Engineered Structures

Technical Report

Hemo Gorge Sculpture

Design Basis Report

GU6706-6001 B

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Issue and Amendments

ISSUE	AMENDMENTS	DATE	APPROVED	INITIAL
A	Preliminary issue for review	25/01/2018	Thomas Basset	T.B.
B	Included cases for IL = 2. Wind pressures updated. Earthquake cases added. Support details updated.	12/07/2018	Thomas Basset	T.B.

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Summary

Kilwell Fibretube is to build a composite sculpture for installation as the centre artwork in the recently completed Hemo Gorge traffic roundabout at the southern entrance to Rotorua, New Zealand.

The sculpture consists of a series of concentric spiral forms constructed from braided carbon fibre and e-glass reinforcements over a 3d printed non-structural former.

The sculpture will be submitted for building consent and requires a PS1 certificate.

The present report summarises the approach to material factors, loads and load combinations, and composite failure modes.

In particular, this report is aimed at covering the requirements of the loads and load combinations as per AS/NZS 1170 New Zealand Structural Design Actions.

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1. Introduction

The spiral sculpture shown in Figure 1 has been selected as the centrepiece for a new roundabout at the Hemo Gorge intersection in Rotorua. The sculpture is 12.0m tall and consists of multiple interconnected spiral tubes. The tubes are separated into inner and outer sets, with internal diameters of 100 and 150mm respectively. Adjacent tubes are supported via small chevron shaped plates interspersed along their length. Four decorative/carved panels will be attached in the openings between the tubes as shown below.

The tubes will be constructed using woven e-glass and carbon sock, over a male former.

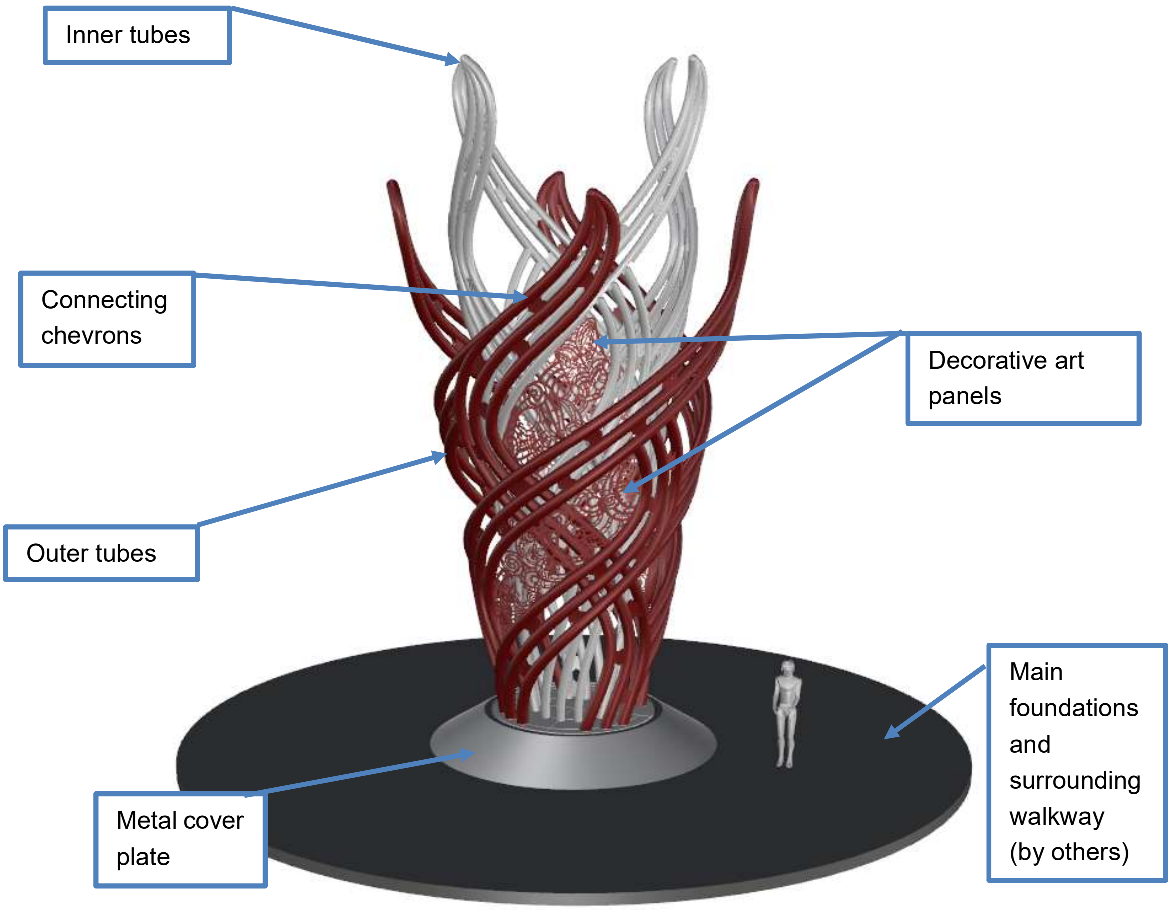


Figure 1. Sculpture general arrangement

Kilwell Fibretube Ltd will construct the sculpture in pieces at their Rotorua factory then assemble it outside the factory, before transporting it (still assembled) to the site.

