The Blade Bridge - From Concept to Reality

Speakers:

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Dr. Angela Nagle

School of Engineering and Architecture,
University College Cork, Ireland

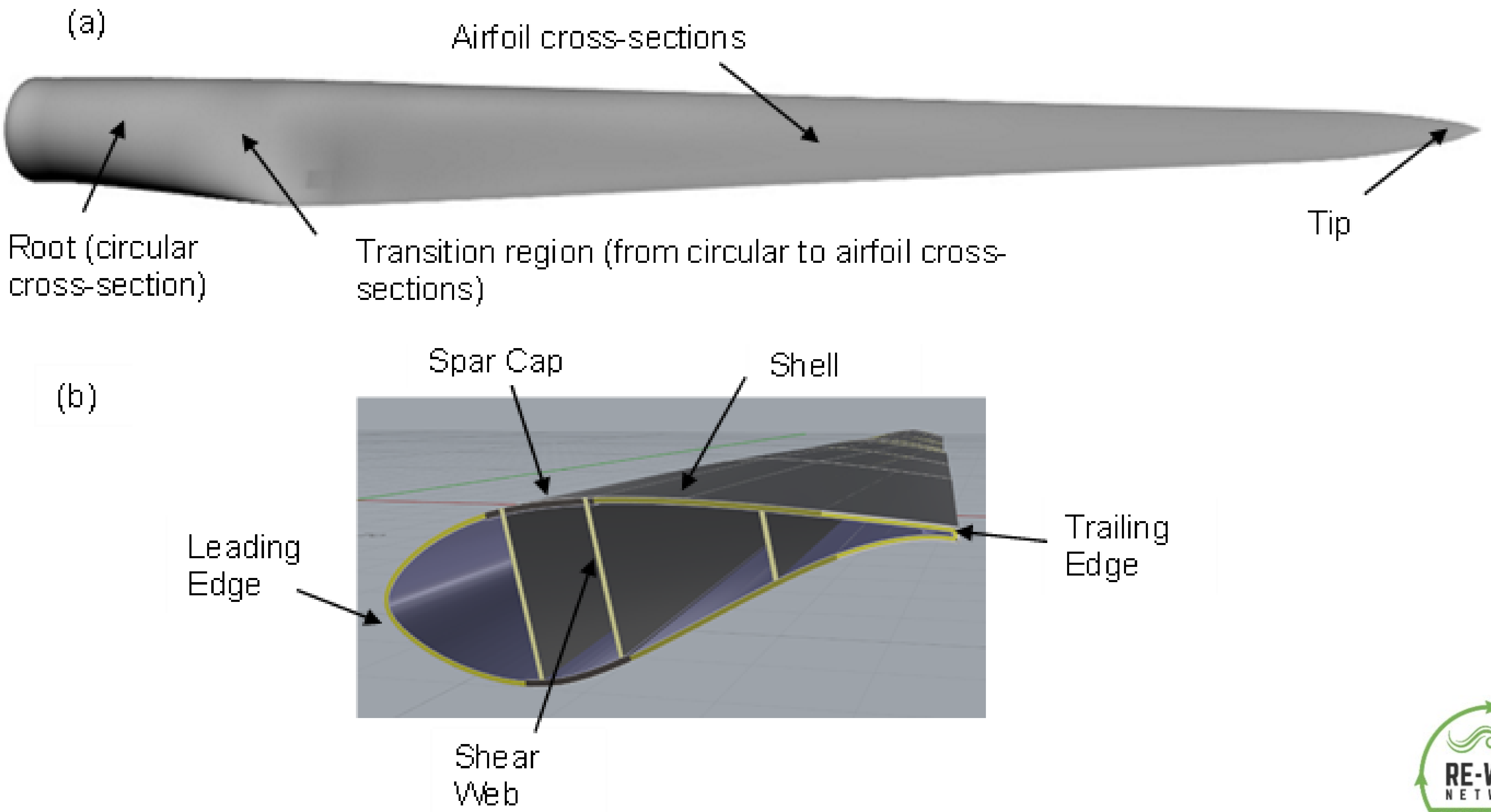
Re-Wind Network

Georgia Tech, QUB, CUNY, UCC, MTU

Georgia Tech | Queen's University Belfast | The City University of New York | UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh | MTU Ollscoil Teicneolaíochta na Mumhan Munster Technological University

https://www.bloomberg.com/news/features/2020-02-05/wind-turbine-blades-can-t-be-recycled-so-they-re-piling-up-in-landfills

https://www.re-wind.info/s/Re-Wind-Design-Catalog-Fall-2021-Nov-12-2021-low-res.pdf

