homes

Many cars, including Dr Best’s, were damaged.

Sint Maarten complete destruction of home

Permits Department
Min of Public Housing, Spatial Planning, Environment & Infrastructure
Appendix E

Sint Maarten / St Martin
Natural Hazard Levels
Figure 3.6: Probability of extreme wind speeds in the Caribbean and Amsterdam.

Comparison between various sites

- Miami
- Windward
- Leeward
- AMS
Figure 6.2 b) Map of PGA values (g) for the 475 years return period
Figure 6.3 d) Map of SA values (g) at 0.2 sec. for 2475 years return period
Appendix F

Hôpital Louis-Constant Fleming
(13\textsuperscript{th} December 2017)
The roof of deep-profiled, thick-gauge, stainless steel

The only damage to the roof was by flying debris.

The major damage to the roof was caused by a shipping container landing on it! Picture shows temporary propping pending repairs.

Major damage to the roof was caused by a shipping container. Picture shows temporary covers at end of roof pending repairs.

The damaged roof of the psychiatric ward

The damaged roof of the psychiatric ward
Impact damage to window

Separation joint is evidence of aseismic design.
Appendix G

Saint Martin after Irma
French Saint Martin – Loss of roof covering

Saint Martin – Hotel Mercure loss of roof and wall cladding

Saint Martin – Beach Bay: not all roof covering was lost

St Martin – Success is feasible, not all roof covering was lost

St Martin – Success is feasible, no loss of roof covering

St Martin – Success is feasible, no loss of roof covering
St Martin – Success is feasible, no loss of roof covering

St Martin – Destruction of wall cladding

Grand Case: Destruction of accordion shutters and glass doors

Grand Case: Destruction of wall cladding and glass doors

Hotel Mercure in Marigot
Properties near the coast were severely impacted.

Hotel Mercure in Marigot
Properties near the coast were severely impacted.
St Martin – Properties near the coast were severely impacted.

But note the intact roofs – Success is feasible.

The Fort Louis Marina, Marigot

St Martin – Properties near the coast were severely impacted.

St Martin – Properties near the coast were severely impacted.

St Martin – Some large industrial buildings were destroyed.