Foundations for the sculpture have been designed by the projects civil engineers OPUS.

The environmental loads are sourced from the building code in force in New Zealand, AS/NZS 1170. These are described in further detail in 6.4 & 6.6. In addition to these transport and assembly load cases are included.

Material properties and usage factors will be reviewed using Eurocomp Design Code and Handbook – Structural Design of Polymer Composites as relevant to the materials and process used. These are outlined in 8.

Non-structural requirements that affect the design are listed in 10.

This document will serve as a reference throughout the design phase and may be updated periodically to reflect changes to the assumptions.

2. Previous work

Initially the sculpture was to be manufactured from stainless steel pipe sections. Structural calculations were completed by engineers from OPUS. Due to manufacturing constraints this design was not able to be produced and the current composite option was proposed in place.

Key section properties of the stainless tube design from OPUS have been included below for reference.

Material: 316L grade stainless steel

Inner Spiral: 90mm NB schedule 40 pipe. (OD = 101.6mm, t = 5.74mm)

Outer Spiral: 125mm NB schedule 40 pipe. (OD= 141.3, t = 6.55mm)

Chevrons: 8mm plate

3. Material palette and manufacturing process

3.1 Process

The intention is to manufacture the sculpture tubes using a vacuum infusion process over a 3D printed male former.

Kilwell Fibretube Ltd have proposed an epoxy resin system, ADR270, be used and cured at ambient temperature. (Post curing is being investigated by Kilwell, but is not in place at this stage.) Care should be taken to ensure that the ultimate HDT is suitable. Refer 10.1.

Devising an infusion strategy is the responsibility of Kilwell Fibretube Ltd.

3.2 Fibre reinforcement

Kilwell Fibretube Ltd have proposed an initial laminate for the spiral tubes and this will be used as a starting point for the analysis. The laminate consists of carbon fibre and e-glass woven sock that will be pulled over the spirals. Should additional stiffness be required unidirectional carbon plies can be added to the laminate.

STYLE	DESCRIPTION	NOMINAL DIAMETER (mm)	FIBRE DIRECTION (@ nominal diameter)	CONSTRUCTION (%)
Sock_E332	332g/m2 E-GLASS Biaxial Sock	100	±45°	50/50
Sock_E332	332g/m2 E-GLASS Biaxial Sock	150	±45°	50/50
Sock_C610	610g/m2 CARBON Biaxial Sock	100	±45°	50/50
Sock_C610	610g/m2 CARBON Biaxial Sock	150	±45°	50/50
UC450	450g/m2 Carbon Unidirectional	-	0°	100

Table 1: Fibre reinforcement

Note: Fibre direction/angle will vary with the sock diameter. Fibre directions are given relative to the nominal sock diameter. Stretching the sock and reducing the diameter will increase the fibre angle. Conversely squashing the sock, therefore increasing the diameter, will decrease the fibre angle.

The assumed mechanical properties for these materials, including resin content, are given in 11.1. Whether or not mechanical testing is conducted (refer 4.1), verifying achieved weight fraction (by burn-off) or volume fraction (by microscopy, which allows for measuring of void fraction), should be considered as a reasonable level of quality assurance testing.

3.3 Core materials

No structural core is used in the sculpture at this stage.

The 3D printed formers are considered non-structural. Weight added from the formers will be included as a distributed non-structural mass.

4. Analysis approach

The limit state design (LSD) method will be used for the analysis. This requires the structure to be checked against two distinct load types:

1. **Serviceability limit state (SLS)**
   These are limit states which concern the functioning of the structure under normal use; comfort of people or appearance of the structure, e.g. excessive deflections or vibrations.

2. **Ultimate limit state (ULS)**
   These are limit states which concern the safety of people or the safety of the structure. They generally correspond to the maximum load carrying capability and are related to structural failure modes which can include; rupture of critical sections of the structure or loss of stability (buckling).

In LSD, factors are applied to the characteristic loads to account for a range of effects including: uncertainty in the loads, uncertainty in the analysis and consequence of failure. The load factors and combinations chosen for the each of the load cases considered in this work are sourced from *AS/NZS 1170.3:2011 Structural Design Actions Part 0 – General principles* (refer 7).

Factors are also applied to the characteristic material properties to account for a range of effects including uncertainty in the manufacturing process and long term strength degradation. For this work the material partial factors recommended in the *EUROCOMP Structural Design of Polymer Composites* design code will be used (refer 8).

4.1 Material Properties

The ply properties assumed in the analysis are not based on specific test data, rather are Gurit's typical characteristic values that are believed to be achievable by experienced laminators. All strain values are characteristic with an estimated confidence of 95%, i.e. only 5% of the population may be less than these values. All moduli are estimated average values.

Laminate mechanical properties will be defined from ply data using classical laminate theory. Material partial factors at the ultimate limit state will be taken from the Eurocomp design code. At serviceability limit state the partial factor for material properties will be 1.0.

For the fibre reinforcement in the skins a strain based first ply failure method will be used as the failure criteria; when one ply within a given laminate reaches one of the strain limits divided by the applicable material factor, then that laminate is considered to be failed. This is the default approach, and is conservative as after first ply failure the structure still has load carrying capacity.

Fibre failure modes will be assessed by a combination of finite element methods and analytical calculations where appropriate.

