STRUCTURAL ANALYSIS

Project **WENDY'S RESTAURANT. NASSAU, BAHAMAS.**

Date FEBRUARY 2020

MEMORY INDEX

APPENDIX INDEX

DESCRIPTIVE REPORT

1 OBJECTIVE

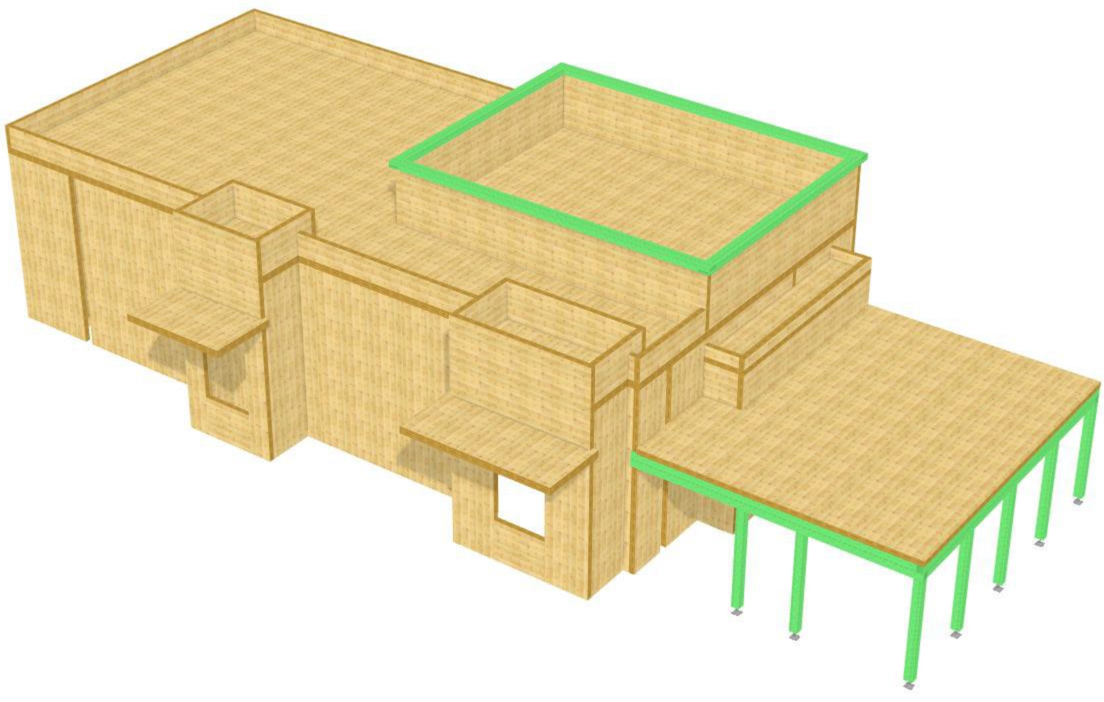
The purpose of this report is to document and justify the structural solution adopted for Wendy´s restaurant project in Nassau, Bahamas. The characteristics of the materials, the verifications and all aspects that have been taken into account, in compliance with the applicable building regulations, are described in detail in this document.

2 DESCRIPTIVE REPORT OF THE PROJECT

This Project consists of a building used for restaurant purposes. It is a one-storey building above ground level, with a built area of 140 m2 (1507 ft²). In front of the main building there is a porch of 42 m2 (450 ft²)

The dimensions of the building envelope are: 17.08 m (56.04 ft) long, 7.90 m (25.92 ft) wide and 4.23 m (13.88 ft) height above level up to upper surface of the roof panel, were parapets of between 0.5 (1.64 ft) and 1.4 m (4.59 ft) are built. The porch is 5.9 m (19.36 ft) long and 7.1 m (23.29 ft) wide.

The roof of the main volume area is flat, and there are several parapets of different heights on the edge of the roof.

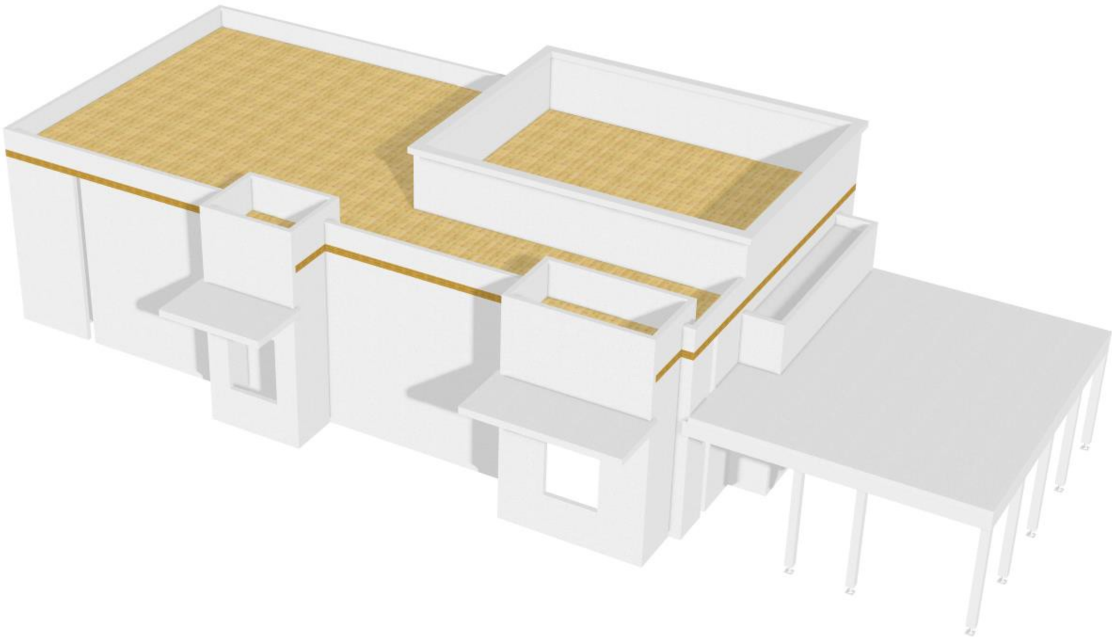


2.1 ROOF

2.1.1 GENERAL DESCRIPTION

The building has a flat roof built of cross laminated timber panels of the following layer composition:

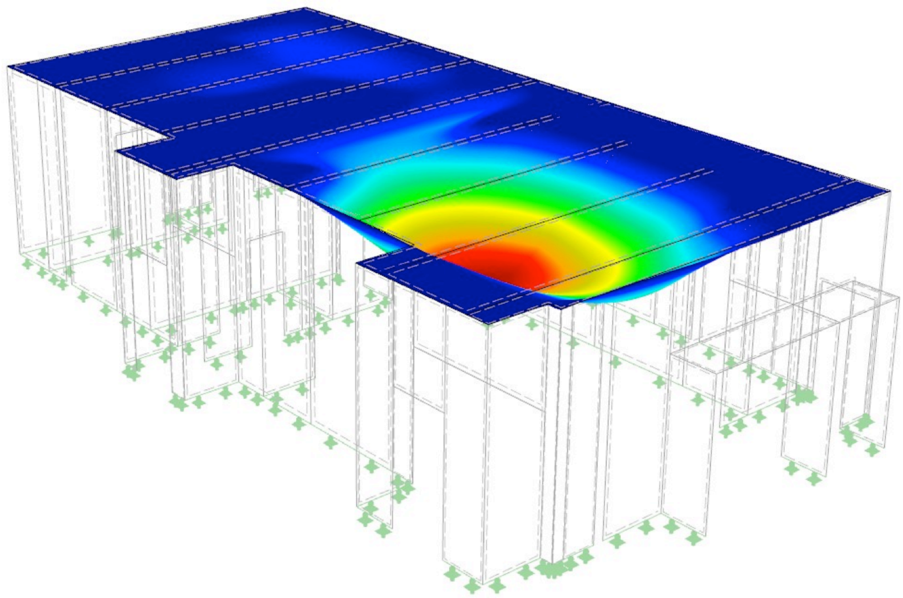
- CLT 160 mm (6.3") 4 layers (40L – 40T – 40L – 40L)



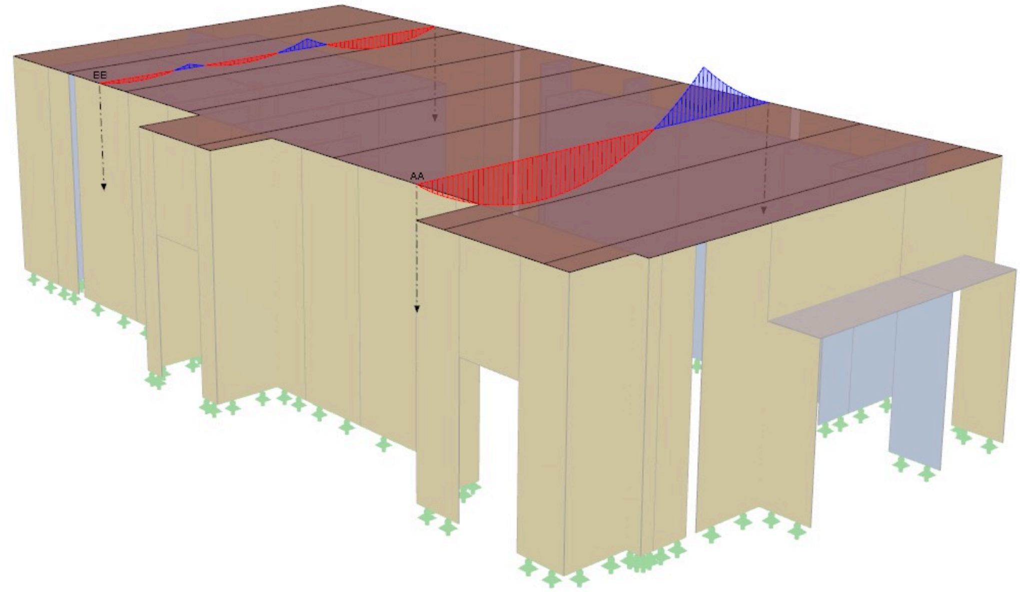
2.1.2 STRUCTURAL BEHAVIOUR

The edges of the panels rest over the facade walls, and in the central area some of them rest over the interior walls of the building in such way that the bending moments and deformations of greater magnitude are produced in panels that have only one off-centre bearing wall.

