WONDERFUL STRUCTURES
PERMITTING DOSSIER

GENERAL CONTENTS

NOTE: Any mentions of Green Magic Homes (GMH) in the documents below, refers to Wonderful Structures Technology (W.S.)

Wonderful Structures by Blake Corporation SA de CV was the manufacturer for GMH.

CHAPTER 1

1. Introduction

1.1. Objective

1.2. Scope

CHAPTER 1

1. Introduction

1.1. Objective

The W.S. building permit dossier compiles many documents that define crucial design features, structural design criteria, and technical documentation or outcomes. It outlines design loading, structural modeling assumptions, material properties, foundation requirements, relevant tests result, and system regulatory compliance. These documents define the calculation procedure, and verification principles followed, providing a complete and clear explanation of the W.S. system.

1.2. Scope

The work scope is to prepare documentation for the building consent application for the Fiber Reinforced Polymer (FRP) panel structure provided by Wonderful Structures. The documents presented below also establish the system design criteria and compliance with its correct operation's relevant regulations.

CHAPTER 2

2. Material properties

2.1. FRP Technical datasheet

2.2. Intertek mechanical test report

FRP PANELS DATA SHEET

1.0 INTRODUCTION

Wonderful Structures panels are prefabricated fiber-reinforced polymer (FRP) panels that are connected to build fabricated engineered structures.

2.0 COMPLIANCE

W.S. panels have endured testing that complies with the requirements with the following codes:

- *2018 and 2015 International Building Code® (IBC)*
- *2018 and 2015 International Residential Code® (IRC)*

3.0 USAGE

W.S. panels are used for Type V-B Construction under the IBC and IRC.

4.0 MATERIALS

W.S. panels have a general layup made by GP Isophthalic Gel Coat, Fiberglass with GP Orthophthalic resin, and Woven Roving.

Notes:

** The laminate must have a weight percentage relation of 39.21% fiber and a 60.79% resin.*
** The resin used in the whole laminate is GP Orthophthalic Resin*

*** The dry thickness of the W.S. panels should be near 4.02 mm (0.158 inch). Class A finish of the faces of the panels is attained with Fireguard applied by the installer.*

*** The wet thickness of each ply depends on the amount of resin absorbed for each mat, which may cause a variation in the general laminate thickness.*

*** The laminate thickness tolerance is ± 0.3 mm*

*** These layers are applied once the reinforcement is fixed to the shell with cuts of Chopped Strand Mat Fiberglass 450 GSM and resin applied over the joint.

5.0 DESIGN AND INSTALLATION

Design:

W.S. must submit structural design calculations and drawings for the prefabricated fiberglass reinforced-polymer panels prepared by a registered engineer, and they must be signed and sealed. The structural design for the W.S. panels must use the materials properties design values noted in the mechanical properties section of this evaluation report. The applicable code sections are 2606.5 and 2613 of the IBC and Section R301.1.3 of the IRC.

Installation:

Installation of the W.S. must be per the W.S. installation instructions and the local code. The W.S., after assembly on the job site must be covered with soil per the manufacturer's installation instructions. The coatings must be applied by the manufacturer's instructions.

6.0 CONDITIONS OF USE

The W.S. panels described in this report comply with, or are a suitable alternative to what is specified in, those codes listed in the introduction of this report, subject to the following conditions:

- The W.S. panels are limited to Type V-B construction or buildings constructed per the IRC.
- Installation must comply with this report, the manufacturer's published installation instructions, and the applicable code.
- Structural design calculations and drawings signed and sealed by a registered engineer shall be submitted to the code official for approval before permitting.
- Foundations, application of polyurethane foam, painting, and installation of windows and doors, and method of fastening panels have not been evaluated under this report.
- The W.S. prefabricated fiberglass reinforced-polymer panels are produced at the W.S. fabric.

7.0 HAZARDS IDENTIFICATION

Threshold Limit Value (TLV)
Fabricating, cutting, drilling, etc. of FRP may produce dust, which should be controlled. Particulate level should not exceed the following OSHA standard: TWA 15 mg/m3 (Total Dust) and TWA 5 mg/m3 (Respirable Particulate).

Primary Route of Entry
Inhalation of or skin contact with dust.

Effects of Overexposure
Exposure to dust in excess of TLV may result in skin or upper respiratory tract irritation. Pre-existing skin or respiratory disorders may cause more susceptibility to these effects.

8.0 FIRE AND EXPOSURE DATA

Flash Point	Material is classified as nonflammable.
Ignition Temperature	Typically 650°F or higher for FRP panels.
Extinguishing Media	Water, CO_2, dry chemical.

Fire Fighting Procedures
Use media best suited to fire environment. Use water to cool fire-exposed containers and to flush spills from ignition sources. Use self-contained breathing apparatus for large scale fires.

Unusual Fire or Explosion Hazards
With other building materials, combustion will yield toxic materials such as carbon monoxide (CO) and carbon dioxide (CO_2) and may also yield aliphatic and aromatic hydrocarbons and halogenated compounds. Fabricating, cutting, drilling, etc., may produce a class ST-1 dust. Safety precautions and ventilation requirements recommended by NFPA-68 should be followed.

9.0 REACTIVITY DATA

Stability and Incompatibility
Stable under normal use conditions. Hazardous polymerization will not occur. Avoid contact with alkali, strong mineral acid or other oxidizers.

Hazardous Decomposition Products
See information in Fire and Explosion Data above.

10.0 PERSONAL PROTECTION INFORMATION

Respiratory Protection
Use adequate ventilation to control dust when machining, cutting, drilling, etc. Cover nose and mouth with mask approved by NIOSH/OSHA.

Eye Protection
Use goggles or safety glasses when machining, cutting, drilling, etc. Have eye washes available.

Skin Protection
Wear protective gloves, long pants, and long sleeves when machining, cutting, drilling, etc. Wash skin with soap and water after handling. Wash dusty work clothes separately.

11.0 MANUFACTURING LOCATION

Blake Corporation SA de CV

Calle Serapio Flota con Lazaro Urbina smza 307 m 104 lote 3 bodega 2, Alfredo V.
Bonfil, Cancún Quintana Roo.
ZIP code: 77560.

12.0 REVISION TABLE

ID	DATE	VERSION	DOCUMENT	DESCRIPTION	APPROVED
1	18/09/2020	1	W.S. - FRP Panels Data sheet		OK
2	19/05/2021	2	W.S. - FRP Panels Data sheet	Format actualization	OK
3	04/01/2021	3	W.S. - FRP Panels Data sheet	W.S. Laminate optimization	OK
4	17/05/2022	4	W.S. - FRP Panels Data sheet	Add reinforcement laminate and imperial units conversion	OK
5	18/05/2022	5	W.S. - FRP Panels Data sheet	Small format change	OK
6	26/05/2022	6	W.S. - FRP Panels Data sheet	Laminate properties table changes	OK
7	14/07/2022	7	W.S. – Act FRP Panels Data Sheet	Document actual datasheet	OK

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Testing	:	**Tensile Properties**
Test Method	:	ASTM D638-14
Project Number	:	P20220139
Customer	:	Magic Homes, Inc.
Attention	:	Tatiana Parra
Analyst	:	S. Polastri
Date	:	March 1, 2022

Attachment: 1 graph

ACCREDITED
Cert. No. 0619.01
TESTING LABORATORY

Material	:	**Fiber Reinforced Polymer laminate with Gel Coat**
Sample Preparation	:	Machined by Intertek PTL.
Sample Type	:	ASTM Type I Tensile Bar
Cross-Head Speed	:	0.2 in/min
Extensometer	:	10% based on 50mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-2) / Elongation (Class C).
Conditioning	:	88+ hours at 23°C ± 2°C / 50%RH ± 10%
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH
Significance	:	ASTM D638 specifies that strength and modulus be reported to 3 significant figures, and standard deviation be reported to 2 significant figures. Elongation reported to 2 significant figures per the recommendations of guide ASTM D6436.

Sample Name	Test Number	**Tensile Strength At Break (psi)**	**Elongation At Break (%)**	**Modulus Of Elasticity (psi)**
GMH Laminate	1	16400	1.9	1320000
0.502" x 0.278" (Avg)	2	17100	2.1	1390000
	3	16900	2.1	1270000
	4	17700	2.2	1300000
	5	16700	2.1	1330000
	Average	**17000**	**2.1**	**1320000**
	Std. Dev.	490	0.11	44000

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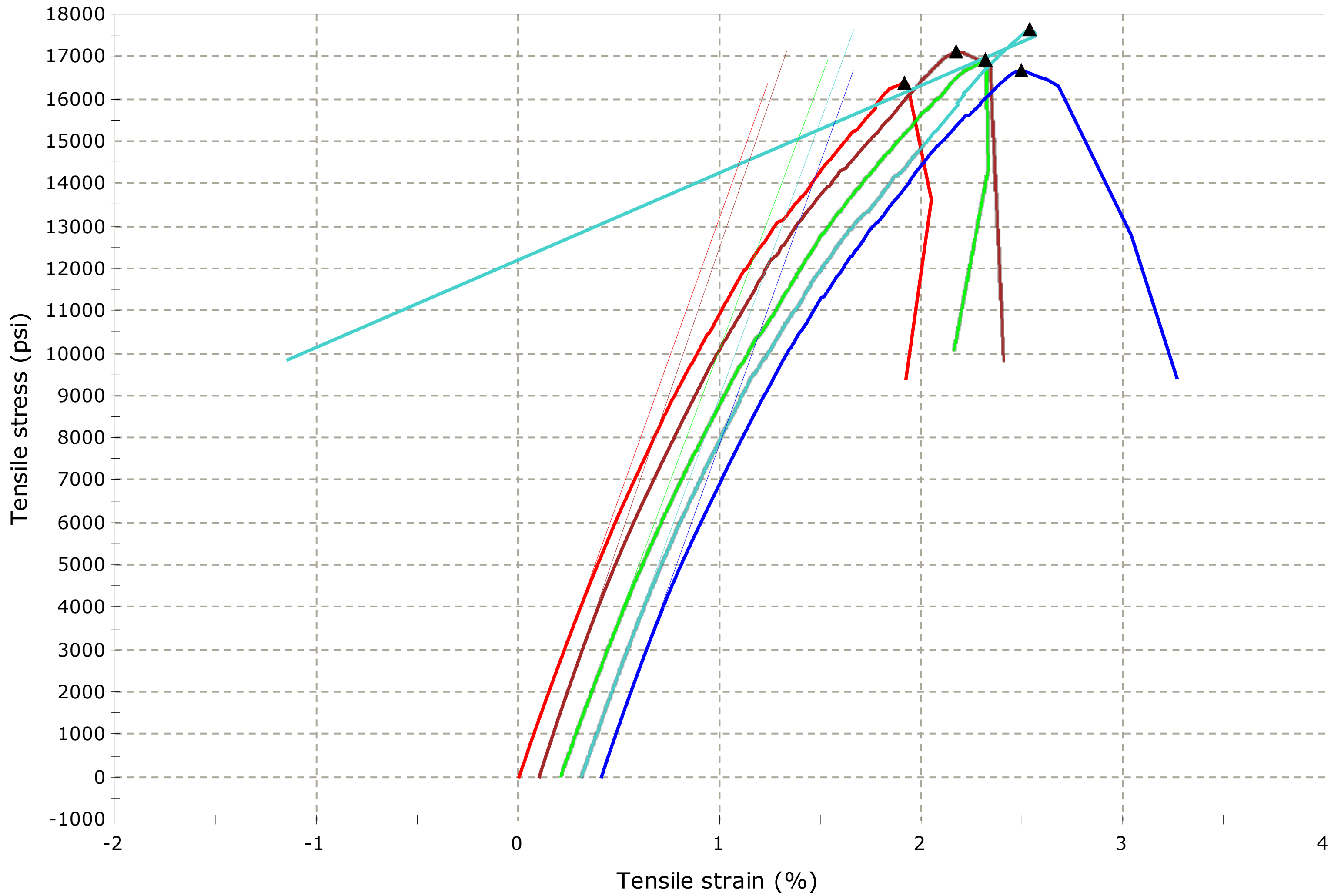
http://www.intertek.com

P20220139 ASTM D638 Tensile - FRP Laminate with Gel Coat - GMH Laminate



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Testing	: **Compressive Properties of Rigid Plastics**
Test Method	: ASTM D695-15
Project Number	: P20220139
Customer	: Green Magic Homes, Inc.
Attention	: Tatiana Parra
Analyst	: J. Storie
Date	: February 28, 2022

A2LA ACCREDITED Cert. No. 0619.01 TESTING LABORATORY

Material	: **Fiber Reinforced Polymer Laminate with Gel Coat**
Specimen Type	: Rectangular Prism
Cross-Head Speed	: 0.05 in/min
Specimen Preparation	: Machined by Intertek PTL
Conditioning	: 88+ hours at 23°C ± 2°C / 50%RH ± 10%
Test Conditions	: 23°C ± 2°C / 50% ± 10% RH
Significance	: ASTM D 695 specifies that strength and modulus be reported to 3 significant figures, and standard deviation be reported to 2 significant figures.

Sample Name	Test Number	Width (in)	Thickness (in)	**Maximum Compressive Strength (psi)**
GMH Laminate	1	0.288	0.285	31200
	2	0.289	0.295	27900
	3	0.289	0.295	29100
	4	0.289	0.289	30400
	5	0.287	0.298	28300
			Average	**29400**
			Std. Dev.	1400

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TESTING LABORATORY

Material	: **Fiber Reinforced Polymer Laminate with Gel Coat**
Specimen Type	: Rectangular Prism
Cross-Head Speed	: 0.05 in/min
Compressometer	: 10% based on 10 mm gage length. Meets minimum requirements for Practice E 83: Modulus (Class B-2) / Elongation (Class C).
Specimen Preparation	: Machined by Intertek PTL
Conditioning	: 88+ hours at 23°C ± 2°C / 50%RH ± 10%
Test Conditions	: 23°C ± 2°C / 50% ± 10% RH
Significance	: ASTM D 695 specifies that strength and modulus be reported to 3 significant figures, and standard deviation be reported to 2 significant figures.

Sample Name	Test Number	Width (in)	Thickness (in)	**Compressive Modulus (psi)**
GMH Laminate	1	0.289	0.285	1590000
	2	0.289	0.287	1810000
	3	0.289	0.290	1710000
	4	0.289	0.288	1840000
	5	0.289	0.279	1830000
			Average	**1760000**
			Std. Dev.	110000

Testing	:	**Shear Strength Of Plastics By Punch Tool**
Test Method	:	ASTM D732-17
Project Number	:	P20220139
Customer	:	Green Magic Homes, Inc.
Attention	:	Tatiana Parra
Analyst	:	J. Storie
Date	:	February 28, 2022

ACCREDITED
Cert. No. 0619.01
TESTING LABORATORY

Material	:	**Fiber Reinforced Polymer Laminate with Gel Coat**
Diameter Of Punch (in)	:	1.0
Specimen Size	:	2.0 Inch Square
Cross-Head Speed (in/min)	:	0.05
Sample Conditioning	:	88+ Hours at 23°C ± 2°C / 50% ± 10% RH
Sample Preparation	:	Machined by Intertek.
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH

Sample Name	Test Number	Thickness (in)	**Shear Force (lbf)**	**Shear Strength (psi)**
GMH Laminate	1	0.266	11900	14200
	2	0.291	12000	13100
	3	0.265	11400	13700
	4	0.263	11200	13600
	5	0.276	11600	13400
	Average		**11600**	**13600**
	Std. Dev		335	406

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Testing	:	**Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials**
Test Method	:	ASTM D790-17
Project Number	:	P20220139
Customer	:	Magic Homes, Inc.
Attention	:	Tatiana Parra
Analyst	:	S. Polastri
Date	:	March 1, 2022

A2LA ACCREDITED Cert. No. 0619.01 TESTING LABORATORY

Material	:	**Fiber Reinforced Polymer laminate with Gel Coat**
Sample Preparation	:	Machined by Intertek PTL.
Sample Type	:	ASTM Flex Bar
Sample Dimensions (Avg)	:	5" x 0.502" x 0.281"
Span Length (in)	:	4.496
Cross-Head Speed (in/min)	:	0.120
Span-To- Depth Ratio	:	16±1:1
Procedure	:	A (0.01 in/in/min strain rate)
Deflection Measurement	:	Type I (crosshead). Machine compliance not used.
Radius Of Supports (in)	:	0.197
Radius Of Loading Nose (in)	:	0.197
Conditioning	:	88+ hours at 23°C ± 2°C / 50%RH ± 10%
Test Conditions	:	23°C ± 2°C / 50% ± 10% RH
Significance	:	ASTM D790 specifies the average of all values to be reported to 3 significant figures and standard deviation be reported to 2 significant figures. Stress and modulus reported to 3 significant figures per the recommendations of guide ASTM D6436.

Sample Name	Test Number	**Flexural Strength (psi)**	**Flexural Strain at Yield (%)**	**Flexural Modulus (tangent *) (psi)**
GMH Laminate	1	20700	3.25	844000
	2	19600	3.00	862000
	3	20700	2.92	920000
	4	24200	3.43	963000
	5	20400	3.15	859000
	Average	**21100**	**3.15**	**890000**
	Std. Dev.	1800	0.20	50000

* = computer generated curve fit

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Testing	: **Density And Specific Gravity Of Plastics By Displacement**
Test Method	: ASTM D792-20 Method A
Project Number	: P20220139
Customer	: Magic Homes, Inc.
Attention	: Tatiana Parra
Analyst	: S. Polastri
Date	: March 1, 2022

A2LA ACCREDITED Cert. No. 0619.01 TESTING LABORATORY

Sample Preparation	: Machined by Intertek PTL
Temperature Of Water (°C)	: 21.3
Sample Type	: 0.79" x 0.79" x 0.27" Nominal
Conditioning	: 88+ hours at 23°C ± 2°C / 50%RH ± 10%
Significance	: ASTM D792 specifies that density be reported to 3 significant digits.

Sample Name	Test Number	Dry Weight (g)	Wet Weight (g)	**Specific Gravity (23/23°C)**	**Density (g/cm^3)**	**Density (kg/m^3)**
GMH Laminate	1	3.9768	1.2985	1.49	1.49	1490
	2	3.9698	1.2744	1.47	1.47	1470
	3	4.0488	1.3126	1.48	1.48	1480
			Average	**1.48**	**1.48**	**1480**

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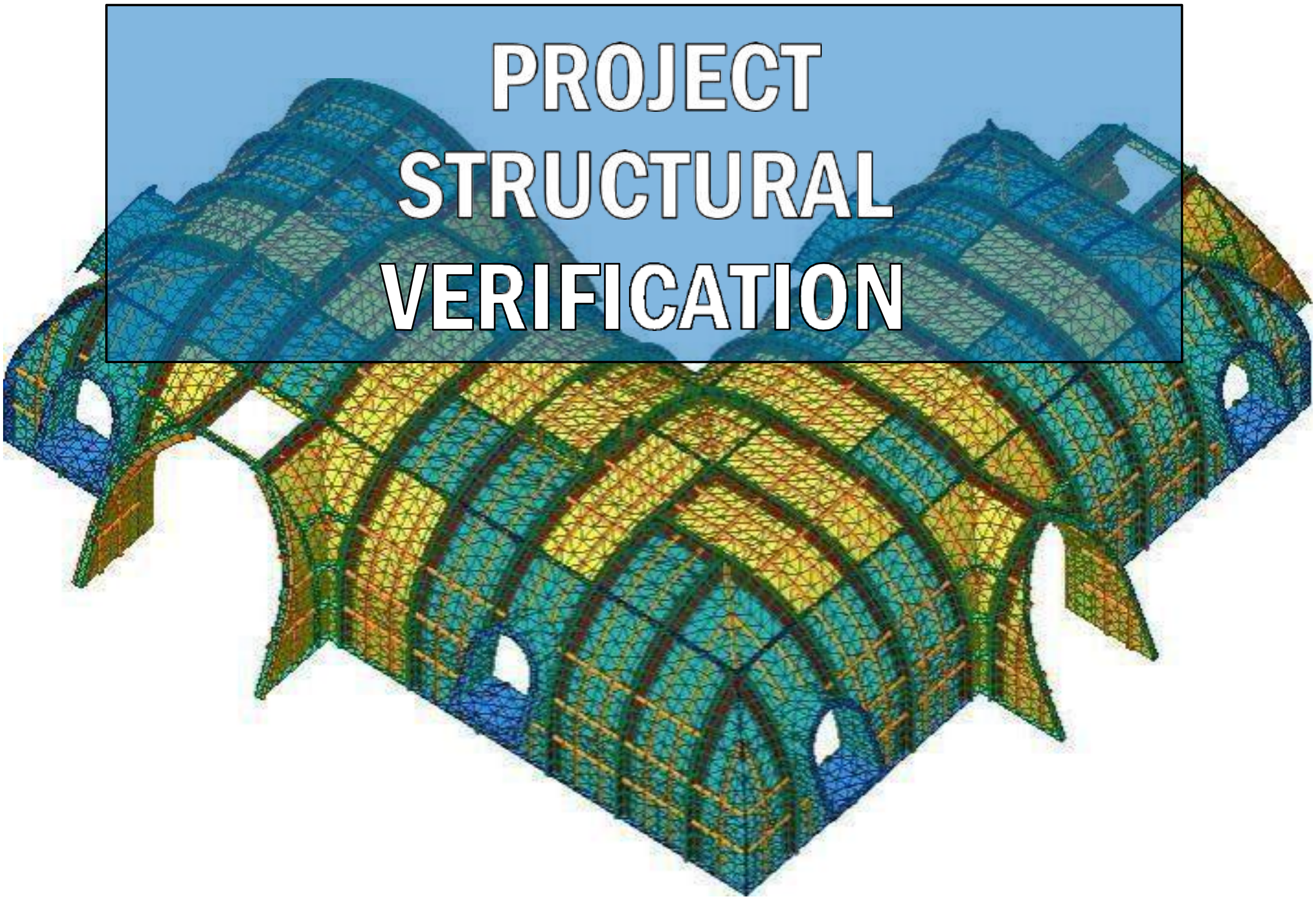
CHAPTER 3

3. Structural memories

3.1. Structural calculation report
3.2. Wind resistance and seismic analysis
3.3. BRANZ ST1146: Joint module tensile testing report
3.4. CECAM Full-scale module gravity test

PROJECT STRUCTURAL VERIFICATION



Version 1.00

By: Juan Salvador Mantilla, Civil Eng. M. SC.

Freddy Andres Mantilla, Civil Eng., esp.

For: WONDEFUL STRUCTURES

March 2021

1. Scope

This analysis aims to carry out the structural verification of the fiber-glass elements that are part of the resistance system of the wonderful Structures (W.S.)®. This document shows the procedure used to verify the structural behavior of the modules proposed and the elaboration of the structural models.

The present analysis is based on the ASCE/SEI 7-16 provisions.

In previous works, the structural behavior of the panels was analyzed as independent modules. Based on the results of this analysis, W.S. proposed the geometry shown below.

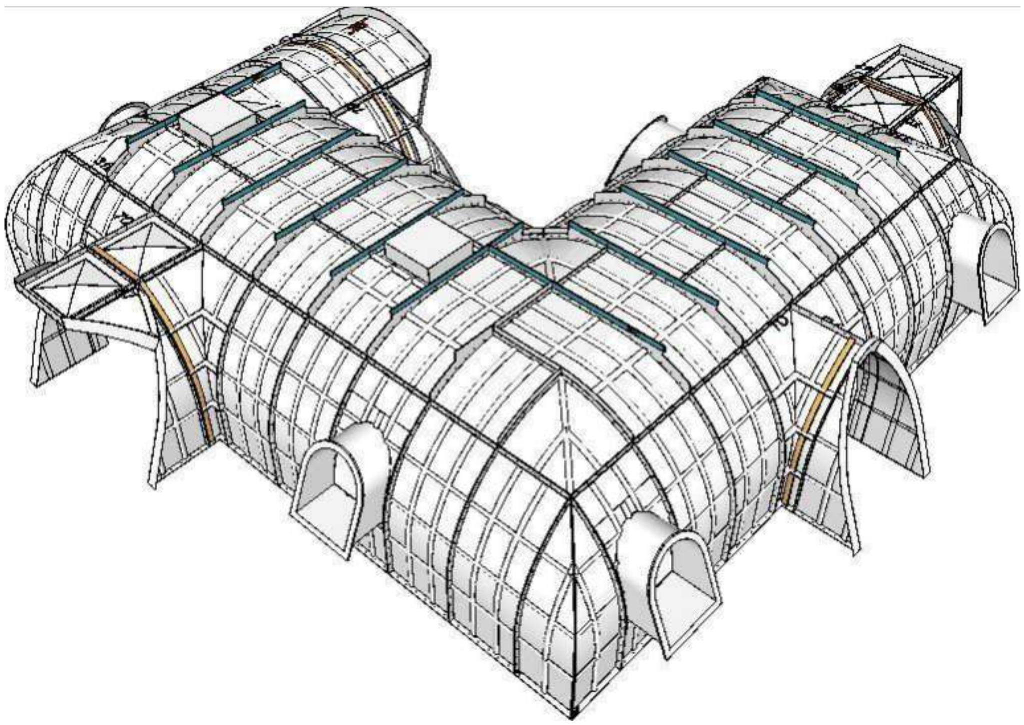


FIGURE 1. GEOMETRY 3D VIEW

In this work, the general structural behavior of the W.S. will be determined and, if necessary, the required reinforcement.

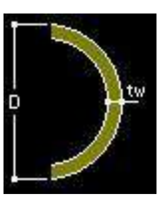
2. Materials and structural sections

Based on the mechanical characterization tests the panels are modeled as an isotropic material, which properties are described below:

For the panel elements:

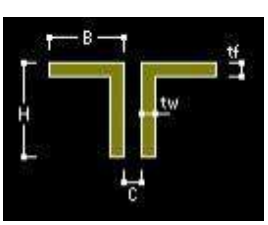
W.S. Test Material			Woven Roving		
Density =	960 kg/m^3	(60 lb/ft^3)	Density =	1627 kg/m^3	(102 lb/ft^3)
Tensile strength = (σ_y)	12.29 MPa	(1.87 ksi)	Tensile strength = (σ_y)	176 MPa	(25.52 ksi)
Flexural strength = (σ_f)	43.16 MPa	(6.26 ksi)	Flexural strength = (σ_f)	229 MPa	(33.21 ksi)
Poisson =	0.305		Poisson =	0.245	
Elastic Modulus =	4.62 GPa	(960 ksi)	Elastic Modulus =	12.22 GPa	(1772 ksi)
Thickness =	4.88 mm	(0.19 in)	Thickness =	2.93 mm	(0.12 in)

For the pipe elements:



Outer diameter =	100 mm	(3.94 in)
Wall thickness =	7.0 mm	(0.28 in)

For the double L reinforcement:



B = H =	150 mm	(6 in)
tf = tw =	12 mm	(1/2 in)

3. Load and Combinations

3.1. Vertical Loads (*D*, *L*)

TYPE	VALUE	UNITS	OBSERVATION
Dead (D)	3.7	kN/m^2	>> Hanging elements (up to 50 kg/m^2) >>Soil and grass cover (up to 320 kg/m^2) >>Additional to self-weight, which is automatically considered in the software.
Live (L)	2.0	kN/m^2	Possible pedestrian and installation traffic over the dome

3.2. Snow load

The design snow load is defined as:

$$p_f = 0.7\, C_e C_t I_s p_g$$

C_e	0.90
C_t	1.00
I_s	1.00
p_g (psf)	79
p_f (psf)	**49.8**
p_f (kg/m^2)	**243.0**

3.3. Wind Load (W)

WIND LOAD ANALYSIS - Main Wind-Force Resisting System
Per ASCE 7-16 Code for Enclosed or Partially Enclosed Buildings
Chapter 27: Directional Procedure for buildings of all heights

1. Basic Wind Speed (V) and Wind directionality factor (K_d) - 26.5, 26.6

V = 166 km/h
Structure type = Arched roofs K_d = 0.85

2. Risk Category - Table 1.5-1

Risk Category = II
Hurricane Region= N
I_w = 1.00

3. Exposure Category and Velocity Pressure Exposure Coefficient (K_z or K_h) - 26.7

Exposure Category	C	= (MWFRS)
B =	13.800	= horizontal dimension of building measured parallel to ridge, (m)
L = = horizontal dimension of a	4.560	building measured normal to ridge, (m)
Eave Height, he	1.080	= m
Ridge Height, hr	3.460	= m
Mean Roof Ht, h	2.27	= m
α =	9.50	
Z_g =	274.32	m
K_h =	0.850	(K_h = K_z evaluated at z = h)

If z < 4.6m (15ft)	then:	$K_z = 2.01 \cdot (4.6 / Z_g)^{(2/\alpha)}$,
If 4.6m (15ft) ≤ z ≤ Z_g	then:	$K_z = 2.01 \cdot (Z / Z_g)^{(2/\alpha)}$

4. Topographic factor (K_{zt}) and Ground elevation factor (K_e) - 26.8, 26.9

Note: The effect of wind speed-up shall not be required to be considered (Kzt = 1.0) when:

- $H/L_h < 0.2$, or
- H < 4.5m (15ft) for Exposures "C" and "D", or - H < 18m (60ft) for Exposure "B".

K_{zt} =	1.00	(Sect. 26.8.2 & Figure 26.8-1)
K_e =	1.00	(Sect. 26.9)

5. Gust Effect Factor (G or G_f) - 26.11

Rigid structure: A building or other structure whose fundamental frequency is greater than or equal to **1 Hz**.

G = (Sect. 26.11.4 or 26.11.5), | 0.850 | for normal to ridge wind direction

G = | 0.850 | (Sect. 26.11.4 or 26.11.5), for parallel to ridge wind direction

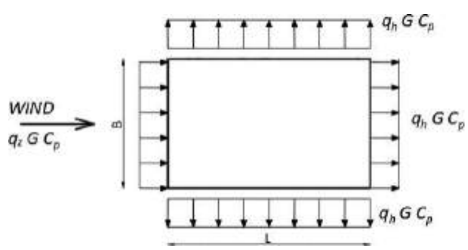
6, 7. Enclosure classification and Internal Pressure Coefficient (GC_{pi}) - 26.12, 26.13

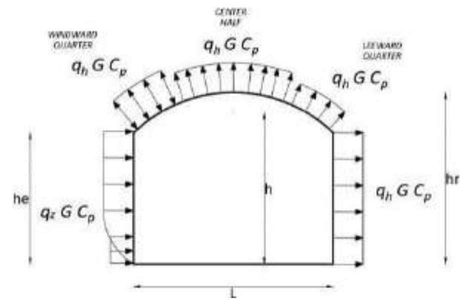
Enclosure = | Partially Enclosed Buildings |

GC_{pi} = | ± 0.55 |

Note: Plus and minus signs signify pressures acting toward and away from the internal surfaces, respectively and Two cases shall be considered to determine the critical load requirements for the appropriate condition (i) a positive value of GC_{pi} applied to all internal surfaces (ii) a negative value of GC_{pi} applied to all internal surfaces

8. External pressure coefficients (C_p or GC_{pf}) - 27.3-3





L/B = rf = Reduction area factor h/L | 0.522 / 0.330 / 0.498 | r = ≤ 0.6 Rise-to-span ratio = (hr-he)/L = h/B** = | 0 0.164 |

Normal to ridge Wind Direction **Parallel to ridge Wind Direction***

Windward Wall, Cp = (Fig. 6-6), use | 0.800 | with q_z 0 to h/2, Cp = (Fig. 6-6), use with q_h Leeward | -0.90 , -0.18 | Wall, Cp = (Fig. 6-6), use

with q_h h/2 to h, Cp = (Fig. 6-6), use | -0.500 | with q_h | -0.90 , -0.18 |

Side Walls, Cp = | -0.700 | (Fig. 6-6), use with q_h h to 2h, Cp = | -0.50 , -0.18 | (Fig. 6-6), use with qh

Windward quarter, Cp = | 1.435 | (Fig. 6-6), use with q_h > 2h, Cp = | -0.30 , -0.18 | (Fig. 6-6), use with qh

6r - 2.1 , Cp = | -1.222 | (Fig. 6-6), use with q_h

| -0.500 |

LeewardCenter half, Cp = quarter, Cp = ((Fig.Fig. 66--8)6),, use with quse with q_{hh} * Figu re 27.3-3, note 3: arch,For wind d use pressuirectedreparallel coefficients to the from axis Fig.of the

zt d q_h = N/m2

27.3- 1 with directed parallel to ridge

** NOTE: For parallel to ridge Wind Direction, "B" is the horizontal dimension measured parallel to the wind direction

9. Velocity pressure (q_z or q_h) - Eq. 26.10-1

$q_z = 0.613 \cdot K \cdot K \cdot K \cdot Ke \cdot V^2 \cdot I$ (N/m^2), V in m/s q_z evaluated

z | 941.67 | at z = h

10. Design wind load (p or F)

$p = q_z\,G\,C_p - q_i\,(\pm\,GC_{pi})$ (N/m^2) for windward wall, where: $q_i = q_h$ (Eq. 27.3-1, Sect. 27.3.1)

$p = q_h\,G\,C_p - q_i\,(\pm\,GC_{pi})$ (N/m^2) for leeward wall, sidewalls, and roof, where: $q_i = q_h$ (Sect. 27.3.1)

Normal to ridge Wind Load Tabulation for MWFRS - Buildings of Any Height

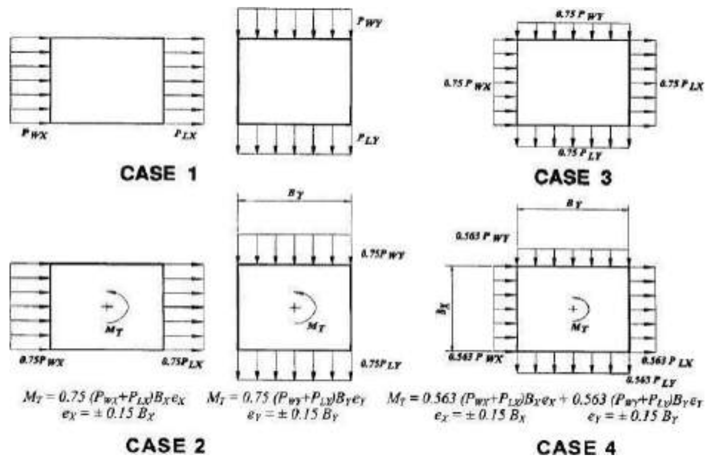
Surface	z (m)	K_z	q_z (N/m^2)	C_p	p =Net Design Press. (N/m^2) (w/ $+GC_{pi}$)	(w/ $-GC_{pi}$)
Windward Wall	0.00	0.850	941.67	0.80	122.42	1158.25
	0.25	0.850	941.67	0.80	122.42	1158.25
	0.50	0.850	941.67	0.80	122.42	1158.25
	0.75	0.850	941.67	0.80	122.42	1158.25
for z = he:	1.08	0.850	941.67	0.80	122.42	1158.25
Leeward Wall	All	-	-	-0.50	-918.13	117.71
Side Walls	All	-	-	-0.70	-1078.21	-42.38
Windward quarter	-	-	-	1.44	630.93	1666.76
(6r -2.1) Center half	-	-	-	-1.22	-1495.97	-460.14
Leeward quarter	-	-	-	-0.50	-918.13	117.71

Parallel to ridge Wind Load Tabulation for MWFRS - Buildings of Any Height

Surface	z (m)	K_z	q_z (N/m^2)	C_p		p =Net Design Press. (N/m^2) (w/ $+GC_{pi}$)		(w/ $-GC_{pi}$)	
Windward Wall	0.00	0.850	941.67	0.80		122.42		1158.25	
	0.25	0.850	941.67	0.80		122.42		1158.25	
	0.50	0.850	941.67	0.80		122.42		1158.25	
	0.75	0.850	941.67	0.80		122.42		1158.25	
for z = he:	1.08	0.850	941.67	0.80		122.42		1158.25	
Leeward Wall	All	-	-	-0.50		-918.13		117.71	
Side Walls	All	-	-	-0.70		-1078.21		-42.38	
0 to h/2, Cp	-	-	-	-0.90	-0.18	-1238.29	-661.99	-202.46	373.84
h/2 to h, Cp				-0.90	-0.18	-1238.29	-661.99	-202.46	373.84
h to 2h, Cp	-	-	-	-0.50	-0.18	-918.13	-661.99	117.71	373.84
> 2h, Cp	-	-	-	-0.30	-0.18	-758.04	-661.99	277.79	373.84

Notes: 1. (+) and (-) signs signify wind pressures acting toward & away from respective surfaces. 2. The minimum wind load for MWFRS shall not be less than **0.48kN/m²** (480N/m^2).