This approach has been used for a number of FRP structures designed using load combinations based on the International Building Code.

5. Configurations, supports and sub components

5.1 Configurations

Once in place the sculpture will be static with no alternative configurations.
Plans for supporting the sculpture during assembly, transportation and installation are the responsibility of Kilwell Fibretube Ltd.

5.2 Supports

The sculpture will be supported at the base by fabricated metal baseplates and angled metal tubes (for a socket type fitting), similar to that shown below. The baseplate is required to interface with the existing studs cast into the concrete foundation. It is intended that the base plate itself be constructed as a ring which can be match drilled to the foundation studs, thereby ensuring that, after being assembled off site, the sculpture assembly will locate to the foundation without issue.
Design of the baseplate is by OPUS.
The length of support required, along with the maximum forces and moments at the base, will be provided by Gurit as an output from the detailed analysis stage.

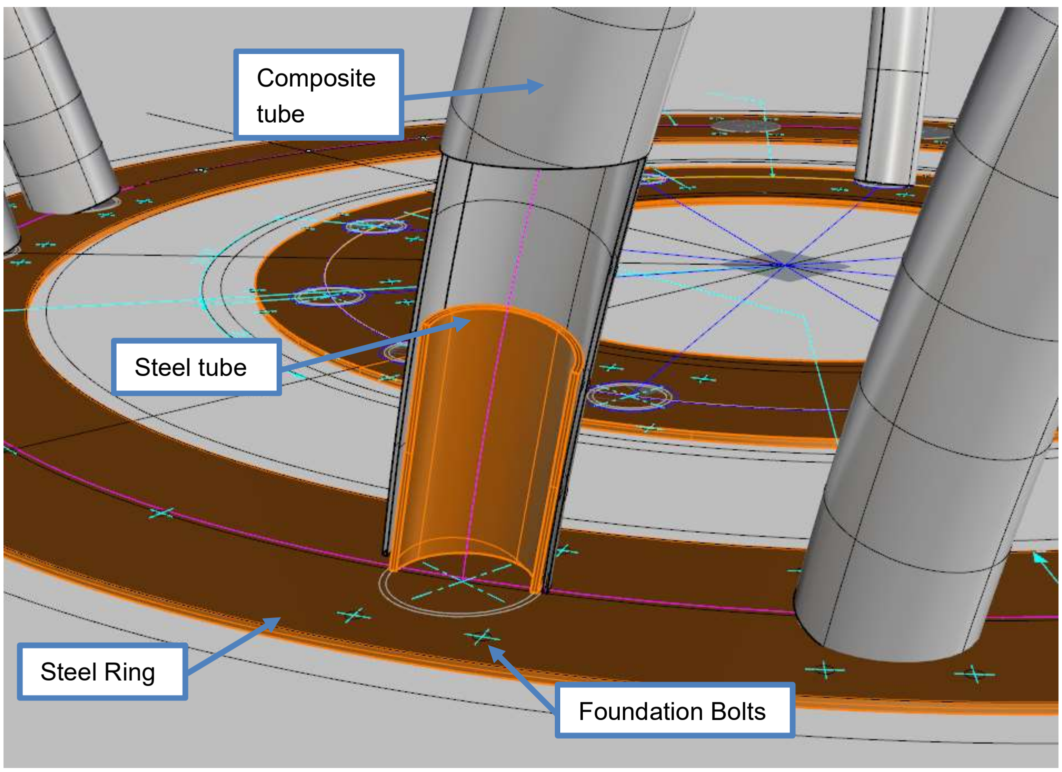


Figure 2. Baseplate preliminary design. Section through outer tube.

5.3 Sub components

5.3.1 Chevrons

Each spiral tube is connected to its adjacent tube via multiple chevron shaped plates. These plates are spaced approximately every 1.5m along the tubes.

Chevrons will be constructed from a structural carbon plate, bonded to which will be a 3D printed shape which is wrapped with a non-structural composite laminate.