Deformation mode caused by vertical loads



Moment diagram caused by vertical loads



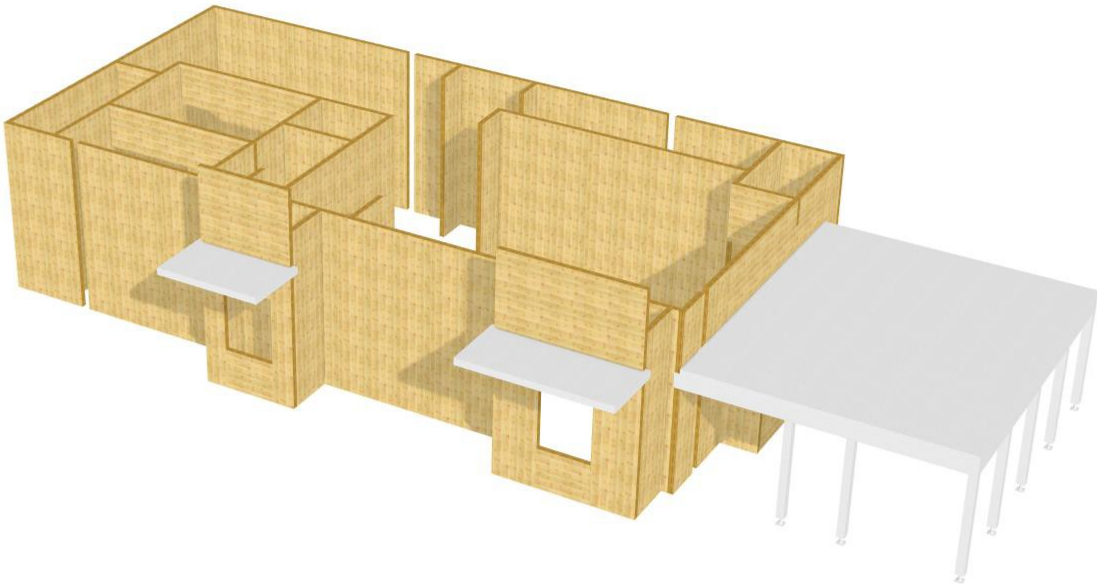
2.2 STRUCTURAL WALLS

2.2.1 GENERAL DESCRIPTION

All bearing walls are made of cross laminated timber panels, which have the following composition:

- CLT 120 mm (4.72”) 3 layers (40L – 40T – 40L)

Cross laminated timber panels allow the vertical loads to be transferred to the foundation and guarantee the lateral stability of the building caused by horizontal wind stress. In the refrigerator area, panels of the same composition above mentioned are horizontally placed, acting as beams for the roof panels.

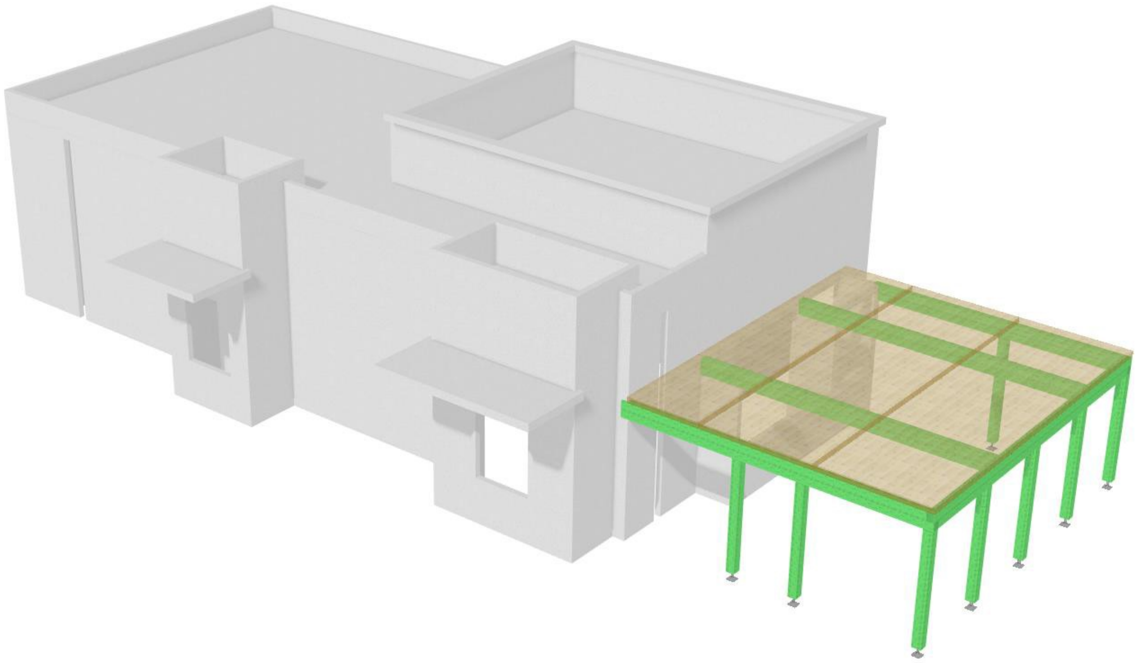


2.3 PORCH

2.3.1 GENERAL DESCRIPTION

The porch shall have the following structure. Firstly, a number of columns and glulam beams (GL24H) which provide support to the cross laminated timber panels of the roof.

- Columns: Glued laminated timber (glulam) 160x175 mm (6.3x6.89”)
- Beams: glulam 140x315 mm (5.51x12.4”)
- Roof panels: CLT 120 mm (4.72”) 3 layers (30L – 40T – 30L)

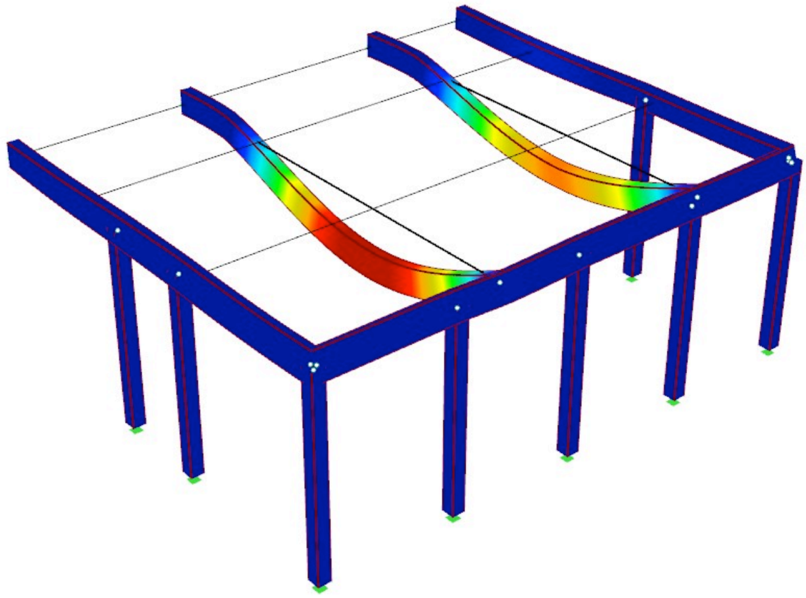


2.3.2 STRUCTURAL BEHAVIOUR

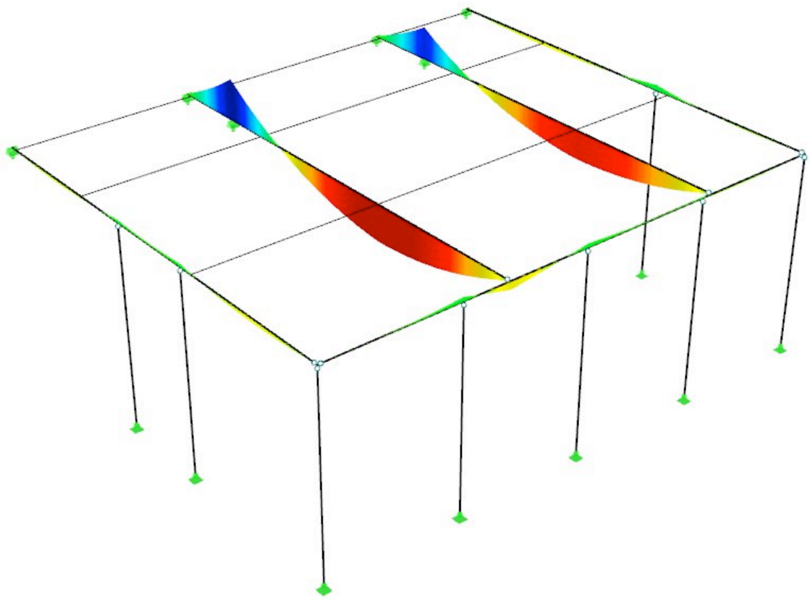
Given the corresponding width the load, the most requested beams are those in the centre. The last segment of these beams rest on the exterior wall panels and have a smaller span, hence allowing the deflection in the center area of the porch to be within the established structural limits.}