11. Design wind load cases



Case 1: Full design wind pressure acting on the projected area perpendicular to each principal axis of the structure considered separately along each principal axis.

Case 2: Three-quarters of the design wind pressure acting on the projected area perpendicular to each principal axis of the structure in conjunction with a torsional moment as shown, considered separately for each principal axis.

Wind pressure as defined in Case 1, but considered to act simultaneously at 75% of the specified value.

Case 3: Wind pressure as defined in Case 2, but considered to act simultaneously at 75% of the specified value.

Case 4:

3.4. Earthquake (E)

Input Parameters

Class = g		D	S_s =	0.946	6.00	Site
	T_L = sec	1.00	S_1 =	0.298	2.00	
					I_e = g	R =

Site Class

11.4.3 Where the soil properties are not known in sufficient detail to determine the site class, Site Class D, subject to the requirements of Section 11.4.4, shall be used unless the authority having jurisdiction or geotechnical data determine that Site Class E or F soils are present at the site. ▯ *Site Class D will be used for conservative purposes.*

Mapped Acceleration Parameters

11.4.2 Electronic values of mapped acceleration parameters and other seismic design parameters are provided at the U.S. Geological Survey (USGS) website at https://doi.org/10.5066/F7NK3C76.

11.4.4 Site Coefficients and Risk-Targeted Maximum Considered Earthquake (MCER) Spectral Response Acceleration Parameters.

1.20	≥1.20	S_{MS} =	1.135	F_a = g	$(F_a \cdot S_s)$
2.00		S_{M1} =	0.597	F_v = g	$(F_v \cdot S_1)$

11.4.5 Design Spectral Acceleration Parameters

0.757	S_{DS} = g	(2/3 ·S_{MS})
0.398	S_{D1} = g	(2/3 ·S_{M1})

11.4.6 Design Response Spectrum

T_o = 0.11 sec T_s = 0.53 sec

11.4.8 Site-Specific Ground Motion Procedures

Structures on Site Class D sites with S_1 greater than or equal to 0.2, provided the value of the seismic response coefficient C_s is determined by Eq. (12.8-2) for values of T ≤ 1.5T_s and taken as equal to 1.5 times the value computed by either Eq. (12.8-3) for T_L ≥ T > 1.5T_s or Eq. (12.8-4) for T > T_L.

12.8.1.1 Calculation of Seismic Response Coefficient

Cs = 0.378 (Eq. 12.8-2)

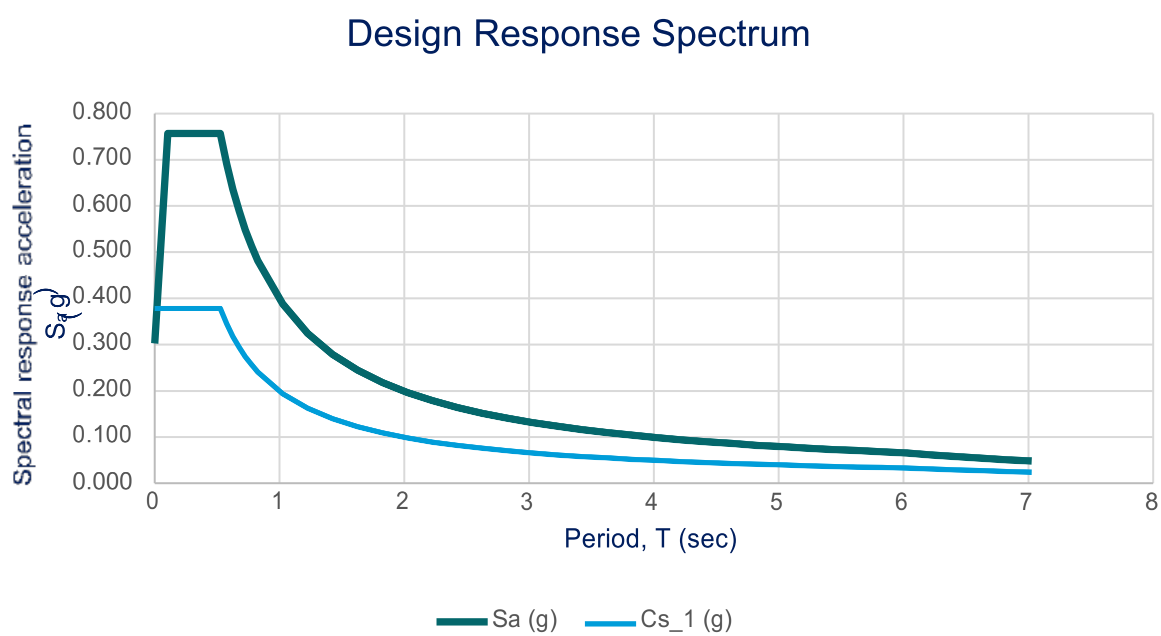
· (1/T) 0.199 (max. for T ≤ T_L) · (1/T^2) (max. for T > T_L)

1.194

(min) 0.033

11.6 Seismic Design Category

Category S_{DS}= D Category S_{D1}= D ▯Category = D



3.5. LOADS COMBINATION

3.5.1. Load Combinations for Strength Design

- 1.4D
- 1.2D + 1.6L + 0.5(Lr or S or R)
- 1.2D + 1.6(Lr or S or R) + (L or 0.5W)
- 1.2D + 1.0W + L + 0.5(Lr or S or R)
- 0.9D + 1.0W
- 1.2D + E + L + 0.2S
- 0.9D + E

3.5.2. Load Combinations for Allowable Stress Design

- D
- D + L
- D + (Lr or S or R)
- D + 0.75L + 0.75(Lr or S or R)
- D + (0.6W)
- D + 0.75L + 0.75(0.6W) + 0.75(Lr or S or R)
- 0.6D + 0.6W

No.	Name	Description
1	gLCB1	1.4D
2	gLCB2	1.2(D) + 1.6(L) + 0.5S
3	gLCB3	1.2D + 1.6S + 1.0L
4	gLCB4	1.2D + 1.6S + 0.5Wx{+}
5	gLCB5	1.2D + 1.6S + 0.5Wy{+}
6	gLCB8	1.2D + 1.0Wx{+} + 1.0L + 0.5S
7	gLCB9	1.2D + 1.0Wy{+} + 1.0L + 0.5S
8	gLCB12	1.2D + 1.0(1.0)Ex(R=2) + 1.0L + 0.2S
9	gLCB13	1.2D + 1.0(1.0)Ey(R=2) + 1.0L + 0.2S
10	gLCB14	1.2D - 1.0(1.0)Ex(R=2) + 1.0L + 0.2S
11	gLCB15	1.2D - 1.0(1.0)Ey(R=2) + 1.0L + 0.2S
12	gLCB16	0.9D + 1.0Wx{+}
13	gLCB17	0.9D + 1.0Wy{+}
14	gLCB20	0.9D + 1.0(1.0)Ex(R=2)
15	gLCB21	0.9D + 1.0(1.0)Ey(R=2)
16	gLCB22	0.9D - 1.0(1.0)Ex(R=2)
17	gLCB23	0.9D - 1.0(1.0)Ey(R=2)

No.	Name	Description
18	gLCB24	(D)
19	gLCB25	(D) + L
20	gLCB26	(D) + S
21	gLCB27	(D) + 0.75L + 0.75S
22	gLCB28	(D) + 0.6Wx{+}
23	gLCB29	(D) + 0.6Wy{+}
24	gLCB32	(D) + 0.7(1.0)Ex(R=2)
25	gLCB33	(D) + 0.7(1.0)Ey(R=2)
26	gLCB34	(D) - 0.7(1.0)Ex(R=2)
27	gLCB35	(D) - 0.7(1.0)Ey(R=2)
28	gLCB36	(D) + 0.75L + 0.75(0.6)Wx{+} + 0.75S

(D) + 0.75L + 0.75(0.6)Wy{+} + 0.75S 29
gLCB37
(D) + 0.75L + 0.75(0.7(1.0)Ex(R=2)) +

30 gLCB40 0.75S

(D) + 0.75L +
31 gLCB41 0.75(0.7(1.0)Ey(R=2)) + 0.75S
(D) + 0.75L -

32 gLCB42 0.75(0.7(1.0)Ex(R=2)) + 0.75S

No.	Name	Description
33	gLCB43	(D) + 0.75L - 0.75(0.7(1.0)Ey(R=2)) + 0.75S
35	gLCB45	0.6D + 0.6Wy{+}
36	gLCB48	0.6(D) + 0.7(1.0)Ex(R=2)
37	gLCB49	0.6(D) + 0.7(1.0)Ey(R=2)
38	gLCB50	0.6(D) - 0.7(1.0)Ex(R=2)

No.	Name	Description
39	gLCB51	0.6(D) - 0.7(1.0)Ey(R=2)
STL 34	gLCB44	0.6D + 0.6Wx{+} ENV_ST
40	R	Steel Strength Envelope
	STL	
	ENV_SE R	
41		Steel Serviceability Envelope

4. FEM Models

4.1. Geometry and sections

A three-dimensional finite element model was developed, this model considers the elements that are part of the structural system, namely fiber-glass panels, GFR L-shape angles, and semi-circular pipes. Two different classes of GFR-panels are used. In the images below, the yellow elements are made of Woven Roving fiber reinforced panels.

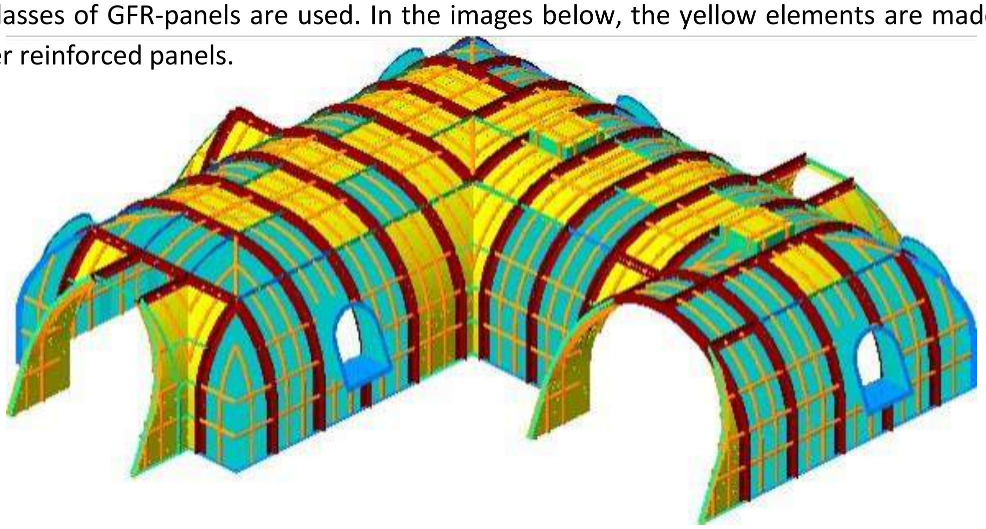


FIGURE 5. FEM MODEL – 3D VIEW.

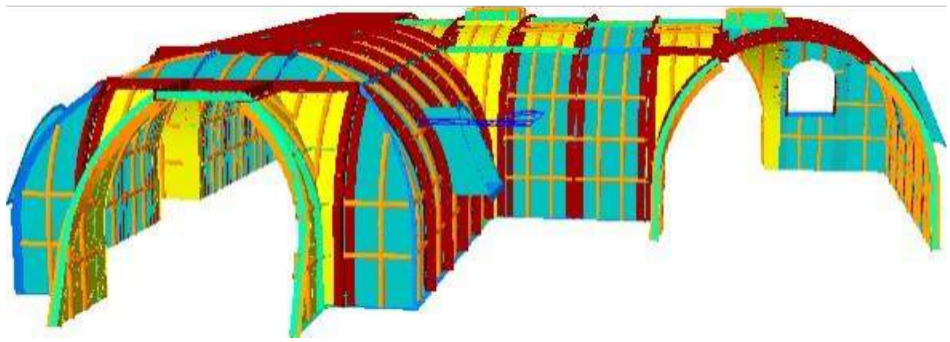


Figure 6. FEM model – Lateral view.

4.2. Boundary conditions

The structure has been modeled considering simple support under all vertical elements in contact with the ground, as shown in the following figure. In other words, the supports do not transmit moments, they only transmit forces, which must be transmitted to the ground by the anchoring system.

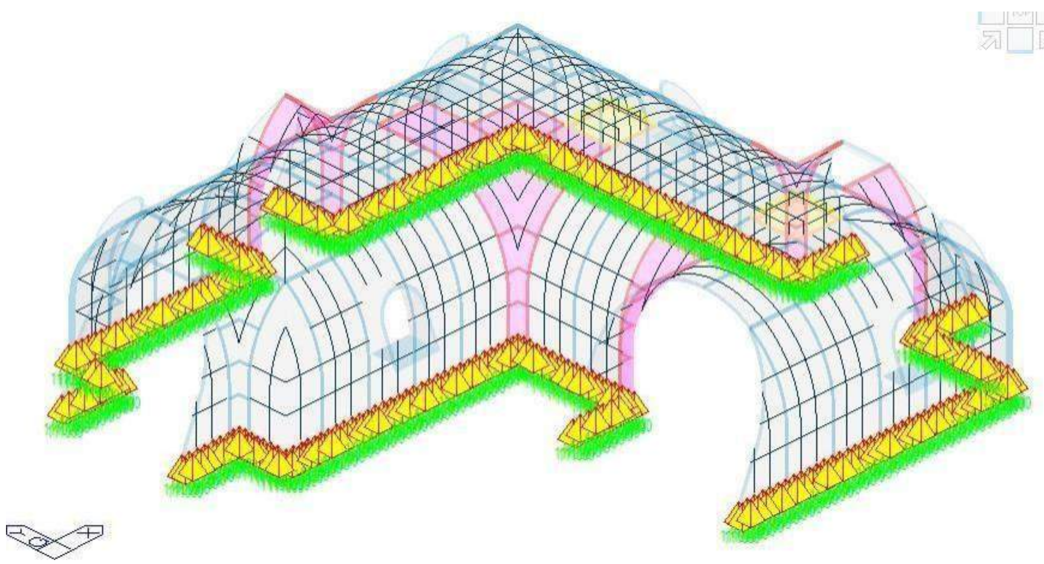


Figure 7. Boundary conditions

4.3. Vibration mode shapes

Some vibration mode shapes are shown in the images below.

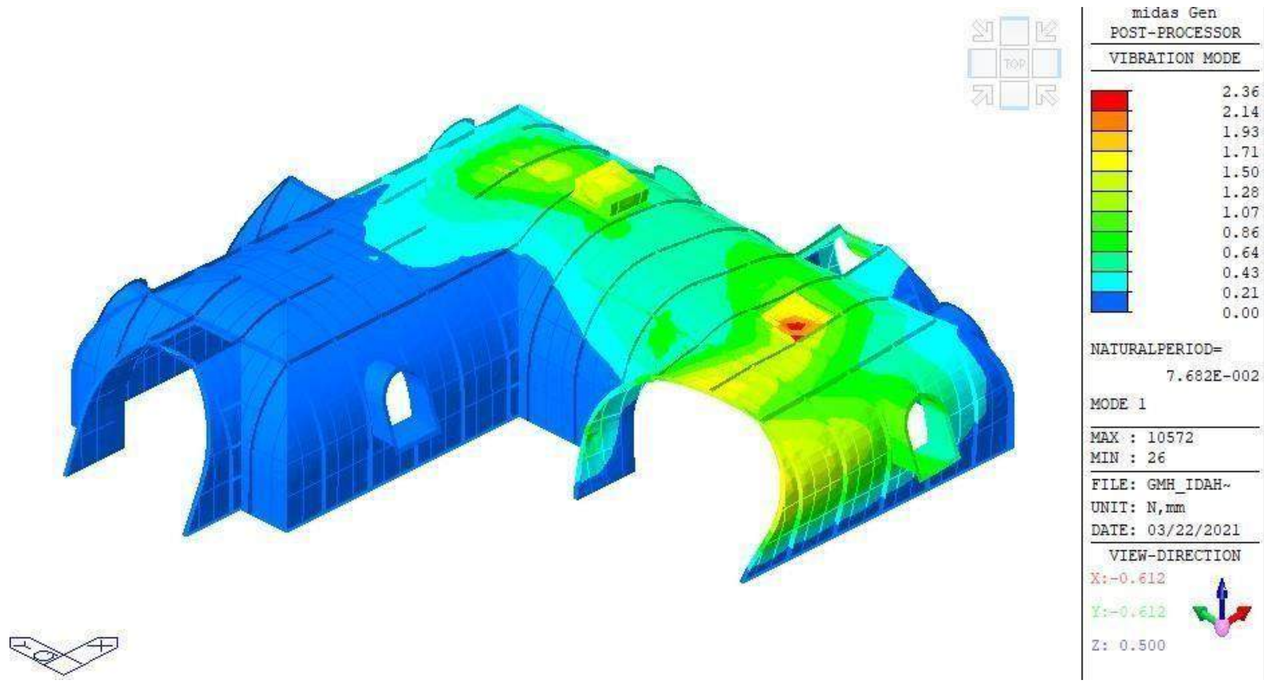


FIGURE 8. FIRST MODAL SHAPE.

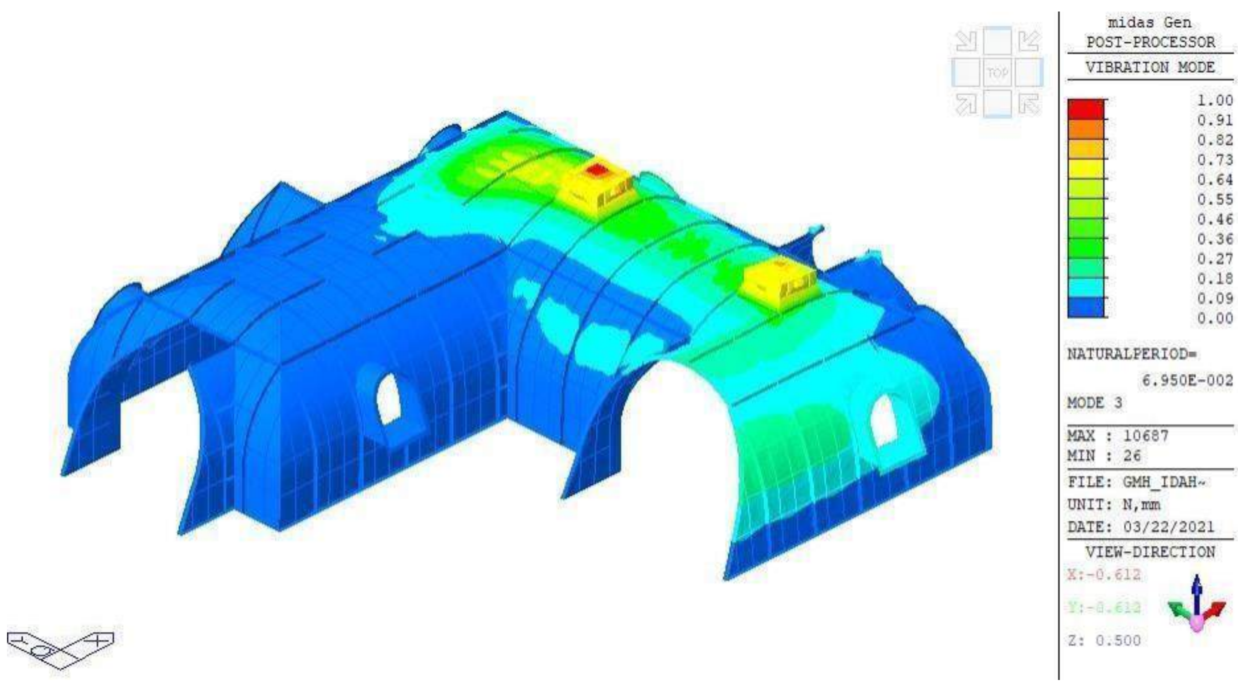


FIGURE 9. THIRD MODAL SHAPE.

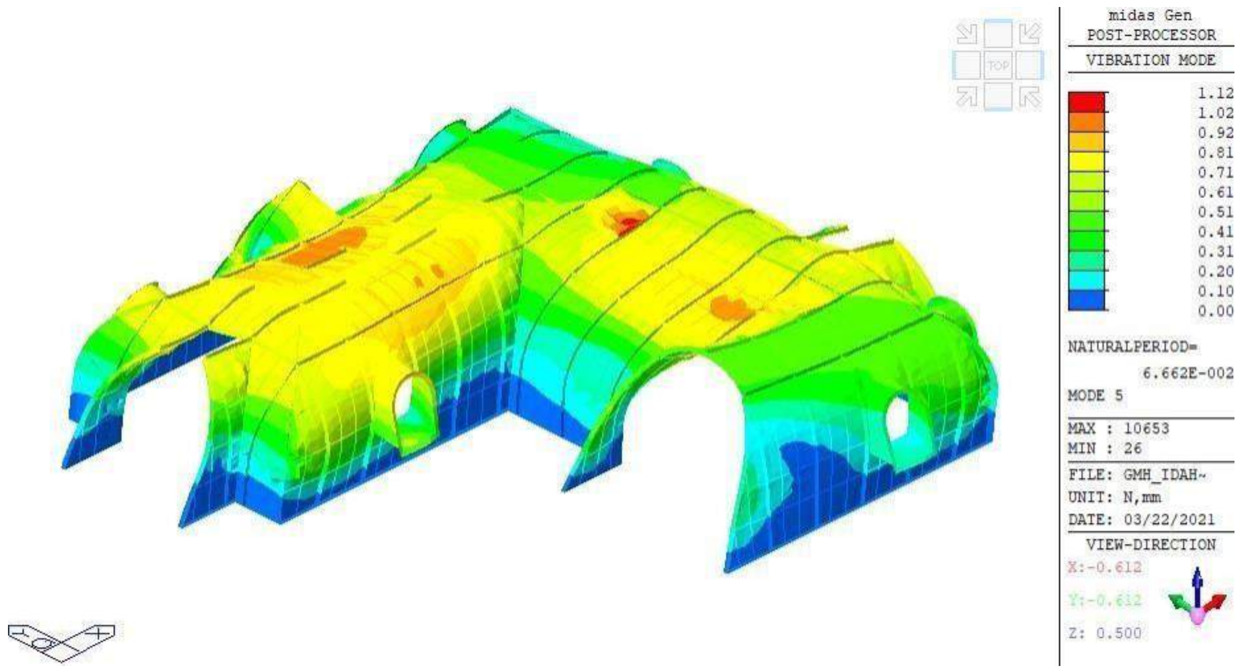


FIGURE 10. FIFTH MODAL SHAPE.

The tables with the detail of the 50 vibration modes considered are shown below.

			UX		UY		RZ	
Mode No	Frequency (hz)	Period (sec)	TRAN-X MASS(%)	SUM(%)	TRAN-Y MASS(%)	SUM(%)	ROT-Z MASS(%)	SUM(%)
1	13.0	0.0768	9.9	9.9	11.6	11.6	1.1	1.1
2	14.4	0.0695	0.0	9.9	0.0	11.6	0.0	1.1
3	14.4	0.0695	0.1	9.9	0.0	11.7	0.1	1.2
4	14.4	0.0695	0.2	10.1	0.2	11.9	1.6	2.8
5	15.0	0.0666	5.9	16.0	44.3	56.2	6.4	9.2
6	17.0	0.0590	2.2	18.2	4.3	60.5	0.0	9.2
7	17.4	0.0576	4.5	22.7	3.1	63.6	0.2	9.4
8	18.5	0.0542	1.4	24.1	0.9	64.5	0.2	9.5
9	18.6	0.0538	0.0	24.1	0.0	64.5	0.0	9.5
10	18.6	0.0537	0.0	24.1	0.0	64.5	0.0	9.5
11	18.6	0.0537	0.0	24.1	0.0	64.5	0.0	9.5
12	18.6	0.0537	0.0	24.1	0.0	64.5	0.0	9.5
13	18.6	0.0537	0.0	24.1	0.0	64.5	0.0	9.5
14	18.6	0.0537	0.1	24.2	0.0	64.6	0.0	9.5
15	19.6	0.0511	1.5	25.7	0.0	64.6	0.2	9.8
16	19.9	0.0503	7.4	33.1	0.5	65.0	0.6	10.4
17	20.1	0.0499	2.1	35.2	0.4	65.4	1.0	11.3
18	20.1	0.0497	0.1	35.3	0.0	65.4	0.0	11.4
19	20.5	0.0489	3.1	38.4	0.3	65.7	0.1	11.4
20	21.1	0.0474	1.1	39.5	0.0	65.7	0.1	11.5
21	22.0	0.0455	1.1	40.6	1.4	67.1	2.1	13.6
22	23.4	0.0427	1.1	41.7	0.9	68.0	1.7	15.3

23	24.7	0.0406	9.4	51.1	1.8	69.8	29.1	44.4
24	25.4	0.0393	1.9	53.0	5.5	75.3	2.6	47.0
25	26.1	0.0384	2.5	55.4	1.4	76.7	0.0	47.0
26	26.6	0.0377	0.3	55.7	0.2	76.9	1.6	48.6
27	27.1	0.0369	6.8	62.5	0.0	76.9	0.1	48.7
28	28.1	0.0356	0.1	62.7	0.1	77.1	0.6	49.3
29	28.2	0.0355	0.1	62.7	0.0	77.1	0.1	49.4
30	28.2	0.0355	0.0	62.7	0.0	77.1	0.0	49.4
31	28.2	0.0355	0.0	62.7	0.0	77.1	0.0	49.4
32	28.2	0.0355	0.0	62.8	0.0	77.1	0.0	49.4
33	28.2	0.0354	0.0	62.8	0.0	77.1	0.0	49.5
34	28.8	0.0347	0.3	63.1	0.0	77.1	2.1	51.5
35	29.3	0.0341	0.0	63.1	0.0	77.1	0.0	51.5
36	29.3	0.0341	0.0	63.1	0.0	77.1	0.0	51.5
37	29.3	0.0341	0.0	63.1	0.0	77.1	0.1	51.6
38	29.3	0.0341	0.0	63.1	0.0	77.1	0.0	51.6
39	29.3	0.0341	0.0	63.1	0.0	77.2	0.0	51.6
40	29.4	0.0340	0.1	63.2	0.0	77.2	0.2	51.9
41	29.4	0.0340	0.1	63.3	0.0	77.2	0.3	52.2
42	29.4	0.0340	0.0	63.3	0.0	77.2	0.0	52.2
43	30.3	0.0330	0.2	63.5	1.1	78.3	2.1	54.3
44	30.6	0.0326	1.1	64.5	0.1	78.4	0.2	54.5
45	31.0	0.0322	1.4	66.0	0.4	78.8	1.0	55.5
46	31.4	0.0319	0.9	66.9	0.0	78.8	0.2	55.8
47	31.5	0.0317	0.3	67.1	0.1	78.9	0.3	56.1
48	31.6	0.0317	0.5	67.7	0.1	79.0	0.4	56.4
49	32.0	0.0312	1.0	68.7	0.1	79.1	0.0	56.4
50	32.7	0.0305	0.6	69.3	0.1	79.3	1.2	57.6

4.4. Deformations

Below are the results due to different load cases and load combinations (LCB), however LCB3 controls.

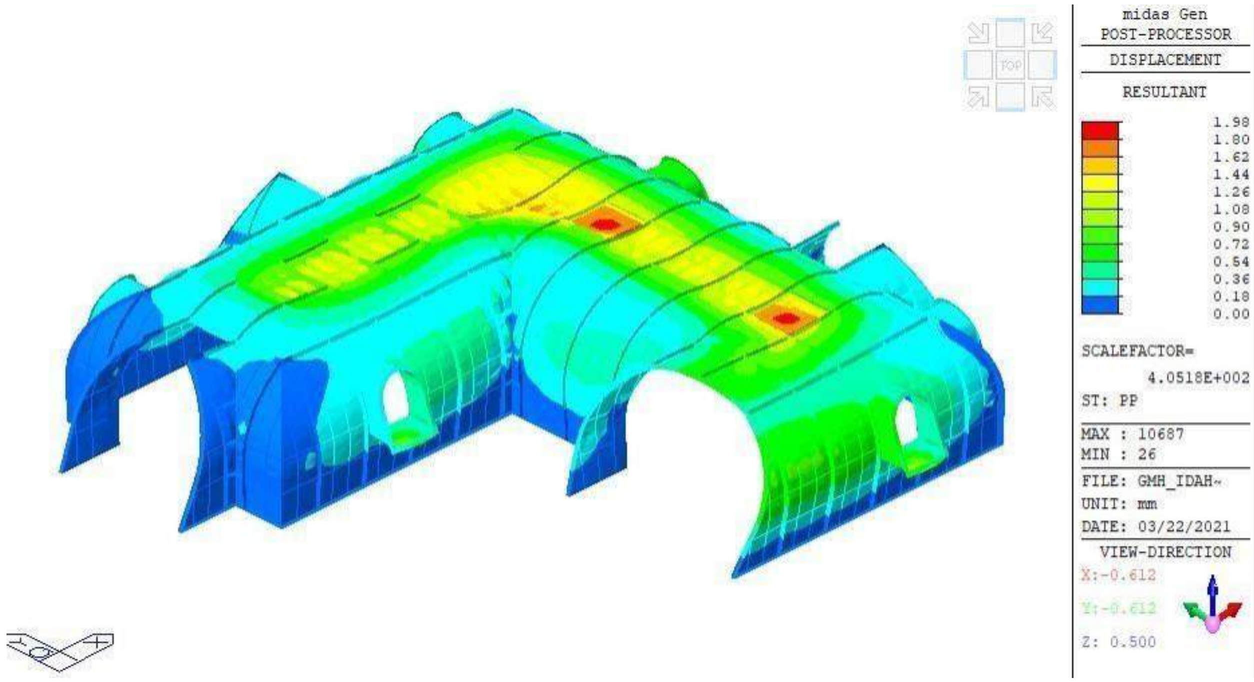


FIGURE 11. DEFORMATIONS DUE TO SELF-WEIGHT.