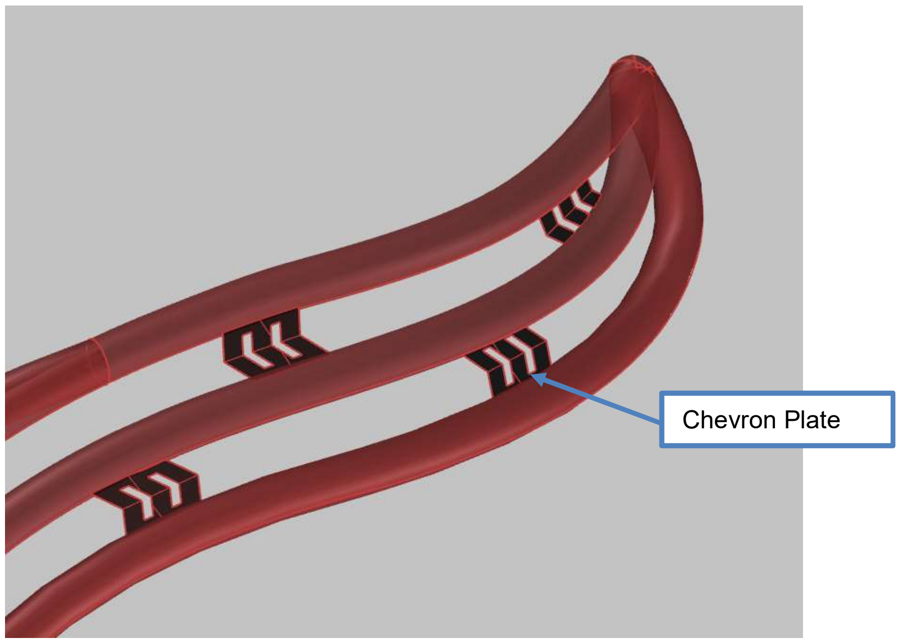


Figure 3. Chevron details

5.3.2 Art Panels

In discussions with Kilwell Fibretube Ltd it was decided to make these panels non-structural, due to their intricate details being difficult to model accurately while not providing any significant structural benefit.

The attachment method to the surrounding spirals is yet to be confirmed. It will be necessary for the mounts to flex and absorb deflections of the sculpture.

For the purposes of calculating the structure self-weight the panels have been assumed to be constructed from an 8mm thick 3D printed former, wrapped with 2x RC200 plies.

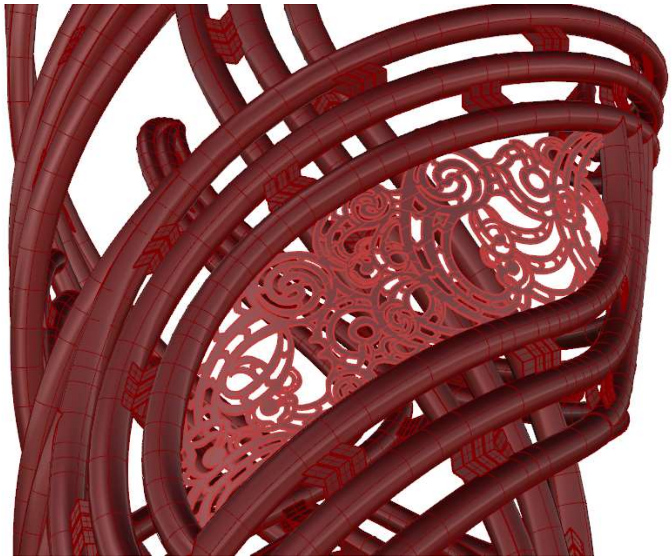


Figure 4. Decorative art panels

6. Characteristic values of actions

6.1 Site Parameters

For the purposes of establishing design actions according to AS/NZS1170 the following parameters have been defined for the structure:

Design Life	50 years
Importance Level (IL)	1 & 2 (see following section)

6.1.1 Wind load classification

Due to concern that wind loads calculated using AS/NZS1170 at Importance Level (IL) = 2 are overly conservative, discussions were held between Gurit, Kilwell, OPUS, and a representative from the Rotorua District Council. A decision was made to calculate wind actions for both IL = 2 and IL =1 (less severe), to be evaluated as follows:

- SLS wind actions do not change between IL = 1 and IL = 2.
- ULS wind actions will be considered under two situations:
  - Wind pressures at IL = 2 will be considered as accidental loading under the Eurocomp code and evaluated using accidental material factors
  - Wind pressures at IL = 1 will be considered as short term loading and evaluated using short term material factors

6.2 Permanent action

6.2.1 Dead Load (G)

The dead load of the sculpture consists of the self-weight of the FRP structure (tubes, chevrons and decorative panels) and finishing[1] along with the self-weight of the formers[2], and a contingency of ~10% to account for laminate variations and construction variables.

Superimposed dead load from finishing, formers and contingency will be applied as uniform non-structural masses.

Based on the laminate specification used in the design, the mass breakdown is as shown in Table 2 overleaf.

[1] Finish weights have been estimated at 154g/sqm for a 0.1mm sprayed clear coat.
[2] Former weight has been calculated as:
100mm diameter = 62g/100mm. Measured Kilwell sample 23-11-2017
150mm diameter = TBC. Preliminary estimate scaled by area from 100mm diameter sample weight.

Component		Weight (kg)
Outer Spiral	Composite tubes and former	1267
	Chevron structural & non-structural	235
	Art panels	17
	Paint	20
	Subtotal	**1539**
Inner Spiral	Composite tubes and former	1179
	Chevron structural & non-structural	224
	Art panels	17
	Paint	15
	Subtotal	**1435**
	Subtotal – both spirals	**2974**
	Contingency	10%
	Total	**3271**

Table 2: Sculpture weight estimate

Any changes in laminate weight during the design process will be inherently accounted for in the analysis.

Additional weights that may need to be considered, eg. for transport and installation purposes, include the metal base components. These weights have been estimated in the following table:

Component	Weight (kg)
Outer base ring and spigots	257
Inner base ring and spigots	145
Total	**402**

Table 3. Metal base fitting weight

As a comparison the weight of the initial stainless steel design by OPUS is shown below.

Component	Weight (kg)
Outer Spiral	4950
Inner Spiral	3210
Total	**8158**

Table 4. Steel design weights

6.2.2 Pre-stressing

There is no global pre-stressing of the structure

6.3 Imposed loads

6.3.1 Occupancy load (Q)

No occupancy loads are considered.