The lateral beams, apart from bearing less load than the central beams, also have intermediate supports and are therefore not much demanded. On the other hand, the front beams receive the load of the central beams, but they also count with intermediate supporting columns and therefore the mechanical behavior is satisfactory.

Beam deformations caused by vertical loads



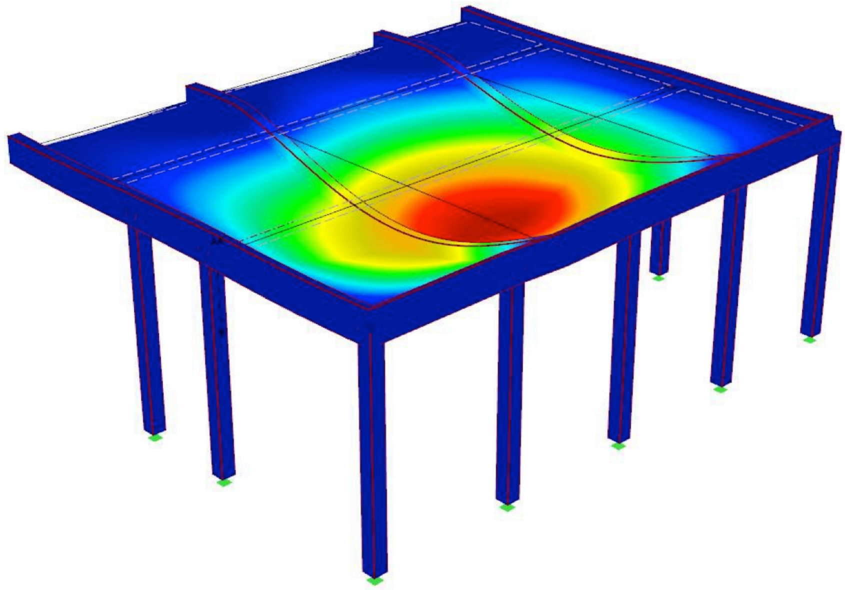
Bending moment diagram of beams subject to vertical loads



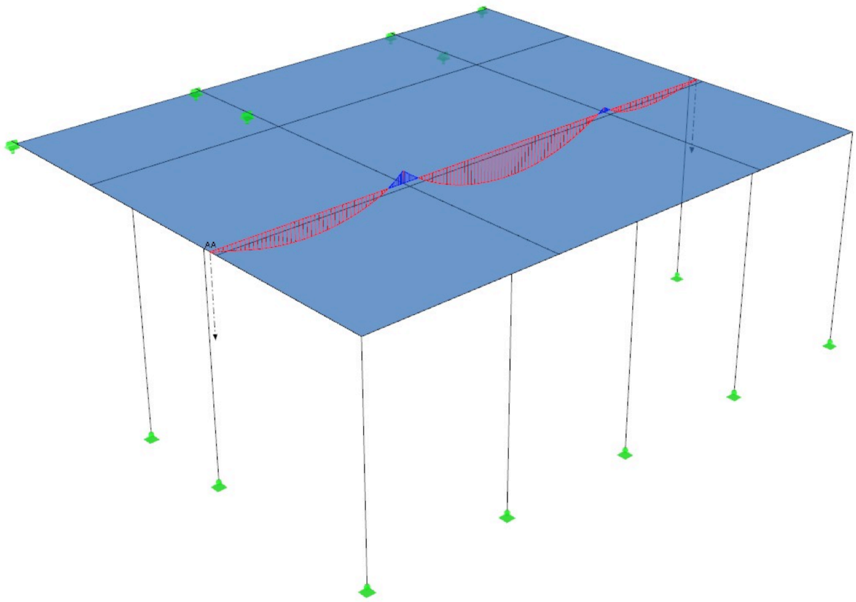
Vertical loads are resisted by the bending strength of the CLT, which rest on 4 support beams.

Moreover, they create a high stiffness structure capable of resisting horizontal loads and maintaining lateral stability.

Bending effect caused by vertical loads



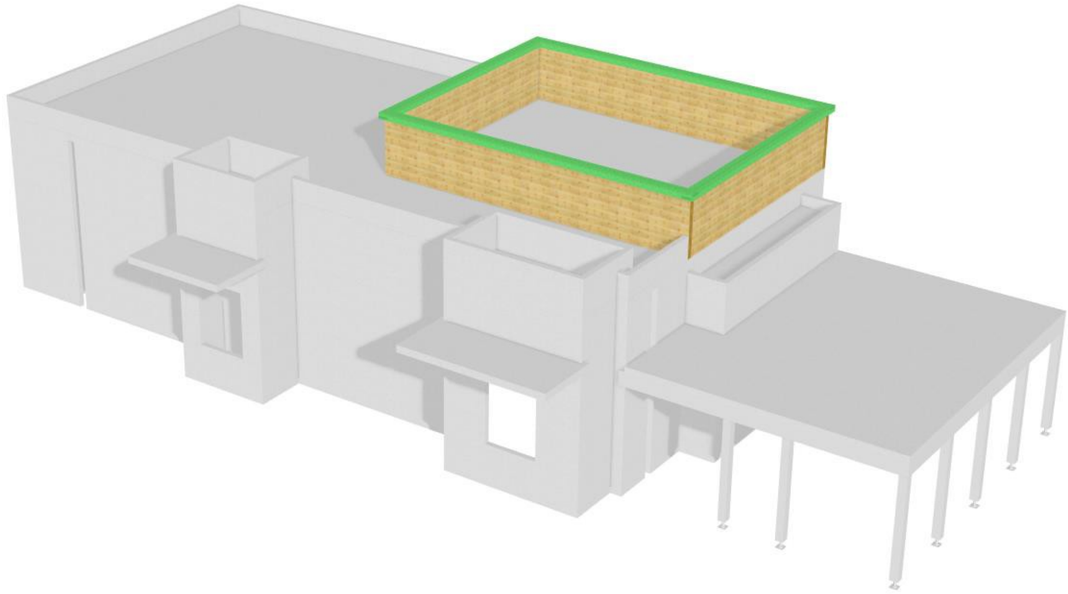
Panel bending diagram caused by vertical loads



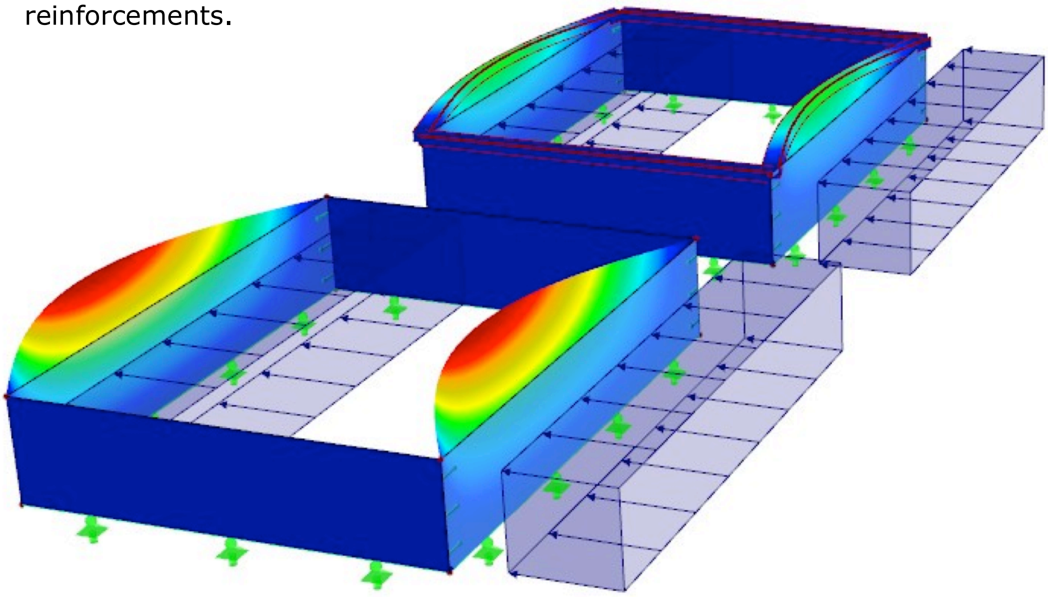
2.4 ROOF PARAPETS

2.4.1 GENERAL DESCRIPTION

A parapet f 1.4m height (4.59 ft) is built in part of the upper roof, making it necessary to use other reinforcement materials such as glued laminated timber GL24h of 140x245 mm (5.51x9.65”) in order to prevent excessive deformations caused by wind pressure.