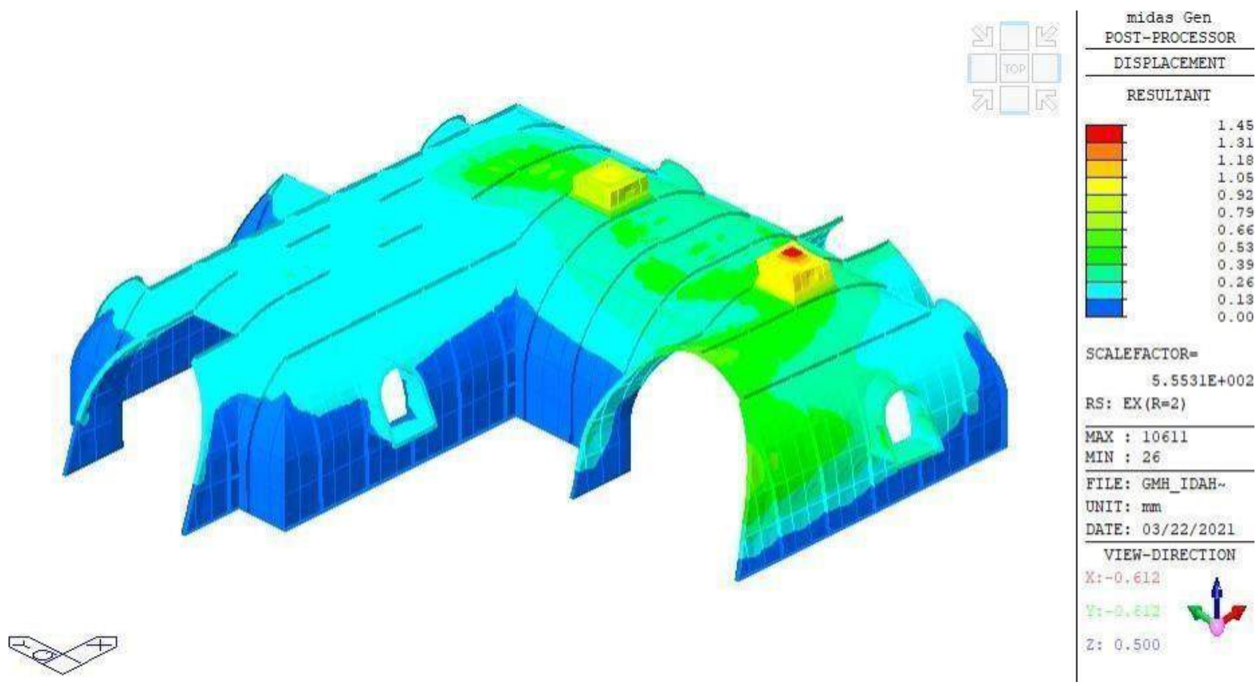


FIGURE 12. DEFORMATIONS DUE TO SEISMIC LOAD (X-DIRECTION).

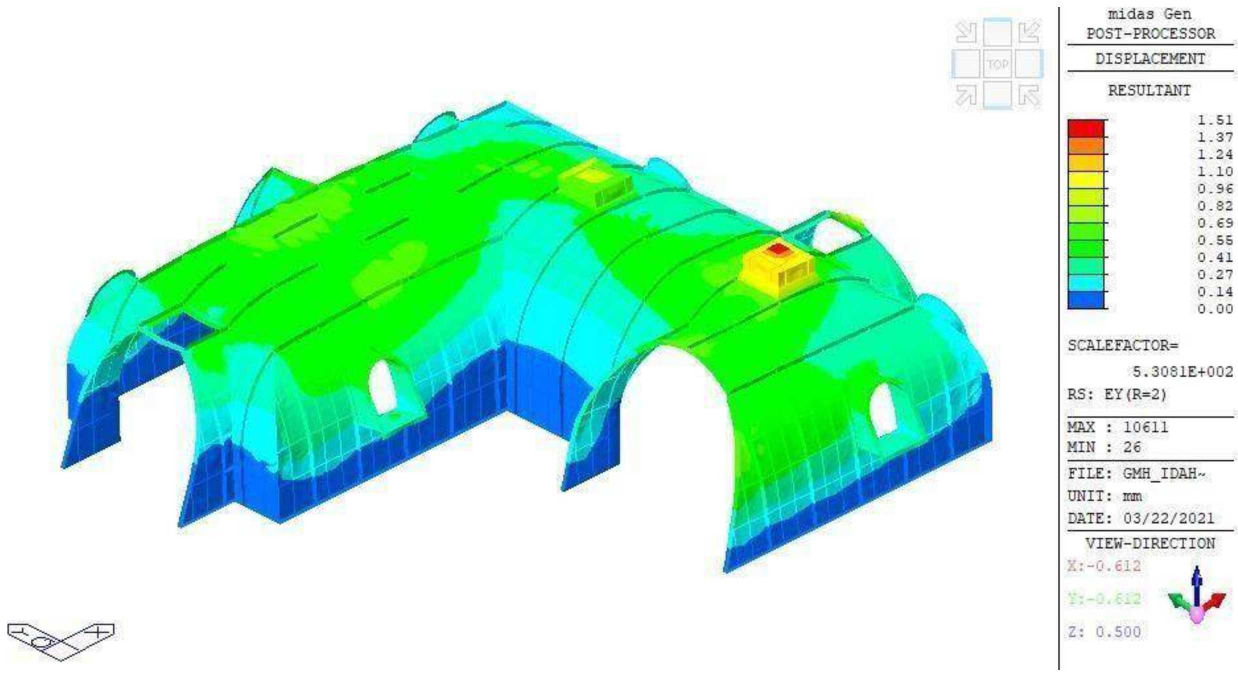


FIGURE 13. DEFORMATIONS DUE TO SEISMIC LOAD (Y-DIRECTION).

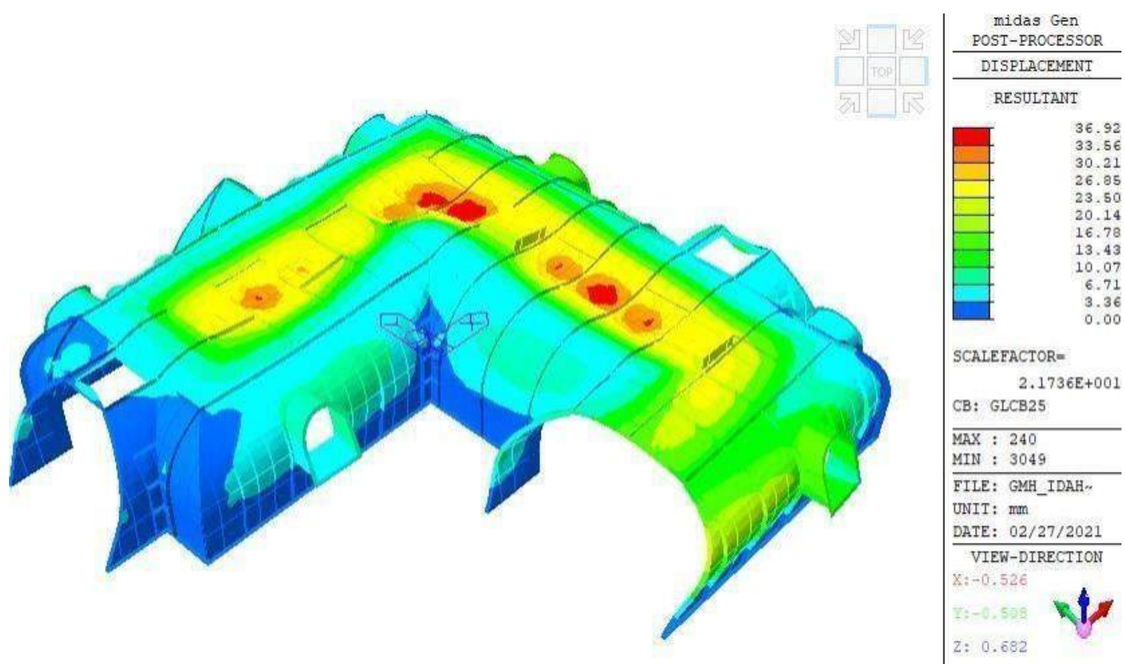


FIGURE 14. DEFORMATIONS DUE TO LCB25 (D+L).

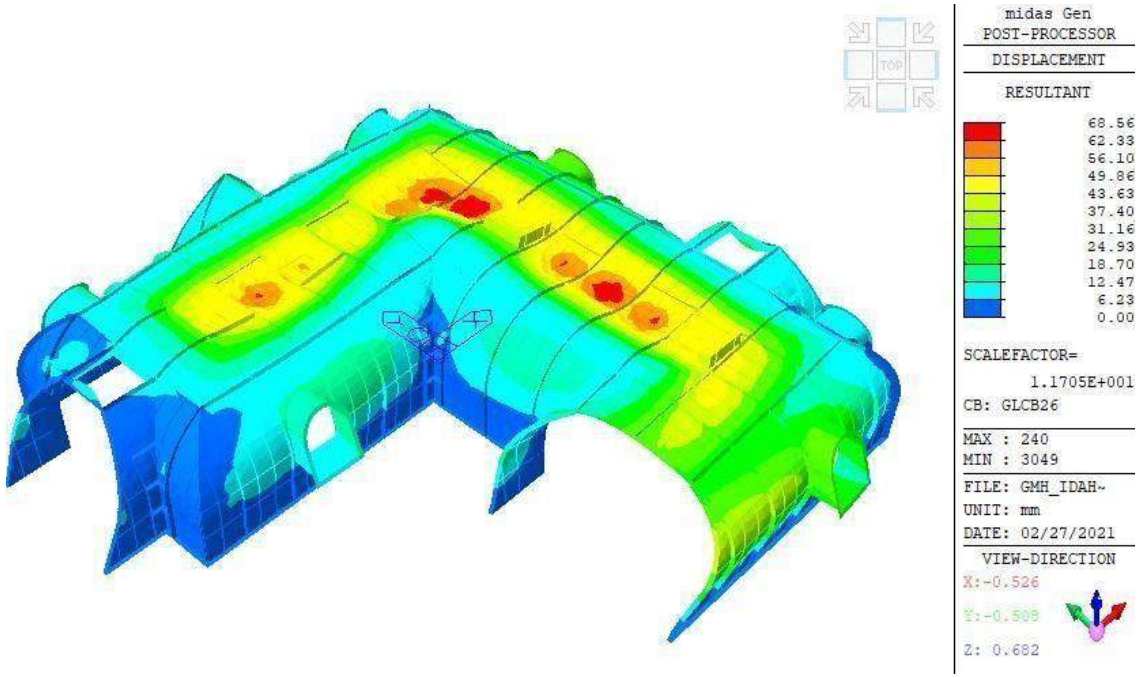


FIGURE 15. DEFORMATIONS DUE TO LCB26 (D+S).

4.5. Panels stresses

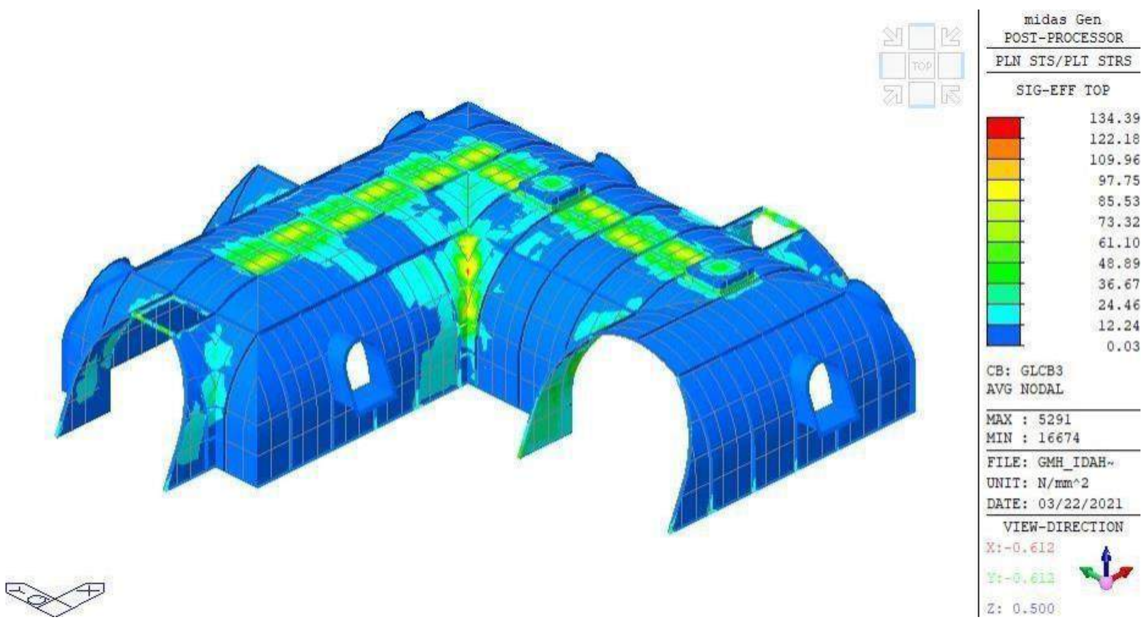


FIGURE 16. VON MISES STRESS – LCB3 – 3D VIEW.

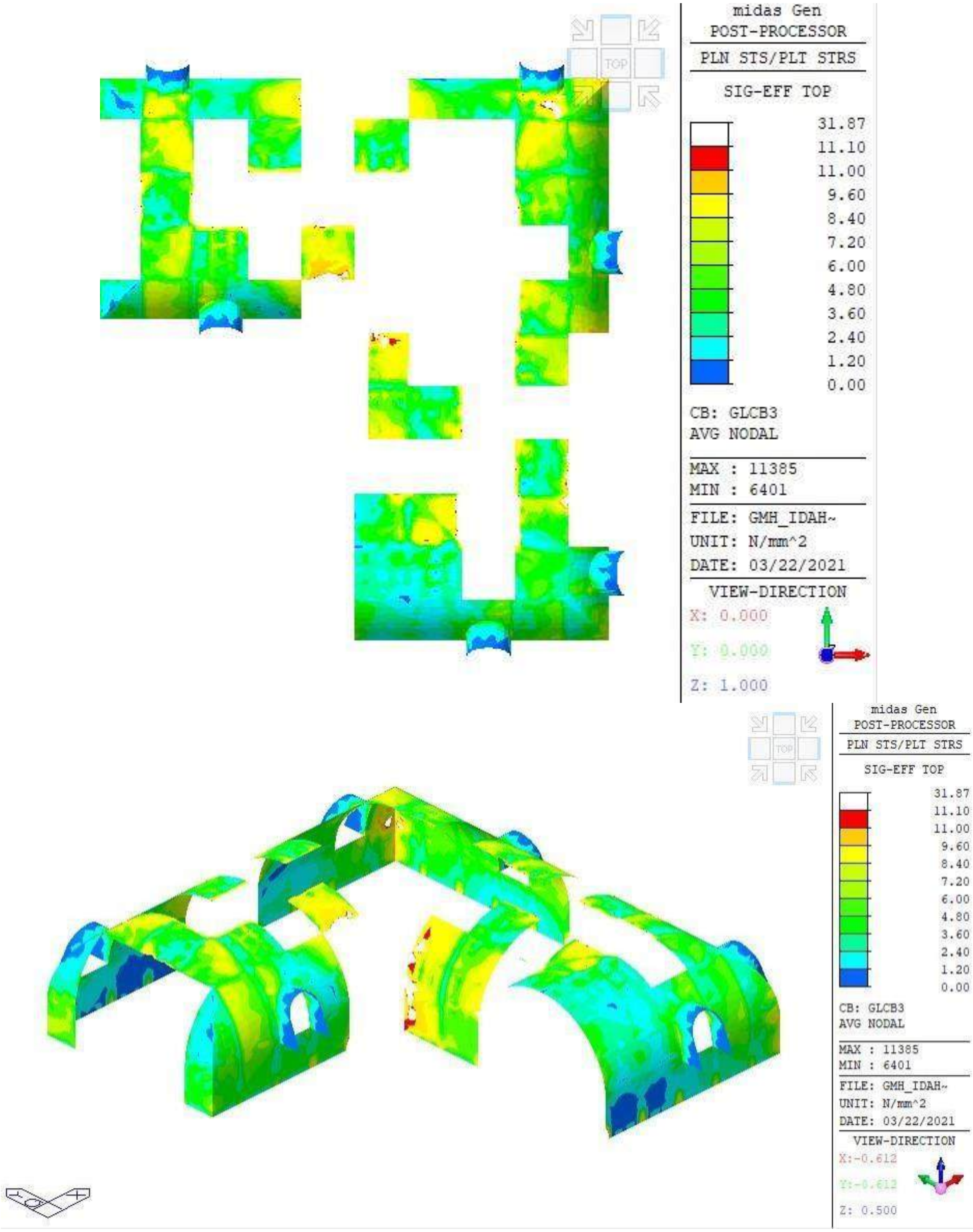
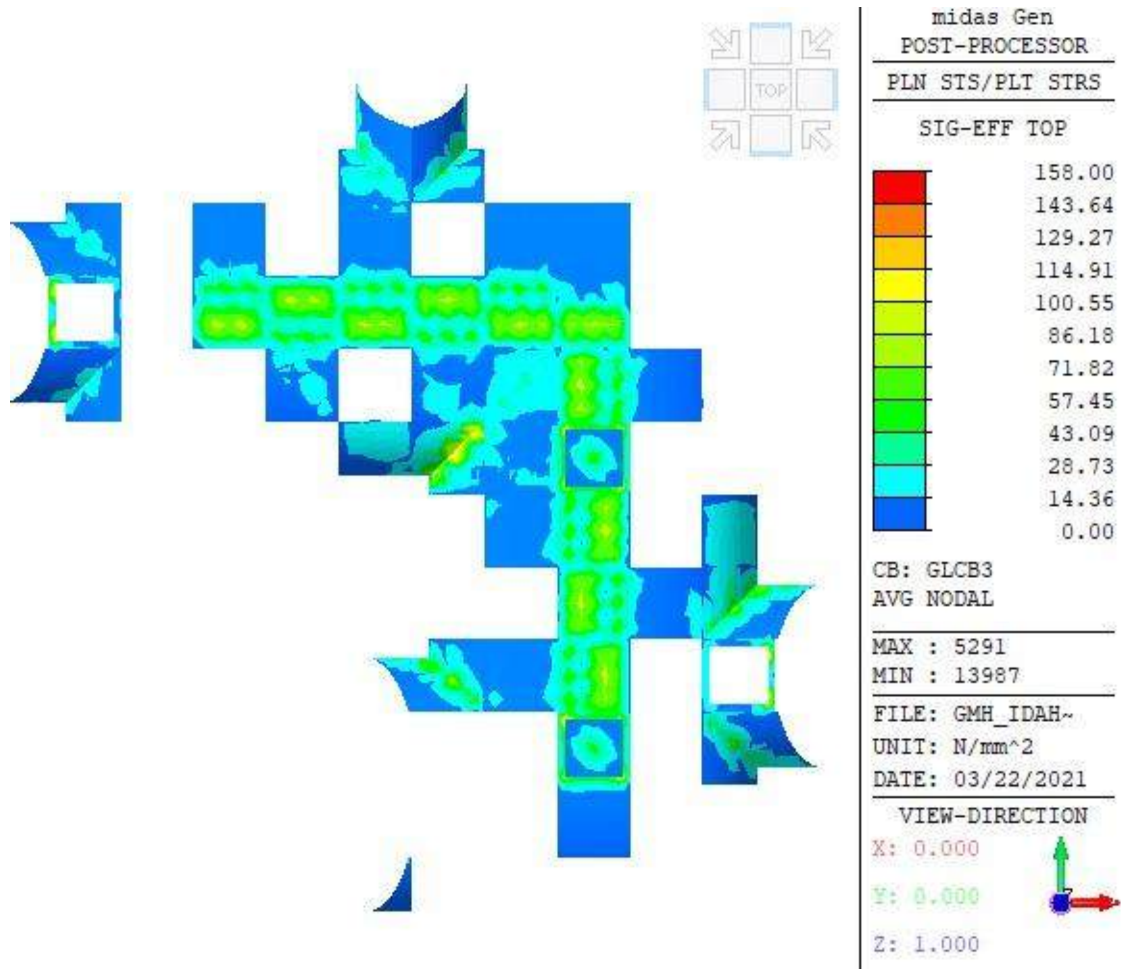


Figure 17. Von Mises Stress – LCB3 (limited to $\phi\sigma_y$ = 11 MPa, W.S. Test Material) – Top view and side view.


midas Gen
POST-PROCESSOR
PLN STS/PLT STRS
SIG-EFF TOP
158.00
143.64
129.27
114.91
100.55
86.18
71.82
57.45
43.09
28.73
14.36
0.00
CB: GLCB3
AVG NODAL
MAX : 5291
MIN : 13987
FILE: GMH_IDAH~
UNIT: N/mm^2
DATE: 03/22/2021
VIEW-DIRECTION
X: 0.000
Y: 0.000
Z: 1.000

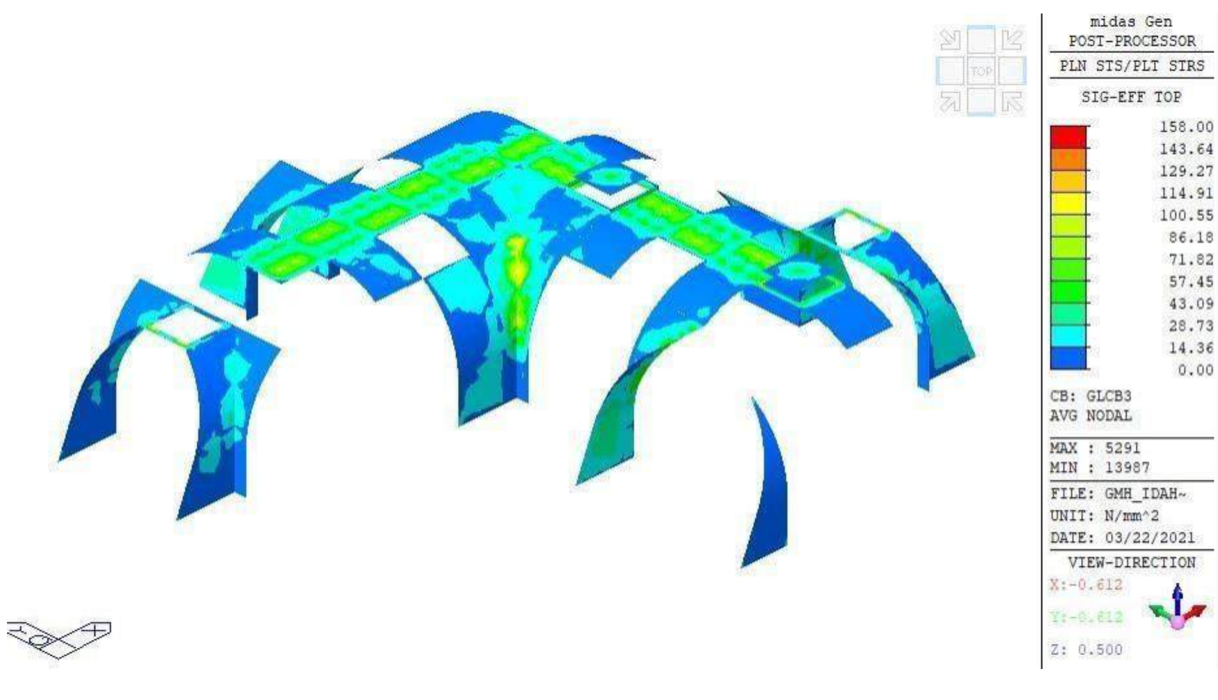

midas Gen
POST-PROCESSOR
PLN STS/PLT STRS
SIG-EFF TOP
158.00
143.64
129.27
114.91
100.55
86.18
71.82
57.45
43.09
28.73
14.36
0.00
CB: GLCB3
AVG NODAL
MAX : 5291
MIN : 13987
FILE: GMH_IDAH~
UNIT: N/mm^2
DATE: 03/22/2021
VIEW-DIRECTION
X:-0.612
Y:-0.612
Z: 0.500

FIGURE 18. VON MISES STRESS – LCB3 (LIMITED TO $\phi\sigma_y$ = 153 MPA, WOVEN ROVING FIBER REINFORCED PANELS) – TOP VIEW AND SIDE VIEW.

4.6. Beam elements resistance

Combined stress for the pipe section is compared to the design Flexural Strength ($\phi\sigma_f$).

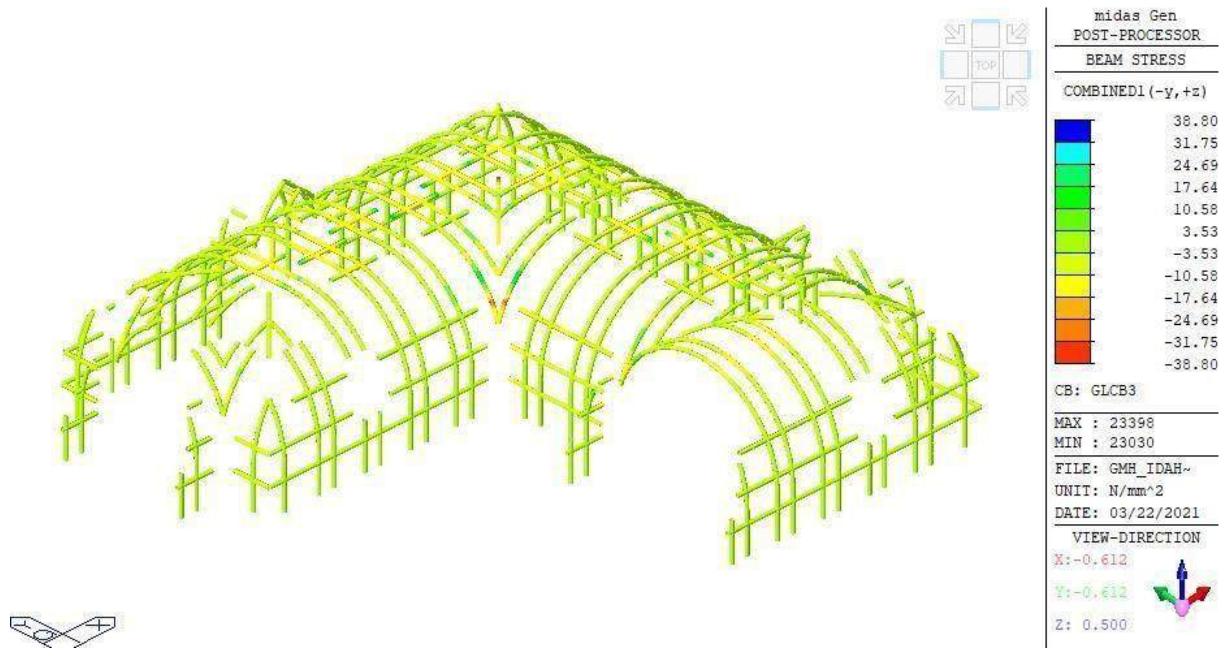


FIGURE 19. COMBINED STRESS – LCB3 (LIMITED TO $\phi\sigma_f$ = 38 MPA, W.S. TEST MATERIAL).

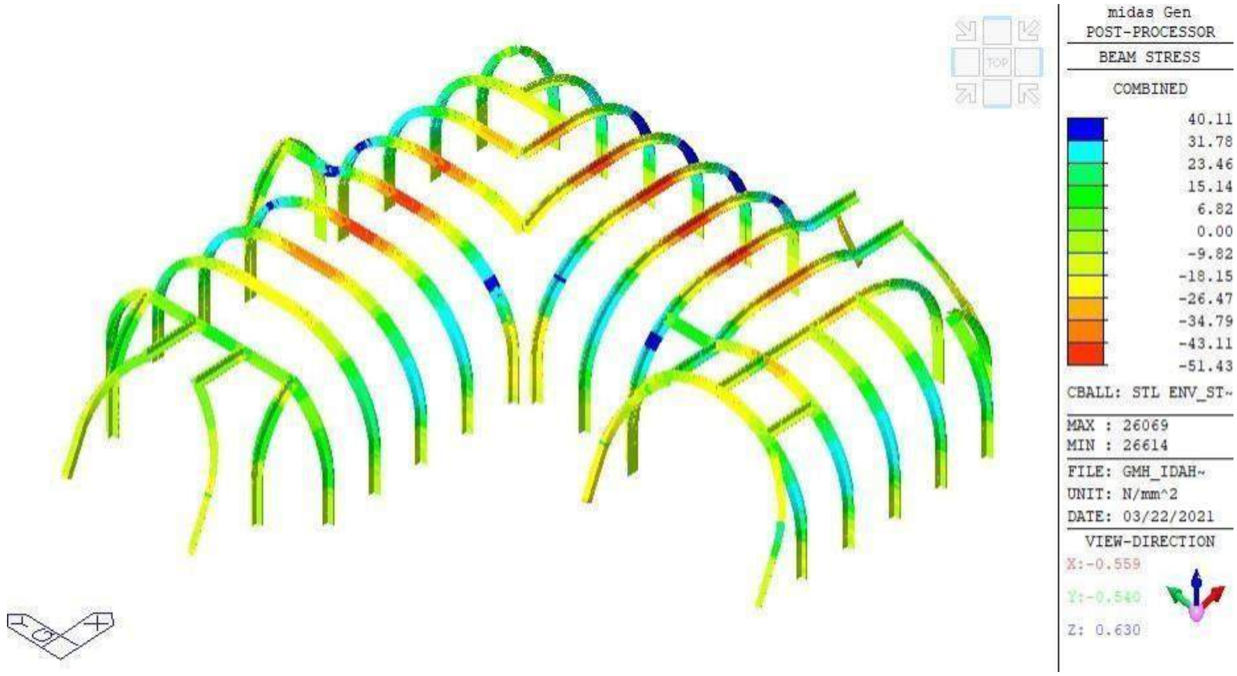
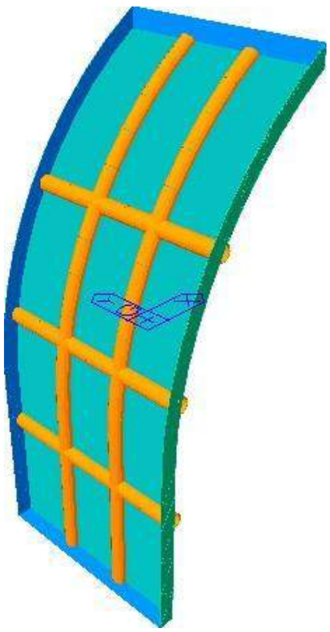
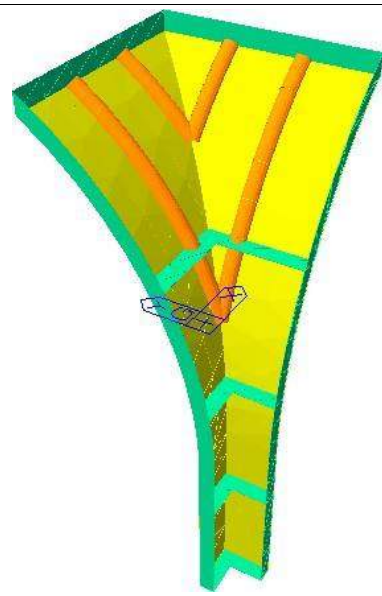
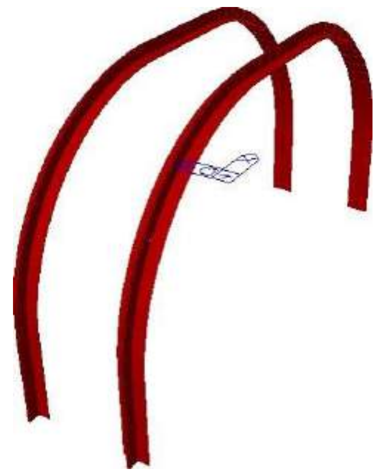


FIGURE 20. COMBINED STRESS – ENVELOPE (LIMITED TO $\phi\sigma_f$ = 206 MPA, WOVEN ROVING GFRP).

5. CONCLUSIONS

GENERAL AND GEOMETRY:

It is recommended to implement:

		
Traditional fiberglass panels with their respective semicircular ducts.	Reinforced panels, made of woven roving fiberglass.	The double angle between panel tabs Reinforcement.

The final distribution of these panels and reinforcements can be seen in the following images. The modules to be reinforced are listed in the following image.