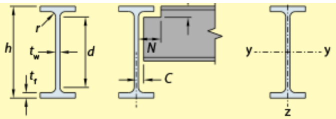

(a)
Airfoil cross-sections
Root (circular cross-section)
Transition region (from circular to airfoil cross-sections)
Tip
(b)
Spar Cap
Shell
Leading Edge
Trailing Edge
Shear Web

Type	Depth	Area	Height of centroid above soffit	Section modulus		Second moment of area	Self weight/m	Top of beam dimensions	
	D	A	Y_c	Z_t	Z_b	I_{xx}		L1	L2
	(mm)	mm^2	(mm)	$(mm^3 \times 10^6)$	$(mm^3 \times 10^6)$	$(mm^4 \times 10^9)$	(kN/m)	(mm)	(mm)
U1	800	479470	353.4	68.2	86.19	30.459	11.99	1195	520
U3	900	510460	398.4	84.39	106.27	42.335	12.76	1208	558
U5	1000	543840	444.8	102.49	127.91	56.898	13.60	1236	586
U7	1100	577220	491.7	121.93	150.83	74.168	14.43	1264	614
U8	1200	610600	539	142.68	174.99	94.315	15.27	1292	642
U9	1300	643980	586.5	164.69	200.36	117.51	16.10	1320	670
U10	1400	677360	634.3	187.93	226.9	143.91	16.93	1348	698
U11	1500	710740	682.2	212.4	254.6	173.69	17.77	1376	726
U12	1600	744120	730.4	238.07	283.45	207.03	18.60	1404	754

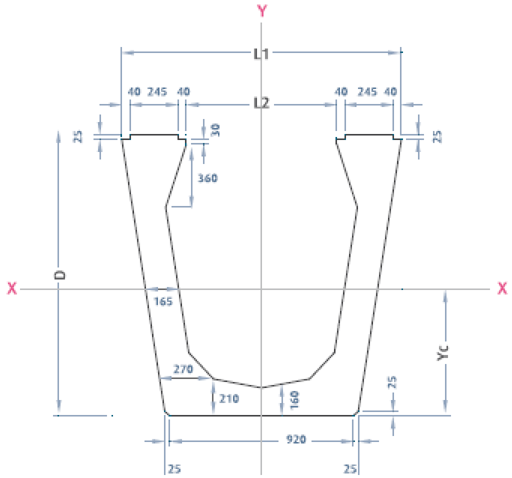
Universal beams (UB) ⌄ Section properties ⌄

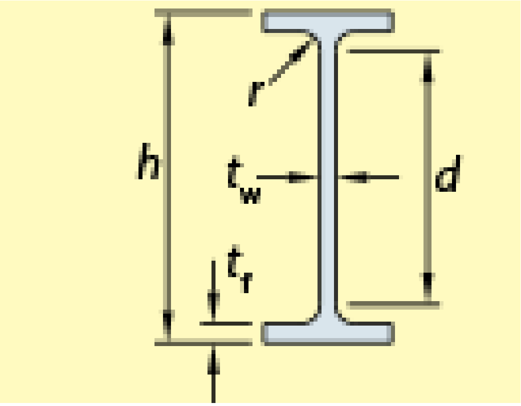
Dimensions & properties

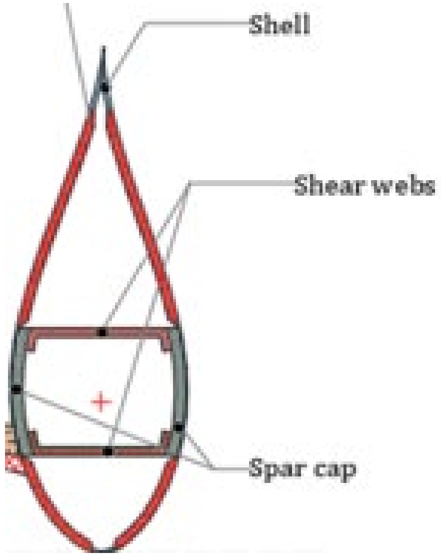
Print design data   Export to excel



Section designation		Properties										
		Radius of gyration		Elastic modulus		Plastic modulus		Buckling parameter	Torsional index	Warping constant	Torsional constant	Area of section
		Axis y-y	Axis z-z	Axis y-y	Axis z-z	Axis y-y	Axis z-z	U	X	I_w	I_T	A
		cm	cm	cm^3	cm^3	cm^3	cm^3			dm^6	cm^4	cm^2
	x 176	33.1	5.90	5890	535	6810	842	0.856	46.5	13.0	221	224
762 x 267	x 197	30.9	5.71	6230	610	7170	958	0.869	33.2	11.3	404	251
	x 173	30.5	5.58	5390	514	6200	807	0.865	38.0	9.39	267	220
	x 147	30.0	5.40	4470	411	5160	647	0.859	45.2	7.40	159	187