Comparative picture of lateral deformations with parapet with and without reinforcements.



2.5 UNIONS

The unions used on the different parts of the structure are detailed below.

The geometric details of said unions must be checked in the structural plans attached hereto.

2.5.1 CLT PANELS

UNION	DESCRIPTION
Between vertical panels	Partial Threaded screw Ø8-L140 c/250
Between roof panels	Partial Threaded screw Ø8-L200 c/250
Roof panels and wall panels	Partial Threaded screw Ø8-L240 c/200
Encounters on "L" or "T" between vertical walls	Partial Threaded screw Ø8-L200 c/250
Traction connections GF panels to foundation	Hold-Down 340/20 nails Ø4-L60/Bar M16
Traction connections GF panels to foundation	Angular 200/30 nails Ø4-L60/Connectors SKR
Parapet panels with roof	Angular 100/28 nails Ø4-L60
Reinforcement upper parapet peto superior	Partial Threaded screw Ø8-L200 c/200

2.5.2 PORCH

UNION	DESCRIPTION
Panels over beams	Partial Threaded screw Ø8-L200 c/200
Columns to foundation	Pie pilar TYP R20_2/Connectors SKR
Beams over columns	Screw bar M16 glued to column
Lateral beams to CLT panels	Complete Threaded screw Ø7-L260
Centre beams to CLT panels	Punchboards 200x600x2/110 nails Ø4-L60
Beams to front beam	Double couple fully threaded screw Ø7-L260

3 CALCULATION BASIS

3.1 REFERENCE NORM

The regulations detailed hereinafter were taken into consideration for creating this document:

- Bahamas Building Code. Third edition. 2003. Part V, Engineering and Construction Regulations.

- Norma EN 1990 Eurocode: Basis of structural design.

- Norma EN 1991 Eurocode 1: Actions on structures.
    - EN 1991-1-1:2002 Part 1-1: General actions. Densities, self-weight, imposed loads for buildings
    - EN 1991-1-2:2002 Part 1-2: General actions - Actions on structures exposed to fire
    - EN 1991-1-3:2003 Part 1-3: General actions - Snow loads
    - EN 1991-1-4:2005 Part 1-4: General actions - Wind actions

- Norma EN 1995 Eurocode 5: Design of timber structures.
    - EN 1995-1-1:2004 Part 1-1: General - Common rules and rules for buildings
    - EN 1995-1-2:2004 Part 1-2: General - Structural fire design

- ASCE/SEI 7-16. American Society of Engineers. Minimum Design Loads and Associated Criteria for Buildings and Other Structures.

- Consultation document: Country Risk Profile: Bahamas. CCRIF: Caribbean Catastrophe Risk Insurance Facility. Agosto de 2013.

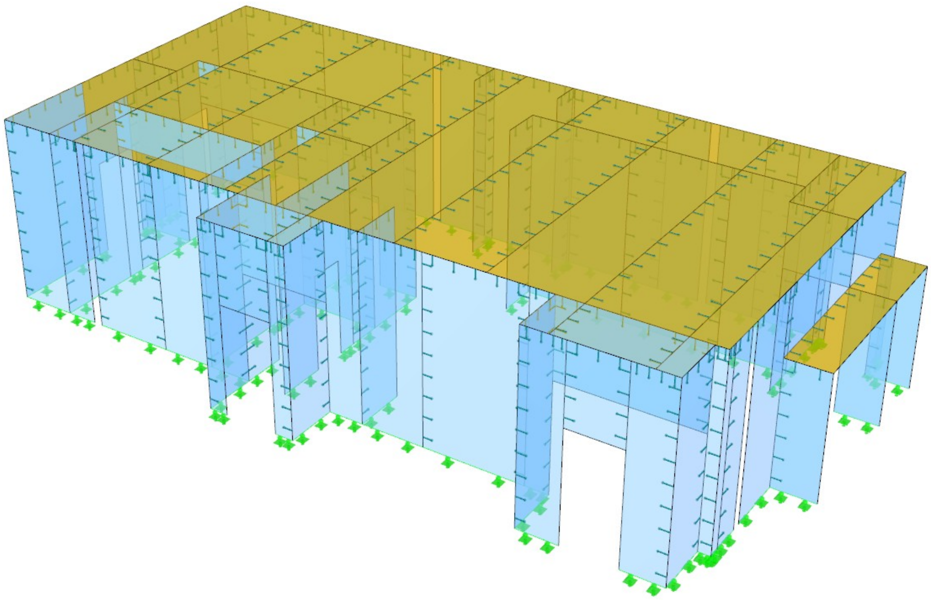
- Consultation document: GAPS Guidelines GAP 15.2.3.3. Earthquake hazard zones – Caribbean, Central America and South America.

3.2 CALCULATION METHODS & MODELS

3.2.1 MAIN VOLUME

The finite element analysis program RFEM from Dlubal was used for modeling and designing the whole building model and for calculating and designing the cross laminated timber panels. Models of specific roof and façade elements had been previously created, and a high level or correlation concerning deformations and stress of both models was detected.

The panels have been introduced as laminated surfaces considering the mechanical properties of the materials, their stratigraphy and orientation of the layers. The unions between the panels bending moment and shear movements have been considered and addressed with the use of threaded screws



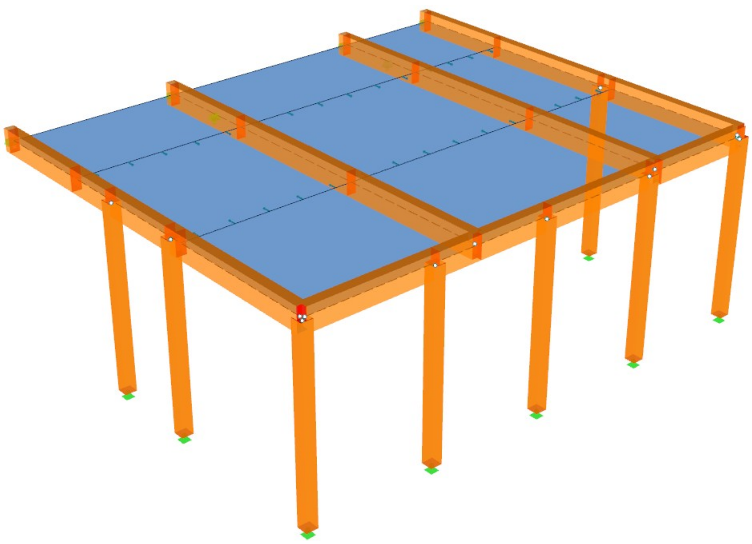
This model has been used for the following calculation phases:

- Dimensioning of cross laminated timber
- Obtaining reactions in the "supports/reinforcements" for designing the foundation loads plan
- Obtaining efforts between panels for designing and calculating the unions.

3.2.2 PORCH

The structural verification of the porch was made from an independent using the finite elements program RFEM of Dlubal Software.

The panels have been introduced as laminated surfaces considering the mechanical properties of the materials, their stratigraphy and orientation of the layers. The unions between the panels bending moment and shear movements have been considered and addressed with the use of threaded screws



This model has been used for the following calculation phases:

- Dimensioning/Sizing of beams and columns.
- Dimensioning/Sizing of CLT
- Obtaining reactions in the "supports/reinforcements" for designing the foundation loads plan
- Obtaining efforts between panels for designing and calculating the unions.

3.2.3 TRACTION CONNECTIONS

On the basis of the complete model in RFEM, a second model has been generated, replacing the supports of the vertical panels of the ground floor with supports with failure if they receive traction efforts. This model includes some specific supports in any necessary area, simulating that all the traction efforts produced by wind action is concentrated on traction brackets.

This model has been used in the following calculation phases:

• Obtaining vertical reactions for the design of traction plates

3.2.4 FIRE SITUATION

Given the high level of correlation between the results of the complete model and of the independent panel models, new roof and wall panel models have been created. Their composition was adjusted considering they were exposed to fire during 60 minutes, based on the reduced cross section method.