For servicing and cleaning, it is assumed that a scaffold will be erected around the sculpture from which work can be carried out.

6.3.2 Transport and assembly loading

Load cases covering assembly, transport and installation are not part of the current project scope. For the preliminary design stage these loads will be assumed to be less than the other load combinations applied, and thus not drive the design.

Transport and assembly loads can be discussed with Kilwell Fibretube Ltd at a later date and incorporated into the analysis if required. This report would be updated as necessary to include these details.

6.4 Wind Actions (W)

Wind actions are derived from speeds and pressures calculated using *AS/NZS 1170.2:2011 Structural Design Actions Part 2 - Wind actions.*

Wind actions will be applied to the spiral tubes and the art panels. For modelling simplicity no wind action will be applied to the individual chevrons. As the chevrons constitute less than 10% of the projected area this will not greatly affect the results.

6.4.1 Basic wind speed

The following site parameters have been used to calculate the site wind speed:

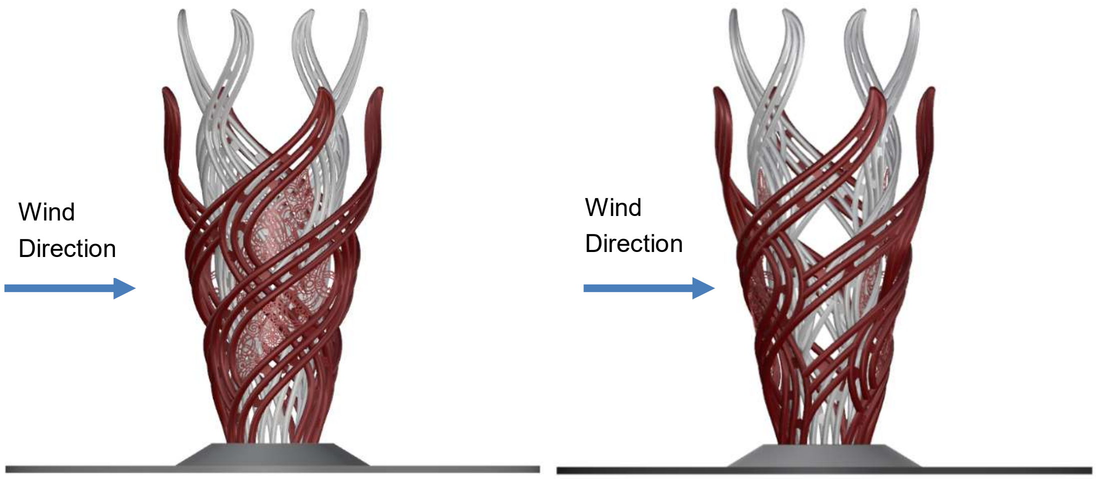
Importance level	1	2
Design Life	50 years	50 years
Exceedance probability:		
ULS	1/100	1/500
SLS	1/25	1/25
Region	A7	A7
Multipliers:		
Md	1.00	1.00
Mz,cat	1.05	1.05
Ms	1.00	1.00
M1	1.00	1.00

The maximum site wind speed (V_sit) was then determined as:

Importance Level	1	2
V_sit, SLS, m/s (km/h)	39.1 (141)	39.1 (141)
V_sit, ULS, m/s (km/h)	43.2 (156)	47.2 (170)

6.4.2 Wind directions

The maximum wind speed from any direction has been used as the site wind speed, and thus the orientation of the sculpture relative to the compass is irrelevant for the analysis. However as the sculpture is only axi-symmetrical at angles of 180°, the orientation of the sculpture relative to the oncoming wind will have an effect on the resultant net force. Therefore two wind directions will be analysed: One with the wind parallel to the art panels (expected to produce a lower net force, due to less drag from the art panels), and the second rotated 90° such that the wind is normal to the art panels. These cases are shown in Figure 5 below.



Left = Wind parallel to panels, Right = Wind normal to panels

Figure 5. Wind directions

6.4.3 Drag Force coefficient

The drag force coefficient for the spiral tubes was calculated for a cylindrical cross section using Appendix E, Table E3 of the design code. Appendix E is relevant for wind loading on individual structural members as is the case for this sculpture where the structure is quite open.

A separate drag coefficient will be used for the art panels. These have been treated as a perforated flat plate with 50% of the projected area perforated. The resulting drag coefficient, C_d, is 0.80[3]

	IL = 1	IL = 2
Case	C_d	C_d
ULS Outer Spiral	1.00	0.95
SLS Outer Spiral	1.05	1.05
ULS Inner Spiral	1.18	1.15
SLS Inner Spiral	1.21	1.21
Art Panels	0.80	0.80

Table 5: Drag force coefficients

[3] Refer technical paper: http://naca.central.cranfield.ac.uk/reports/arc/cp/0323.pdf

6.4.4 Wind pressures

The design wind pressures can be calculated based on the drag force coefficients and site wind speeds calculated in the preceding sections.