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What is needed for Engineering Analyses

1. **External geometry** – Airfoil shapes along the length, prebend and twist along the length.
2. **Internal geometry** – location and thickness of spar caps, webs, and shell sandwich panels along the length.
3. **Material types** (e.g., glass, polyester, epoxy) and laminates (or sandwich laminates) for spar cap, shell and webs, Mass (or volume fractions) of fiber and resin in the laminates in the spar cap, shell and webs, Fabric types used (e.g., +-45, mats, UD)
4. **Strength and stiffness** in the longitudinal and transverse directions and shear strength and stiffness of the spar cap, shell and web laminates; of the spar cap, shell and web laminates. Bearing strength for connections. As-received properties and estimate of residual related to virgin.
5. **Global blade structural properties** along the length EI_x, EI_y, GJ, kAG (where x and y and the chord axis and its perpendicular through the centroid of the cross-section. Principal axes and shear centre.)

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European Commission

JRC SCIENCE FOR POLICY REPORT

PROSPECT FOR NEW GUIDANCE IN THE DESIGN OF FRP

Support to the implementation, harmonization and further development of the Eurocodes

Authors

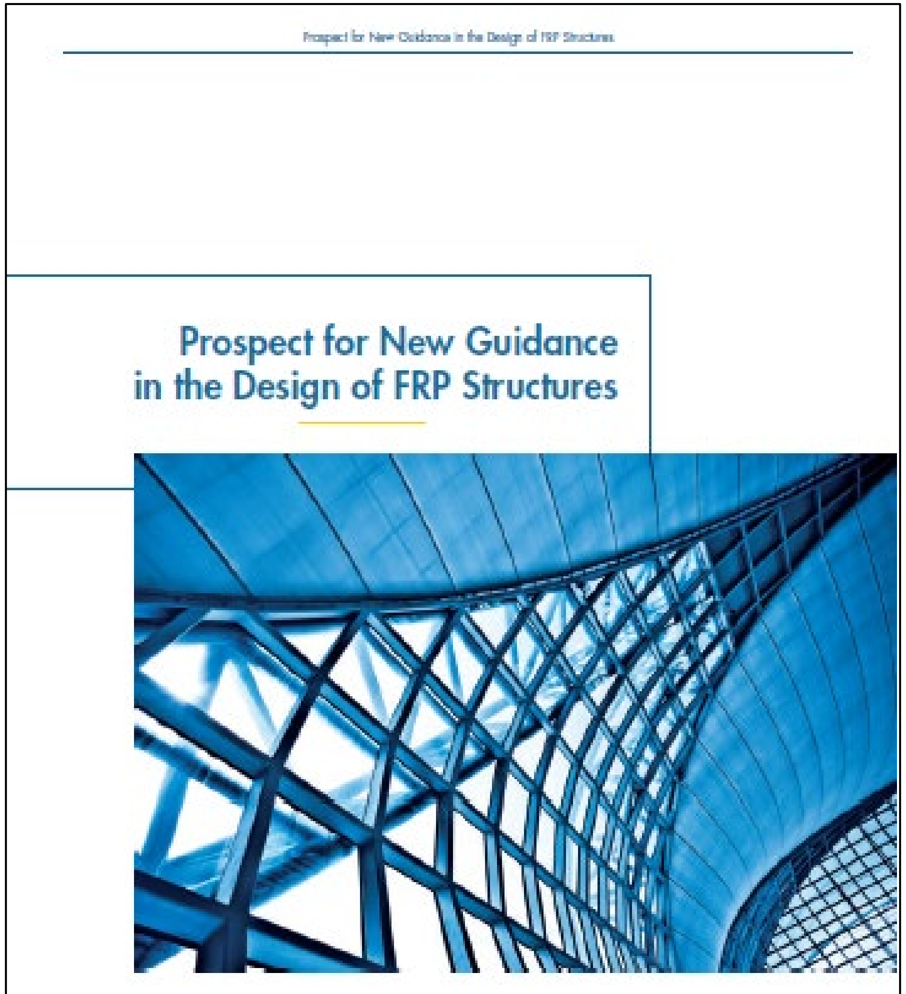
Luigi Ascione, Jean-François Caron, Patrice Godonou, Kees van IJselmuijden, Jan Knippers, Toby Mottram, Matthias Oppe, Morten Gantriis Sorensen, Jon Taby, Liesbeth Tromp