These models have been used in the following calculation phases:
• Verification of compliance with the last limited states in a fire situation

3.3 MECHANICAL PROPERTIES OF THE MATERIALS

3.3.1 CROSS LAMINATED TIMBER

The design and calculation of the cross laminated timber panels has been carried out based on the properties of the EGO_CLT material included in ETA-11/0464 from manufacturer EGOIN

C24 graded sawn timber, a premium structural and resistant timber, is used in the manufacturing of the panels. According to the Standard "*UNE-EN 338:2016 Madera estructural. Clases resistentes*", said timber has the following resistance characteristics:

Resistance Properties		C24			
Bending	$f_{m,k}$	24.00	N/mm²	3.48	ksi – kip/in²
Parallel traction	$f_{t,0,k}$	14.00	N/mm²	2.03	ksi – kip/in²
Perpendicular traction	$f_{t,90,k}$	0.40	N/mm²	0.06	ksi – kip/in²
Parallel compression	$f_{c,0,k}$	21.00	N/mm²	3.05	ksi – kip/in²
Perpendicular compression	$f_{c,90,k}$	2.50	N/mm²	0.36	ksi – kip/in²
Shear (Shear & twist)	$f_{v,k}$	4.00	N/mm²	0.58	ksi – kip/in²
Shear by rolling	$f_{R,v,k}$	0.65	N/mm²	0.09	ksi – kip/in²
Stiffness					
Elasticity module half parallel	$E_{0,mean}$	11600	N/mm²	1683.16	ksi – kip/in²
Elasticity module half perpendicular	$E_{90,mean}$	370	N/mm²	53.69	ksi – kip/in²
Half shear module	G_{mean}	690	N/mm²	100.12	ksi – kip/in²
Module shearing by rolling	$G_{R,mean}$	50	N/mm²	7.26	ksi – kip/in²
Density					
Characteristic density	ρ_k	350	kg/m³	21.84	lbm/ft³
Average density	ρ_{mean}	420	kg/m³	26.21	lbm/ft³

3.3.2 GLUE LAMINATED TIMBER

According to the *Standard "UNE-EN 14080 Estructuras de madera. Madera laminada encolada y madera maciza encolada. Requisitos"*, GL 24h glue laminated timber has the following strength and stiffness characteristic values:

Resistance Properties		GL 24h			
Bending	$f_{m,k}$	24.00	N/mm²	3.48	ksi – kip/in²
Parallel traction	$f_{t,0,k}$	19.20	N/mm²	2.79	ksi – kip/in²
Perpendicular traction	$f_{t,90,k}$	0.50	N/mm²	0.07	ksi – kip/in²
Parallel compression	$f_{c,0,k}$	24.00	N/mm²	3.48	ksi – kip/in²
Perpendicular compression	$f_{c,90,k}$	2.50	N/mm²	0.36	ksi – kip/in²
Shear (Shear & twist)	$f_{v,k}$	3.50	N/mm²	0.51	ksi – kip/in²
Shear by rolling	$f_{r,k}$	1.20	N/mm²	0.17	ksi – kip/in²
Stiffness					
Elasticity module half parallel	$E_{0,mean}$	11500	N/mm²	1668.65	ksi – kip/in²
Elasticity module parallel 5%	$E_{0,05}$	9600	N/mm²	1392.96	ksi – kip/in²
Elasticity module half perpendicular	$E_{90,mean}$	300	N/mm²	43.53	ksi – kip/in²
Elasticity module perpendicular 5%	$E_{90,05}$	250	N/mm²	36.28	ksi – kip/in²
Half shear module	G_{mean}	650	N/mm²	94.32	ksi – kip/in²
Half shear module	G_{05}	540	N/mm²	78.35	ksi – kip/in²
Shear Module by Rolling half	$G_{r,mean}$	65	N/mm²	9.43	ksi – kip/in²

Module shearing by rolling characteristic	$G_{r,05}$	54	N/mm²	7.84	ksi – kip/in²
Density					
Characteristic density	ρ_k	385	Kg/m³	24.02	lbm/ft³
Average density	ρ_{mean}	420	Kg/m³	26.21	lbm/ft³

3.4 CALCULATION HYPOTHESIS

3.4.1 SERVICE CATEGORIES

The elements for the structure are classified according to the environmental conditions to which they are exposed according to Eurocode 5.

Structural component	Exposure	Service categories
Cross laminated timber wall panels and interior floor slabs	Interior, under roof	1
Floor beams and panels	Exterior, protected	2
Floor porch columns	Exterior, exposed	3

3.4.2 LOAD DURATION

The load duration significantly affects the wood resistance and it is defined by each load as stated in the Eurocode.

Action	Load duration
Structural materials weight	Permanent
Roof and coating materials weight	Permanent
Roof use loads: type G roof access only for maintenance	Short
Wind	Immediate

3.4.3 MATERIALS COEFFICIENT and ACTIONS

Partial coefficient of materials safety:

	Ordinary situation	Extraordinary situation
Cross laminated timber	1.25	1.00
Glue laminated timber	1.25	1.00
Steel pins	1.25	1.00
Unions	1.30	1.00

K_{mod} values for materials, services categories and load duration:

Material	Standards	Service categories	Load duration category				
			Permanent	Long	Medium	Short	Immediate
CLT and MLE	EN 14080	1	0.60	0.70	0.8	0.9	1.10
		2					
		3	0.50	0.55	0.65	0.70	0.90

Partial coefficient of action safety:

To assess the Ultimate Limit State (ULS) and Service Limit State (SLS) the following partial coefficients of action safety are considered in accordance with the recommendations shown in table A.1.2 (B), Eurocode O, structure calculation bases:

Load type	**Negative effect**	**Positive effect**
Permanent actions	1.35	1.00
Variable actions	1.50	0.00

Simultaneity coefficient:

The numerical values of simultaneity coefficients for structures used in the calculation are shown in table A.1.1, Eurocode O, structure calculation basis:

Load type	**Ψ0**	**Ψ1**	**Ψ2**
Use load (G, roof access only for maintenance)	0	0	0
Wind	0.6	0.2	0

Yield strength

The yield strength is applied to permanent loads or to the permanent aspect of the variable loads. The values K_{def} used for calculations are shown in the following table:

Material	Standard	Service category		
		1	2	3
CLT and MLE	EN 14080	0.60	0.80	2.00

3.4.4 CALCULATION SITUATION

The following verifications have been carried out, corresponding to the Ultimate Limit State and Service Limit State:

- Verification of roof and main building walls in the ULS and SLS
- Verification of roof and main building walls in the ULS in a fire situation
- Verification of roof porch structures in the ULS and SLS

All the details regarding the verifications are stated in calculation exhibit.

3.4.5 DEFLECTION LIMIT CRITERIA

The Eurocode considers the following criteria deflections:

Immediate deflection – characteristic situation

$$w_{in} = \sum G + Q_{k,1} + \sum \Psi_{0,} \cdot Q_{k,}$$

Permanent deflection – quasi-permanent characteristic

$$w_{in} = \sum G \cdot (1 + k) + Q_{k,1} \cdot (1 + \Psi_{2,1} \cdot k) + \sum Q_{k,i} \cdot \ (\Psi_{0,i} + \Psi_{2,i} \cdot k)$$

According to the applicable regulation, the following deflection limit has been set for ELS verification in the structural elements (according to table 7.2, Eurocode 5, Timber Structural Projects).

	Immediate deflection	Permanent deflection

Elements on two supporting member	l/300 to l/500	l/150 to l/300
Cantilevered / Overhang	l/150 to l/250	l/75 to l/150

3.4.5 FIRE EXPOSURE SITUATION

To guarantee the building evacuation in a fire situation, the structural resistance of the building has been verified in **a 60 minute fire**.

The calculation has taken into consideration the sheetrock employed in cladding and the suspended ceiling that delays the carbonization process and alters the carbonization rates in the different fire phases.

The structural geometrical elements are shown herein below after a 60 minute fire according to the reduced cross-section method.

3.4.6.3 Roof panels

			Time (min)	Kg	d_o(mm)
			60	1	7
Initial CLT	β_o mm/min				
40	0.65	Phase 1 $0 \le t_{ch} \le t$ $\beta = 0$			
40	0.65	For walls or floors formed by a board joined to timber framework			
40	0.65	Elements protected with 1 layer of plasterboard A,F or H type			
40	0.65	Board width (h_p)	19.00	Mm	
0	0.65	Time of carbonization	39.20	min	CTE DB SI E.10
CLT after phase 2					
37.18	Phase 2 $t_{ch} \le t \le t_f$ $\beta = k_2 . \beta_n$				
40.00		Time until protection failure	EC 5		
40.00		Failure time of the protection layer t_f	45.80	min	
40.00		Reduction coefficient $k_2 = 1 - 0.018 . h_p$	0.66		CTE DB SI E.3
0.00		carbonization of 1 layer in phase 2	2.82	mm	CTE DB SI E.2.3.2.1
CLT after 60 min	Phase 3 $t_f \le t \le t_a$ $\beta = k_3 . \beta_n$ $k_3 = 2$				
11.72	Limit time t_{a1}(d_{char} = 25mm)		62.86	Min	
40.00	Final time t_{a1} (min (t_{a1}; $t_{requested}$))		60.00	Min	
40.00	Burning time of 1 layer β		14.20	Min	