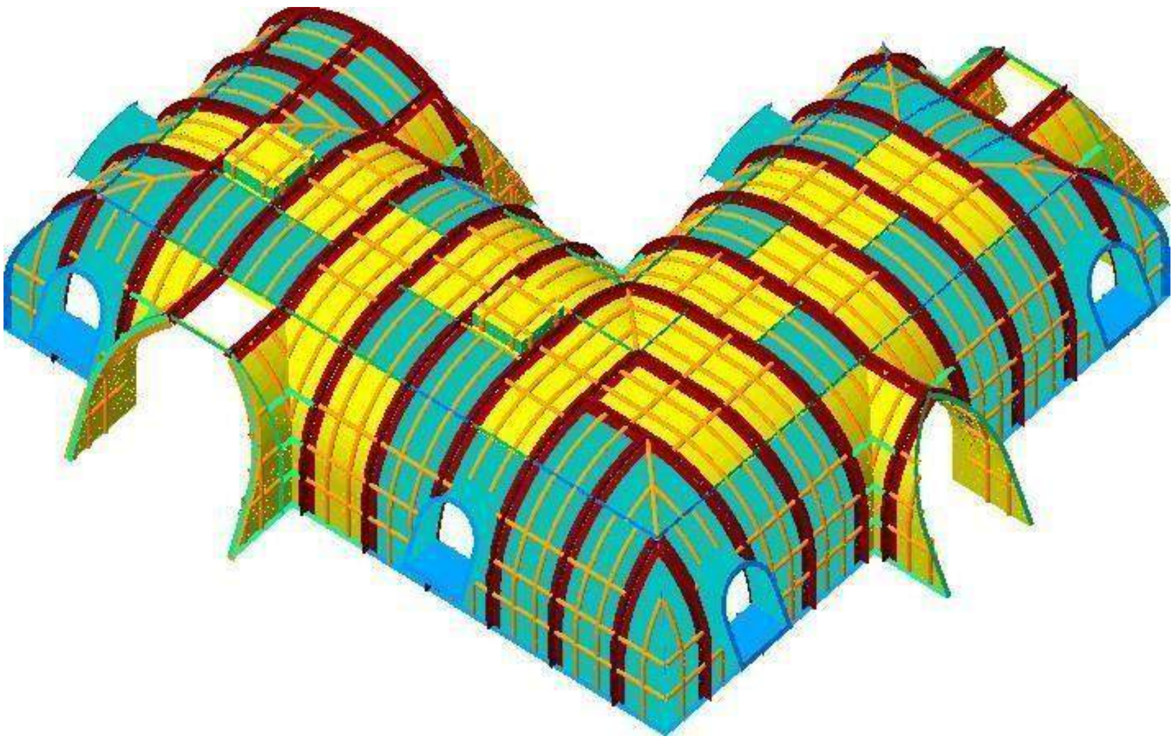


FIGURE 21. FINAL DISTRIBUTION OF ELEMENTS AND PANELS.

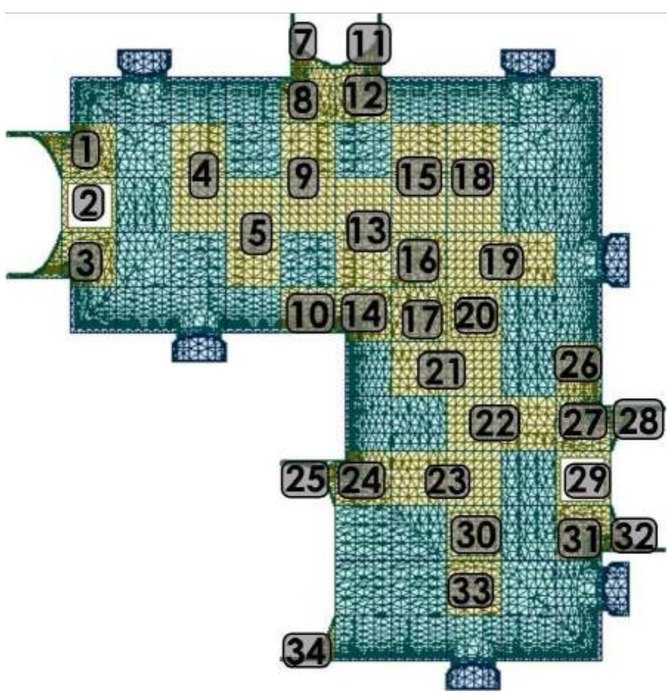


FIGURE 22. WOVEN ROVING FIBERGLASS ELEMENTS.

DEFORMATIONS:

Considering the recommendation of ASTM D 3841 *"Standard Specification for Glass- Fiber-Reinforced Polyester Plastic Panels"*, the maximum deformation allowed is **L/40** for roof panels applications and **L/20** for wall panel applications. In this case, the deflections obtained are less than any of the recommended limits.

$$\Delta = 68.56mm < \frac{L}{40} = \frac{6{,}060mm}{40} = 151.5mm\ O.K!$$

RESISTANCE:

Through the LRFD design methodology, the resistance of the panels is verified according to their composition material. The Von Mises stress for the critical load combination is compared to the tensile strength, considering a strength reduction factor (ϕ) of 0.9.

FINITE ELEMENT SIMULATION FEM FOR A REINFORCED COMPOSITE STRUCTURE W.S.

Arch module 5

1. GOALS AND METHODOLOGY

In this following paper, we get the mechanical behavior of an arch structure made of reinforced, laminated fiber parts with a gel coat of 7.5mm thickness and approximately 7 meters span, as shown in figure 1. Through the analysis, we understand the mechanical behavior of the product against service loads in an adversative condition. Then we also calculate the arches' maximum capability and valuable information for offering the arches in upcoming uses whereit’s needed to face higher load conditions.

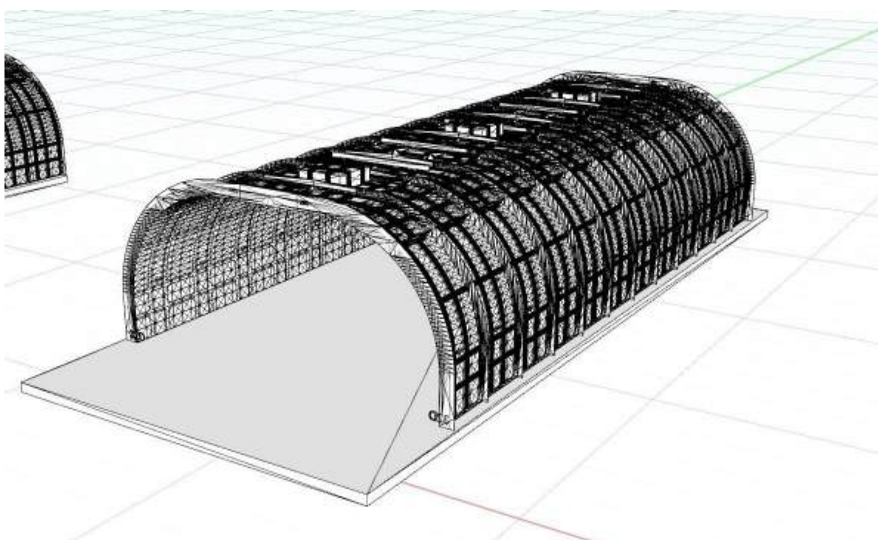


Figure 1 Current model of the arches

From this three-dimensional model, we create a mathematical simulation for modeling the composite material behavior in a finite element analysis software with the material properties shown in figure 2 and summarized in table 1.

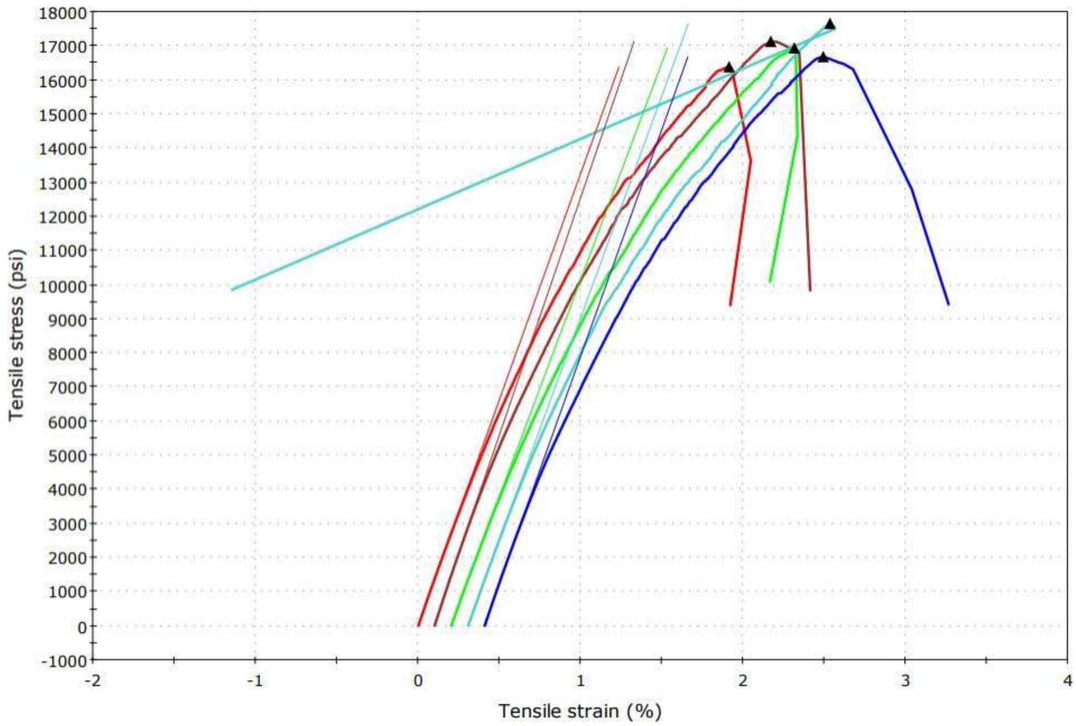
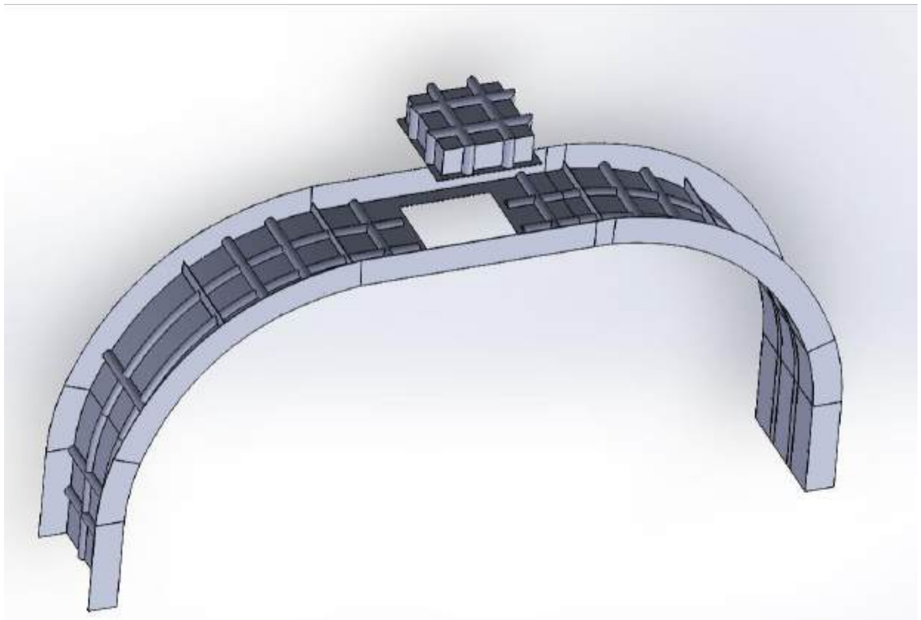


Figure 2 Tested equivalent laminate engineering constants based on input thicknesses.

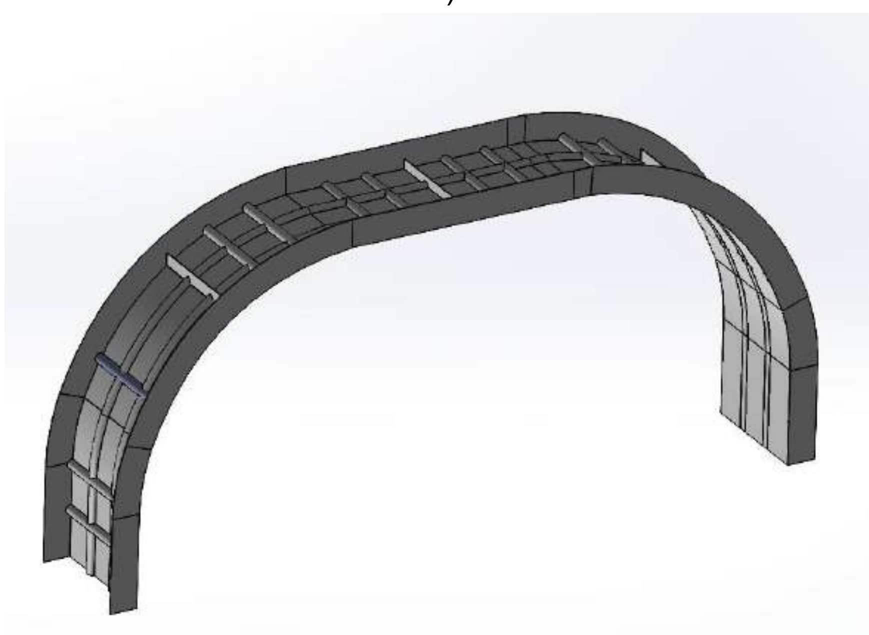
Properties	
Maximum tensile strength	117 MPa
Maximum compressive strength	202 MPa
Young module	9100 MPa
Max. unitary strain for breaking	2.1%
Poisson coefficient	0.4 *

Table 1 Engineering inputs for the simulation

First, the 3D model was exported from SketchUp to Rhino to model the composite structure and apply the loads. In Rhino, the critical points of the structure are identified to simplify the analysis. With solid engineering data, we already could predict that the critical arches present a hole in the center; however, being conservative, we analyze two types of arches, the one with the center hole and the one that does not. Figure 3.



a)



b)

Figure 3 Arches typologies a) type A with the center hole (exploded view) b) type B without hole.

Hence before, it is important to define loads of the System, which are:

● Dead and Live Loads: for our analysis, the weight of the considered material and the structure are represented in the software with a gravity vector. On the other hand, dead and live weight is also considered with the concrete material, the

The roof and the hanging elements in the system give us a subtotal of 4.8 kPa.

Load type	**Use of area of floor or roof**	**Minimum specified load kPa**
Dead load	Grandstands (Areas without fixed seats that have backs)	4,8
Live loads	Grandstands (Areas without fixed seats that have backs)	4,8

● Snow Loads S:

Snow Load - S	
Pf – Load placed over the plane parts	*4.52 kPa*
Ps – load placed over the curve parts	2.05 kPa

Curve – angle tangent on the curve and horizontal 15° - 60°

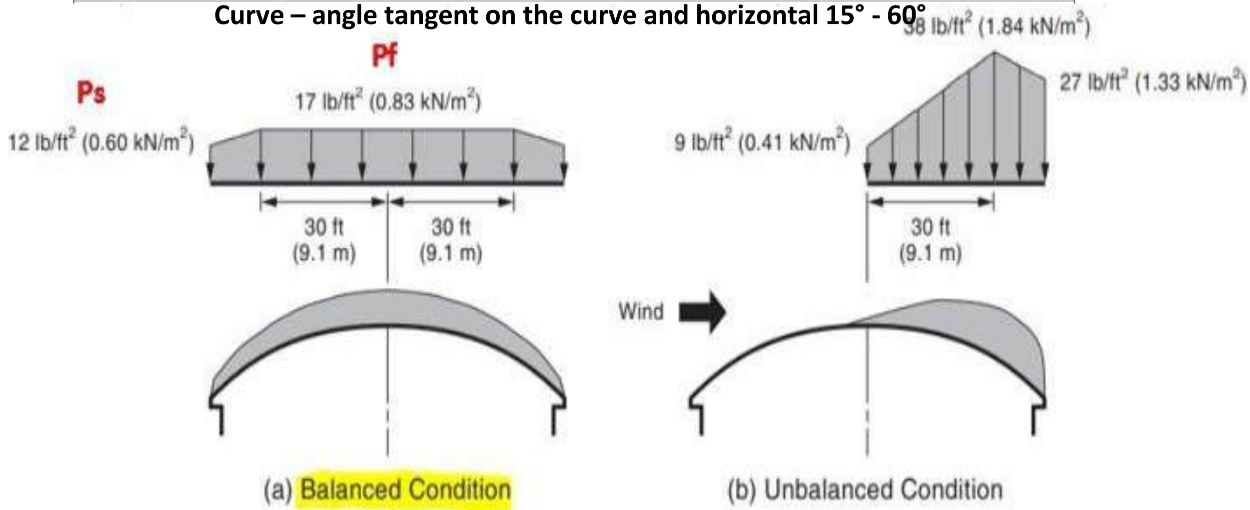


Figure 4 Design snow loads ASCE 7-16 Example 2

● **Wind Load W:**

The wind load is calculated in a simplified way using a drag equation givenby:

$$W = \frac{1}{2} pV^2$$

Where p is the air density and V is the wind speed.

Wind load	0.72	kPa

2. ANALYSIS

Applying the boundary conditions, load cases, and load conditions to the model with the corresponding load combination:

A. 1.4 D
B. D +1.5 L
C. 1.25 D + 1.5 S
D. 1.25 D + 1.4W
E. D + E
F. D + L + W+ S

Solving the analysis and studying the results:

a) For the arches, type A with the center hole:

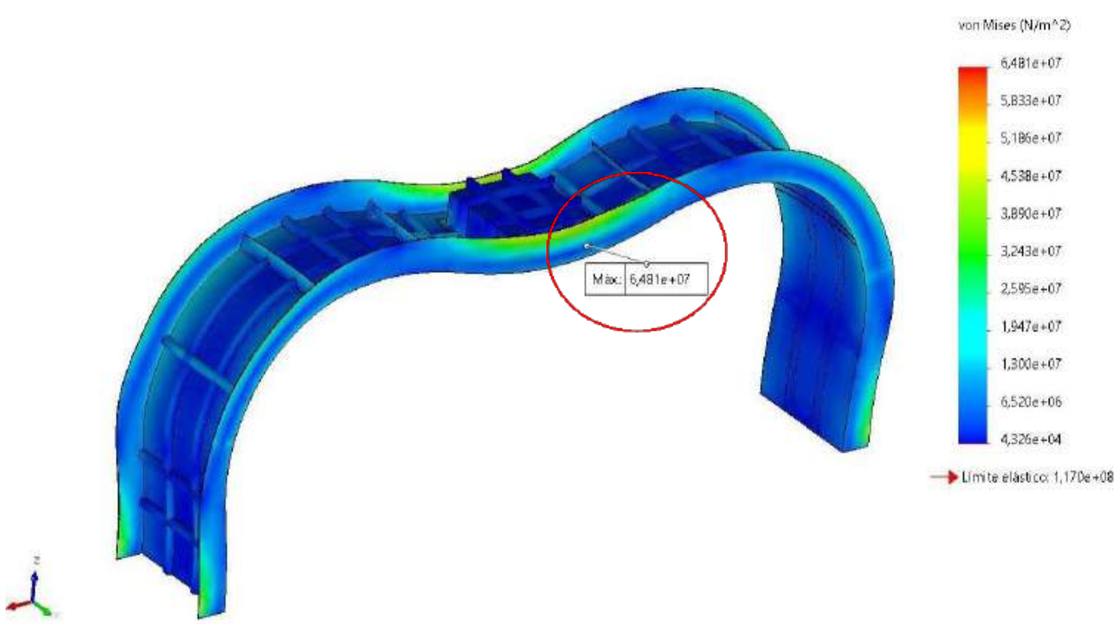
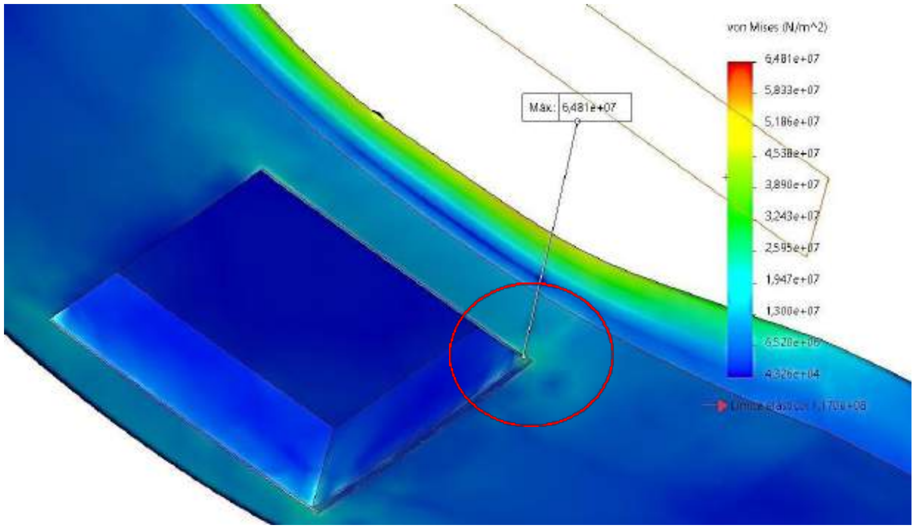


Figure 5 Mechanical stresses in the arch type A, distortion view 12:1



:

Figure 6 Critical point of stresses, edges in the hole are supporting.

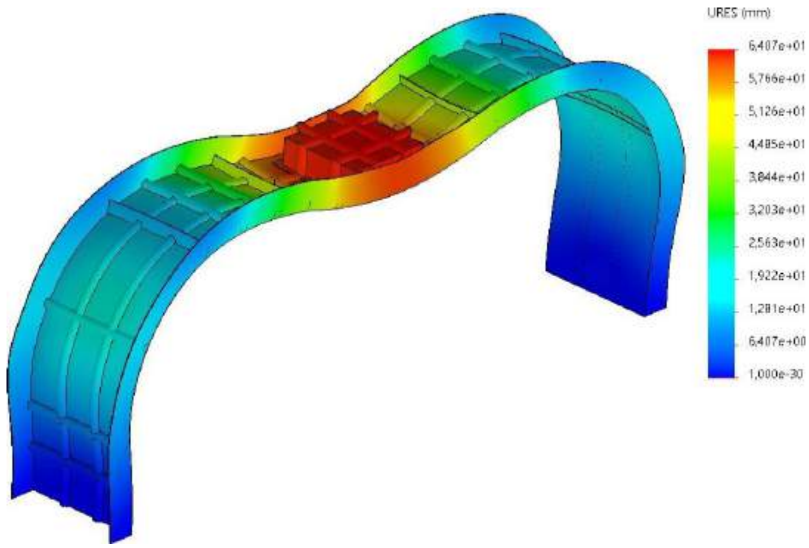


Figure 7 deformation in the arch type A, distortion view 12:1

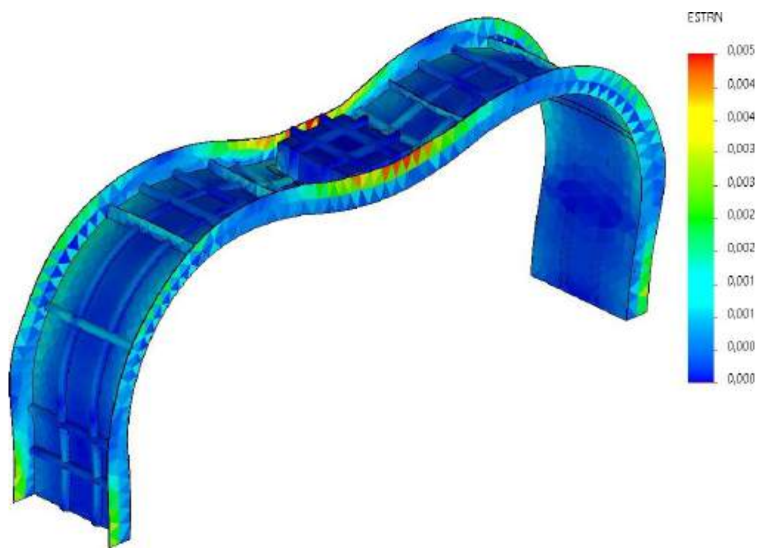


Figure 8 Unitary deformation in the arch type B, distortion view 12:1

a) **For the arches, type B without center hole:**

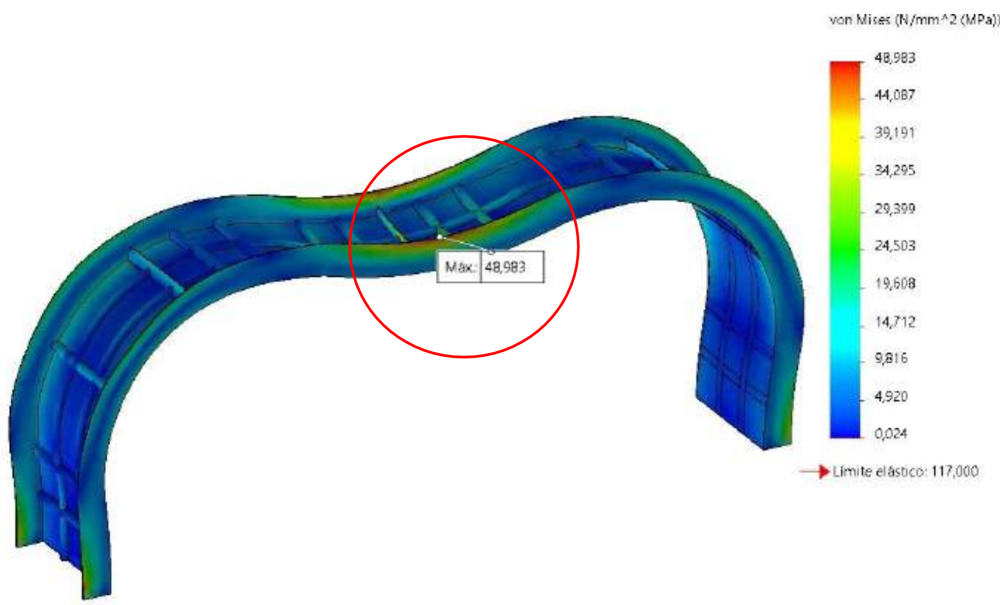


Figure 9 Mechanical stresses in the arch type B, distortion view 12:1

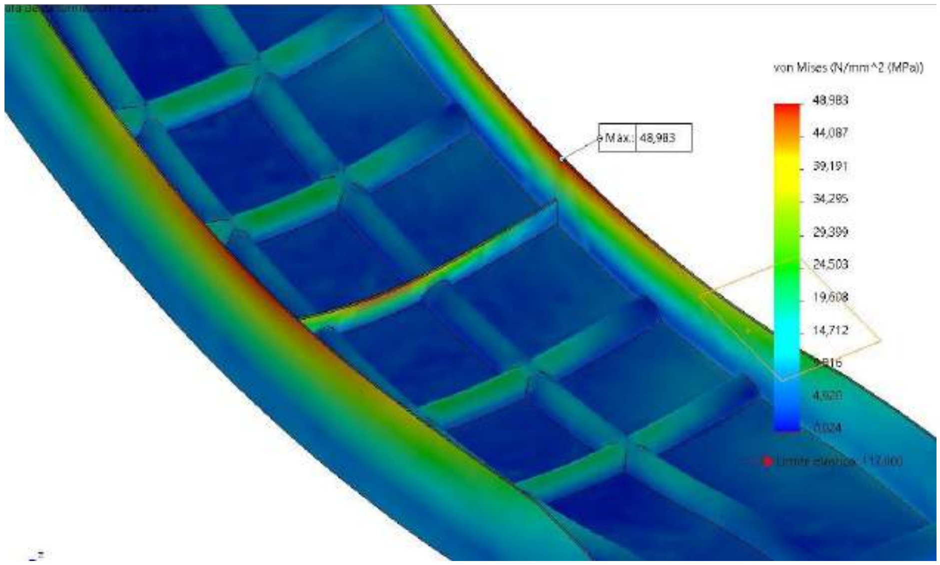


Figure 10 load concentration in the arch, distortion view 12:1

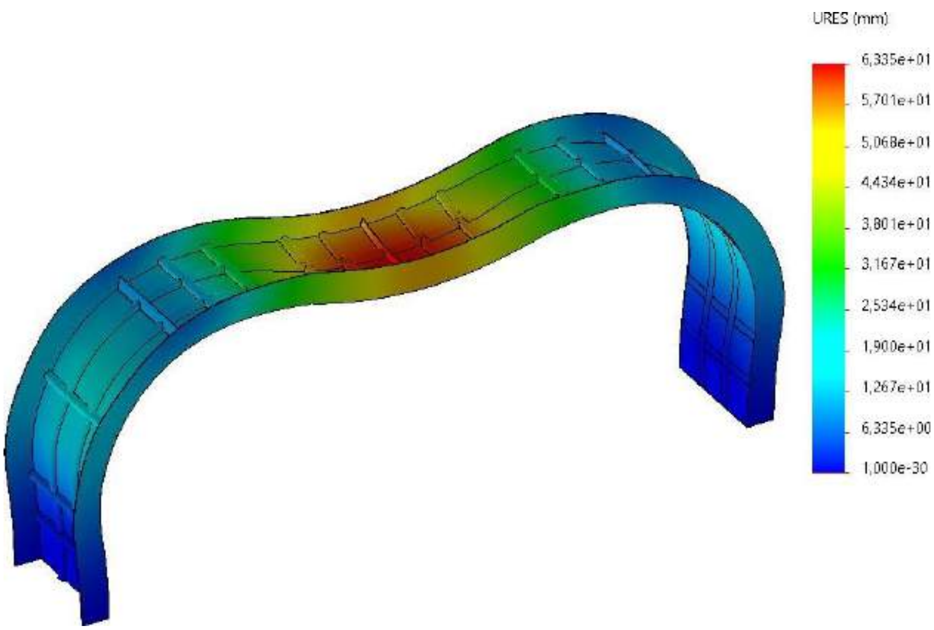


Figure 11 deformation in the arch type B, distortion view 12:1

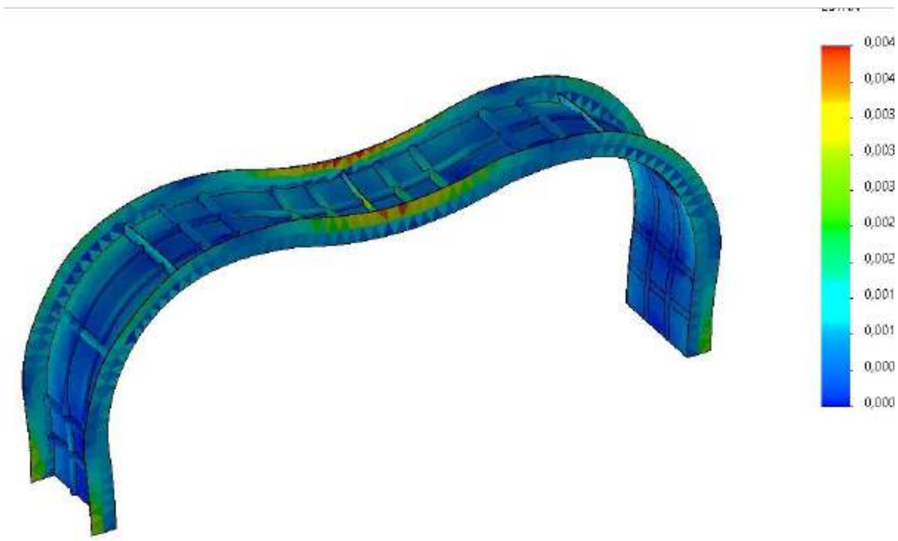


Figure 12 Unitary deformation in the arch type B, distortion view 12:1

3. RESULTS

PARAMETER	VALUE
Max. stress in arch type A	65 MPa < 117 MPa OK
Max. stress in arch type B	49 MPa < 117 MPa OK
Max. deformation in arch type A	64 MM $\approx L/100$
Unitary deformation in arch type A	0.5 % < 2.1 % OK
Max. deformation in arch type B	63 MM $\approx L/100$
Unitary deformation in arch type B	0.4 % < 2.1 % OK

The above results show that the structure has a satisfactory design with a satisfactory safety factor; the mechanical stresses do not exceed the minimum stress of the material, and nor do the unitary strains of rupture according to the curve of the curve delivered material. The fabric has properties quite good relatively; It is also shown that the type A arch is the critical design arch, then the center hole generates an area of stress concentration; on the other hand, it’s important to highlight that the maximum displacements are 64 mm, that is, approximately L/100, the value that would not be favorable depending on the functionality or use of the arches.

Subsequently, using the type A arch for the analysis, we run a new analysis loading this arch to the limit to know how much additional load it is possible to support.

LOAD: D + L + W+ S + Additional	LOAD
Dead load	4.8 kPa
Live load	4.8 kPa
Wind load	0.7 kPa
Average Snow load	3.5 kPa
Additional load	9.5 kPa
TOTAL	23.3 kPa

Iterating the analysis, we find that with the previously loaded structure, in this analysis, the rupture occurs at the instance when an additional 9.5 kPa is loaded.
So, it can be said that the arch resists in terms of mechanical stresses up to 23.3 kPa, uniformly distributed. However, in terms of displacement, a very high value is reached at this level, being 99 mm.

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Structural Calculation Report – Wind resistance and seismic analysis

Juan Salvador Mantilla López
Civil Engineer, Ms. C. – Professional I.D. 76202-267608 VLL

August of 2018

CONTEND

FIGURE LIST

STRUCTURAL CALCULATION REPORT

For USA Virgin Island

1. PROJECT DESCRIPTION

This document intends to analyze in a general way the structural behavior of Wonderful Structures (W.S.), and evaluate the viability of its construction in high wind and hurricane prone areas including the US Virgin Islands which undergo wind speeds of up to 165 mph (266 km/h), and compliance with IBC Seismic Design Category D and the AISC 07-10.