Editors

Luigi Ascione, Eugenio Gutierrez, Silvia Dimova, Artur Pinto, Steve Denton

2016

2016

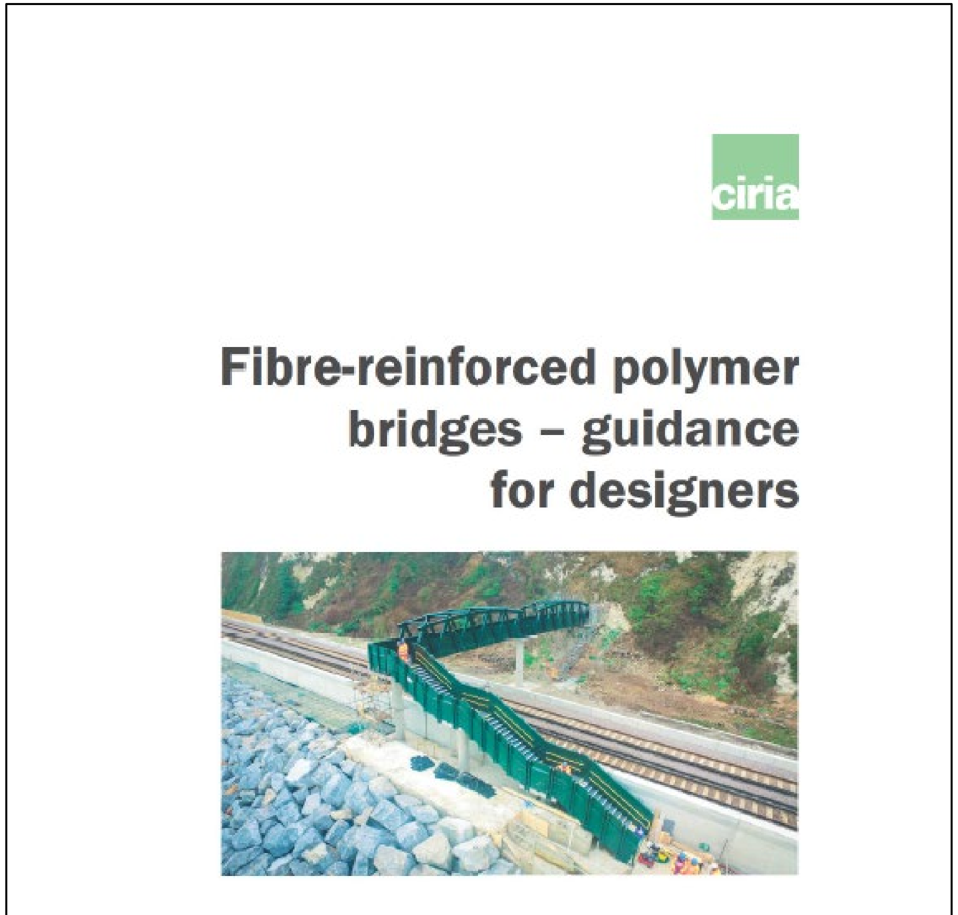

Prospect for New Guidance in the Design of FRP Structures

Prospect for New Guidance in the Design of FRP Structures

https://eucia.eu/userfiles/files/Eucia_Prospect%20for%20New%20Guidance%20in%20the%20Design%20of%20FRP%20Structures_web2.pdf