	= k3. βn				
40.00	Burning of 1 layer β = βn		15.00	Min	
0.00	Residual time of 1 layer resistance β = βn		23.08	Min	
	Time 1 layers is burning β = βn		0.00	Min	
	carbonization 1 layer		21.28	Min	
	Time passed until 1 layer is charred (t_{c1})		60.00	Min	
	Time that other layers should resist		0.00	Min	

Panel composition after 60 minutes 40-40-40- 11.72 mm

3.4.6.2 Wall Panel

			Time (min)	Kg	d_o(mm)
			60	1	7
Initial CLT	$β_o$ mm/min				
40	0.63	Phase 1 $0 \le t_{ch} \le t$ β = 0			
40	0.86	For walls or floors formed by a board joined to timber framework Elements protected with 1 layer of plasterboard A,F or H type			
40	0. 86				
0	0. 86	Board width (h_p)	19.00	Mm	
0	0. 86	Time of carbonization t_{ch} = 2.8 . h_p - 14	39.20	min	CTE DB SI E.10
CLT after phase 2					
37.18		Phase 2 $t_{ch} \le t \le t_f$ $β = k_2 . β_n$			
40.00		Time until protection failure	EC 5		
40.00		Failure time of the protection layer t_f	45.80	min	
0.00		Reduction coefficient k_2 = 1 -0.018 . h_p	0.66		CTE DB SI E.3
0.00		carbonization of 1 layer in phase 2 $d_{char.0.2}$	2.74	mm	CTE DB SI E.2.3.2.1

		Phase 3 $t_f \leq t \leq t_a$ $\beta = k_3 . \beta_n$ $k_3 = 2$			
		Limit time t_{a1}(d_{char} = 25mm)	63.47	min	
		Final time t_{a1} (min (t_{a1}; $t_{requested}$))	60.00	Min	
		Phase 3 duration	14.20	Min	
		Residual time of 1 layer resistance (d_{ef} = βo)	29.57	Min	
CLT after phase 3		Time 1 layers is burning in phase 3	14.20	Min	
19.37		carbonization 1 layer in phase 3	17.89	Mm	
40.00		Time the remaining layers are burning in phase 3	0.00	Min	
40.00		Charred layers in phase 3	0.00	Mm	
0.00		Charred in phase 3	17.89	Mm	CTE DB SI E.2.3.2.1
0.00		Total carbonization in phase 3 ($d_{char\cdot 0.3}$)	20.63	mm	CTE DB SI E.2.3.2.1
		Phase 4 $t_a \leq t \leq t_{requested}$ $\beta = \beta_n$			
		Phase 4 duration	0.00	min	
		Residual time of 1 layer resistance (d_{ef} = βo)	30,75	Min	
		Time 1 layers is burning in phase 4	0.00	Min	
CLT after 60 min		carbonization 1 layer in phase 4	0.00	mm	
12.37		Time the remaining layers should resist	0.00	min	
40.00		carbonization of remaining	0.00	mm	

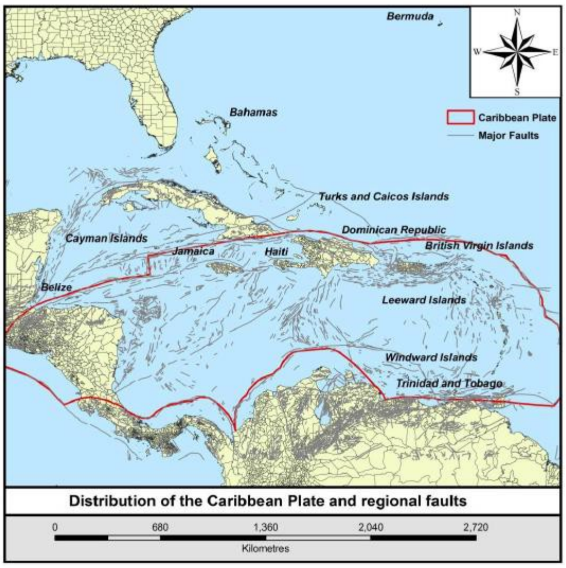
		layers in phase 4			
40.00		carbonization $d_{char.\ 0.4} = \beta_0 \cdot t$	0.00	mm	
0.00		Effective carbonation depth	60.00	min	
0.00		Def= $\sum d_{char.0} + k_o \cdot d_o$	27.63	mm	

Panel composition after 60 min 40-40-12,37

3.4.7 EARTHQUAKE SITUATION

The Bahamas is located close to the Caribbean plate. To determine the seismic activity and to assess how it affects Nassau, Country Risk Profile: Bahamas by CCRIF, Caribbean Catastrophe Risk Insurance Facility, August 2013 has been referred to.

The following map made by USGS Earthquake Hazards Program of the U.S. Geological Survey (USGS) shows how close the Bahamas is to the Caribbean plate.



Distribution of the Caribbean Plate and regional faults

In Nassau, the seismic acceleration value for a return period of 475 years (equivalent to 10% probability of overcoming 50 years) is between **0.005 and 0.01 g** according to the map herein below [Bahamas Country Risk Profile].

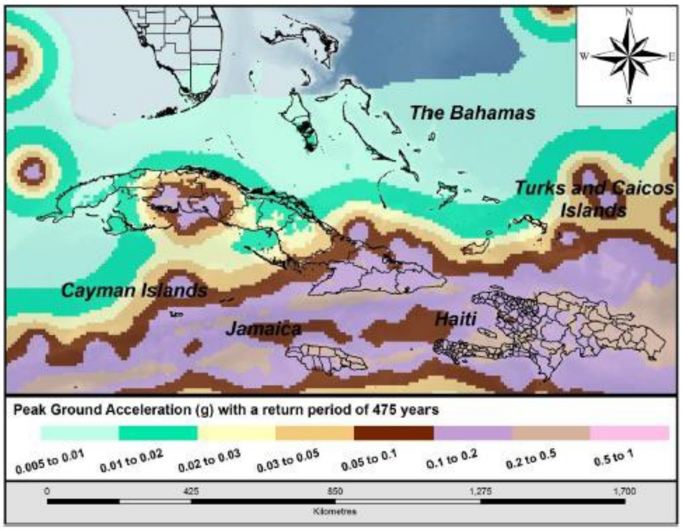


Figure 2.5: Sub-regional map for peak ground acceleration with return period of 475 years.

For the same area, the seismic acceleration value for a return period of 2475 years (equivalent to 2% probability of overcoming 50 years) is between **0.01 and 0.02 g** according to the map herein below [Bahamas Country Risk Profile].

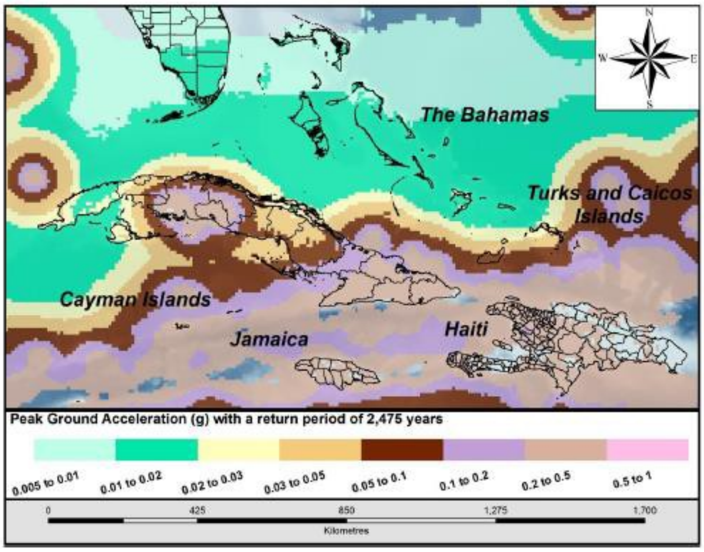


Figure 2.6: Peak Ground Acceleration with return period of 2,475 years (equivalent to 2% probability of exceedance in 50 years).

According to the data published by Global Asset Protection Services LLC in GAPS Guidelines GAP 15.2.3.3 "Earthquakes hazard zones – Caribbean, Central America and South America", the Bahamas can be deemed almost an earthquake free zone and has been categorized as zone 1, similar to Florida.

Aruba
Hazard zone ….4
Bahamas
Hazard zone ….1
Barbados
Hazard Zone…. 5
Barbuda
Hazard zone…. 5

In accordance with the abovementioned data, the earthquake risk in Nassau, Bahamas is classified as low considering that the ground acceleration is within the low seismic activity cases, in which ground acceleration is lower than 0.04g. Therefore, structure verification under seismic activity has not been tested.

3.5 ACTION TAKEN FOR CALCULATION

3.5.1 Permanent Actions

3.5.1.1 Roof

The following table shows the pitched roof materials determined in the project, from exterior to interior:

Category	Width (mm)	Weight (kN/m2)	Weight (lbf/ft2)
TPO membrane	5	0,048	0,992
ISO Board	50	0,090	1,880
Suspended ceiling	-	0,150	3,133
Light suspended objects	-	0,100	2,089
Total Roof Panel		**0,388**	**8,089**

Additionally, the permanent weight of the AC equipment to be installed in the roof (2 units reference R-410A, 960 lbs. and 1 unit reference MUA-1, 1132 lbs.) have been considered.