Case	IL = 1 Pressure (kPa)	IL = 2 Pressure (kPa)
ULS Outer Spiral	1.12	1.27
SLS Outer Spiral	0.96	0.96
ULS Inner Spiral	1.32	1.53
SLS Inner Spiral	1.11	1.11
ULS Art Panels	0.90	1.07
SLS Art Panels	0.73	0.73

Table 6: Wind pressures

The windward spirals are likely to apply some shielding effect to those on the leeward side of the sculpture. This will be represented by assuming that the leeward half of the sculpture sees a reduced wind pressure, 70% of that on the windward side. The reduction will apply up to 6.5m and 8.0m on the outer and inner spirals respectively, as the sculpture becomes much more open above these heights.

No wind pressures will be applied over the bottom 2.0m of the sculpture as the centre of the roundabout is recessed below the local ground level.

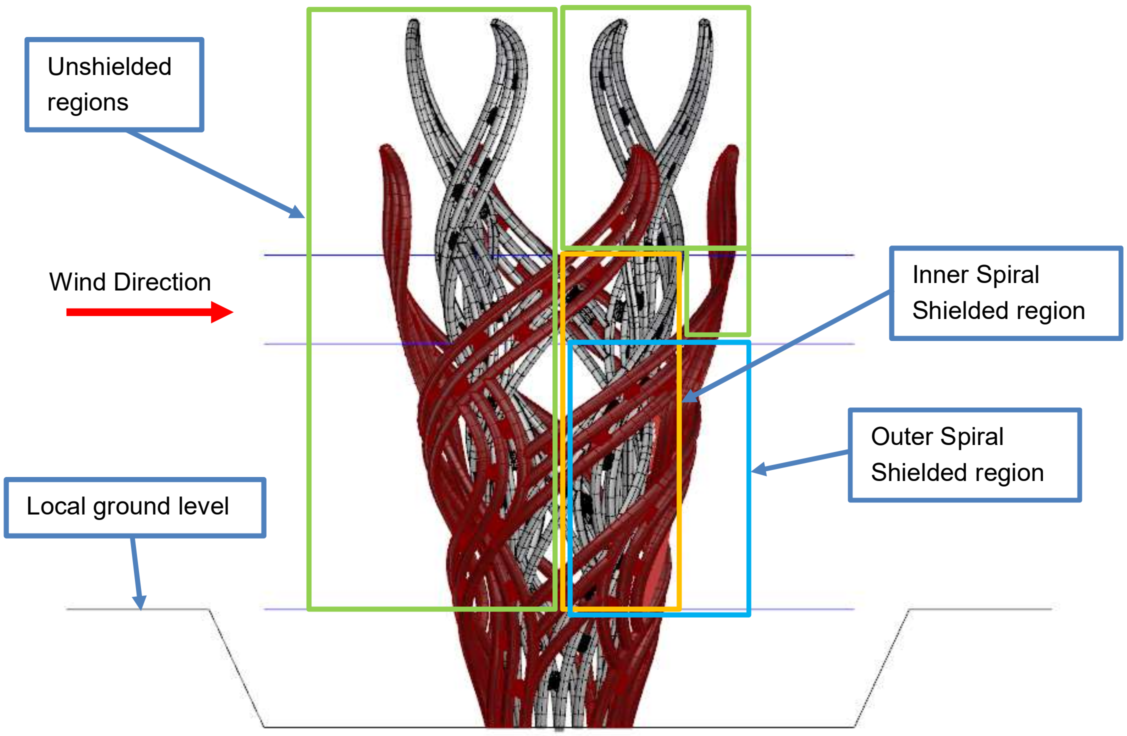


Figure 6. Wind pressure distributions

6.5 Earthquake loading (E)

Earthquake loading of the sculpture will be analysed. OPUS has calculated the base shear coefficient for the structure using the equivalent static method based on the following site parameters:

Importance level	2
Design Life	50 years
Location	Rotorua
Z	0.24
Soil Class	D
Fault Distance	25km
Period	0.4s
Ductility	1
Sp	1

The resulting base shear coefficient (Cd(T)) is 0.720 (equivalent to 0.72g). This will be applied to the sculpture as an acceleration in two orthogonal directions.

6.6 Snow and water Actions (S)

6.6.1 Snow Actions (S)

The sculpture is at an elevation of approximately 280m above sea level, located in sub-alpine region N1 (no significant snow below 1200m). Therefore snow actions need not be considered.

6.6.2 Water Action

Due to the shape of the sculpture, water pooling actions are irrelevant.

7. Load Combinations

AS/NZS 1170.3:2011 Structural Design Actions Part 0 – General principles provides load factors for reviewing combinations of actions.

7.1 Ultimate limit sates

Description	Combination Load Factors
Persistent Design Situations	
Permanent actions only (G)	1.35 G
Permanent (G) and Wind action (W)	1.2G + W
Seismic design Situations	
Permanent (G), earthquake (E)	1.2 G + E
Transient design Situations	
Transport	1.5 G
Installation	1.5 G

Table 7. Ultimate limit state combinations and load factors

7.2 Serviceability limit states

Description	Load Factors
Frequent Design Situations	
Reversible limit states	
Permanent loads	1.0 G
Wind loads	1.0 G +1.0 W
Dynamic analysis	
Natural frequencies	

Table 8. Serviceability limit state combinations and load factors

8. Design criteria FRP

8.1 Ultimate limit state

8.1.1 Material factors

Material factors address the level of confidence in the material design strength values. This depends on the type of design values being used (tested or derived from theory), the controllability of the manufacturing process (in this case vacuum infusion, which is a sub-form of resin transfer moulding), the variability of material behaviour with operating conditions (in this case epoxy laminating resin, no post cure), and the nature of the load case (long term, short term or accidental)

As a result the following material factors are used for the failure modes, in the long, short and accidental load cases.