EuCIA

2017


ciria

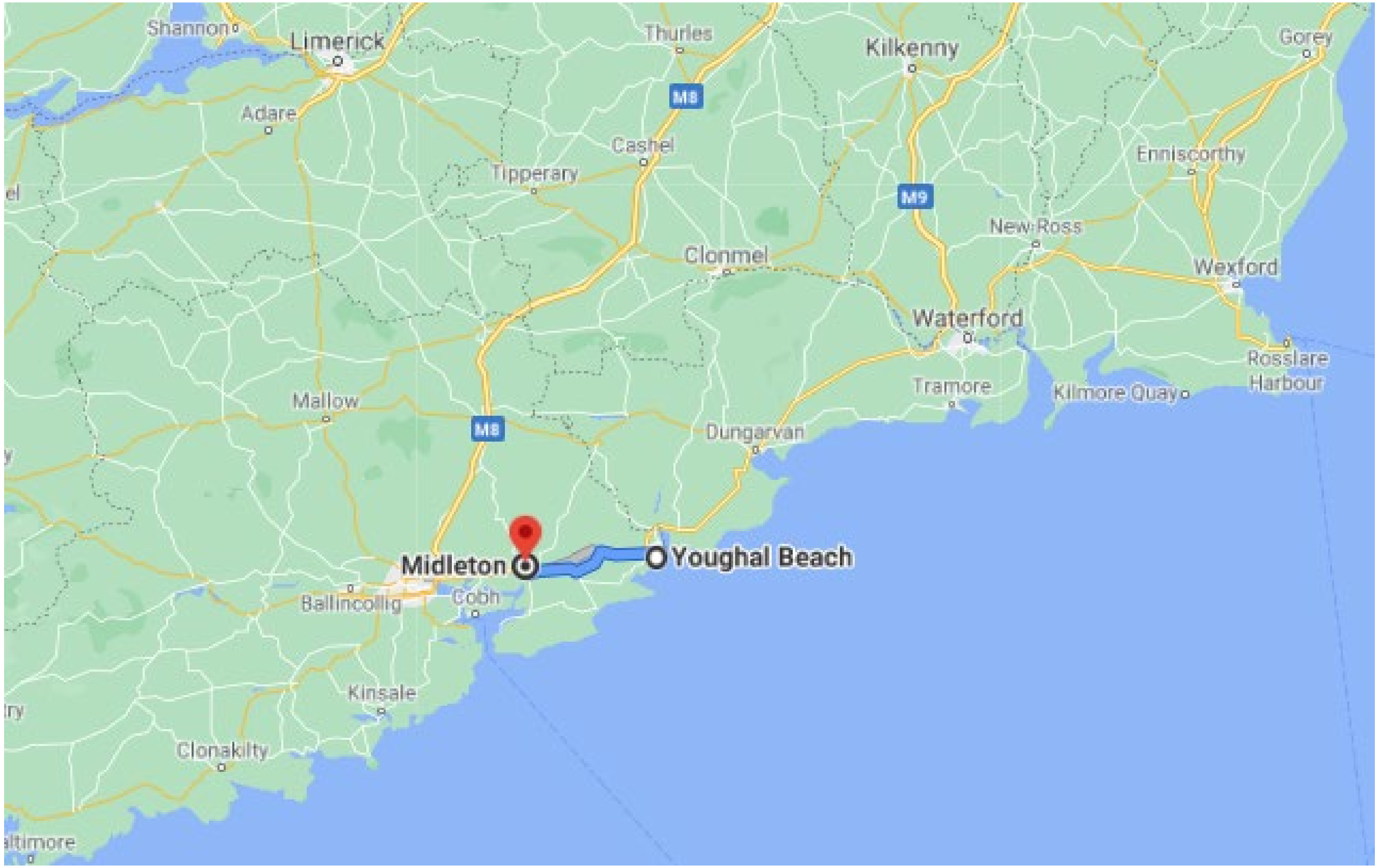
Fibre-reinforced polymer bridges – guidance for designers

https://www.ciria.org/ItemDetail?iProductCode=C779F&Category=FREEPUBS

Composites UK

2017

Context


Shannon
Limerick
Thurles
Kilkenny
Gorey
M8
Adare
Cashel
Tipperary
Enniscorthy
M9
New Ross
Clonmel
Wexford
Waterford
Rosslare Harbour
Tramore
Kilmore Quay
Mallow
M8
Dungarvan
Midleton
Youghal Beach
Ballincollig
Cobh
Kinsale
Clonakilty