3.5.1.2 Exterior walls

The following table shows the wall materials weight for the exterior wall, from exterior to interior:

Category	Width (mm)	Weight (kN/m2)	Weight (lbf/ft2)
Face Brick	-	0,350	7,310
Durock Board	19	0,285	5,952
Battens 50x100 c/450	-	0,025	0,522
Insulation	100	0.200	4,177
Fermacell Board	19	0,134	2,799
Total Exterior Walls		**0.994**	**20,760**

3.5.1.3 Interior walls

The following table shows the wall materials weight for the interior walls, from exterior to interior:

Category	Width (mm)	Weight (kN/m2)	Weight (lbf/ft2)
Fermacell Board	19	0,134	2,799
Fermacell Board	19	0,134	2,799
Total Exterior Walls		**0,268**	**5,598**

3.5.2 VARIABLE ACTIONS

3.5.2.1 USE LOAD

<table>
<tr><td rowspan="2">Roof</td><td>Use load in roof (main building)</td><td>1,5
31,33</td><td>kN/m2
lbf/ft2</td></tr>
<tr><td colspan="3">The roof is classified as loading zone H, non-accessible roof unless it is for maintenance and repairs. According to Eurocode 1, table 6.10, a load of 1.0 kN/m2 would be admitted. Considering that the Bahamas Code makes reference to the use of roofs of 30 lbf/ft2, such value was taken to make an approximation upto 1,5 kN/m2.</td></tr>
</table>

3.5.2.2 SNOW LOADS

The American Standard ASCE 7-16 for South Florida, the closest and more similar area to Bahamas, considers a 0 lbf/ft2 load for snow loads.
Therefore, considering that the project is located in Nassau, Bahamas, at a 10-20 msnm from the sea level, it is not necessary to verify the structure for the snow loads.

3.5.2.3 WIND LOADS

Basic wind speed

To obtain the basic wind speed value the American Standard ASCE 7 is referred to, to which the Bahamas Building Code makes references. According to ASCE 7-16, table 1.5-1, the building structure is classified as **risk category II**.

Table 1.5-1 Risk Category of Buildings and Other Structures for Flood, Wind, Snow, Earthquake, and Ice Loads

Use or Occupancy of Buildings and Structures	Risk Category
Buildings and other structures that represent low risk to human life in the event of failure	I
All buildings and other structures except those listed in Risk Categories I, III, and IV	II
Buildings and other structures, the failure of which could pose a substantial risk to human life	III
Buildings and other structures, not included in Risk Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure	
Buildings and other structures not included in Risk Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing toxic or explosive substances where the quantity of the material exceeds a threshold quantity established by the Authority Having Jurisdiction and is sufficient to pose a threat to the public if released[a]	
Buildings and other structures designated as essential facilities	IV
Buildings and other structures, the failure of which could pose a substantial hazard to the community	
Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity of the material exceeds a threshold quantity established by the Authority Having Jurisdiction and is sufficient to pose a threat to the public if released[a]	
Buildings and other structures required to maintain the functionality of other Risk Category IV structures	

According to the Bahamas Building Code recommendations, the basic wind speed shall be referred to in a 50 year period.

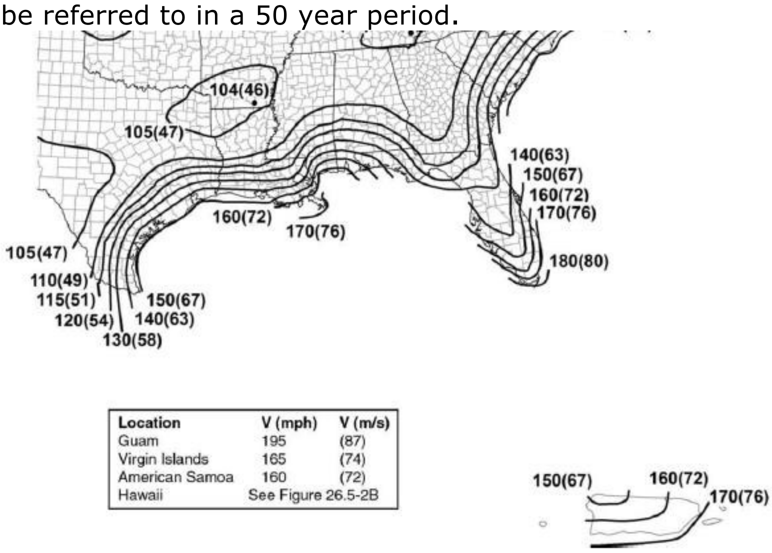
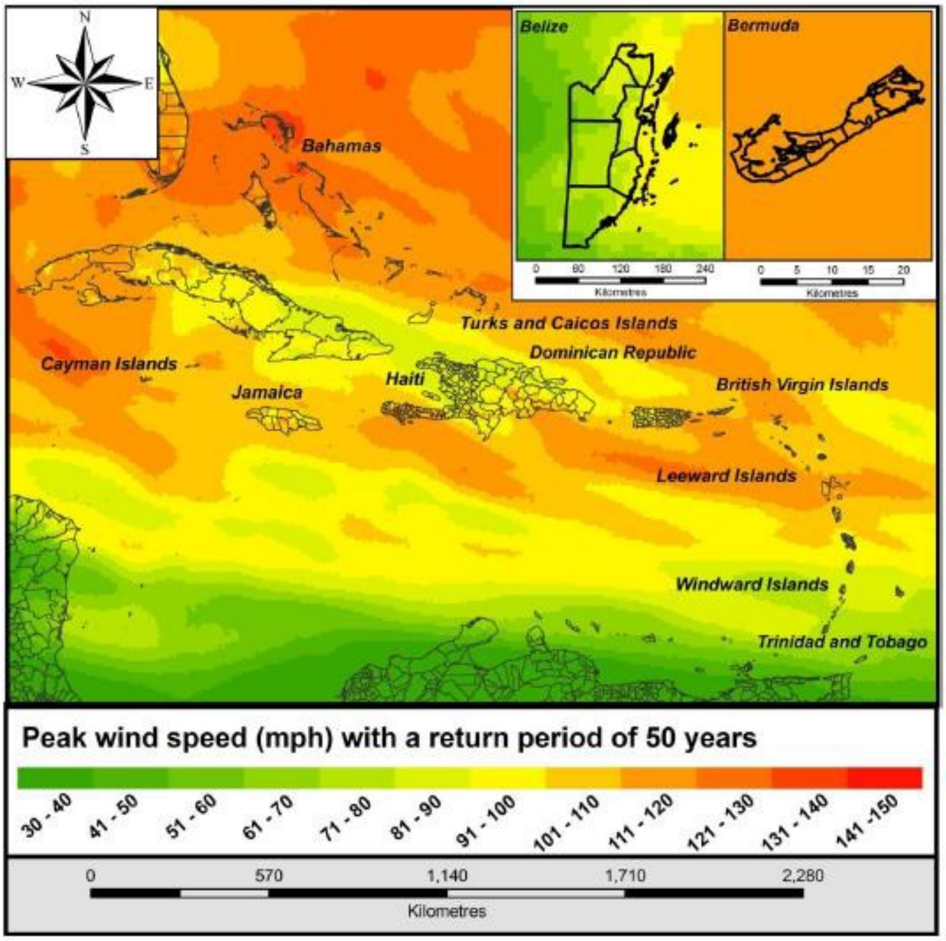


FIGURE 26.5-1B (*Continued*). Basic Wind Speeds for Risk Category II Buildings and Other Structures

Florida can be considered as a similar zone to Bahamas for its proximity and similar wind exposure from the Atlantic Ocean and Caribbean. In the map above, the basic wind speed for Florida is 180 mph = 80.47 m/s.

The Country Risk Profile by CCRIF Caribbean Catastrophe Risk Insurance Facility issued in August 2013 is also consulted. The following map, taken from the previous publications, shows the peak wind speed in the Bahamas with a return period of 50 years. Nassau is between 131-140 mph for a peak wind speed. As it is a peak wind speed and the measurement criteria are unknown, such value cannot be used for calculation but it can be taken as reference.



As it can be drawn from the previous analysis, there are great similarities between the American Standard values for the Florida area and the design requirements of the client, in which a wind speed of 300km/h is contemplated.

Taking the similarities of the values, a basic wind speed value of 300 km/h is taken so as to provide an acceptable reliability level for hurricanes in the Bahamas with a return period of 50 years: $\mathbf{V_{ASCE\text{-}7} = 300\ km/h} = 83.33\ m/s = 197\ mph$.

The basics wind speed value is determined by the American Standard ASCE 7. According to ASCE 7-16, to obtain the wind speed VO, an interval of 3 seconds is used whereas according to Eurocode the interval is of 10 minutes.

Therefore, it is necessary to translate the two intervals to carry out structural verification in accordance with Eurocodes. The translation is carried out using the formula suggested by Solari (G.Solari (1993a). Gust Buffeting. O: Peak wind velocity and equivalent pressure. Journal of Structural Engineering 119 (2), 365-382).

