Designing Climate Resilient Buildings
What is Climate Change?

Climate change is the long-term shift in weather patterns.

Climate change is the catch-all term for the shift in worldwide weather phenomena associated with an increase in global average temperatures.

A change in the world's climate.

A change in the world's climate global climate change temperature change.
What are the effects of Climate Change?

- More destructive hurricanes and storm surges
- More frequent and intense heat waves
- Increase in vector-borne diseases
- Rising seas and increase costal flooding
- Changing seasons
- Heavier precipitation and flooding - Increase in extreme weather events
Climate Resilience

Climate-resilient buildings reduces, but may not fully eliminate, the risk of climate-related disruptions.

Resilience means that the risks have been considered and managed to achieve an acceptable level of performance given the available information, and that capacities to withstand and recover from shocks are in place.

Risk management requires making trade-offs between risk minimization and cost, where it becomes more expensive and increasingly technically challenging to prepare for events that are very unlikely to occur.

This definition of climate resilience focuses on the process used and outcomes achieved to assess whether climate change impacts have been considered and managed.
**Climate Resilience**

**Structural adaptation measures**
- Changing the composition of road surfaces so that they do not deform in high temperatures
- Building seawalls
- Ecosystem-based approaches using natural infrastructure to design
- Adaptation measures are also key alternatives to be considered alongside structural adaptation measures.

**Management (or non-structural) adaptation measures**
- Changing the timing of maintenance to account for changing patterns of energy demand and supply,
- Investment in early warning systems or purchasing insurance to address financial consequences of climate variability.
- These measures can also include enhanced monitoring of existing assets to reduce the risk of failure as climate conditions change.
Let’s Consider the Effects of Climate Change on......
## Climate Resilience – Civil Works

<table>
<thead>
<tr>
<th>Temperature changes</th>
<th>Sea-level rise</th>
<th>Changing patterns of precipitation</th>
<th>Changing patterns of storms</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Melting road surfaces</td>
<td>• Inundation of coastal infrastructure, such as ports and roads</td>
<td>• Disruption of transport due to flooding</td>
<td>• Damage to assets, such as bridges</td>
</tr>
</tbody>
</table>
Civil Works

- Road design considerations
- Pavement design
- Transverse bars
- Super elevation
- Road widening
Civil Works

OUTSLOPED
3 - 5%
Typical for temporary roads with dirt surface (no ballast)

IN SLOPED
3 - 5%
DITCH LINE
Water flows onto protected and/or stable fill areas

BALLAST
Typical for permanent roads; with or without ballast or ditch line

CROWNED SURFACE
3 - 10%
DITCH LINE
Fastest water removal. Requires water control on both sides.
Civil Works

- Water Level
- Materials Specifications
- Maintenance
- Bridge Design Considerations
Civil Works

Drainage
## Climate Resilience – Building

<table>
<thead>
<tr>
<th>Temperature changes</th>
<th>Sea-level rise</th>
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<tr>
<td>• Increased cooling demand</td>
<td>• Inundation, storm surge and increased flood risk</td>
<td>• Flooding</td>
<td>• Damage to buildings</td>
</tr>
<tr>
<td></td>
<td>• Changes in land use due to relocation of people living in exposed areas</td>
<td>• Prolonged dry season</td>
<td>• Deaths and injuries</td>
</tr>
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</table>
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This definition of climate resilience focuses on the process used and outcomes achieved to assess whether climate change impacts have been considered and managed.
Design Considerations

- Stronger winds
- Increase chance of flooding
- Changes in temperature
- Health impact
Climate resilient design features make buildings resistant to climate vulnerabilities, such that they maintain an acceptable level of functioning and structure.
Design Considerations
Increase chance of flooding

Complete micro and macro level hydraulic analysis on building sites
Increase chance of flooding
Hydraulic Analysis
Increase chance of flooding

Hydraulic Analysis
Avoid building in flood zones; buildings located on a river bed, close to running water, will be vulnerable to flooding.

Elevate buildings which are found in areas that may be remotely prone to flooding.

That is watershed analysis should consider from 100-year floods up to 500-year flood events.

A full map of the flood prone areas is available at the Land-Use Division at the Ministry of Agriculture and Lands.
Increase chance of flooding

Storm water conveyance should be considered on both micro and macro levels

On the micro this would include the immediate surroundings of the structures being built, the conveyance for the structure itself (rainwater guttering)

Retaining walls should be adequately drained

Retaining walls are not meant to stop flooding
Increase chance of flooding
Retaining Walls
Design Considerations

Retaining Walls
Increase chance of flooding
Slope Stabilization

- Do not completely remove vegetation at the base of hills
- Complete slope stability analysis
Design Considerations
Slope Stabilization
Design Considerations
Slope Stabilization
Slope Stabilization

- Soil Type
- Slope Angle
- Addition and Removal of Slope Material
- Vegetation
- Water
- Climate
- Time
Design Considerations
Slope Stabilization
Slope Stabilization
Mechanical

Typical dimensions of different types of retaining walls

Gravity walls
Cantilever Wall
Counterform Walls
Slope Stabilization

- Developments to adhere to natural site contours
- Development to be planned in a manner to leave natural vegetation protected
- Grading large flat terraces on hill side sites should not be allowed
- Reduce impervious paving
Slope Stabilization
Erosion control measures are especially important for construction on slopes; absence of such measures often trigger landslides and failure of storm drainage systems (manmade/natural).
Design Considerations Costal Zones

When building near to the sea, flood prone mitigation techniques should be considered and the building needs to be built according to regulations pertaining to the high water mark.