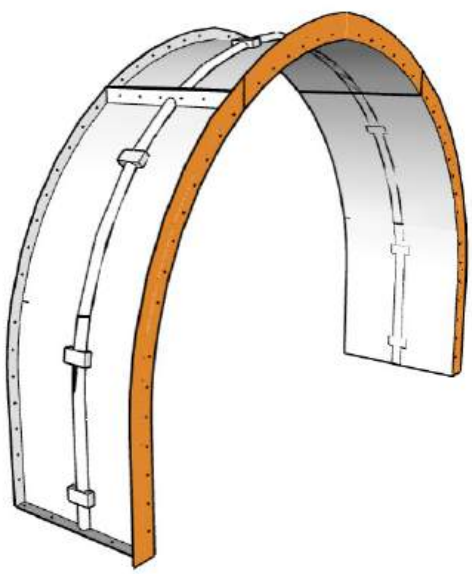


Figure 1. Typical panel sketch.

Figure 2. Construction of a W.S.

Because W.S. are modular structures, a typical panel will be analyzed. This is the main module of the structural geometry, all the others are based on this. It consists of a flat section of 1.065m (3ft 5.92in) and an upper semicircular section [diameter Φ = 4.6m (15ft 1.5in)]. This panel has a width of 1.3m (4ft 1.8in).

2. MATERIALS

Glass Fiber Reinforced Resins

Based on the mechanical characterization tests:

Panel thickness	=	7mm	(0.28 in)
Density	=	980 kg / m_3	(60 lb/ft^3)
Flexion Resistance	=	40 MPa	(5.8 KSI)
Longitudinal Extension Resistance	=	13.5 MPa	(1.96 KSI)
Joint design strength (round washer) /150mm	=	1.46 kN	(225 lb)
Joint design strength (Square washer)/150mm	=	2.41 kN	(542 lb)
Elastic Modulus	=	9000 MPa	(1305 KSI)
Poisson Ratio (Supposed)	=	0.3	

Lateral Backfill Sand-Cement

Density	= 19 kN/m_3	(120 lb/ft^3)
ϕ	= 40°	
C	= 241 kPa	(35 psi)

Concrete

Compressive Strength (fc) = 210 kg/cm^2 (21 MPa) (3.0 ksi)

Reinforcing Steel bar

Yield Stress (fy)	= 4200 kg/cm^2 (420 MPa) (60 ksi)	
Diameter	=100 mm	(3.9 in)
Thickness	= 12 mm	(0.47 in)

3. LOADS EVALUATION

3.1. Dead Loads (D)

In this loads the self-weight of the panels is not included because it is considered in the analysis software. This load only includes the additional loads that are permanent.

200 mm of soil cover [kPa]	3.6
Lamps and hanging furniture [kPa]	0.2
Total additional dead loads [kPa]	**3.8**

Total permanent loads D is the sum of self-weigth of the panels and dead loads.

3.2. Live Loads (L)

Considering the possible transit of people and light animals on the roof, it is considered a live load:

Roof live load [kPa]
2.0

3.3. Earth Pressure (H)

The lateral earth pressure of the sand-cement is considered through the trapezoidal distribution of active pressure.

H [m]	Ka	Density [kN/m3]
1,07	0,22	19
Base pressure (fb) [kN/m^2]		4.1

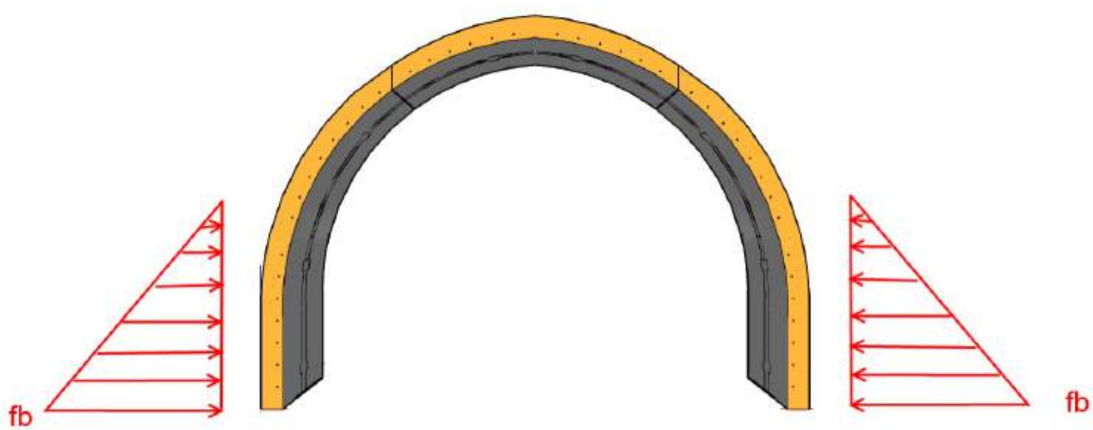


Figure 3. Earth pressure distribution.

3.4. WIND (W)

The wind loads for the Main Wind-Force Resisting System (MWFRS) shall be determined using one of the procedures specified in the ASCE 7-10, chapters 26-31. An outline of the overall process is provided in the Figure 4.

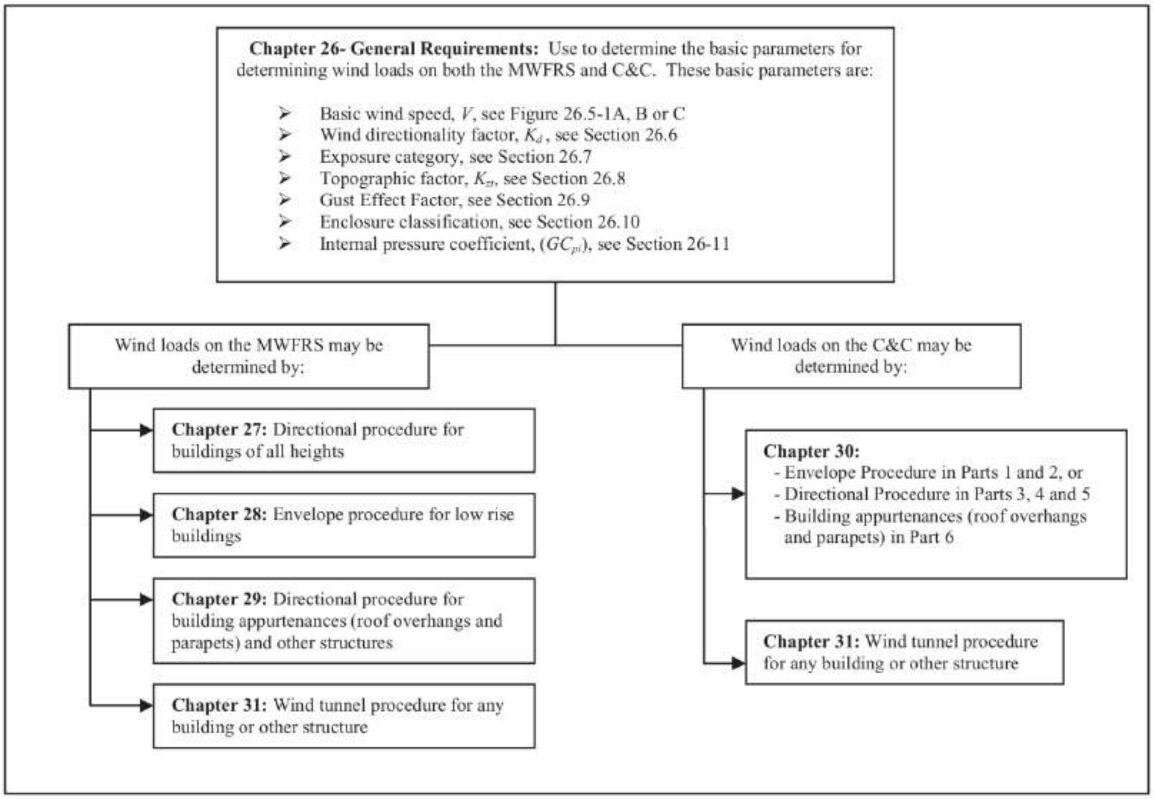


Figure 4. Wind loads determination overall process (ASCE 7-10, Figure 26.1-1).

In this study case, it will be used the *Directional procedure for buildings of all heights*, as it is described in ASCE 7-10 chapter 27. Therefore it's necessary to determine the basics parameters of the chapter 26.

<u>Directional Procedure</u>

1. Determine the risk category according to Figure 5.

    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 a 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. 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 their quantity exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.	III
Buildings and other structures designated as essential facilities. 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 exceeds a threshold quantity established by the authority having jurisdiction to be dangerous to the public if released 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.	IV

[a]Buildings and other structures containing toxic, highly toxic, or explosive substances shall be eligible for classification to a lower Risk Category if it can be demonstrated to the satisfaction of the authority having jurisdiction by a hazard assessment as described in Section 1.5.2 that a release of the substances is commensurate with the risk associated with that Risk Category.

Figure 5. Risk Category of Buildings and Other Structures (ASCE 7-10, Table 1.5-1).

2. Determine the basic wind speed (V). The basic wind speed is a three-second gust speed at 10m above the ground in Exposure C.

Basic Wind Speed (V): 165.53 mph (74 m/s).

US Virgin Islands

Query Date: Thu Aug 02 2018
Latitude: 17.7486
Longitude: -64.7753

ASCE 7-10 Windspeeds (3-sec peak gust in mph*):

Risk Category I: 150
Risk Category II: 165
Risk Category III-IV: 175
MRI 10-Year:** 74
MRI 25-Year:** 112
MRI 50-Year:** 130
MRI 100-Year:** 143

ASCE 7-05 Windspeed:
145 MPH* (3-sec peak gust in mph)
ASCE 7-93 Windspeed:
125 MPH* (fastest mile in mph)

Taken from: Windspeed Website Information (http:// http://windspeed.atcouncil.org/).

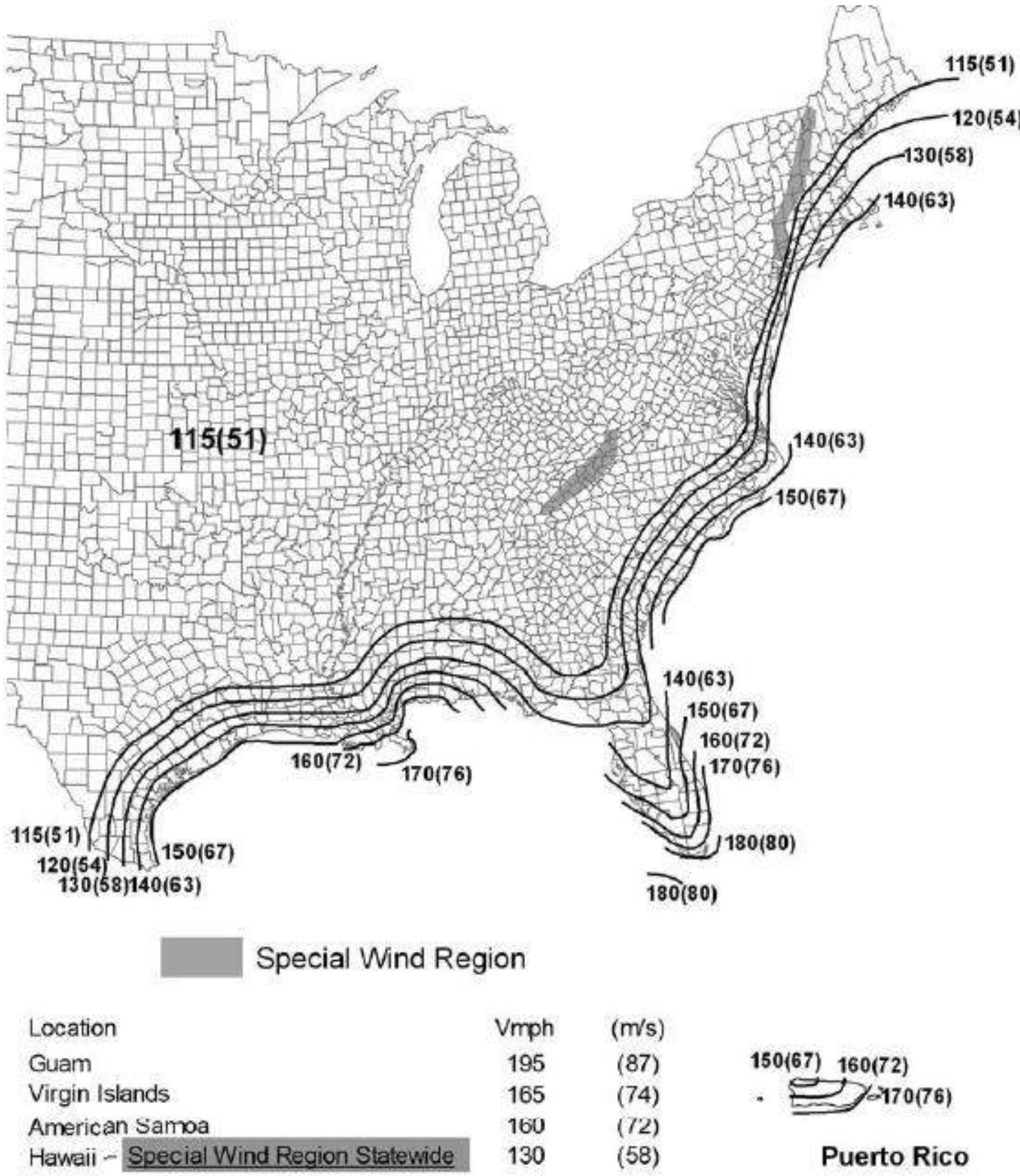


Figure 26.5-1A *(Continued)*

Figure 6. ASCE 7-10 Wind Map for Risk Category II.

3. Determine wind load parameters:

a. Determine wind directionally factor (K_d).

Directionally Factor (K_d): 0.85.

Structure Type	Directionality Factor K_d*
Buildings Main Wind Force Resisting System Components and Cladding	0.85 0.85
Arched Roofs	0.85
Chimneys, Tanks, and Similar Structures Square Hexagonal Round	0.90 0.95 0.95
Solid Signs	0.85
Open Signs and Lattice Framework	0.85
Trussed Towers Triangular, square, rectangular All other cross sections	0.85 0.95

Figure 7. Wind directionally Factor (ASCE 7-10, Table 26.6-1).

b. Determine exposure category for each wind direction considered. The upwind exposure shall be based on ground surface roughness as it is described in the ASCE 7-10, C26.7.

Exposure Category: C.

Surface Roughness B: Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.

Surface Roughness C: Open terrain with scattered obstructions having heights generally less than 30 ft (9.1 m). This category includes flat open country and grasslands.

Surface Roughness D: Flat, unobstructed areas and water surfaces. This category includes smooth mud flats, salt flats, and unbroken ice.

Figure 8. Surface Roughness (ASCE 7-10, C26.7.2).

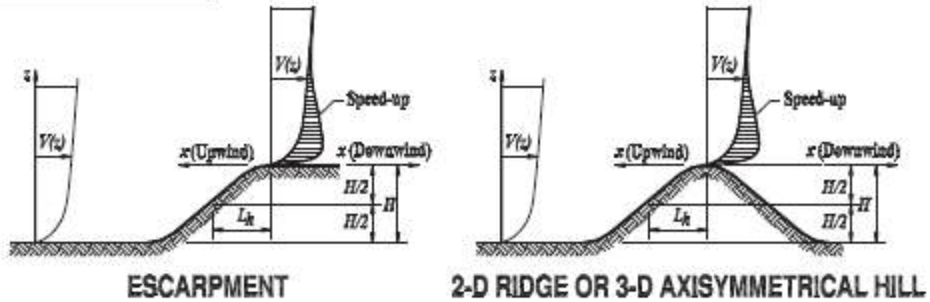
c. Determine topographic factor (K_{zt}), for flat terrains this factor equals 1.0.

$$K_{zt} = (1 + K_1 K_2 K_3)^2$$

Topographic Factor (K_{zt}): 1.00

Topographic Factor, K_{zt}

Figure 26.8-1



Topographic Multipliers for Exposure C

H/L_h	K_1 Multiplier 2-D Ridge	K_1 Multiplier 2-D Escarp.	K_1 Multiplier 3-D Axisym. Hill	x/L_h	K_2 Multiplier 2-D Escarp.	K_2 Multiplier All Other Cases	z/L_h	K_3 Multiplier 2-D Ridge	K_3 Multiplier 2-D Escarp.	K_3 Multiplier 3-D Axisym. Hill
0.20	0.29	0.17	0.21	0.00	1.00	1.00	0.00	1.00	1.00	1.00
0.25	0.36	0.21	0.26	0.50	0.88	0.67	0.10	0.74	0.78	0.67
0.30	0.43	0.26	0.32	1.00	0.75	0.33	0.20	0.55	0.61	0.45
0.35	0.51	0.30	0.37	1.50	0.63	0.00	0.30	0.41	0.47	0.30
0.40	0.58	0.34	0.42	2.00	0.50	0.00	0.40	0.30	0.37	0.20
0.45	0.65	0.38	0.47	2.50	0.38	0.00	0.50	0.22	0.29	0.14
0.50	0.72	0.43	0.53	3.00	0.25	0.00	0.60	0.17	0.22	0.09
				3.50	0.13	0.00	0.70	0.12	0.17	0.06
				4.00	0.00	0.00	0.80	0.09	0.14	0.04
							0.90	0.07	0.11	0.03
							1.00	0.05	0.08	0.02
							1.50	0.01	0.02	0.00
							2.00	0.00	0.00	0.00

Notes:

1. For values of H/L_h, x/L_h and z/L_h other than those shown, linear interpolation is permitted.
2. For $H/L_h > 0.5$, assume $H/L_h = 0.5$ for evaluating K_1 and substitute 2H for L_h for evaluating K_2 and K_3.
3. Multipliers are based on the assumption that wind approaches the hill or escarpment along the direction of maximum slope.
4. Notation:
   - H: Height of hill or escarpment relative to the upwind terrain, in feet (meters).
   - L_h: Distance upwind of crest to where the difference in ground elevation is half the height of hill or escarpment, in feet (meters).
   - K_1: Factor to account for shape of topographic feature and maximum speed-up effect.
   - K_2: Factor to account for reduction in speed-up with distance upwind or downwind of crest.
   - K_3: Factor to account for reduction in speed-up with height above local terrain.
   - x: Distance (upwind or downwind) from the crest to the building site, in feet (meters).
   - z: Height above ground surface at building site, in feet (meters).
   - μ: Horizontal attenuation factor.
   - γ: Height attenuation factor.

Figure 9. Topographic Factor (ASCE 7-10, Figure 26.8-1).

d. Determine gust factor (G). For rigid building, where natural frequency is greater than 1 Hz, is permitted to be taken as 0.85.

Gust Factor (G): 0.85.

e. Determine enclosure classification.

Enclosure classification: Partially Enclosed Building.

Open Building: A building having each wall at least 80 percent open. This condition is expressed for each wall by the equation $A_o \geq 0.8\ A_g$ where

A_o = total area of openings in a wall that receives positive external pressure
A_g = the gross area of that wall in which A_o is identified

Partially Enclosed Building: A building that complies with both of the following conditions:
1. The total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings in the balance of the building envelope (walls and roof) by more than 10 percent.
2. The total area of openings in a wall that receives positive external pressure exceeds (0.37 m2) or 1 percent of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building envelope does not exceed 20 percent.
Enclosed Building: It is a building that is not classified as open or partially enclosed.

Figure 10. Enclosure classification (ASCE 7-10, C26.2).

f. Determine internal pressure coefficient (GCP_{pi}).

Internal Pressure Coefficient (GC_{pi}): ± 0.55

Enclosure Classification	(GC_{pi})
Open Buildings	0.00
Partially Enclosed Buildings	+0.55 -0.55
Enclosed Buildings	+0.18 -0.18

Notes:

1. Plus and minus signs signify pressures acting toward and away from the internal surfaces, respectively.
2. Values of (GC_{pi}) shall be used with q_z or q_h as specified.
3. Two cases shall be considered to determine the critical load requirements for the appropriate condition:
   (i) a positive value of (GC_{pi}) applied to all internal surfaces
   (ii) a negative value of (GC_{pi}) applied to all internal surfaces

Figure 11. Internal Pressure Coefficient (ASCE 7-10, Table 26.11-1).

4. Determine velocity pressure exposure coefficient (K_z or K_h)

$$K_z = K_h = 2.01\left(\frac{4.0}{Z_g}\right)^{\frac{2}{\alpha}} = 2.01\left(\frac{4.0}{274.32}\right)^{\frac{2}{9.5}} = 0.825$$

Main Wind Force Resisting System – Part 1	All Heights
Velocity Pressure Exposure Coefficients, K_h and K_z	
Table 27.3-1	

Height above ground level, z		Exposure		
ft	(m)	B	C	D
0-15	(0-4.6)	0.57	0.85	1.03
20	(6.1)	0.62	0.90	1.08
25	(7.6)	0.66	0.94	1.12
30	(9.1)	0.70	0.98	1.16
40	(12.2)	0.76	1.04	1.22
50	(15.2)	0.81	1.09	1.27
60	(18)	0.85	1.13	1.31
70	(21.3)	0.89	1.17	1.34
80	(24.4)	0.93	1.21	1.38
90	(27.4)	0.96	1.24	1.40
100	(30.5)	0.99	1.26	1.43
120	(36.6)	1.04	1.31	1.48
140	(42.7)	1.09	1.36	1.52
160	(48.8)	1.13	1.39	1.55
180	(54.9)	1.17	1.43	1.58
200	(61.0)	1.20	1.46	1.61
250	(76.2)	1.28	1.53	1.68
300	(91.4)	1.35	1.59	1.73
350	(106.7)	1.41	1.64	1.78
400	(121.9)	1.47	1.69	1.82
450	(137.2)	1.52	1.73	1.86
500	(152.4)	1.56	1.77	1.89

Notes:

1. The velocity pressure exposure coefficient K_z may be determined from the following formula:

   For 15 ft. $\leq z \leq z_g$ — $K_z = 2.01\,(z/z_g)^{2/\alpha}$

   For $z < 15$ ft. — $K_z = 2.01\,(15/z_g)^{2/\alpha}$

2. α and z_g are tabulated in Table 26.9.1.
3. Linear interpolation for intermediate values of height z is acceptable.
4. Exposure categories are defined in Section 26.7.

Figure 12. Velocity Pressure Exposure Coefficient (ASCE 7-10, Table 27.3-1).

In metric

Exposure	α	z_g (m)	$\hat{a}$	$\hat{b}$	$\bar{\alpha}$	$\bar{b}$	c	ℓ (m)	$\bar{\epsilon}$	z_{min} (m)*
B	7.0	365.76	1/7	0.84	1/4.0	0.45	0.30	97.54	1/3.0	9.14
C	9.5	274.32	1/9.5	1.00	1/6.5	0.65	0.20	152.4	1/5.0	4.57
D	11.5	213.36	1/11.5	1.07	1/9.0	0.80	0.15	198.12	1/8.0	2.13

*z_{min} = minimum height used to ensure that the equivalent height $\bar{z}$ is greater of 0.6h or z_{min}.
For buildings with h ≤ z_{min}, $\bar{z}$ shall be taken as z_{min}.

Figure 13. Terrain Exposure Constants (ASCE 7-10, Table 26.9-1).

5. Determine velocity pressure (q_z or q_h)

$$\boldsymbol{q_z} = \boldsymbol{q_h} = 0.613 K_z K_{zt} K_d V^2 = 0.613(0.825 \times 1.00 \times 0.85 \times 74^2) = 2354.89\ N/m^2$$

6. Determine external pressure coefficients (C_p)

f	2 m
h_D	1.42 m
D	4.56 m

Domed roof geometric properties

f/D	0.44
h_D/D	0.31

Domed roof ratios

C_p (A)	0.457
C_p (B)	*-1.307*
C_p (C)	*-0.317*

Domed roof external pressure coefficients

Two load cases shall be considered:

- Case A: Cp values beetwen A and B and beetwen B and C shall be determined by linear interpolation along arcs on the dome parallel to the wind direction.
- Case B: Cp shall be the constant value of A for θ < 25°, and shall be determined by linear interpolation from 25° to B and from B to C.

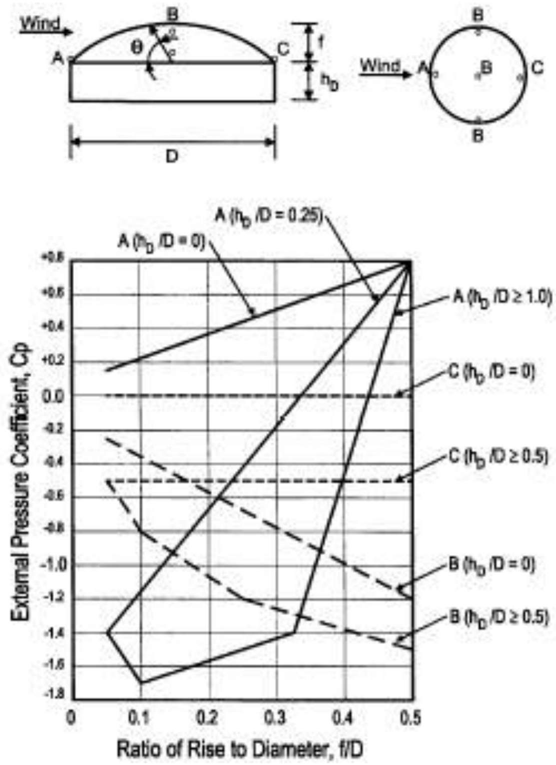


Figure 14. External Pressure Coefficients Domed Roof (ASCE 7-10, Table 27.4-2)

The windward, leeward and side walls pressure coefficients shall be determined using Figure 15. And the pressure distribution for the wind direction in study is as shown in Figure 16.

Wall Pressure Coefficients, C_p			
Surface	**L/B**	**C_p**	**Use With**
Windward Wall	All values	0.8	q_z
Leeward Wall	0-1	-0.5	q_h
	2	-0.3	
	≥4	-0.2	
Side Wall	All values	-0.7	q_h

Figure 15. Wall Pressure Coefficients (ASCE 7-10, Figure 27.4-1 cont')

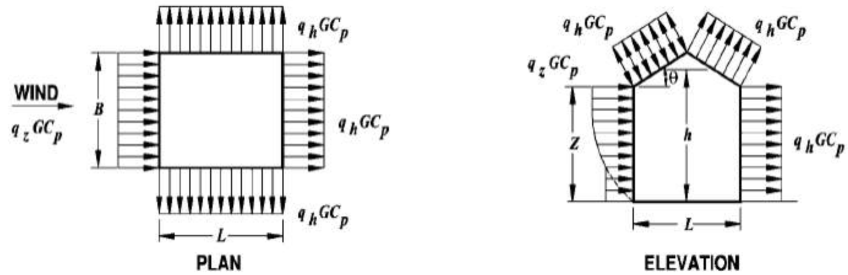
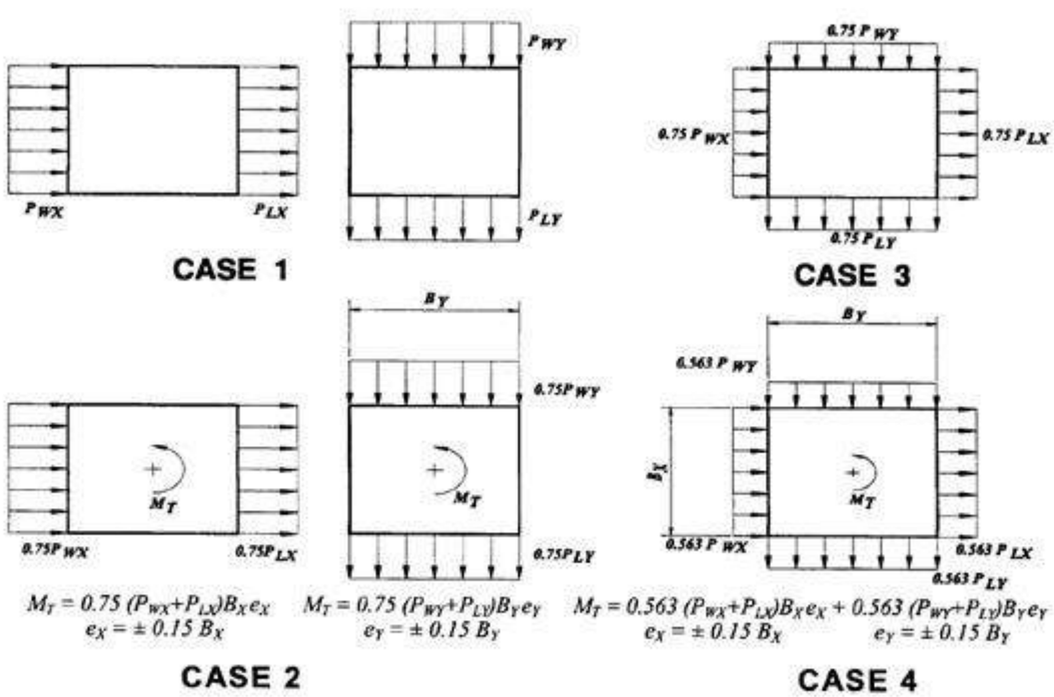


Figure 16. Wind pressure distribution (ASCE 7-10, Figure 27.4-1)

7. Determine design pressure (p)

$$p = qGC_p - q_h(GC_{pi})$$

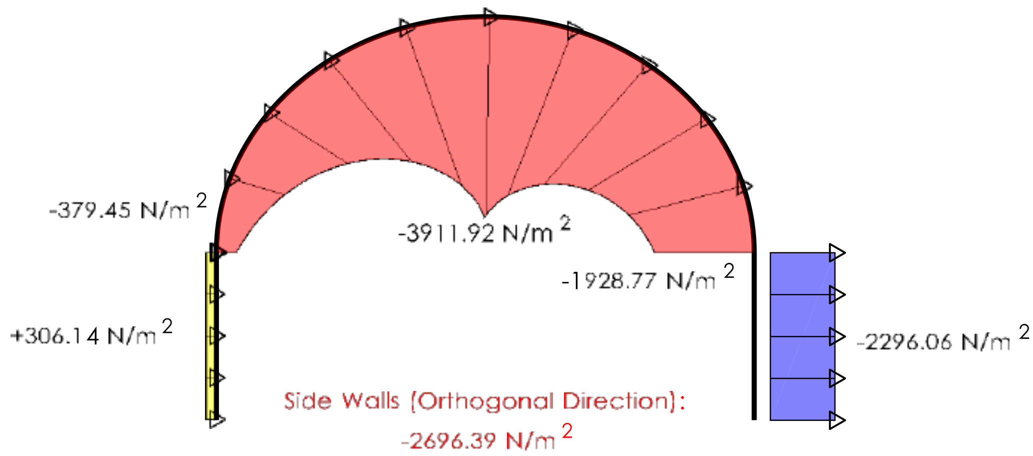
The design wind loads cases are shown in Figure 17. Cases 2 and 4 are exempted for low-rise building.



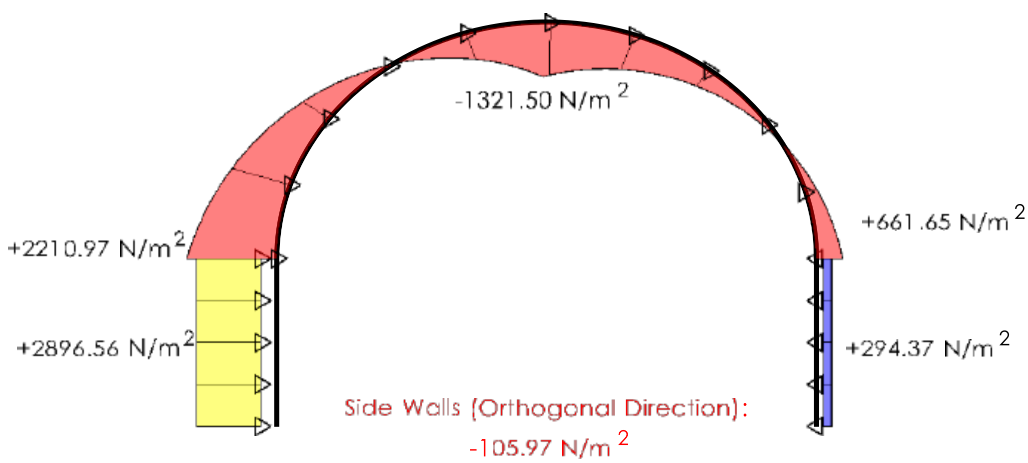
EXCEPTION: One-story buildings with h less than or equal to 30 ft, buildings two stories or less framed with light-frame construction, and buildings two stories or less designed with flexible diaphragms need only be designed for Load Case 1 and Load Case 3 in Fig. 6-9.