To translate the wind speed using an interval of 3 seconds into a 10 minutes interval, the first speed should be multiplied by 0.676.

The basic wind speed for the calculation of the wind load is:

$\mathbf{v_b} = 300\ km/h \cdot 0.676 = \mathbf{202.8\ km/h = 133.17\ mph = 56.33\ m/s.}$

3.5.2.3.1 Wind pressure for main building

In the table herein under the pressure corresponding to the peak wind speed (peak dynamic pressure) is shown: $qp = ce \cdot qb$

For the following calculations, the project is considered as category ground 0, open sea or coastal zone exposed to open sea.

Pressure corresponding to medium speed used a wind reference **(q_p)**				
	Return period	50	*years*	
	Correction. Coef T	1		
$v_b(T)$		56.33	*m/s*	
ρ		1.25	*kg/m³*	
	q_p	**1.983**	***kN/m²***	*expression (4.8.)*
q_p 41,42	***lbf/ft²***			
Exposure factor (C_e)				
	Ground Category	III. Rural area with obstacles		*table 4.1.*
z 5,0	*m*			
	Ground Factor | k_r	0,19		*expression(4.5.)*
	Roughness length | z_0	0.05	*m*	*table 4.1.*
	Minimum height| z_{min}	2	*m*	*table 4.1.*
	Roughness factor | $c_r(z)$	0,87		*expression (4.4.)*
	c_e	**1.93**		$c = c \cdot (c + 7 \cdot k)$
Peak dynamic pressure (q_p)				
	qp = ce.qp	**3.83 kN/m² = 79.99 lbf/ft²**		

The effect wind has on the structure is calculated using the wind pressure acting in a perpendicular direction to the exposed exterior surface and is obtained as follows: $we = qp \cdot cpe$

The following sections show wind pressure in vertical walls and flat roofs.

The structure verification has been carried out considering the action of the wind in the two main directions of the building and taking into account the effects of pressure and suction that is generated on the vertical walls and the roof.

Vertical walls

VERTICAL PARAMETERS

Dimensions	b	16,20	*m*	$q_p \cdot c_e$	3,83
	d	7,0	*m*		
	h	5,00	*m*		

Transversal wind

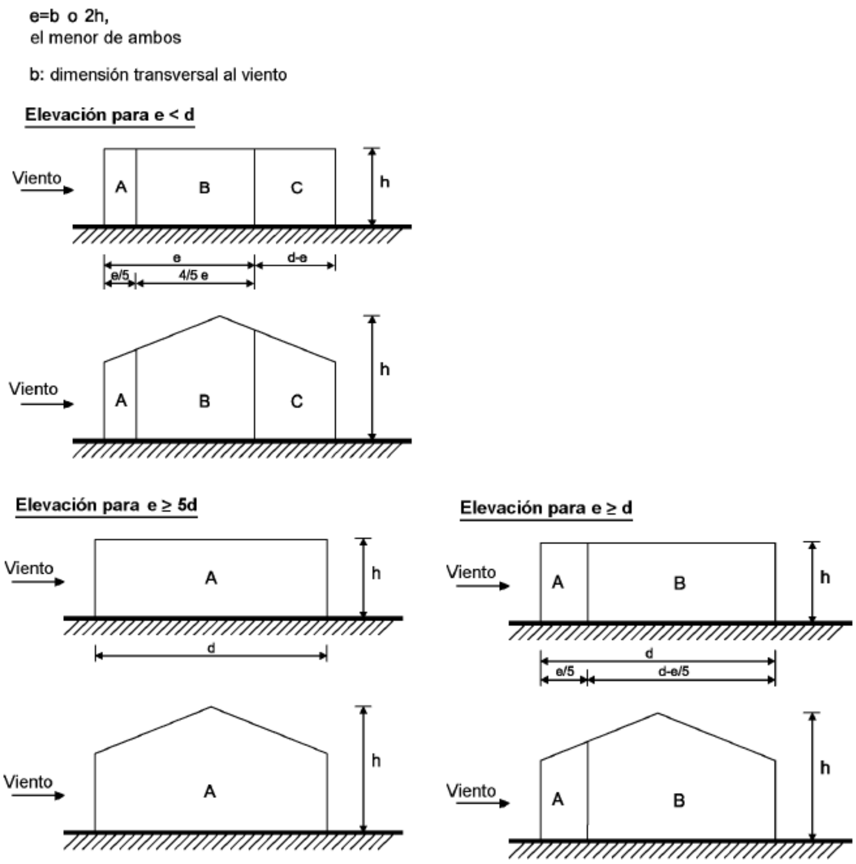
b	16,2	*m*
d	7,8	*m*
h	5,0	*m*
e	10	

	h/d	A	B	C	D	E
c_p	1,00	-1.20	-0.80	-0.50	0.75	-0.40
q_e	**kN/m²**	-4,59	-3,06	-1,91	2,88	-1,55
	kN/m²				**2,45**	**-1,31**
	lbf/ft²				**51,17**	**-27,36**

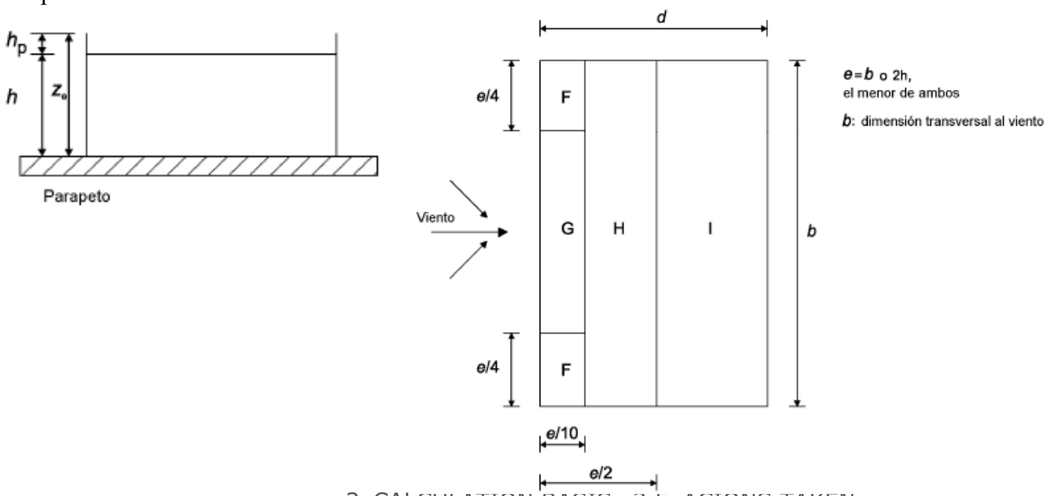
Longitudinal wind

b	7,8	*m*
d	16,2	*m*
h	5	*m*
e	7,8	

	h/d	A	B	C	D	E
c_p	0,68	-1.20	-0.80	-0.50	0.71	-0.32
q_e	kN/m²	-4,59	-3,06	-1,91	2,71	-1,21
	kN/m²				**2,30**	**-1,03**
	lbf/ft²				**48,04**	**-21,51**



Four pitches roof



Geometry					
	b	16,2		$q_p \cdot C_e$	3,83
	d	7,8			
	h	5,0	*m*		
	h_p	0,5	*m*		

Transversal wind

b	16,2 *m*		
d	7,8 *m*	e/10	1,0
h	5,0 *m*	e/4	2,5
e	10,0 *m*	e/2	5,0

	h_p/h	F	G	H	I
$c_{p,10}$ Wind 1	0,1	-: 57	-0,8	-0,7	0,2
$c_{p,10}$ Wind 2	0,1	-: 57	-0,8	-0,7	-0,2
q_e Wind 1	**kN /m²**	**- 5,99**	**-3,07**	**-2, 68**	**0,77**
q_e Wind 2	**kN /m²**	**- 5,99**	**-3,07**	**-2, 68**	**-0,7 7**
q_e Wind 1	**lbf /ft²**	**-125,1 -6**	**4,12 -55**	**,97**	**16,0 8**
q_e Wind 2	**lbf /ft²**	**-125,1 -6**	**4,12 -55**	**,97**	**-16,08**

Longitudinal wind

b	7.83 *m*		
d	11.49 *m*	e/10	0.78
h	7.80 *m*	e/4	1.96
e	7.83 *m*	e/2	3.90

	h_p/h	F	G	H	I
$c_{p,10}$ Wind 1	0,1	-: 57	-0,8	-0,7	0,2
$c_{p,10}$ Wind 2	0,1	-: 57	-0,8	-0,7	-0,2
q_e Wind 1	**kN /m²**	**- 5,99**	**-3,07**	**-2, 68**	**0,77**
q_e Wind 2	**kN /m²**	**- 5,99**	**-3,07**	**-2, 68**	**-0,7 7**
q_e Wind 1	**lbf /ft²**	**-125,1 -6**	**4,12 -55**	**,97**	**16,0 8**
q_e Wind 2	**lbf /ft²**	**-125,1 -6**	**4,12 -55**	**,97**	**-16,08**