As per OECS Building Code 2015 “No Building shall be erected on a site which Cannot be put into such a condition as to prevent any harmful effect to the building or to its occupants by storm or flood waters.”

There is also the high risk of the aggressive environment affecting the structure.

The materials used should be able to resist the saline conditions. The concrete mix should adhere to specifications for this environment.
Design Considerations - What are the effects of Climate Change?

- More destructive hurricanes and storm surges
- More frequent and intense heat waves
- Increase in extreme weather events
- Rising seas and increase coastal flooding
- Changing seasons
- Heavier precipitation and flooding
Design Considerations
Resilient Buildings (Design Loads)

Foundation must resist
- Dead Load
  - Weight of building
- Live Load
  - Weight of Occupants
  - Weight of Furniture
  - Weight of Equipments
- Lateral Load
  - Wind
  - Seismic

SOIL REACTIONS
Design Considerations - What are the effects of Climate Change?

Officially, from 1924 to 2018, 34 Category 5 hurricanes have been recorded.

The decade with the most Category 5 hurricanes is 2000–2009, with eight.

Between 2003–2018, there has been 12 category 5 hurricanes.

35% of the category 5 hurricanes occurred between 2003–2018.
Design Considerations
Resilient Buildings
(Load Transfer)
Design Considerations

Resilient Buildings (Load Transfer)
Ensure a continuous load path for the structure, by guaranteeing there are proper connection between elements, this may be done by employing hurricane straps, proper anchorage and laps of reinforcement.

Poorly mixed concrete will adversely affect its strength. During hot weather (temperatures in excess of 29 degrees C), steps shall be taken to reduce concrete temperature and water evaporation by proper attention to ingredients, production methods, handling, placing, protection and curing.

Designing elements based on the loads prescribed by the OECS Building Code 2015.
Design Considerations

Resilient Buildings

<table>
<thead>
<tr>
<th>OCCUPANCY CATEGORY</th>
<th>NATURE OF OCCUPANCY</th>
</tr>
</thead>
</table>
| I                  | Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to:  
  * Agricultural facilities.  
  * Certain temporary facilities.  
  * Minor storage facilities. |
| II                 | Buildings and other structures except those listed in Occupancy Categories I, III, and IV. |
| III                | Buildings and other structures that represent a substantial hazard to human life in the event of failure, including but not limited to:  
  * Buildings and other structures whose primary occupancy is public assembly with an occupant load greater than 300.  
  * Buildings and other structures containing elementary school, secondary school or day care facilities with an occupant load greater than 250.  
  * Buildings and other structures containing adult education facilities, such as colleges and universities, with an occupant load greater than 500.  
  * Group I-2 occupancies with an occupant load of 50 or more resident patients but not having surgery or emergency treatment facilities.  
  * Group I-3 occupancies.  
  * Any other occupancy with an occupant load greater than 5,000.  
  * Power-generating stations, water treatment facilities for potable water, waste water treatment facilities and other public utility facilities not included in Occupancy Category IV.  
  * Buildings and other structures not included in Occupancy Category IV containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released. |
| IV                 | Buildings and other structures designated as essential facilities, including but not limited to:  
  * Group I-2 occupancies having surgery or emergency treatment facilities.  
  * Fire, rescue, ambulance and police stations and emergency vehicle garages.  
  * Designated earthquake, hurricane or other emergency shelters.  
  * Designated emergency preparedness, communications and operations centers and other facilities required for emergency response.  
  * Power-generating stations and other public utility facilities required as emergency backup facilities for Occupancy Category IV structures.  
  * Structures containing highly toxic materials as defined by Section 307 where the quantity of the material exceeds the maximum allowable quantities of Table 307.1(2).  
  * Aviation control towers, air traffic control centers and emergency aircraft hangars.  
  * Buildings and other structures having critical national defense functions.  
  * Water storage facilities and pump structures required to maintain water pressure for fire suppression. |
Design Considerations
Resilient Buildings

Basic Wind Speed for Category II Buildings: Grenada 154 miles/hour

Basic Wind Speed for Category III and IV Buildings: Grenada 133 miles/hour

In order to take into account climate change, all of the wind speeds shall be increased by factors of: (i) 1.13 for most buildings or for Category II Buildings (ii) 1.10 for critical facilities or for Category III and IV Buildings
Climate resilient design features make buildings resistant to climate vulnerabilities, such that they maintain an acceptable level of functioning and structure.
Climate Resilient Buildings – Secret Ingredient
<table>
<thead>
<tr>
<th></th>
<th>With Insurance</th>
<th>Without Insurance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home Valuation</td>
<td>EC$300,000.00</td>
<td>EC$300,000.00</td>
</tr>
<tr>
<td>Insurance/yr.</td>
<td>EC$1,800.00</td>
<td>Nil</td>
</tr>
<tr>
<td>Total Insurance after 10 yrs.</td>
<td>EC$18,000.00</td>
<td>Nil</td>
</tr>
<tr>
<td>Cost of Damages</td>
<td>EC$45,000.00</td>
<td>EC$45,000.00</td>
</tr>
<tr>
<td>Total Borne by Home Owner</td>
<td>EC$318,000.00</td>
<td>EC$345,000.00</td>
</tr>
<tr>
<td>Difference</td>
<td>EC$27,000.00</td>
<td></td>
</tr>
</tbody>
</table>