Partial factor	Description	Long Term Factor	Short Term Factor	Accidental Factor
gm1	Properties of constituent materials from test specimen data, and properties of individual laminae from theory.	2.25	2.25	-
gm2	Panels to be manufactured by resin transfer moulding, not post cured.	1.70	1.70	-
gm3	Resin system HDT 55-80deg, operating in 25-50deg environment	3.00	1.20	-
gm	**Total material factor**	**10***	**4.59**	**3.06***

Table 9: Material factors for Epoxy, vacuum consolidated laminates – skin failure modes

*Accidental factors are taken as 2/3 x short term factor, but no less than 1.5. Material factors need not be taken as more than 10 for a building.

Strengths of individual plies and core materials are divided by the total material factor to give the maximum permissible strains in the structure.

Long term factors will be applied to static cases such as self-weight.

Short term factors will apply to transient load cases such as wind at IL =1, snow, self-weight during transport and assembly, and other imposed actions.

Accidental factors will be applied to extreme events such as seismic loading and wind at IL = 2.

8.1.2 Stability

A minimum buckling reserve factor of 1.5 is required above ultimate limit state loads.

8.2 Serviceability limit state

8.2.1 Stiffness – Deflection of components

There are no set limits for deflections in the relevant codes for this type of structure and factors such as appearance, cost, and self-contact are likely to play a part in determining the appropriate limits. As a guide deflections from the initial steel design and those from the Eurocomp code will be used to determine the acceptable order of magnitude of deflection during the preliminary design. Once the preliminary design review has been completed further discussion will occur to establish suitable limits for this sculpture.

Deflections from the initial steel design will be retrieved from the preliminary model modified with the steel section properties.

Deflection limits defined in Eurocomp 4.5.2, table 4.2 are L/175 for general non-specific applications and L/250 for situations where the maximum deflection can impair the structures appearance. The following table shows how these limits would apply to the sculpture and also the typical deflections for the initial steel design, calculated for self-weight and with the wind loading normal to the art panels.

Load case	Span (mm)	Eurocomp L/175 Allowable deflection (mm)	Eurocomp L/250 Allowable deflection (mm)	Steel design deflection (mm)
Self-weight	12000	69	48	85
Wind load normal to art panels	12000	69	48	354

Table 10. Deflection limit examples

8.2.2 Strain

Maximum principle strain in the FRP components should be less than 0.45% under SLS loads to minimise the risk of micro-cracking of the resin system

8.2.3 Vibration

Natural frequency of the sculpture spirals should be greater than 2Hz to minimise the risk of visible vibration.

8.3 Design life

The design life of the structure has been taken as 50 years.

9. Design Criteria metal

Metal components, such as the attachment of the sculpture to the foundations, are excluded from Gurit's scope, and are by others.

10. Non-structural requirements

10.1 Temperatures

Maximum external surface temperatures for the FRP components may get as high as 110°C (data from typical colour – temperature graph for a black surface in 35°C ambient conditions. This could be verified by testing if required). The builder should satisfy themselves that the chosen resin system and cure cycles used result in a suitable HDT for the conditions expected.

10.2 Cosmetic

10.2.1 Surface finish

The outer surface of the sculpture will be finished with a tinted clear coat and then coated with a polymeric resin for UV protection.

It is intended that any surface fairing is done prior to the final laminate layer in order to maintain a continuous carbon weave finish.

10.3 Interfacing requirement

In order to prevent damage and abrasion of the surface finish there is to be no contact between the inner and outer spirals when deflected under load.

Displacements at selected points surrounding the art panels will be output to assist in designing the panel attachments to a suitable tolerance.

Forces and moments at the base supports will be output to assist in the design of the baseplates.

10.4 Fire resistance

The sculpture is not subject to a fire resistance requirement.

10.5 Lightning Strike

It is assumed that the structure is adequately protected against lightning strike and that the FRP components do not require any additional protection.

11. Appendices

11.1 Material Properties – FRP

The following fibre material properties are to be assumed in the analysis. It should be noted that these are not based on specific test data, rather are Gurit's typical characteristic values that are believed to be achievable by experienced laminators.

Table 11 shows the material properties for the plies in the proposed laminate. All strain values are characteristic with an estimated confidence of 95%, i.e. only 5% of the population may be less than these values. All moduli are estimated average values.

It should be noted that all values shown exclude material factors.

				Stiffness (GPa)				Strength (% strain)				
Material	Method	Orientation	Fvf	E1	E2	G12	v12	ε1t	ε1c	ε2t	ε2c	ϒ12
Sock_E332	Epoxy, infused	0/90	0.46	20.8	20.8	3.4	0.12	1.50	1.50	1.20	1.20	1.41[1]
		+45/-45	0.46	10.5[3]	10.5[3]	9.3	0.56[2]	0.90[2]	0.90[2]	0.90[2]	0.90[2]	1.50
Sock_C610	Epoxy, infused	0/90	0.53	52.6	52.6	4.2	0.04	0.96	0.67	0.96	0.67	1.36[1]
		+45/-45	0.53	14.7[3]	14.7[3]	25.4	0.73[2]	0.79[2]	0.79[2]	0.79[2]	0.79[2]	1.06
UC450	Epoxy, infused	0	0.55	125.4	7.0	4.1	0.34	1.02	0.66	0.45[1]	1.50	1.20[1]

Table 11: Fibre mechanical properties.