Context

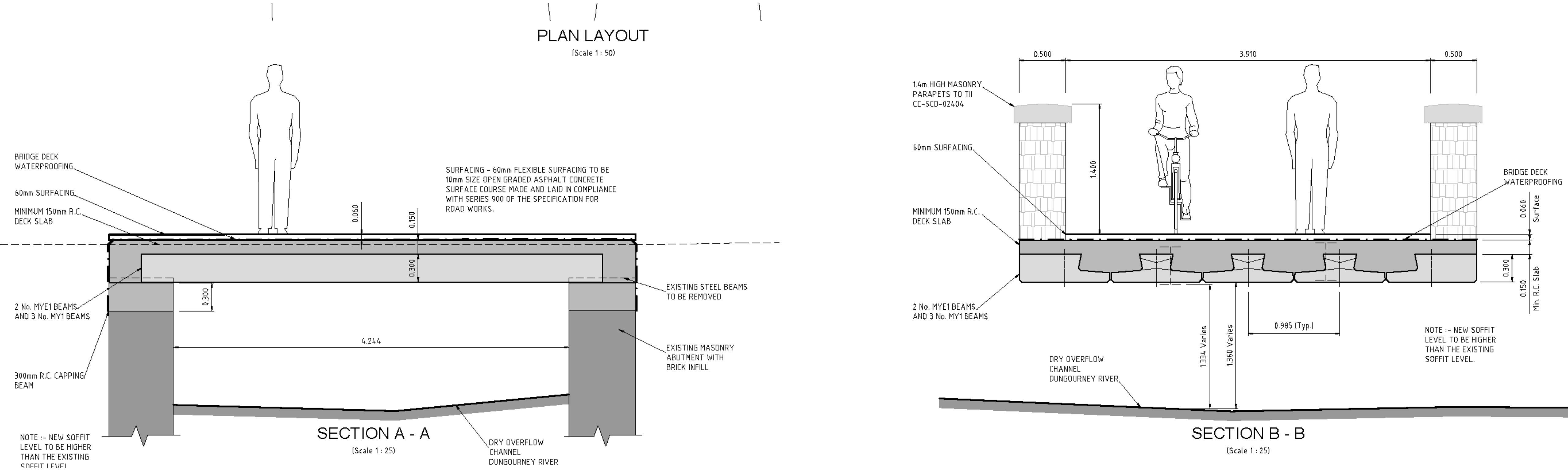
Context

Span ~ 5.0

Width ~ 3-4m

Skew ~ 18^o

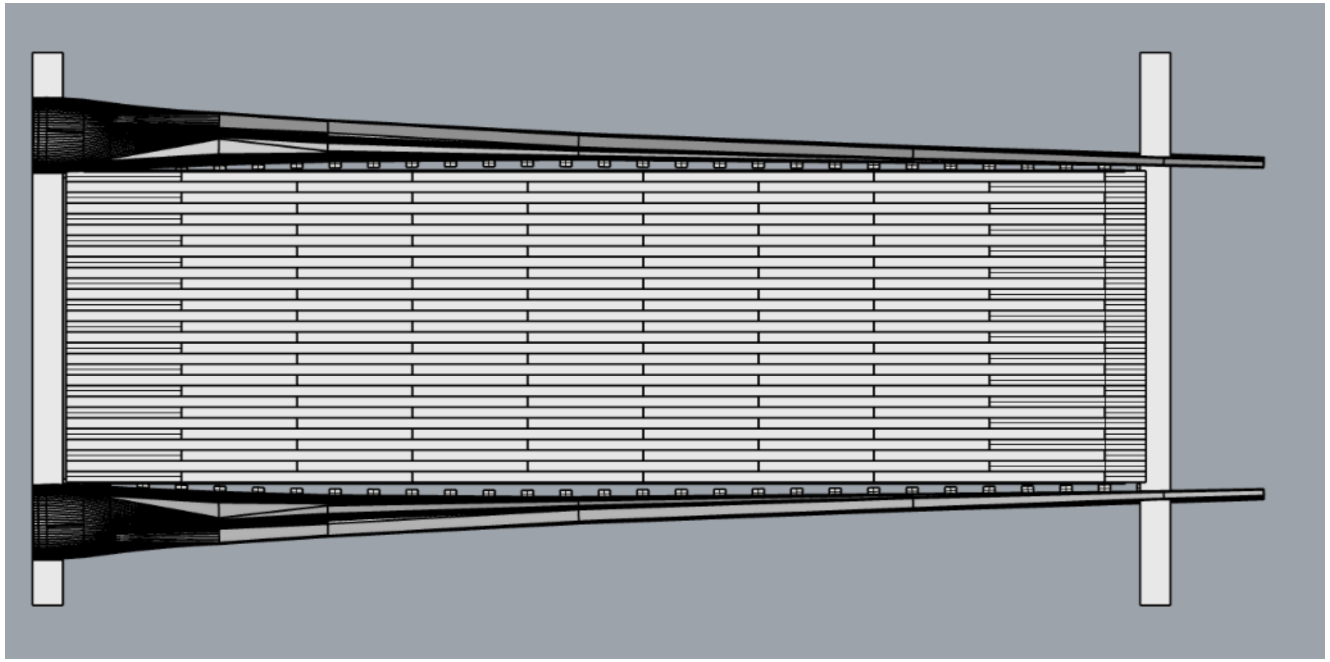
Context – Original Plan

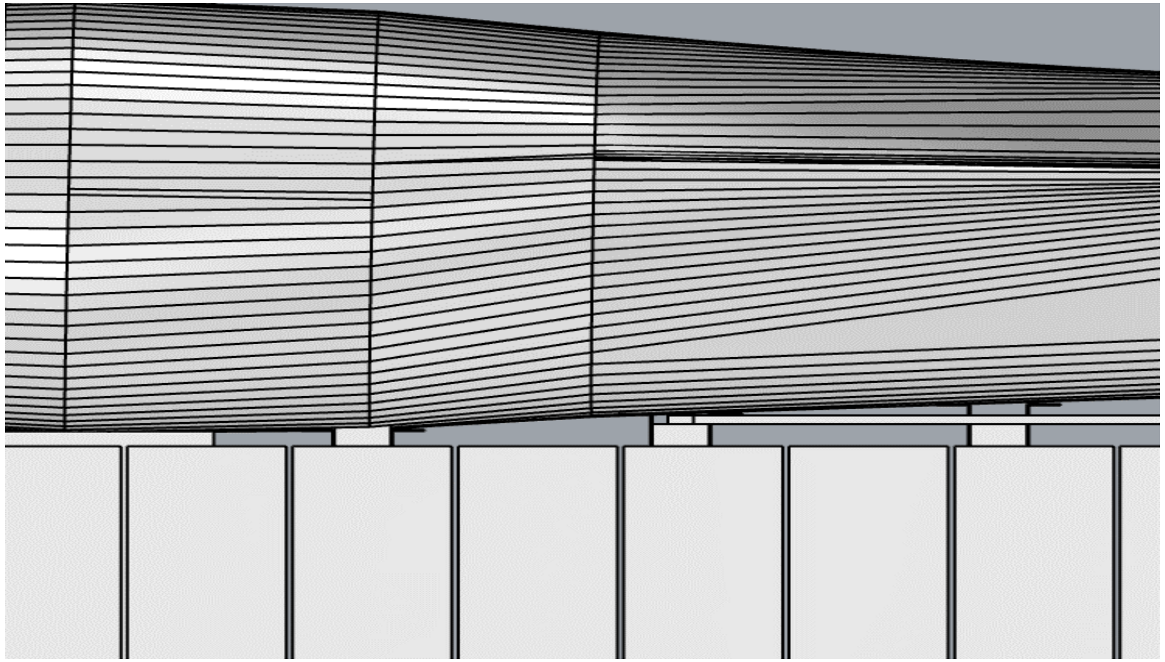


Conceptual Design

Ms. Zoe Zhang, GT

Windblade Alignment





Ms. Zoe Zhang, GT

Complexity of Geometry must be accounted for in actual designs:
Pitch of blades, straightness of blades, spacing between blades