Figure 17. Design wind load cases (ASCE 7-10, Figure 27.4-8)

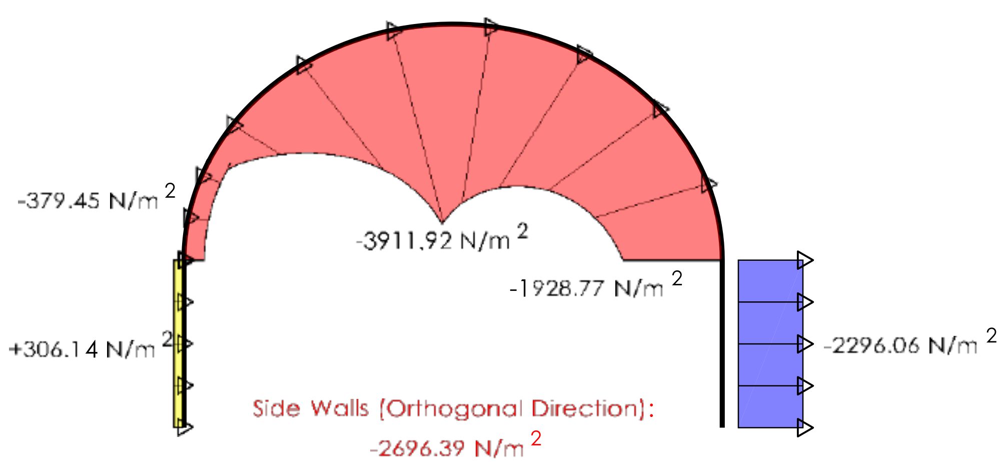
RESULTS



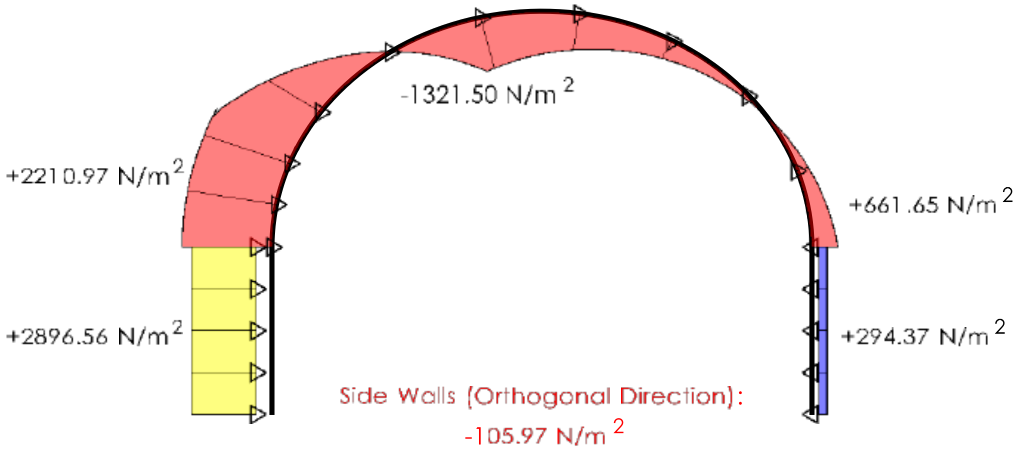
Case A (+GCpi)



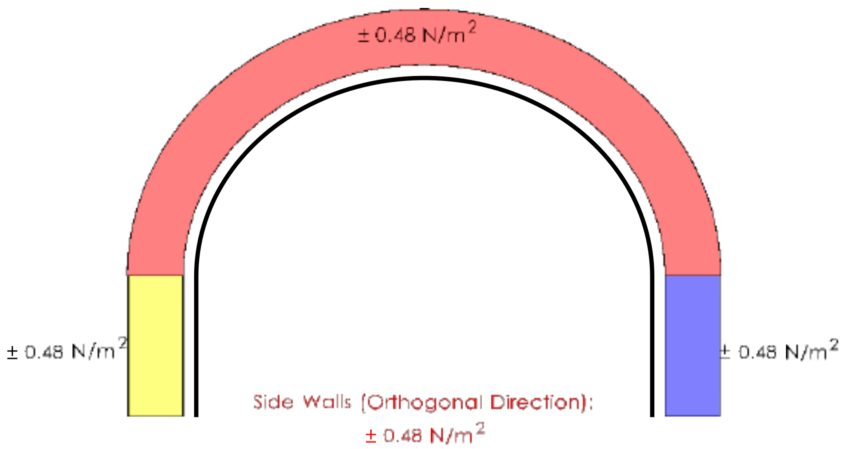
Case A (-GCpi)



Case B (+GCpi)



Case B (-GCpi)



Minimum Wind Load (±480 N/m²)

3.5. SEISMIC (E)

The design spectrum is built based on the ASCE 7-10.

The following parameters have been assumed conservatively; these must be verified and adjusted according to the geotechnical studies of the project area.

Site Subsoil Class	E

Using a computational U.S. Geological Survey (USGS) online tool for Seismic Design Maps:

USGS Design Maps Summary Report

User–Specified Input

Building Code Reference Document ASCE 7-10 Standard
(which utilizes USGS hazard data available in 2008)

Site Coordinates 17.72811°N, 64.81909°W

Site Soil Classification Site Class E – "Soft Clay Soil"

Risk Category I/II/III

USGS–Provided Output

$S_S =$	0.856 g	$S_{MS} =$	0.918 g	$S_{DS} =$	0.612 g
$S_1 =$	0.311 g	$S_{M1} =$	0.858 g	$S_{D1} =$	0.572 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.

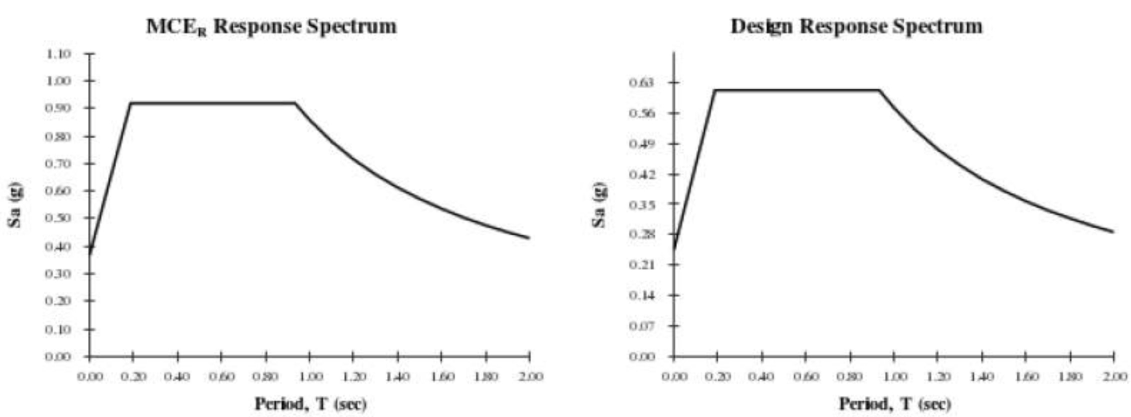


Figure 18. Seismic Design parameters and spectrum (https://earthquake.usgs.gov/designmaps/us/application.php?).

3.6. LOAD COMBINATIONS

The design is made by the **Ultimate Limit States** methodology. The combination of loads is based on the **ASCE 7/10** chapter 2.3.2 is:

1. $1.4D$
2. $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.5W)$
4. $1.2D + 1.0W + L + 0.5(L_r \text{ or } S \text{ or } R)$
5. $1.2D + 1.0E + L + 0.2S$
6. $0.9D + 1.0W$
7. $0.9D + 1.0E$

For analyzing deformations results the services load combination is used:

1.0D + 1.0L

4. ANALYSIS

4.1. FEM MODEL

This process uses a mathematical model that integrates project geometry, the material properties and the design loads. This model is developed in finite element software, which is a widely accepted method for the engineering and scientific community. In this model the main parts of the W.S. structure are included: panels, tabs, fiberglass pipelines and metallic reinforcement duct.

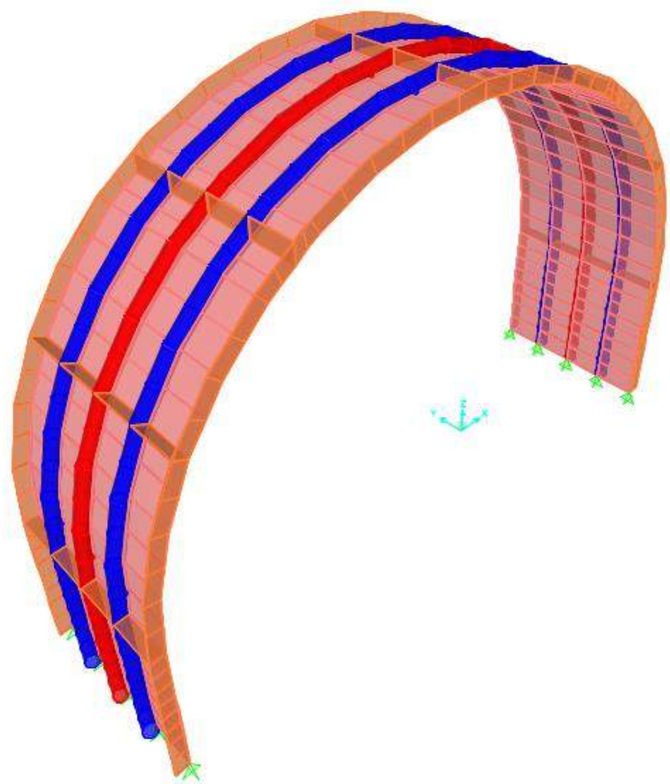


Figure 19. FEM of typical panel

4.2. SEISMIC ANALYSIS

As the structure has a natural period of less than 3.5 Ts, only one floor, the structure is analyzed as category D

$$3.5\ (T_s) = 3.5\ (\frac{S_{D1}}{S_{Ds}}) = 3.5\ (\frac{0.572}{0.612}) = 3.5\ (0.935\ sec) = 3.27\ sec > T_n = 0.868\ sec$$

4.2.1. SEISMIC ANALYSIS METHOD

Equivalent static	
Modal response spectrum	√
Numerical integration time history	

4.2.2. *MODAL COMBINATION METHOD*

Square Root of the Sum of the Square (SRSS)	
Complete Quadratic Combination (CQC)	√

4.2.3. *DIRECTIONAL COMBINATION METHOD*

Square Root of the Sum of the Square (SRSS)	√
Complete Quadratic Combination (CQC)	

4.2.4. *REDUCTION FACTOR (R)*

Due the low ductility of the material, the factor **R is taken as 1**. This means the structure must remain in the elastic range before seismic stresses.

4.3. RESULTS

4.3.1. *DEFORMATIONS*

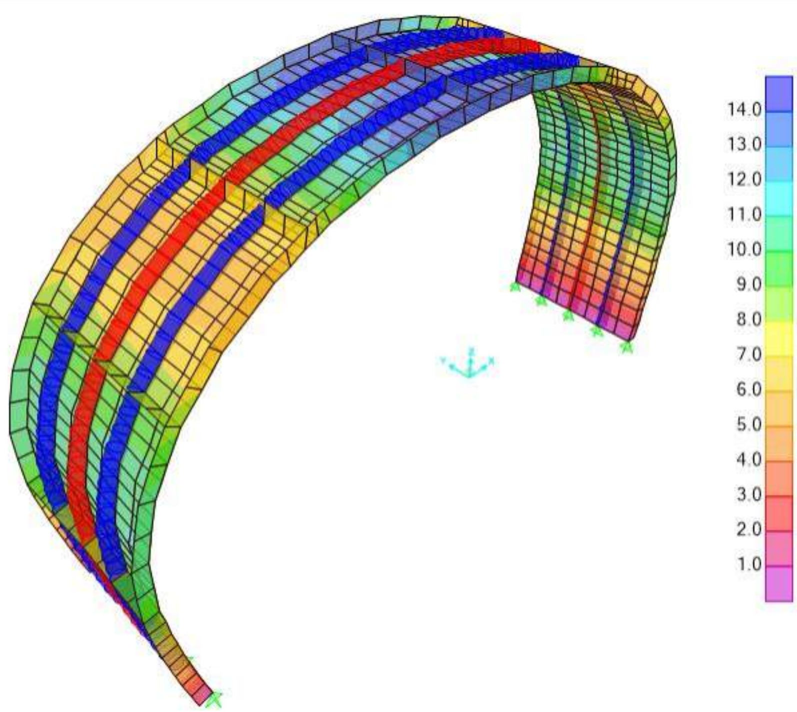


Figure 20. Deformation scheme for services loads, in millimeters.

The deformed shape of the structure due service loads is shown in Figure 20, where the maximum deformation is at the center of the roof and has a value of 14 mm.

4.3.2. MODAL INFORMATION

For dynamic modal analysis is necessary to consider so many modes of vibration until more than 90% of the mass of the structure is excited in each direction of analyses.

Number of modes required	5
Number of modes used	12

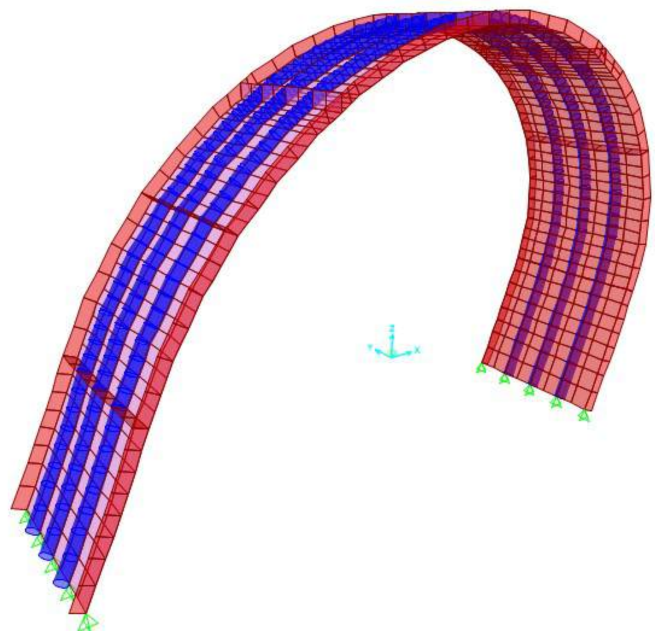


Figure 21. First modal shape; T1=0.868sec.

Mode	Period [sec]	UX	UY	SumUX	SumUY
1	0.868	86.69%	0.00%	86.69%	0.00%
2	0.600	0.00%	48.13%	86.69%	48.13%
3	0.239	0.00%	0.00%	86.69%	48.13%
4	0.220	0.00%	0.00%	86.69%	48.13%
5	0.137	0.00%	6.35%	86.69%	54.48%
6	0.124	5.99%	0.00%	92.68%	54.48%
7	0.102	0.00%	0.00%	92.68%	54.48%
8	0.087	0.00%	0.00%	92.68%	54.48%
9	0.083	0.00%	15.23%	92.68%	69.71%
10	0.082	0.00%	0.00%	92.68%	69.71%
11	0.081	0.00%	8.46%	92.68%	78.17%
12	0.075	2.70%	0.00%	95.37%	78.17%

4.4. Resistance Verification

Due the variable mechanical behavior observed in the characterization tests, the safety factor in the resistance reduction (Φ) is taken as 0.75 (usually used for fragile materials).

Flexion Resistance	=	40 MPa	(5.8 KSI)
Longitudinal Extension Resistance	=	13.5 MPa	(1.96 KSI)

The maximum stresses are compared with the limit:

$$(13.5\ MPa)x0.75 = 10.125\ MPa\ \ (1.47\ KSI)$$

The Von Misses and principal stresses are compared with the limit:

$$(40\ MPa)x0.75 = 30\ MPa\ \ (4.35\ KSI)$$

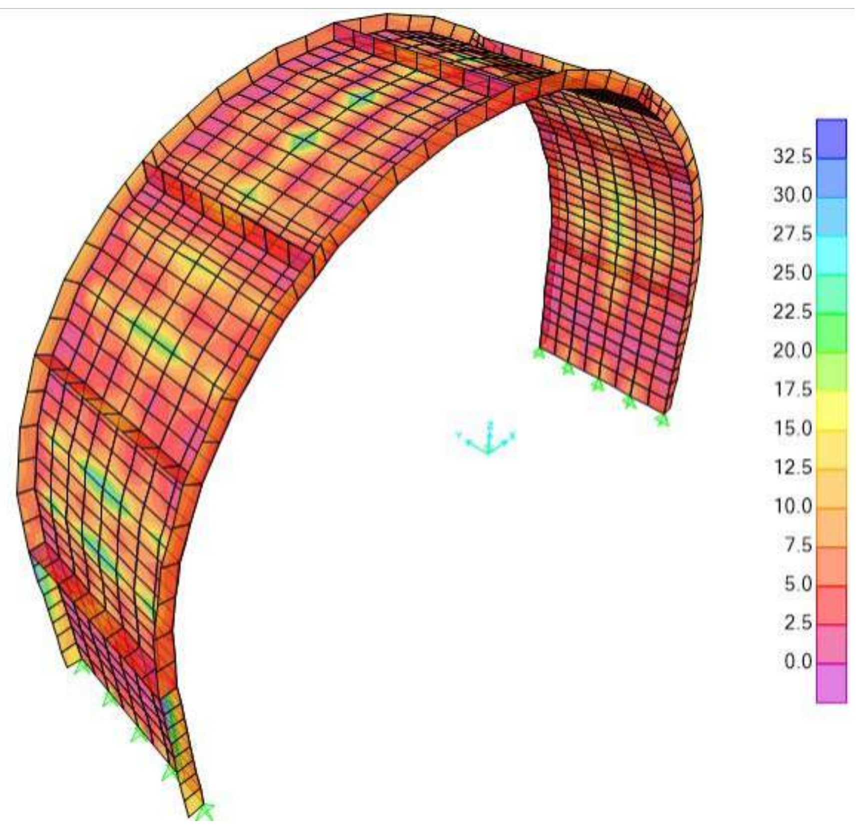


Figure 22. S11 Stress due envelope of load combinations.

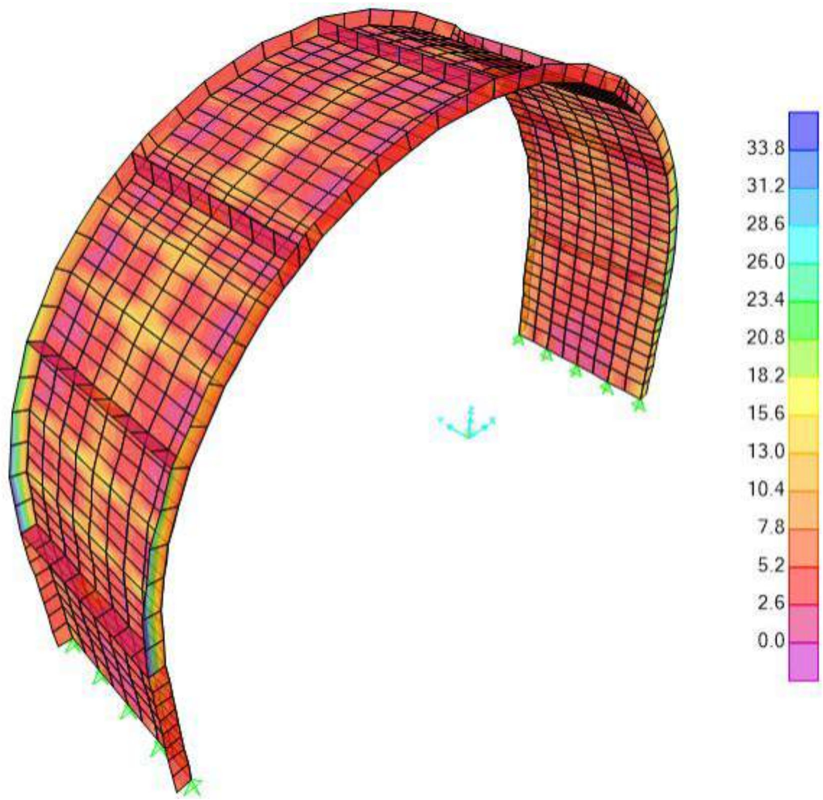


Figure 23 . S22 Stress due to envelope of load combinations .

5. CONCLUSIONS

The structure of the W.S. reinforced with a metallic duct is able to comply with the IBC requirements of Seismic Design Category D which is the requirement in the US Virgin Islands. The critical design load combination for the W.S. system is associated to wind loads, due the high requirements of this kind of load in this zone.

STRUCTURAL ENGINEER
Juan Salvador Mantilla López
Professional ID: 76202-267608 VLL
Universidad del Valle – Colombia

CHAPTER 4

4. Fire code compliance

QAI LABORATORIES
CERTIFICATION TESTING INSPECTION

8385 White Oak Avenue
Rancho Cucamonga, CA 91730
909.483.0250 ph. | 909.483.0336 fx.

CLIENT: **ACCESSIBILITY RESOURCE CENTER, INC.**
7 Tiff Ave.
Neillsville, WI 54456

Test Report No: RJ4241-1	**Date: October 20, 2015**

SAMPLE ID: The Client submitted and identified the following test material as: Firefree 88 fire resistant coating applied to the GRP shower pans at a 20mils dry thickness.

SAMPLING DETAIL: Test samples were submitted to the laboratory directly by the client. No special sampling conditions or sample preparation were observed by QAI.

DATE OF RECEIPT: Samples were received at QAI on October 1, 2015.

TESTING PERIOD: October 5, 2015.

AUTHORIZATION: Testing authorized and witness by Jon Adamek.

TEST REQUESTED: Perform standard flame spread and smoke density developed classification tests on the sample supplied by the Client in accordance with ASTM E2768-11 “Standard Test Method for Extended Duration Surface Burning Characteristics of Building Materials (30 min Tunnel Test). This method is similar to UBC No. 8-1 per Chapter 7A of the 2001 California Building Code, Ignition-Resistant Material 30 minute test

TEST RESULTS:

Flame Spread	**Smoke Developed**
5	85

Detailed test results are presented in the subsequent pages of this report

CONCLUSION: The submitted sample material **meets** the Conditions of Classification.
See Conditions of Classification on page 2.

Prepared By

Brian Ortega
Test Technician

Signed for and on behalf of
QAI Laboratories, Inc.

Greg Banasky
Senior Test Technician

WWW.QAI.ORG
info@qai.org

Conditions of Classification
13.1 The test method has the following conditions of classification for a material or product to be classified as Meeting the requirements of this standard:
13.1.1 The flame spread index shall be 25 or less as determined for the initial 10 min test period,
13.1.2 The flame front shall not progress more than 10.5 ft (3.2 m) beyond the centerline of the burners at any time during the 30 min test period. This is considered evidence of no significant progressive combustion in this test method.
Ignition-Resistant Material: Is any product which when tested in accordance with UBC Standard 8-1 for a period of 30 minutes, shall have a flame spread of not over 25 and show no evidence of progressive combustion. In addition, the flame front shall not progress more than 10 ½ feet (32000 mm) beyond the centerline of the burner at any time during the test.

E 84 TEST DATA SHEET:

CLIENT: ACCESSIBILITY RESOURCE CENTER, INC. **DATE:** 10/05/15

SAMPLE: Firefree 88 fire resistant coating applied to the GRP shower pans at a 20mils dry thickness

FLAME SPREAD:

IGNITION: 3 minutes, 39 seconds.

FLAME FRONT during the first 10 minutes: 1 foot maximum.

MAXIMUM flame Spread: 3 feet at 25 minute, 34 seconds.

TEST DURATION: 30 minutes.

CALCULATION: 5.35 x 0.515 = 2.76

SUMMARY: FLAME SPREAD: 5 **SMOKE DEVELOPED:** 85

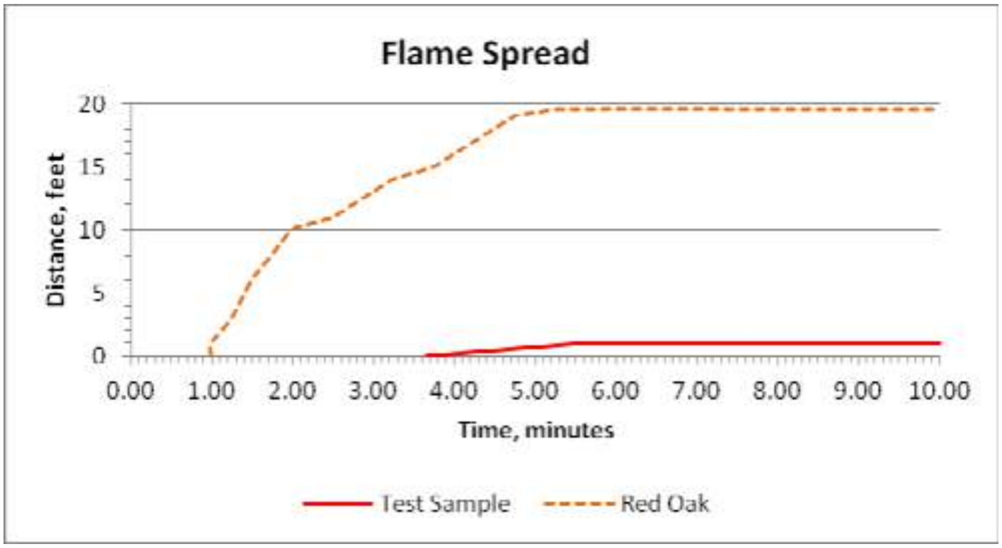
SUMMARY OF ASTM E84 RESULTS: Because of the possible variations in reproducibility, the results are adjusted to the nearest figure divisible by 5. Smoke Density values over 200 are rounded to the nearest figure divisible by 50.
In order to obtain the Flame Spread Classification, the above results should be compared to the following table:

NFPA CLASS	IBC CLASS	FLAME SPREAD	SMOKE DEVELOPED
A	A	0 through 25	Less than or equal to 450
B	B	26 through 75	Less than or equal to 450
C	C	76 through 200	Less than or equal to 450

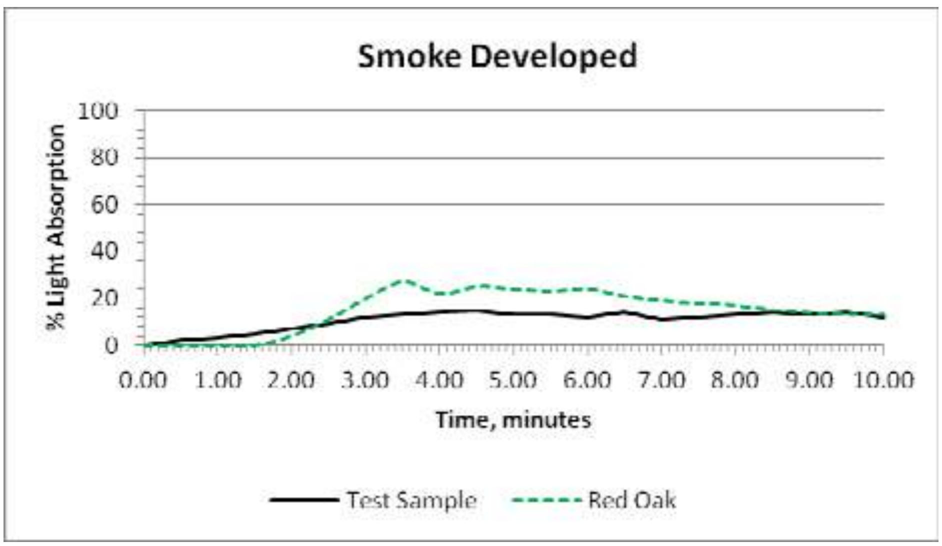
BUILDING CODES CITED:
1. National Fire Protection Association, ANSI/NFPA No. 101, "Life Safety Code".

2. International Building Code, Chapter 8, Interior Finishes, Section 803.

Ten Minute Graph



Ten Minute Graph



End of Report

SOUTHWEST RESEARCH INSTITUTE®

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CHEMISTRY AND CHEMICAL ENGINEERING DIVISION

FIRE TECHNOLOGY DEPARTMENT
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FAX (210) 522-3377

NSF-ISR
Registered to ISO 9001

STANDARD TEST METHOD FOR SURFACE BURNING CHARACTERISTICS PERFORMED IN ACCORDANCE WITH ASTM E84-18

MATERIAL ID: *CGH-1*

FINAL REPORT
Consisting of 7 Pages

SwRI® Project No.: 01.23233.18.039a
Test Date: July 26, 2018
Report Date: August 31, 2018

Prepared for:

Compass Green LLC
144 South Ave
Marietta, GA 30068

Submitted by:

Eugene F. Horton
Principal Engineering Technologist
Material Flammability Section

Approved by:

Matthew S. Blais, Ph.D.
Director
Fire Technology Department

Executive Summary

This report presents the test results for a specimen submitted by Compass Green LLC, located in Marietta, Georgia, and tested at Southwest Research Institute's (SwRI's) Fire Technology Department, located in San Antonio, Texas. The test is conducted in accordance with the procedure outlined in ASTM E84-18, *Standard Test Method for Surface Burning Characteristics of Building Materials* (NFPA 255, ANSI/UL 723 and UBC 8-1).

Material ID: *CGH-1-3*

- Flame Spread Index (FSI): 15
- Smoke Developed Index (SDI): 250

Test Criteria.

Classification	Flame Spread Index	Smoke Developed Index
A	0 – 25	0 – 450
B	26 – 75	0 – 450
C	76 – 200	0 – 450

1.0 INTRODUCTION

The purpose of this test method is to determine the relative burning behavior according to the standard ASTM E84 of materials by observing the flame spread along the specimen. Flame Spread and Smoke Developed index are reported in Appendix A. However, there is not necessarily a relationship between these two measurements.

Test specimens are conditioned as appropriate in an atmosphere maintained between 68 °F and 78 ºF and 45% to 55% relative humidity. Immediately prior to the test, the specimen is mounted in the furnace with the side to be tested facing the test flame. Cement board is placed on the unexposed side of the specimen to protect the furnace lid assembly. Sometimes, because of the nature of the material undergoing testing, additional support (e.g. wire, wire and rods, rods, and/or bars) is used to ensure that the specimen will remain in position during the test. The use of supporting materials on the underside of the test specimen may lower the Flame Spread Index from that which might be obtained if the specimen could be tested without such support, and the test results do not necessarily relate to indices obtained by testing materials without such support.

Two model building codes (2015 International Building Code®, Chapter 8 *Interior Finishes*, Section 803 *Wall and Ceiling Finishes*; NFPA 5000, Chapter 10 *Interior Finish*, Section 10.3 *Interior Wall or Ceiling Finish Testing and Classification*) classify materials based on the Flame Spread and Smoke Developed indices.

This standard should be used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions and should not be used to describe or appraise the fire-hazard or fire-risk of materials, products, or assemblies under actual fire conditions. However, results of the test may be used as elements of a fire-hazard assessment or a fire-risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard or fire risk of a particular end use.

The results apply specifically to the specimens tested, in the manner tested, and not to the entire production of these or similar materials, nor to the performance when used in combination with other materials. More detailed results with graphical illustrations may be found in Appendix A.