[1]These are resin failure modes, which are not ultimate failure modes (unless stated otherwise) and are only considered for serviceability load cases.

[2]These are resin failure modes which are ultimate failure modes only when the laminate consists of purely +/-45° fibres, such as in the preliminary laminate proposed by Kilwell Fibretube Ltd.

[3]These are the apparent material stiffness values when the fibres are orientated at +/-45° and unsupported (i.e. without lateral support). By comparison the stiffness values published on the manufacturer's website are higher as they assume the fibres are supported.

11.2 Load case table

Elemental Load cases

Load	Type	Description
<u>**Permanent Loads**</u>		
G	Self weight	self weight
<u>**Imposed Loads**</u>		
Environmental		
<u>*Wind - static*</u>		
W1_SLS	Wind action	Wind normal to art panels
W1_ULS		
W2_SLS	Wind action	Wind parallel to art panels
W2_ULS		
<u>*Earthquake*</u>		
E1	Earthquake action	TBC

Combined Load cases

Case #	Combined Case	Combination Factor	Structural requirement
SLS			
Basic operation			
10000	self weight	1.00G	dmax TBC & max. Principal strain <0.45%
Environmental			
<u>*Wind - static*</u>			
10011	Wind normal to art panels	1.0G+W1_SLS	
10012	Wind parallel to art panels	1.0G+W2_SLS	
Natural frequency			
10021	First natural frequency	N/A	>2Hz
ULS			
Basic operation			(material factor)
20000	self weight	1.35G	Long Term MF, BF>1.5
Environmental			
<u>*Wind - static*</u>			
20011	Wind normal to art panels	0.9G+W1_ULS	Short term MF, BF>1.5
20012	Wind parallel to art panels	0.9G+W2_ULS	Short term MF, BF>1.5
<u>*Earthquake*</u>			
20013	Earthquake action	G+E1	Accidental MF, BF>1.5

11.3 Earthquake Parameters

Calculation Sheet

Project/Task/File No:		Sheet No	of
Project/Description:	Hemo Roundabout	Office:	
	Rotorua	Computed:	
		Checked:	

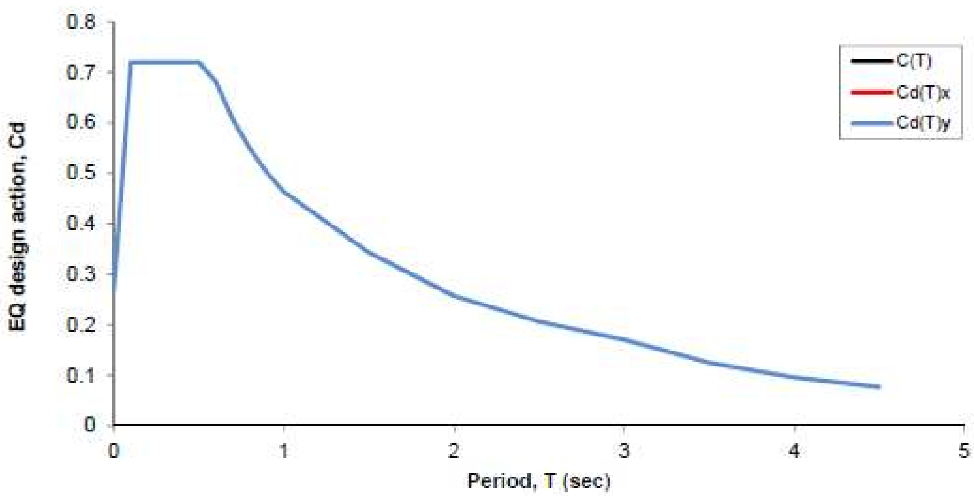
OPUS

NZS 1170.5 - EARTHQUAKE ACTIONS

Location	Rotorua	
Z	0.24	
Soil class	D	
Importance Level,IL	2	
Limit State	ULS	
Fault dist.	25	km
Design Life	50	yrs
R	1.00	1/500yr

	X	Y
Period, T (sec)	0.4	0.4
Ductility, μ	1	1
Sp	1	1
Cd(T)	0.720	0.720

T	C(T)	Cd(T)x	Cd(T)y
0	0.2688	0.269	0.269
0.1	0.72	0.720	0.720
0.2	0.72	0.720	0.720
0.3	0.72	0.720	0.720
0.4	0.72	0.720	0.720
0.5	0.72	0.720	0.720
0.6	0.6816	0.682	0.682
0.7	0.6072	0.607	0.607
0.8	0.5496	0.550	0.550
0.9	0.5016	0.502	0.502
1	0.4632	0.463	0.463
1.5	0.3432	0.343	0.343
2	0.2568	0.257	0.257
2.5	0.2064	0.206	0.206
3	0.1704	0.170	0.170
3.5	0.1248	0.125	0.125
4	0.096	0.096	0.096
4.5	0.0768	0.077	0.077



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