2.0 DESCRIPTION OF SPECIMEN

MATERIAL ID:*	*CGH-1*
DATE RECEIVED:	June 8, 2018
DESCRIPTION:*	FRP panels with gelcoat and resin. Compass panel set 1 (panels 1-3)
THICKNESS:	9 mm (nominal)
WEIGHT:	16.3 kg Nominal
COLOR:*	White
SUBSTRATE:	N/A
ADHESIVE:	N/A
SPECIMEN SIZE:	2463 × 584 mm (nominal) (3 pieces)
CONSTRUCTION:	Applied 15 mil of Fireguard E84; 3-5 mil of Forcefield Fireguard Z1; Sherwin Williams Prime (3-5 mil) and Top coat (3-5 mil).
COMPOSITION:*	Proprietary resin composition
PREPARED BY:	SwRI personnel
CONDITIONING TIME:	41 days at 73.4 °F ± 5 °F (23 °C ± 2.8 °C), 50% ± 5% humidity
SUPPORT USED:	None
WITNESSED BY:	Andrew Broeren and Bruno Cluzel

* From Client's material description and/or instructions

APPENDIX A

TEST RESULTS

(CONSISTING OF 2 PAGES)

Client: Compass Green LLC
SwRI Project No.: 01.23233.18.039a
Test Date: July 26, 2018
Material I.D.: *CGH-1*

TEST RESULTS

ROUNDED FLAME SPREAD INDEX (FSI):	15
ROUNDED SMOKE DEVELOPED INDEX (SDI):	250

TEST DATA

UNROUNDED FSI:	17.2
UNROUNDED SDI:	238.8
FS*TIME AREA (Ft*Min):	33.5
SMOKE AREA (%*Min):	271.9
FUEL AREA (ºF*Min):	4477.2

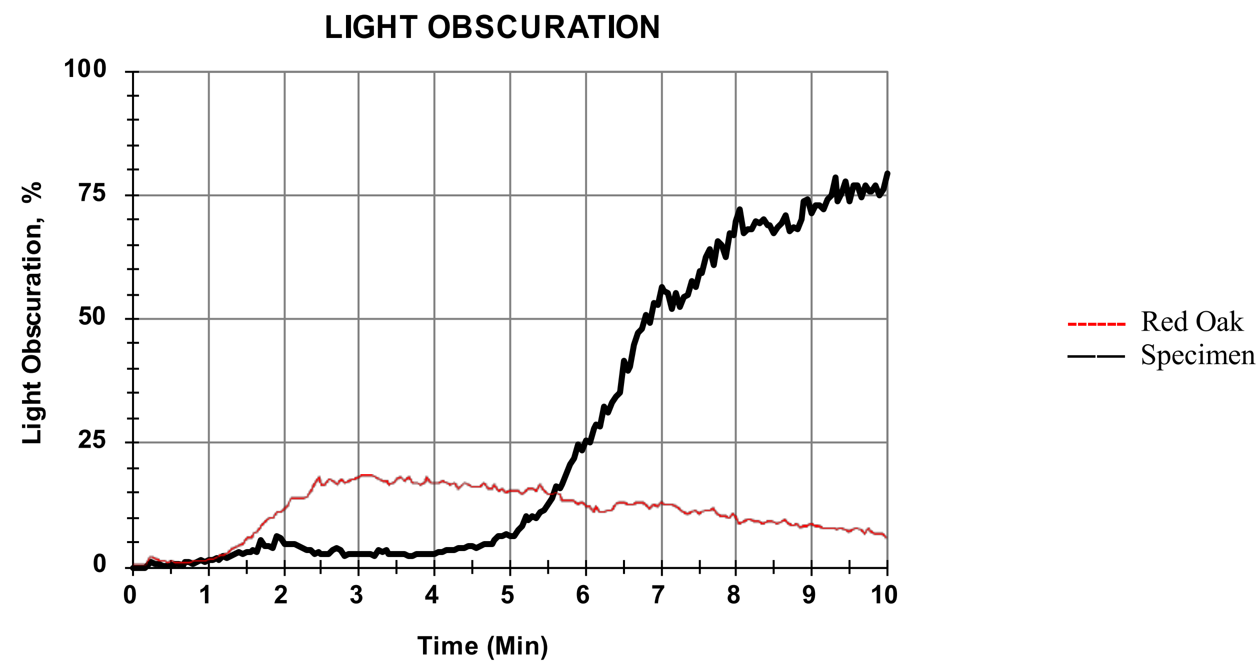
OBSERVATIONS DURING TEST

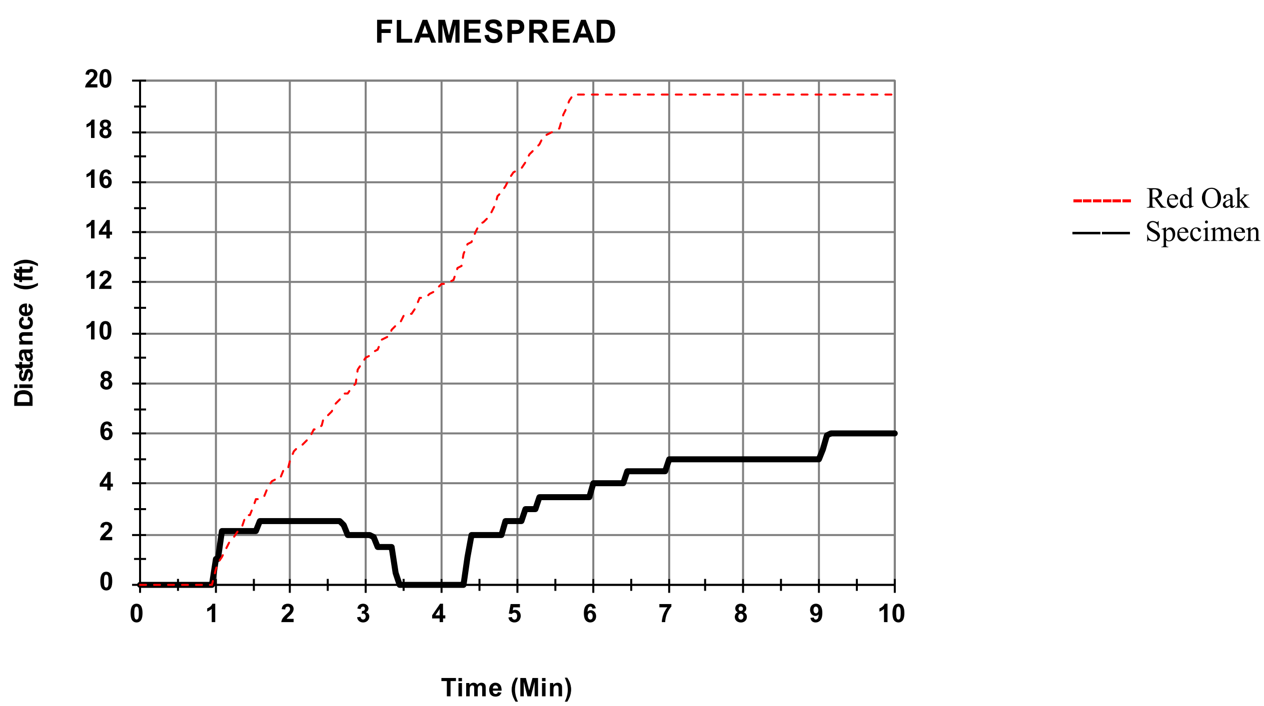
IGNITION TIME (Min: S):	00:30
MAXIMUM FLAME FRONT ADVANCE (Ft.):	6.0
TIME TO MAXIMUM ADVANCE (Min: S):	9:09
MAXIMUM TEMP. AT EXPOSED TC (ºF):	524
TIME TO MAXIMUM TEMP. (Min: S):	10:00
TOTAL FUEL BURNED (Cu. Ft.):	52.0
DRIPPING (Min: S):	None
FLAMING ON FLOOR (Min: S):	01:36
AFTERFLAME TOP (Min: S):	03:00
AFTERFLAME FLOOR (Min: S):	None
SAGGING (Min: S):	None
DELAMINATION (Min: S):	None
SHRINKAGE (Min: S):	None
FALLOUT (Min: S):	01:31

CALIBRATION DATA

RED OAK SMOKE AREA (%*Min):	111.3
RED OAK FUEL AREA (ºF*Min):	1133.2
GRC BOARD FUEL AREA (ºF*Min):	4803

Client: Compass Green LLC
SwRI Project No.: 01.23233.18.039a
Test Date: July 26, 2018
Material I.D.: *CGH-1*





CHAPTER 5

5. Waterproofing test report

5.1. Roof waterproofness using sprinkler NTE QAN -73

cecam CERÀMICA I VARIS
CENTRE D'ESTUDIS DE LA CONSTRUCCIÓ
I ANÀLISI DE MATERIALS SLU

Client:	GREEN MAGIC HOMES PRODUCTIVE SL B55021000
Job:	Prefabricated Sealed Modules
Address:	
Town:	Agullana

Job no:	C160551		C162182
Reference:	**C17X0279**	Delivery note:	16238
Your Reference:	SHOWROOM ESPAÑA		
Date received:	30/11/2016		
Test/s date: Start:	30/11/2016	End:	02/12/2016

Addressed to:

GREEN MAGIC HOMES PRODUCTIVE SL

Ctra. d'Agullana a Terrades s/n
17707 - Agullana

CECAM Celrà, 18/01/2017

TEST REPORT

SAMPLE DESCRIPTION:	Prefabricated Module 8,6x6,3 m
SAMPLING:	In Laboratory.
TYPE OF SAMPLE:	Prefabricated module made from polyester strengthened by organic matter.
CLIENT REFERENCE:	SHOWROOM ESPAÑA.
BRIEFING NOTE:	**This report corresponds to the english version of the C16XH860 file.**

Quantity	Code	Test Description
1	CU04 **	~~Roof Waterproofness using Sprinkler, according to NTE QAN-73.~~

TEST SITE: Prefabricated structure made from strengthened polyester and with an outer waterproofed asphalt layer.

OPERATIONAL PROCEDURES:	To do the test a fluctuating water sprinkler that sprays the whole test site area for a minimum of 48 is installed.

WATERPROOFING:	FEATURES	
SLOPING ROOF:	Material:	Prefabricated
WATERPROOFING OF OUTER ROOF: (data collected from the works material)	Reference:	-----
	Manufacturer:	
	Type:	Asphalt betum laminate.
	Shell:	-----
	Surface:	Not protected
SIDE WALL OF STRUCTURE: (data collected from the works material)	Reference:	-----
	Manufacturer:	-----
	Type:	-----
	Shell:	-----
	Surface:	-----

Observations:	(**) Tests are documented in the Laboratory Register under Declaration. Listings may be consulted at http://www.gencat.cat

Technical Director *Area Manager*

Pol. Industrial - C. Pirineus / 17460 CELRÀ / T 972 492 014 / F 972 494 117 / **Celrà**

Client:	GREEN MAGIC HOMES PRODUCTIVE SL B55021000
Job:	Prefabricated Sealed Modules
Address:	
Town:	Agullana

Job no:	C160551		C162182
Reference:	**C17X0279**	Delivery note:	16238
Your Reference:	SHOWROOM ESPAÑA		
Date received:	30/11/2016		
Test/s date: Start:	30/11/2016	End:	02/12/2016

Addressed to:

GREEN MAGIC HOMES PRODUCTIVE SL

Ctra. d'Agullana a Terrades s/n
17707 - Agullana

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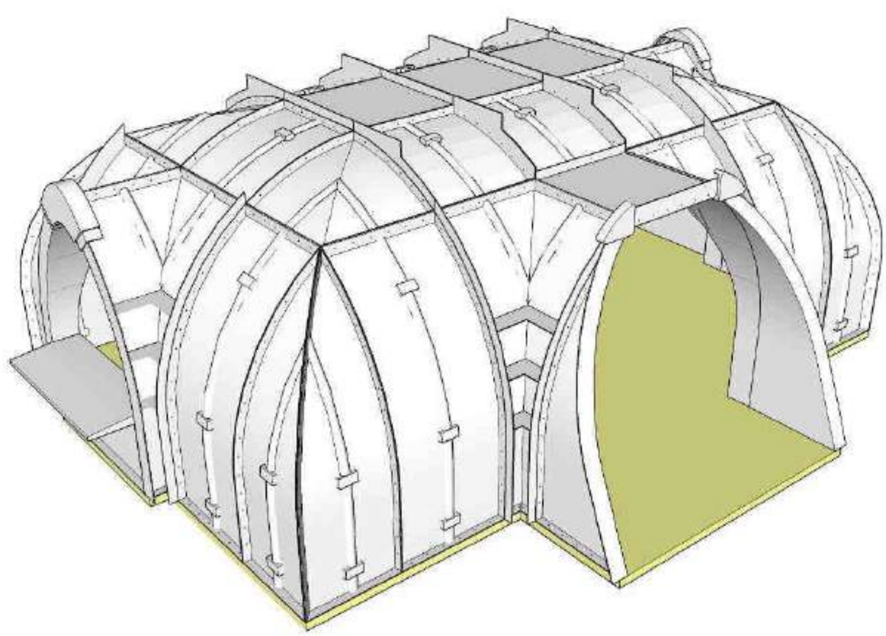
THE CONCLUDED RESULTS ONLY CORRESPOND TO THE ANALISED SAMPLE

CECAM Celrà, 18/01/2017

TEST REPORT

ENVIROMENT DATA (*):	Maximum Temperature.	16±3	ºC
	Minimum Temperature:	3±3	ºC
	Relative Humidity:	85±5	%
	Test Site:	Outside	
	Wind max.:	15±5	Km/h

(*) Source: Meteocat.



Detail of tested Structure

Observations:	(**) Tests are documented in the Laboratory Register under Declaration. Listings may be consulted at http://www.gencat.cat

Technical Director	*Area Manager*
Joaquim Petit Boyero	Maria Vidal Font

Client:	GREEN MAGIC HOMES PRODUCTIVE SL B55021000	
Job:	Prefabricated Sealed Modules	
Address:		
Town:	Agullana	

cecam
CERÀMICA I VARIS
CENTRE D'ESTUDIS DE LA CONSTRUCCIÓ
I ANÀLISI DE MATERIALS SLU

Job no:	C160551		C162182
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CECAM Celrà, 18/01/2017

TEST REPORT




Photographs of tested module.

Observations:	(**) Tests are documented in the Laboratory Register under Declaration. Listings may be consulted at http://www.gencat.cat

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Client:	GREEN MAGIC HOMES PRODUCTIVE SL B55021000
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TEST REPORT



Detail of the outer waterproofing and module's interior.

Observations:	(**) Tests are documented in the Laboratory Register under Declaration. Listings may be consulted at http://www.gencat.cat

Technical Director — Joaquim Petit Boyero

Area Manager — Maria Vidal Font

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Date received:	30/11/2016		
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TEST REPORT

Installation of sprinkler and functioning during test.

Observations:	(**) Tests are documented in the Laboratory Register under Declaration. Listings may be consulted at http://www.gencat.cat

Technical Director	*Area Manager*
Joaquim Petit Boyero	Maria Vidal Font

Client:	GREEN MAGIC HOMES PRODUCTIVE SL B55021000
Job:	Prefabricated Sealed Modules
Address:	
Town:	Agullana

CECAM CERÀMICA I VARIS
CENTRE D'ESTUDIS DE LA CONSTRUCCIÓ I ANÀLISI DE MATERIALS SLU

Job no:	C160551		C162182
Reference:	**C17X0279**	Delivery note:	16238
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TEST REPORT

TEST DATA AND OPERATIONAL PROCEDURES:

Visual inspection of the underside of the roof, sides and outer section to locate and mark the presence of humidity stains existing before the test is carried out.

Inspection Date:	30-11-2016	Inspection carried out before the test
Result:	No humidity stains nor leakages detected	

A sprinkler system was used for the test.

Start Date: 30-11-2016

After 48 hours an inspection was carried out to detect any formimg of humidity or leaks on the underside of the roof.

End Inspection Date:	02-12-2016	Total water m^3 : 33.487
Result:	No humidity stains nor leakages detected	

TEST RESULT:

The roof *automatically complies* with the service test conditions indicated in NTE QAN/73, due to the fact that no humidity stains were detected on the upper side nor on the walls of the structure.

Observations:	(**) Tests are documented in the Laboratory Register under Declaration. Listings may be consulted at http://www.gencat.cat

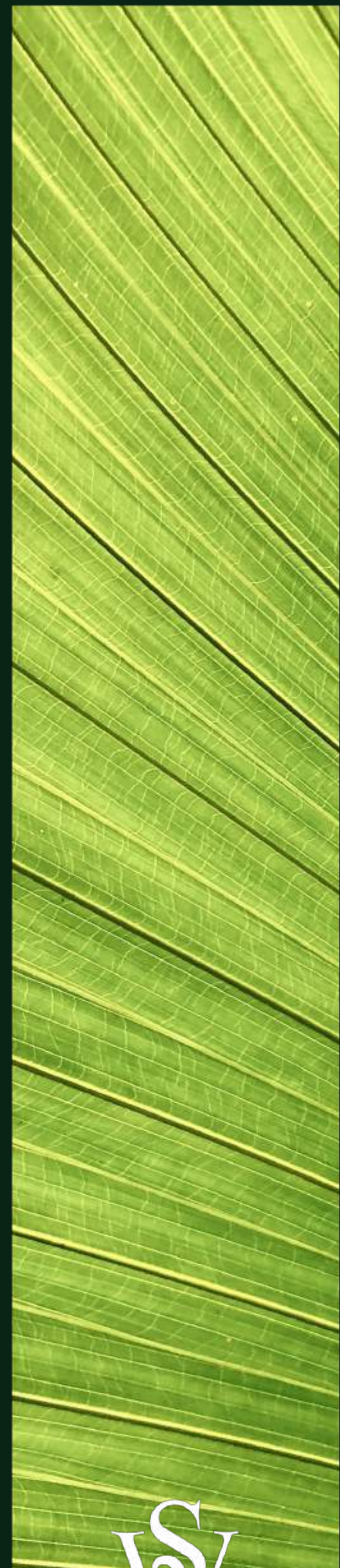
Technical Director	*Area Manager*
Joaquim Petit Boyero	Maria Vidal Font

CHAPTER 6

6. Ecological report

Ecological Report

Table of
Contents



1.0 Introduction

The world faces a particular moment in history; the Anthropocene has made many natural flow changes from human activities. If we could compress the planet's existence in a year, on September 22, life rises. On December 31 at 11:58 pm, modern humans evolve, since then the human race has made enormous changes in the atmosphere, the water in the ground. That's why the present generation has an extraordinary responsibility to consider how we relate to our environment as humankind.

The planet has faced a lot of natural disasters before, and it is tremendously resilient. Still, human impacts have changed the ecosystems since the last century. The damage is not because of the local effects but because of the large number of places where humans are present. Humanity doesn't have to make things with the objective of earth recovery, but stop using the old paradigm and create new alternatives to develop products that lead the environmental and technological change through innovation.

We are looking for alternatives to blend our lifestyle with nature better and take advantage of the resources, going back to the roots without sacrificing comfort thanks to applying advanced technology to building systems.

This document aims to be an evaluation of the environmental impacts derived from the W.S. building system. We use scientific data of the effects, performance, and use of resources distributed in inputs like energy, water, raw materials, and outputs like environmental emissions and benefits from the homes' immediate environment until the whole planet.

2.0 What is **Wonderful Structures Technology?**

Wonderful Structures TM is a building system based on structural modules prefabricated in lightweight composite materials in sizes that allow for easy transportation and manipulation at the site and make up a durable, super-strong waterproof shell. We cover the shell soil and vegetation in various forms. The system has different shape components carefully designed to generate multiple design possibilities, lighting, ventilation, and access to and connecting spaces. Its basic configuration will allow for numerous widths, with modulation in increments of 4.26 feet (1.30 meters) to generate areas of any length required following each project's needs. The structure consists of a collaboration between the robust and watertight shell working in conjunction with a system of soil berms reinforced with geotextiles and completed soil and vegetation roof. A geotextile wraps the shelves and ceiling in a geotextile mesh with an open weave through which grass or other vegetation can grow. In the long run, this vegetation will complement and replace the geotextiles' effect, stabilizing the earth with the roots' action.

The Wonderful Structures TM system requires very simple footings: A running concrete beam, which provides a basis for anchoring the modules, provides enough support in most cases. We can set the system on a concrete slab or over a conventional basement system.

*House in Puerto Morelos, Cancun, Mexico.

*Resort in Puerto Morelos, Cancun, Mexico.

3.0 Technical aspects

3.1 Geometry

The Wonderful Structures System derives a wide variety of possibilities of design from a few primary geometric forms. Its is based on a vaulted arch having uniform characteristics: straight vertical walls up to 3.93 ft (1.20 meters) high, crowned by a two-point arch that has a total height of 11.48 ft (3.50 meters) at its highest point and a full width of 19.22 ft (5.86 meters) maximum width.

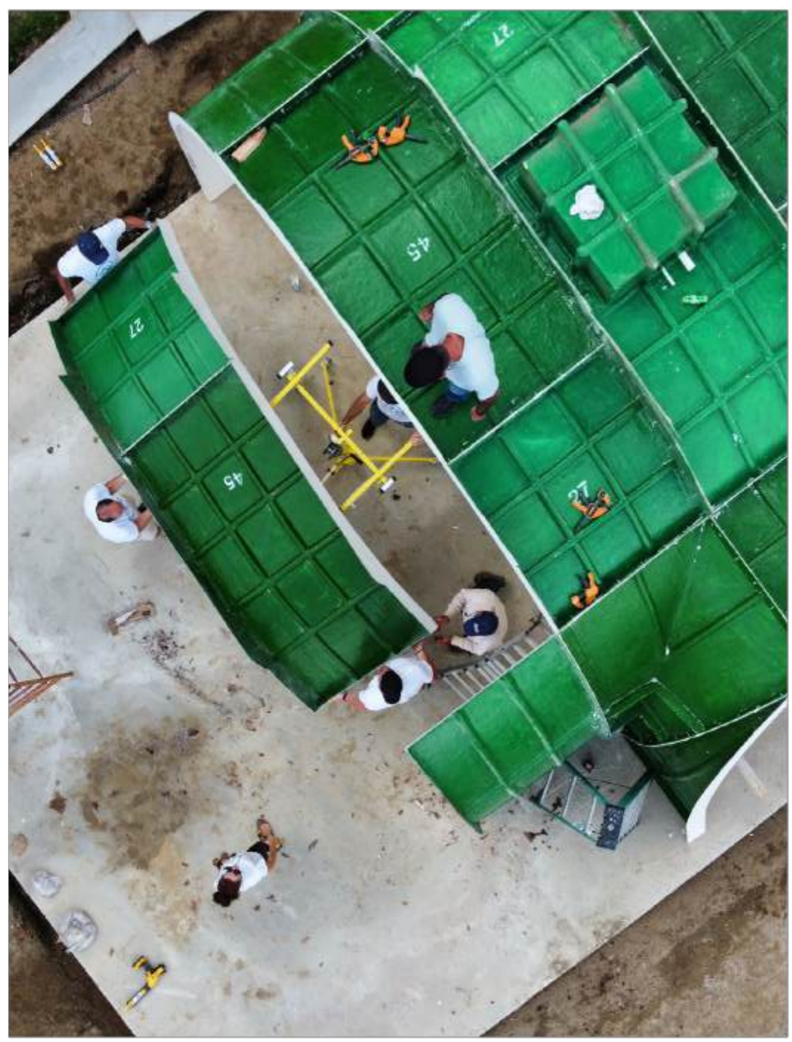
*Brewery under construction in El Valle, Panama.

*Certified Builder Training in Kuwili Lani, Hawaii.

3.2 Materials

The use of earth as a building material in adobe, rammed earth, and earth-sheltered construction is gaining renewed acceptance because of all the reasons mentioned above. In particular, the idea of covering a structure with living soil and plants, and using the thermal stability and security provided by the proximity to the ground, is very appealing. However, this type of construction has always been difficult and expensive to achieve, with questionable results. Achieving adequate ventilation and adequate waterproofing in this type of construction has never been comfortable with traditional methods. The product is often overbuilt, requiring a robust structure that does not collaborate with its surroundings. The Wonderful Structures System has addressed these problems in an entirely new way by using the age of 5 old building methods with earth in conjunction with composite materials' space-age technology. The inner shell of the buildings is stable, light, waterproof, and modular. The ground covering is constructed to collaborate structurally with the surface because of its layered construction and the system's vaulted geometry.

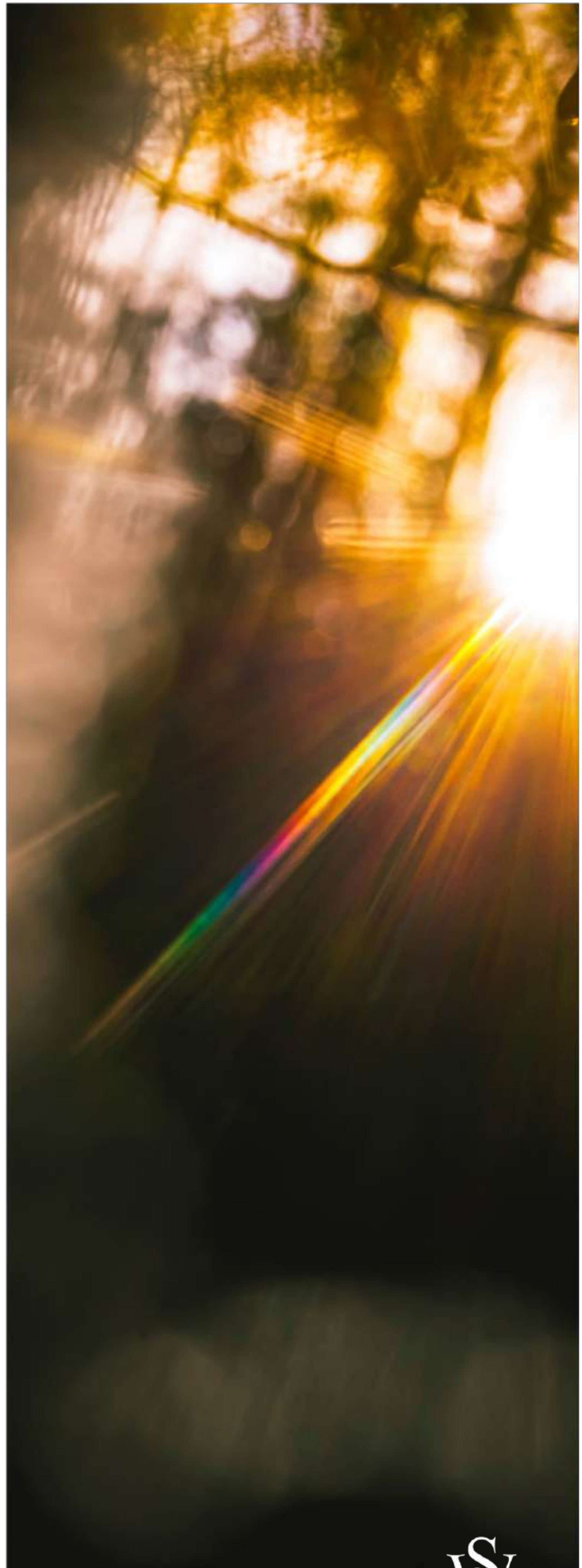
Compared to other traditional materials such as concrete, brickwork, metals, or wood, the total lifecycle assessment of fiberglass composites (FRP) contributes to its viability as a green building product. When consideration is taken for the energy consumed in production and installation, FRP composites generate a much smaller impact than other traditional materials, and they can be used in less energy or carbonintensive. The lightweight of FRP contributes to overall savings, starting with lower transportation costs. There is no need for heavy lifting equipment, and installation is faster, which results in less disruption to the environment. FRP's rigidity and structural integrity, as used in the Wonderful Structures System, means there is less dead weight, and less material is required. It eliminates unnecessary resource consumption and bringing down costs. By contrast, a similar product made of concrete could require up to 200% more material to produce than FRP and would weigh far more. The process of refining cement, from extraction to fabrication, or firing brick and terracotta in high-temperature ovens, generates a large amount of carbon dioxide and other gases. FRP has a life cycle that exceeds other building materials by remaining resistant to rust, rot, and corrosion. FRP's durability reduces the need for replacement, repair, or repainting by increasing the useful lifespan compared to other products. Its durability, low maintenance, and low heat transfer index mark it as environmentally sustainable on its own. Besides, the Wonderful Structures System is based on a lamination process that is formulated with certified green resins. Coupled with the multiple benefits provided by the organic earth covering, in terms of thermal inertia, carbon cycling and oxygen production, and airborne pollutant removal. The Wonderful Structures System has the lowest possible carbon footprint through its lifecycle and the highest sustainability of any industrialized system that we know.



*Certified Builder Training in Puerto Rico.

3.3 **Fire** Resistance

The modules of the Wonderful Structures System adhere to the International Building Code (IBC) since 1996 concerning fire resistance: SECTION 2612 FIBER REINFORCED POLYMER AND FIBERGLASS REINFORCED POLYMER 2612.6 Exterior use. Fiber-reinforced polymer or fiberglass-reinforced polymer shall be permitted to be installed on the exterior walls of buildings of any construction when such polymers meet the requirements of Section 2603.5 and are fire-blocked following Section 717. The fiber reinforced polymer or the fiberglass reinforced polymer shall be designed for uniform live loads as required in Table 1607.1 and for snow loads, wind loads, and earthquake loads as specified in Sections 1608, 1609, and 1613, respectively. 2603.5.7 Ignition. Exterior walls shall not exhibit sustained flaming were tested by NFPA 268. The material is intended to be installed in more than one thickness, and tests of the minimum and maximum thickness intended for use shall be performed. Exception: Assemblies protected on the outside with one of the following: 1. A thermal barrier complying with Section 2603.4.2. A minimum 1 inch (25 mm) thickness of concrete or mason-ry. 3. Glass-fiber-reinforced concrete panels of a minimum thickness of 3/8 inch (9.5 mm). 4. Metal-faced boards have minimum 0.019 in-ches thick (0.48 mm) aluminum or 0.016-inch-thick (0.41 mm) corrosion-resistant steel outer facings. 5. A minimum 7/8 inch (22.2 mm) thick-ness of stucco complying with Section 2510. In other words: the structural system of composite material Wonderful Structures System is effecti-vely fire blocked as installed against a fireproof substrate.



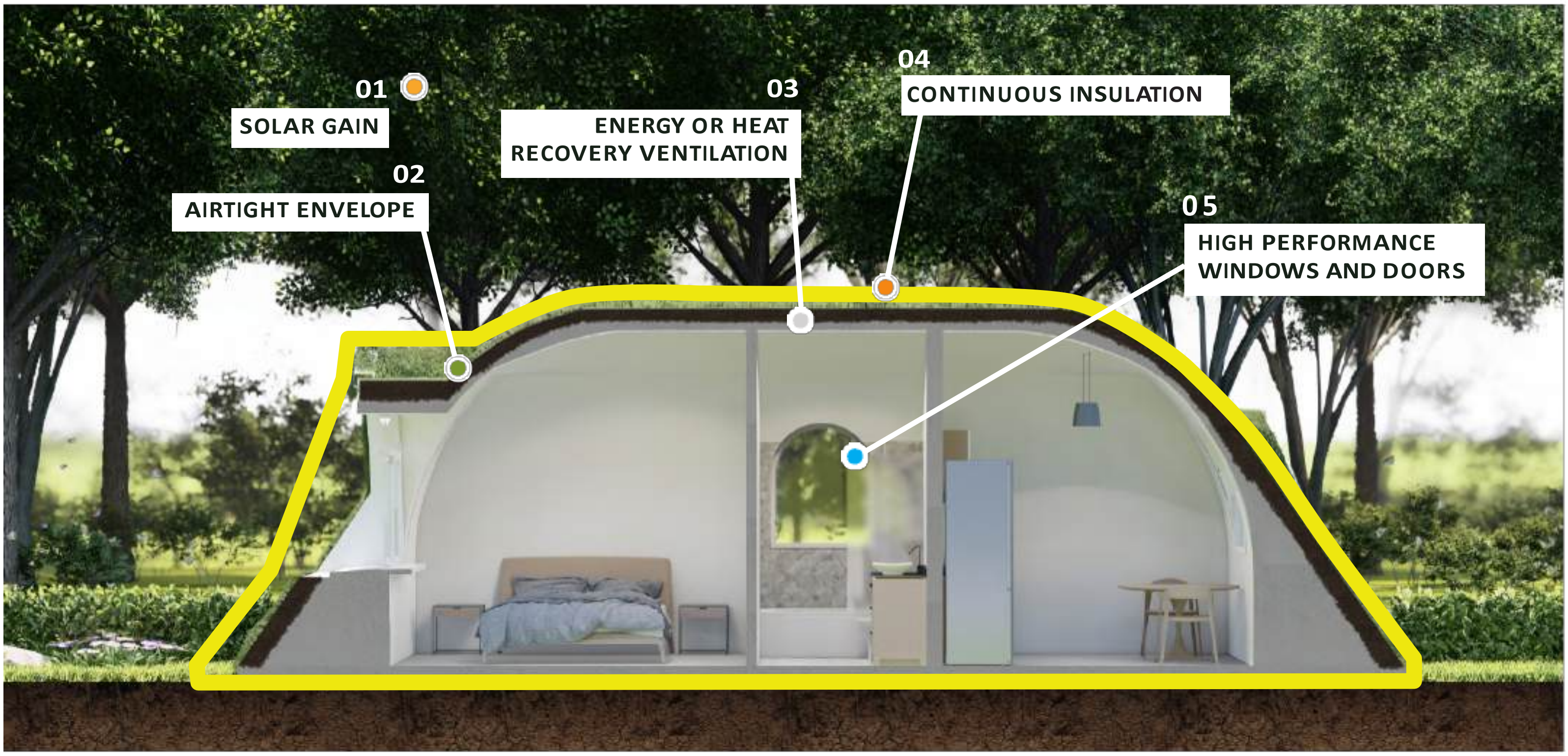
3.4 Resistance to **humidity**

The Wonderful Structures System panels are made from fully waterproof composite materials. However, over time, usually after ten to fifteen years, this material can be prone to hydrolysis or deterioration caused by moisture. This is due to fibers reinforcing the material; sometimes, they will come up to the surface of the elements and form micro-conducts through which wetness can penetrate tiny quantities. The water slides on the inside of the composite material because the moisture cannot pass inward in any case. The structures are fully covered (before applying the soil envelope) with asphalt emulsion or other bituminous type coatings. This ensures the long life of the material through time without any further maintenance.

3.5 **Seismic** resistance and **load-bearing** properties

Wonderful Structures Technology buildings are ideal for high seismic risk areas since they are one-story constructions, intimately linked to the land, and laterally confined integrated with the terrain itself and berms, which provide optimal lateral stability. We designed the system to support the top layer of soil (7.87 inches = 20 centimeters) plus 200 kg/m2 live load, which allows for the installation of lightweight structures (such as wooden pergolas), all this supported by structural studies (as well as actual tests) that ensure structural stability. We provide structural calculations and all other essential support reports for the necessary documentation to obtain building permits and approvals.

4.0 **Space-age-technology** in conjunction with **ancient methods**



The use of the earth's relatively stable temperature can provide occupant comfort at minimal energy costs. The ground moderates the temperature swings that occur daily, and it has been determined that a time lag of approximately 133 hours occurs at a two-foot depth. The time lag occurs proportionately so that an 8 or 10-foot depth has a time lag of 2100 to 2200 hours or about 90 days. A reduction of 50 to 75 percent of the average heating and cooling load requirements can be achieved due to the earth's temperature moderation and time lag. Temperature moderation effects on an earth-sheltered house with a large thermal mass are shown schematically in Figure 1.

FIG 1

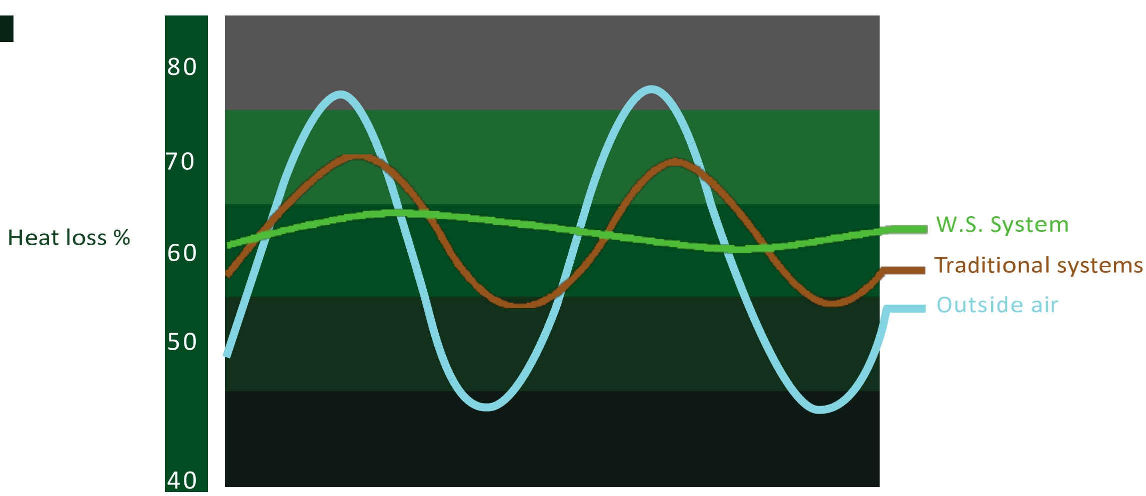


FIG 2 Effects of PAHS and passive cooling on Wonderful Structures earth-sheltered indoor space in summer.

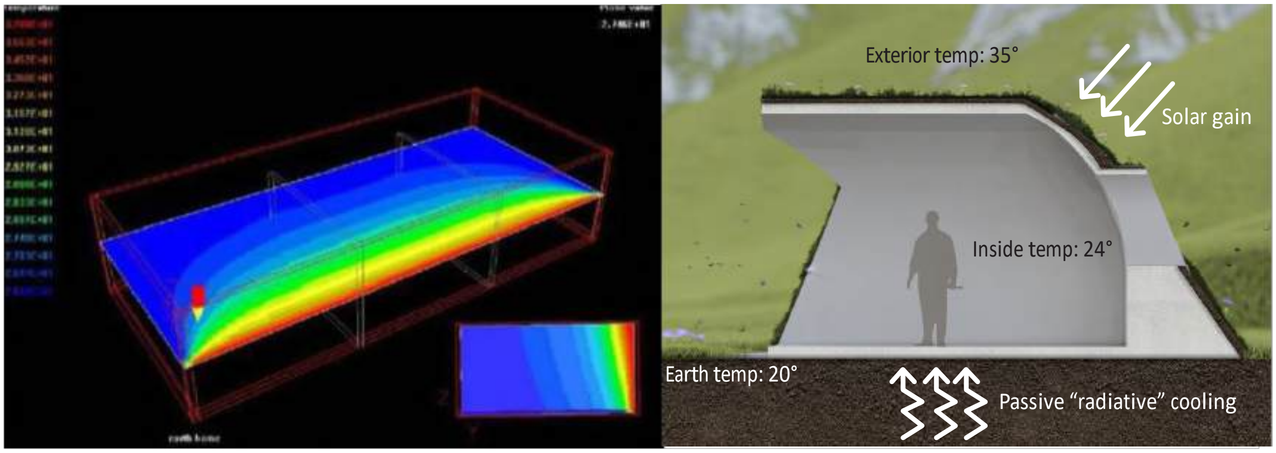
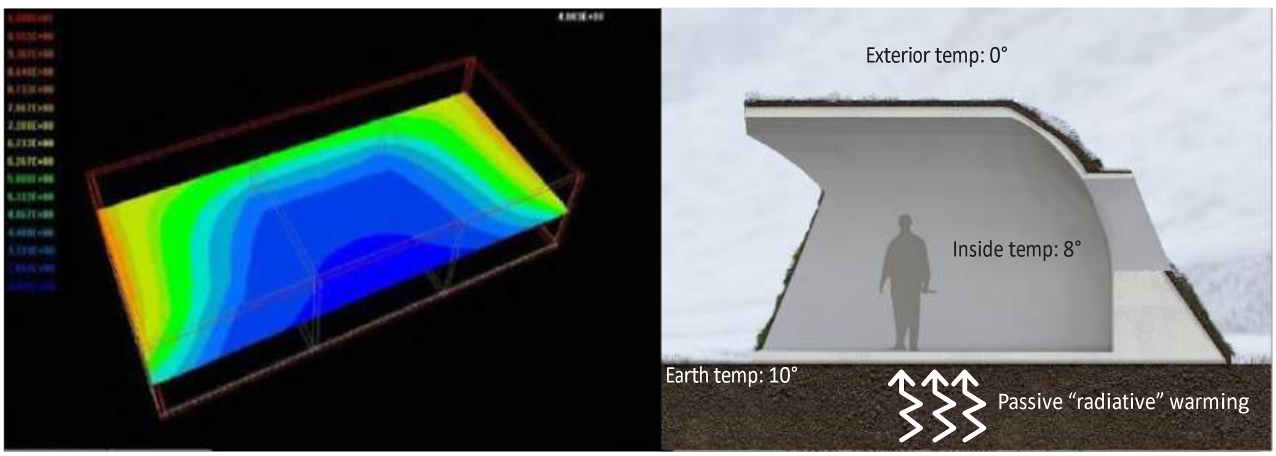


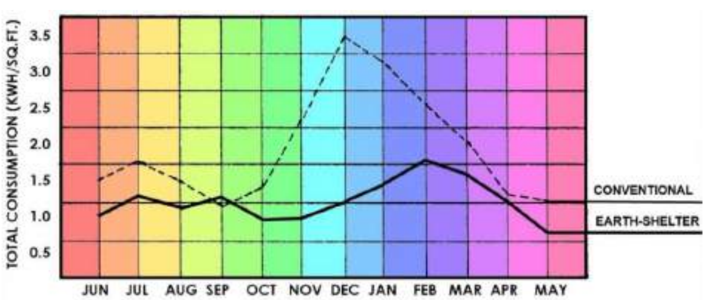
FIG 3 Effects of PAHS and passive cooling on Wonderful Structures earth-sheltered indoor space in winter.



An important question, then, is whether additional insulation is required to optimize the Wonderful Structures System’s energy performance in a seasonal environment. In general, the more insulation is added, the better the understanding in wintertime, and the poorer in summer. The figures are as follows: During the heating season, heat losses from earth-sheltered buildings are about 14%, 8%, and 5% smaller for: 1.96 inches, 3.93 inches, and 7.87 inches (5 cm, 10 cm, and 20 cm) of thermal insulation thicknesses. Increasing soil cover thickness over 19.68 inches (0,5 mt) decreases heat losses about 20 to 25%, 10 to 15%, 5% for 1.96 inches, 3.93 inches, and 7.87 inches (5 cm, 10 cm, and 20 cm) of thermal insulation. Heat gains during the heating season are about 40% higher in earth-sheltered houses than in aboveground homes. In aboveground houses, heat gains are 3% of heat losses. In earth-sheltered houses, heat gains are about 15% of heat losses during the heating season. During the cooling season, heat losses from earth-sheltered buildings are about 20 - 35% greater than from aboveground structures, while heat gains are nearly 80% lower. Every 1.96 inches (5 cm) of thermal insulation lowers the heat losses by about 20% during the summertime. In aboveground buildings, heat gains during the heating season are comparable in the range of analyzed thermal insulation thicknesses. It may be concluded that in aboveground structures, the thickness of thermal insulation does not significantly influence heat gains. In the earth-sheltered houses, heat gains are more significant with increasing thermal insulation thickness. Each 1.96 inch (5 cm) of thermal insulation increases heat gains by about 40%. In aboveground houses, heat gains are 35% of heat losses, while in earth-sheltered houses ratio of heat gains to heat losses are smaller. If heat losses are 100%, then heat gains are only 5%. This is why earth-sheltered buildings need less cooling energy.

It can be stated that the heating and cooling consumption of earth-sheltered buildings is definitively smaller than that of aboveground ones. The difference between them gets smaller with the increase of the thermal insulation thickness. Earth-sheltered buildings require more extended heating periods than conventional aboveground ones, while total heating loads are still smaller. This is due to the lower temperature of the soil surrounding earth sheltered houses. The cooling period is nearly the same. When analyzing the heating energy consumption, it can be noticed that the most considerable difference in heating consumption of an aboveground building and an earth-sheltered one is seen for 0.5 meters of soil cover.

Further increasing of the soil cover thickness doesn't produce such large differences. This relation is also smaller, with increasing thermal insulation thickness. The first 19.68 inch (0.5 mt) of soil cover reduces heating consumption by about 25 % compared to a conventional aboveground building.



4.1 Temperate climates

The temperate and seasonal environment poses the biggest challenge to any building system generally above 35 degrees North and 35 degrees South latitude. The annual temperatures can fluctuate from below freezing in the winter to very hot in summer, and living spaces must be designed for comfort in a continually changing environment. The Wonderful Structures System of earth-sheltered construction, coupled with passive solar principles, will provide energy saving solutions (as in other) environments. All facts and figures given in this section will apply to different climates, as they include the extremes of hot and cold conditions and their relationship to the built environment.
So, the thicker the thermal insulation is, the lower heating energy savings can be obtained. It may be noticed that from the heating energy load's point of view, the thicker soil cover and insulation are, both aboveground and earth-sheltered buildings naturally consume less heating energy. With increasing thermal insulation thickness, soil's influence gets smaller, which causes insignificant differences between aboveground and earth-sheltered structures for large insulation thickness. For cooling loads, the soil cover thickness does not have a significant influence. Thus the thinner the thermal insulation is, the greater the cooling energy savings are than the aboveground ones. This is because thermal insulation acts as a coat. It protects a building from colder outside soil temperatures during wintertime, but it does not allow the soil to cool a building down naturally during summer.

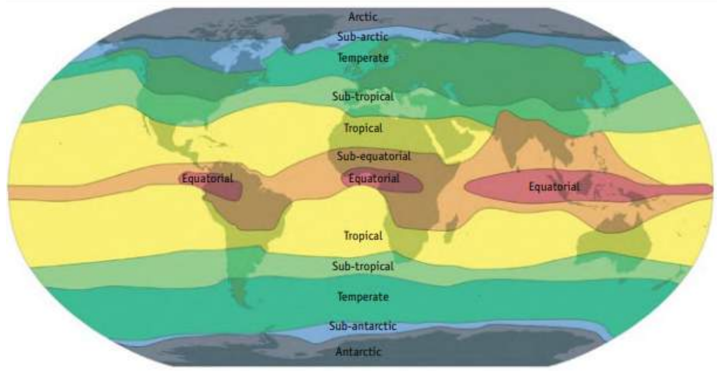
*W.S. House in Norway.

4.2 Subtropical climates

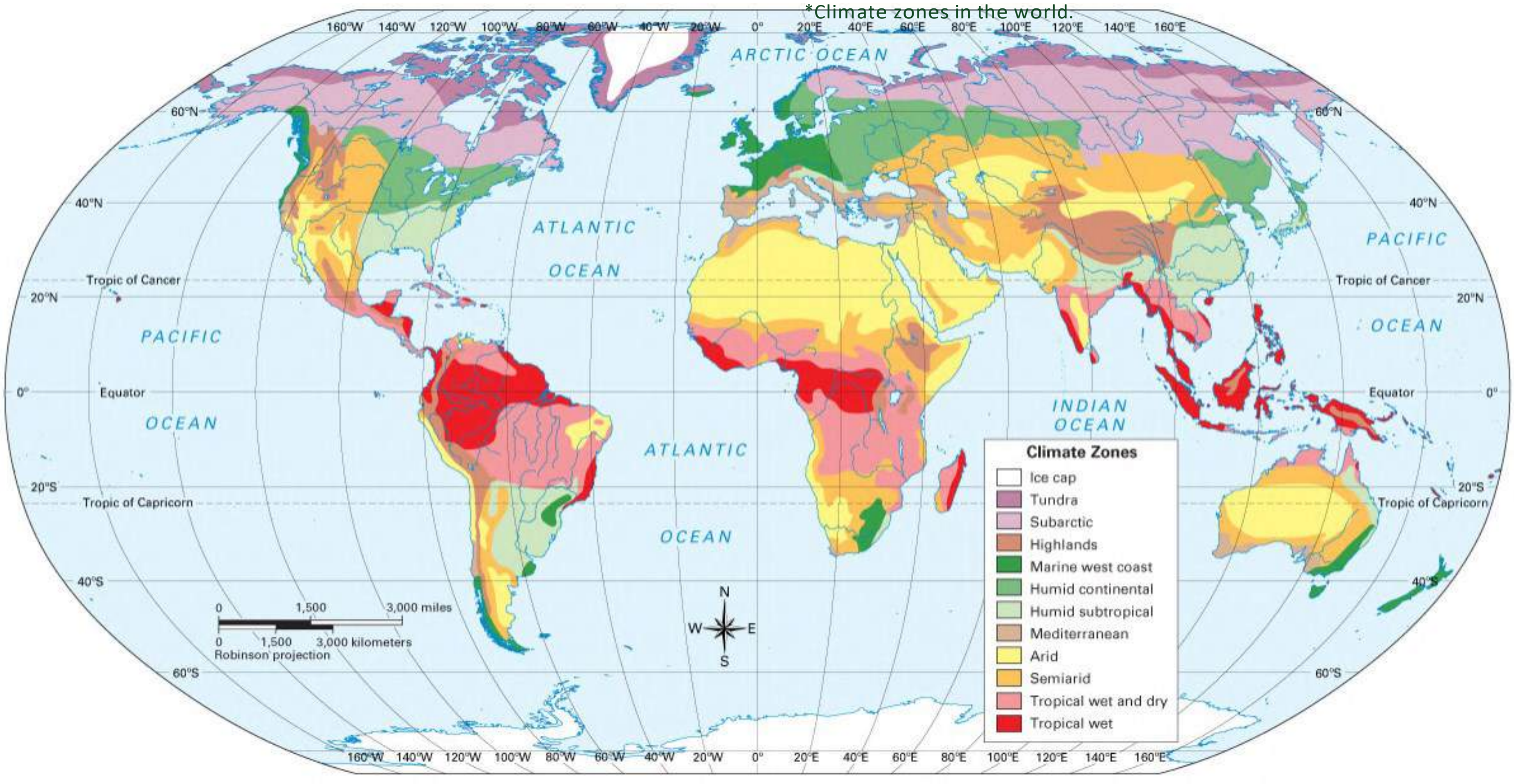
The interest in earth's use to save energy dates back to over 5000 years ago, these cultures built under the ground the whole towns. Examples are: the town of Matmata in Tunisia, the Goreme Valley in Turkey, and the Henan Province in Shanxi (China). All the ancient underground structures are located in hot countries, such as Turkey, Tunisia, or northern China, which means that earth was initially used instead for cooling than heating. This is highly significant if one considers the fact that over one-third of the continents (about 4.7 million km2) is situated in hot-dry climate (i.e., between 15° and 35° respectively north and south of the equator) and only 12% of the continents are situated in the temperate climates (about 1.55 million km2). Considering other climatic conditions, one can say that half of the continents are located in hot climates. Thus the use of earth as the building's cooling component is of major significance, particularly considering that 15% of the world population inhabits desert and semi-arid areas.

The Wonderful Structures System is genuinely ideal in these conditions. The low humidity, high temperatures in summer with little cloudiness, and moderate temperatures in winter make the Wonderful Structures System worthy of serious consideration on a large scale.

Heat losses from earth-sheltered buildings are about 20 to 35% greater than from aboveground structures, while heat gains are nearly 80% lower.



*Climate zones in the world.

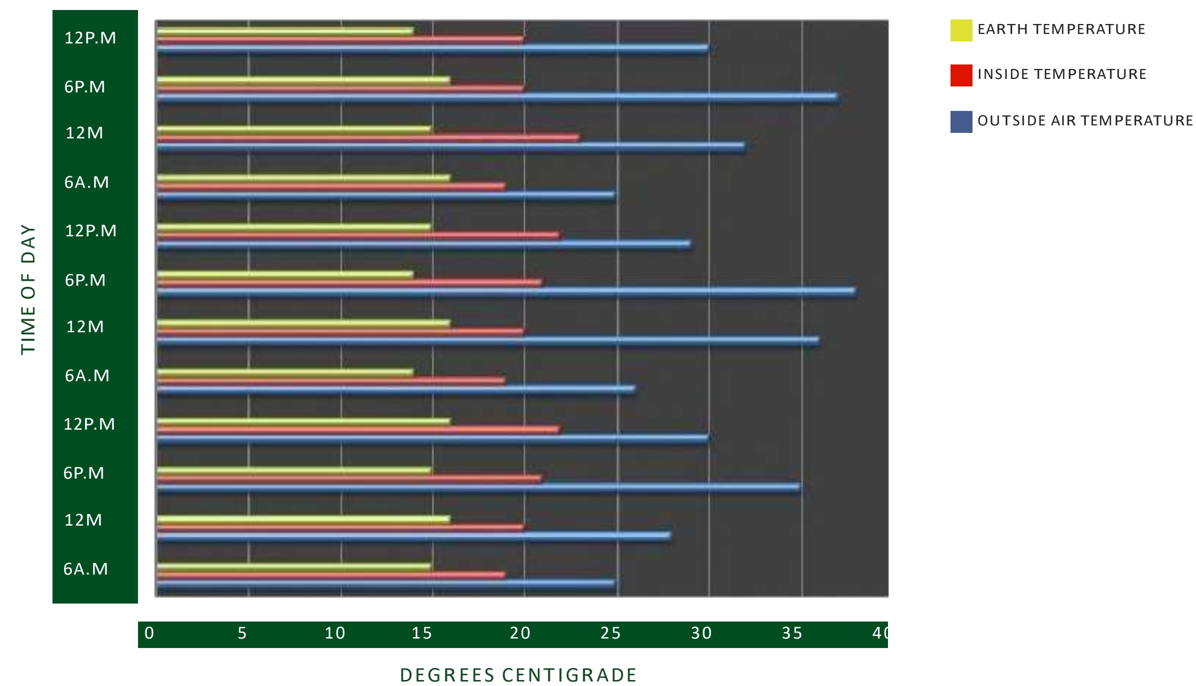


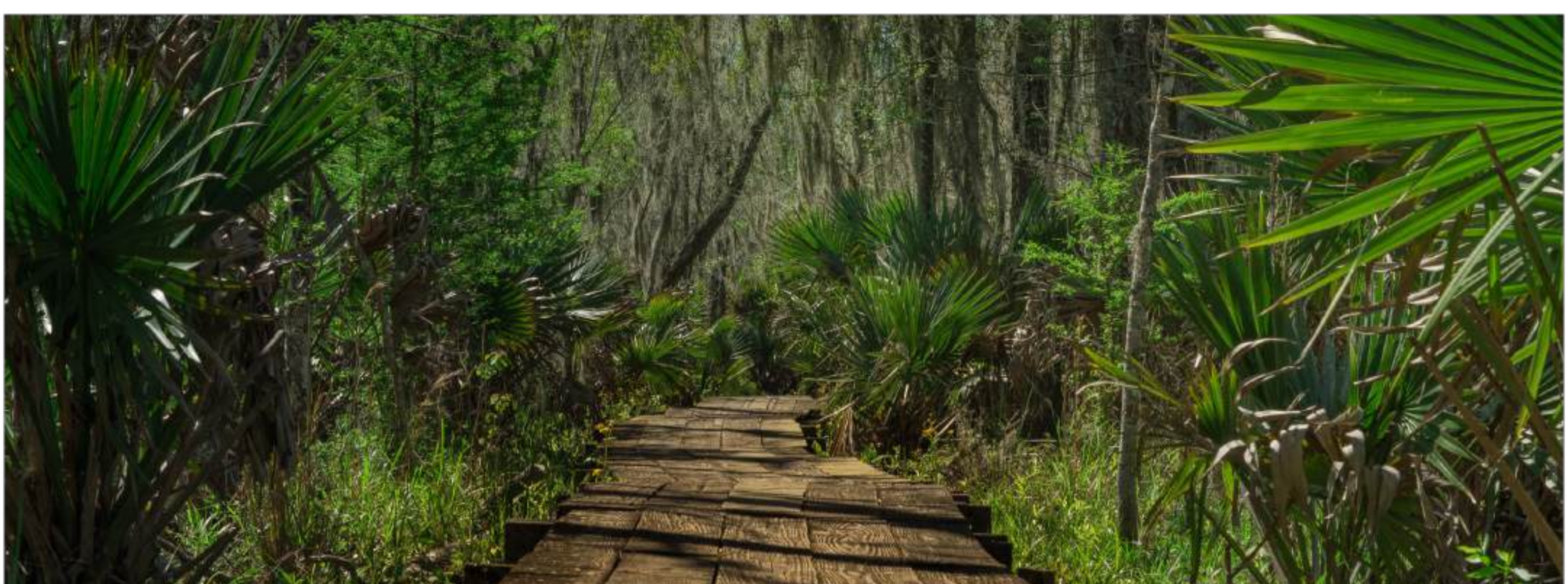
4.3 Tropical climates

In tropical regions (roughly from 15 degrees north to 15 degrees south), temperatures are more or less unchanging throughout the year, as the weather conditions are governed mainly by location and altitude. In Humid environments, an important issue that has to be taken into account with the Wonderful Structures System (as in any other building system) is the judicious placement of windows and skylights to ensure adequate ventilation of interior spaces.

In scorching and humid areas, the most critical factor in naturally achieving a comfortable inside temperature is ventilation, as heat is usually carried by air and does not depend only on the sun's effect. However, in these areas, even the smallest air conditioning system's efficiency will outperform any conventional building, as it will be aided by the heat loss caused by the surrounding earth.

WONDERFUL STRUCTURES SYSTEM OBSERVED DAILY FLUCTIATION IN TROPICAL ZONE





5.0 Use

W.S. evaluates some aspects and gives recommendations about the best way to maximize the Wonderful Structures system's benefits, aiming to extend the lifespan and provide advantages, enjoyment, and satisfaction when installed on the location.

5.1 Green Roofs

An extensive green roof is an entirely natural form of roof covering that uses a low maintenance planting scheme, consisting of hardy, drought-resistant plants. The plants used in the system must be self-regenerating and predominantly short growing. It should also be densely planted and exhibit a high degree of adaptability to survive in relatively extreme climatic conditions (drought, sun, wind, etc.). Ideally, when choosing the plants, regional variations, and local climatic conditions must be considered.

The plants selected should require minimal moisture and demand little from the substrate in the way of nutrients. An extensive green roof is chosen primarily for aesthetic and ecological reasons and, as such, is not designed to be walked upon, except for occasional maintenance and control purposes. Since the types of plants used to make comparatively modest demands on the layer configuration, the overall weight, the composition depth, and the loading of the extensive green roof is relatively small.

*W.S. House in Norway.

5.2 **Orientation** according to the **sun location**

According to the season, the sun's angle of incidence directly affects the performance of the dwellings. Wonderful Structures recommend orient houses looking at the sun's path in each hemisphere, especially during the summer and winter. During these stages, the sunlight is perpendicular or parallel to the ground.

It looks to optimize the daylight use providing breadth, depth, and visual comfort to the residents. It also helps regulate the temperature and take advantage of the clearness by reaching savings of over 70% in light resources.

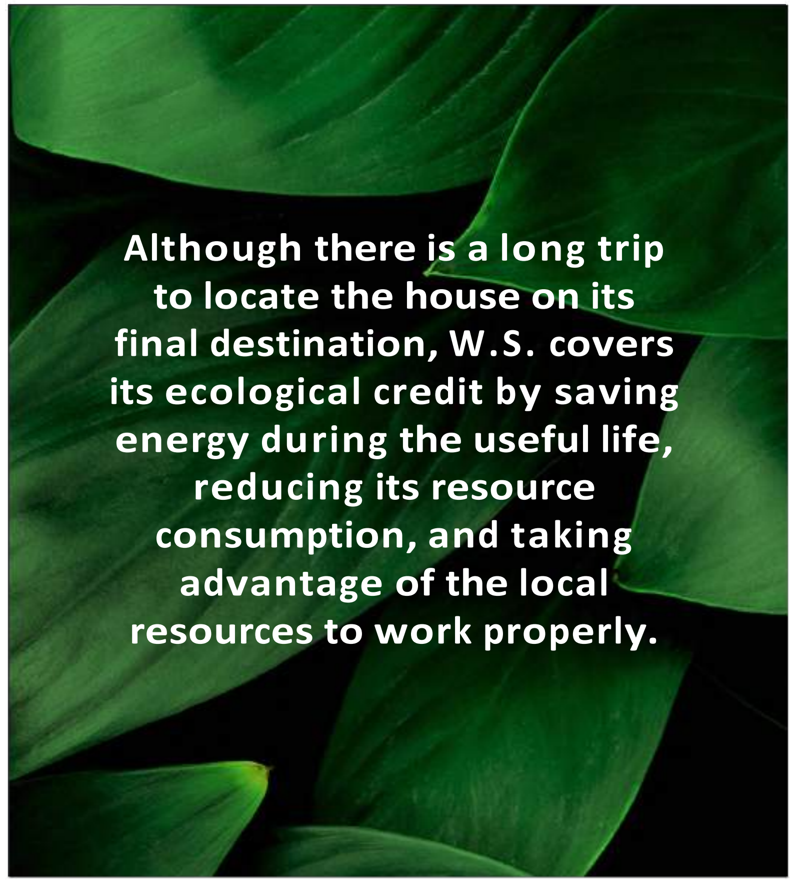
* W.S. Ecoshell built on the edge of a rock quarry in the Appalachian Mountains of Tennessee Johnson City, USA.

6.0 Use

6.1 Reduce impact on site

Nature without humans has its flow. When human settlements occur, there is a permanent ecological disturbance in the ecosystem that affects the environment's normal processes, causing imbalances and undesirable future changes. That is why the less this equilibrium is perturbated, the faster the dwelling becomes part of the ecosystem. That is one of the main objectives of W.S.; to connect with nature by blending with it in a respectful relationship. W.S. system has many ecological benefits like allowing the free transit of the species around the area, reducing the competition for space and resources, favoring ecological succession for first and small species, and giving a favorable habitat for endemic species.

It also brings enormous benefits for the residents like allowing continuous transit from the indoor to the outdoor, crossing from a comfortable space to the natural environment in only one step. We can see this in reducing symptoms associated with the fast lifestyle of nowadays, increasing wellbeing.



6.2 Modular design

This system allows a significant number of possibilities of sizes and distributions with a moderate amount of pieces. Some advantages are being highly flexible and customizable according to the specific purposes or adapting to the terrain.

W.S. system has a very long term life and durability through adequate maintenance, but, like any other product, it has end of life; thanks to modularity, it can be separated into pieces for its right final disposition.

The modular system reduces material at the construction site by 60% and can reduce building time up to 80% compared to traditional construction. Thanks to high-tech composites, there is no need for heavy lifting equipment to build up the homes, which gives advantages in construction speed.

Those modules result from in-depth investigations to archive structural and morphological optimization with high-performance materials

6.3 **Reduction** of transportation resources

During the transport, the resources expended include the fossil fuels to transport the vehicle and int increases with the distance traveled and cargo's weight. Being modular and made by lightweight composites, The transportation the fossil fuel used to transport the cargo is reduced because fewer trucks needed because 60% less material required than the traditional construction systems W.S. doesn't have massive distribution centers but is carried by demand; this traduces fewer distribution paths, fewer contaminant emissions, less spare parts, and chemicals derived from the vehicles' repairs and maintenance.

Some locations are remote and are challenging to build there. W.S. systems are perfect for this intention because heavy lifting equipment is not needed to be transported until that location. It saves many resources (money and fossil fuel); besides that, it is unnecessary to transport heavy materials, just very lightweight composites. Reduction in the transport of material because local materials such as soil are used.

*Modular components packed in a container.

*Hawaii, Kuwili Lani, Oct 2021.

7.0 CONCLUSIONS AND ACKNOWLEDGEMENTS

There is a growing body of evidence that visual and physical contact with the natural world provides a range of benefits to people. These include both mental benefits such as reducing stress and physical benefits, including cleaner air. Access to green space can bring about direct reductions in a person's heart rate and blood pressure and help general wellbeing. A Texan study of post-surgery recovery in hospitals demonstrated that recovery was quicker and less chance of relapse if patients could look out onto green space. Several American hospitals have subsequently been redesigned to bring these benefits to patients.

The adverse effects of 21st-century life can be reduced in many ways by earth-sheltered, green construction. Sound insulation of a 7.87 inch = 20 cm thick earth wall or a roof with vegetation is in the neighborhood of 63 decibels, virtually sound-proofing interior spaces. The increased production of oxygen, reduction of many types of pollution, added to the decrease in energy waste are irrefutable arguments for the cause of earth-sheltered construction. We can envision a world where human presence is once again hidden, and man's negative footprint on the planet's surface is reduced. The many arguments for the sustainability of earth-sheltered housing cannot be denied, and the Wondefrful Structures System will solve many of the impediments to achieving this goal.

8.0 REFERENCES

It contains observations and measurements performed by Wonderful Structures. Still, it is primarily a compendium and summary of respected scientists and professionals in biology, Earth Sciences, Architecture, etc. The sources we have used are listed here, not necessarily in the order, they are referred to.

Rekki L. Helms, PASSIVE SOLAR CONTRIBUTION TO EARTH SHELTER PERFORMANCE, Thesis, 1979.

Al-Temeemi A.A., Harris D.J: A guideline for assessing the suitability of earth-sheltered mass-housing in hot-arid climates, Energy and Buildings, Vol. 36, 2004.

Ickiewicz I.: Heat conduction in building soils (in Polish), Ph.D. Thesis, Białystok Polytechnic, Białystok, 1988. Jacovides C.P., Mihalakakou G., Santamouris M., Lewis J.O.: On the ground temperature profile for passive cooling applications in buildings, Solar Energy, Vol. 3, 1996.

Janssen H.: The influence of soil moisture transfer on building heat loss via the ground, Ph.D. Thesis, Katholieke Universiteit Leuven, Belgium, 2002.

Jędrzejuk H., Marks W.: Optimization of shape and functional structure of buildings and heat source utilization. Partial problems solution, Building, and Environment, Vol. 37, 2002.

Nowak H.: External interaction of environmental thermal radiation on the building (in Polish), Scientific Papers of the Institute of Building Engineering at Wrocław University of Technology, WUT Publishing House, Wrocław, 1999.

Nowak H.: Modeling of the longwave radiation incident upon a building, Archives of Civil Engineering, XLVII, Vol. 2, 2001. PN-ENISO:13370, Thermal performance of buildings – Heat transfer via ground – calculation methods (in Polish).

Sodha M.S.: Short communication: Simulation of dynamic heat transfer between ground and underground structures, International Journal of Energy Research, Vol. 25, 2001.

Staniec M., Nowak H.: Buildings partly or completely sunk in ground, as alternative to conventional aboveground buildings (in Polish), Xth Polish Scientific-Technical Conference on Physics of Buildings in Theory and Practice, Łódź, 2005.

Staniec M., Włodarczyk D., Nowak Ł.: Examples of earth-sheltered buildings in Great Britain (in Polish), Renewable Energy. Innovative ideas and technologies for construction, scientific Papers of Rzeszów Polytechnic, Rzeszów Polytechnic Publishing House, Solina, 2006, pp. 465–476.

Staniszewski B.: Heat exchange. Theoretical basis (in Polish), 2nd Edition, Państwowe Wydawnictwo Naukowe, Warsaw, 1980.

Thompson R.D.: Man's Impact on Climate with particular reference to energy balance changes at the earth's surface, Recourses and Planning, Pergamon Press, 1979.

Xianting L., Zhen Y., Bin Z., Ying L.: Numerical analysis of outdoor thermal environment around buildings, Building and Environment, Vol. 40, 2005.

Staniec M.: Analysis of the influence of earth-sheltering on the building's energy balance (in Polish), PhD Thesis, Series PRE No. 01/09, Wrocław University of Technology, 2009.

Jun Yang a,c,*, Qian Yu b, Peng Gong c Quantifying air pollution removal by green roofs in Chicago. Shapira, H. B., Cost and Eriergy Comparison Study of Above- and Below-Ground Lkuellings, Oak Ridge National Laboratory report, ORNL/CON-91.

Feisel, L. D., EcorLornic and Design Considerations f i an Underground House, South Dakota School of Mines and Technology, December 1979.

Goldberg, L. F. and C . A. Lane, A Preliminary Experimental Energy Performance Assessment of Five Houses in the MHFA Earth sheltered Housing Demonstration Pro-Turn, University of Minnesota, Minneapolis, 1981.

Eoyer, L. L. and W. T. Grondzik, Habitability and Energy Performance of Earth- Sheltered Dwelliwgs, Oklahoma State University, Stillwater, December 1980.

Lewis, D. and W. Fuller, Solar Age, (December 1979). Shureliff, W. A., Superinsdated Houses and DoubleEnvelope Houses, A Shureliff, W. A., Superinsdated Houses and Double-Envelope Houses, A Preliminary Surveg of Principles and Practice, 2nd Ed., available from author, 19 Appleton Street, Cambridge, Mass., April 1980.

Lahs, K., Regional Analysis of Ground and Aboveground Climate, Undercurrent Design Research, New Haven, Conn., 1981.

Carmody J, Sterling R, (1984) Design considerations for underground buildings, Underground Space 8: 352-362.

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