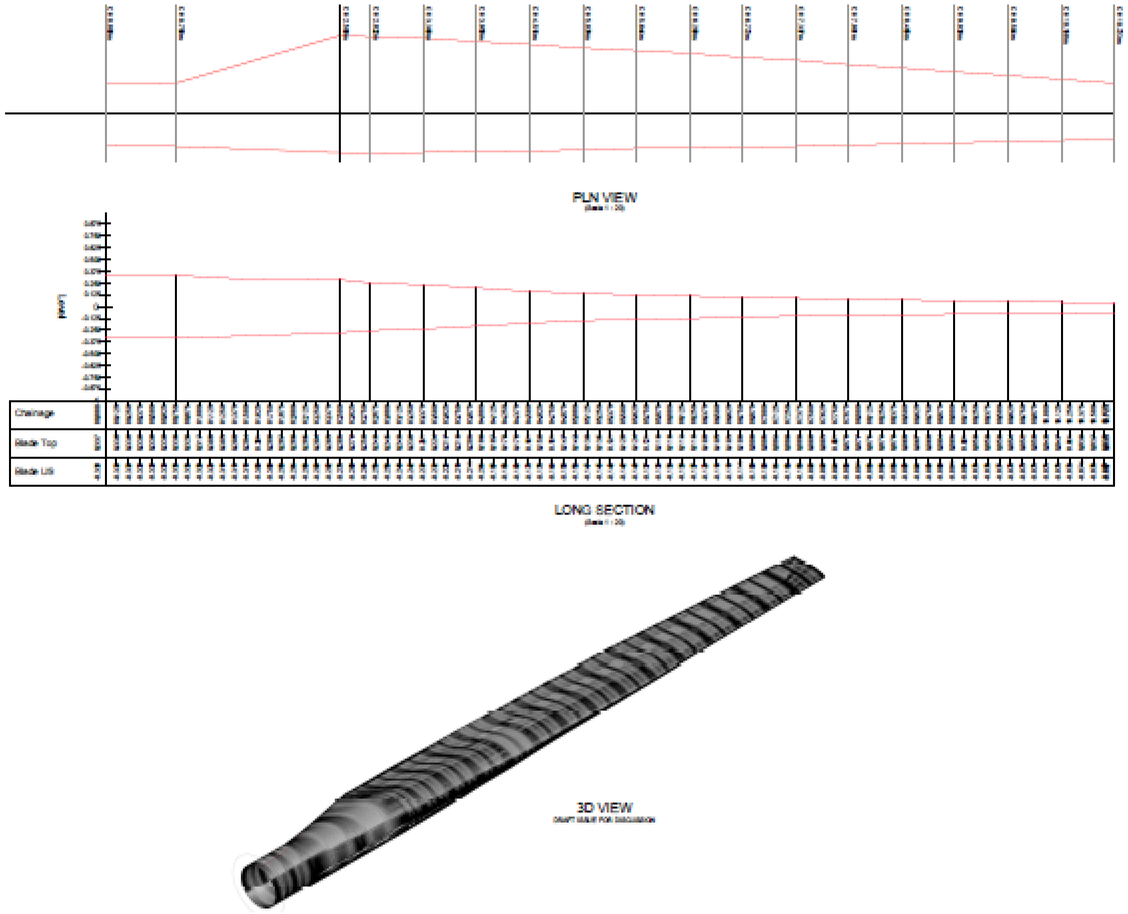
Sourcing Blades – Laser Scanning

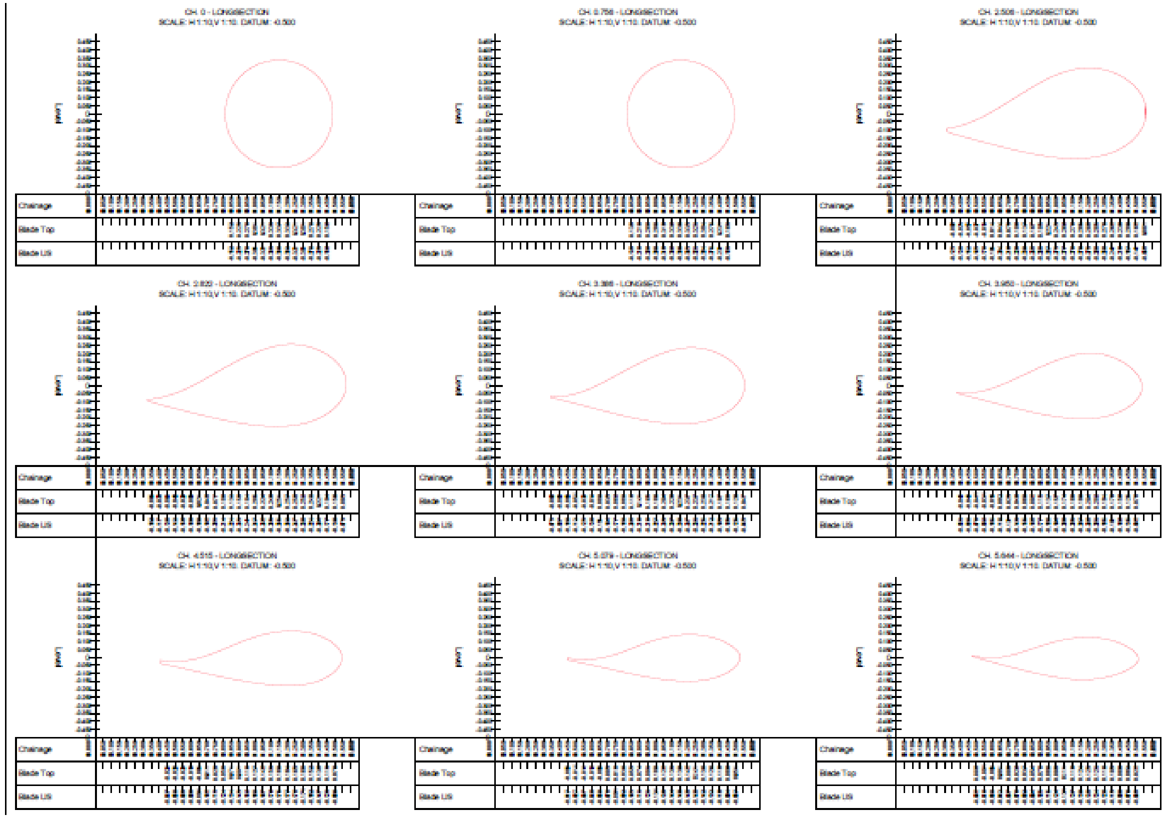
Working with the N29 Blades – MTU Structures Laboratory

Working with the N29 Blades – MTU Structures Laboratory

Working with the N29 Blades – Scanning & Measuring

Working with the N29 Blades – Scanning and Measuring



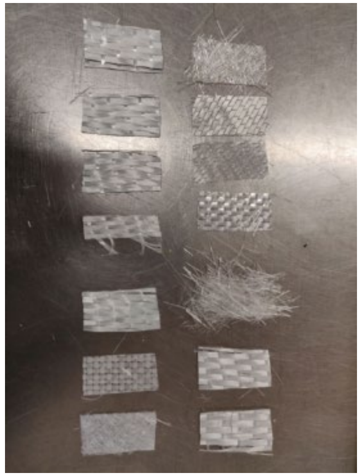


N29 Testing and Investigating

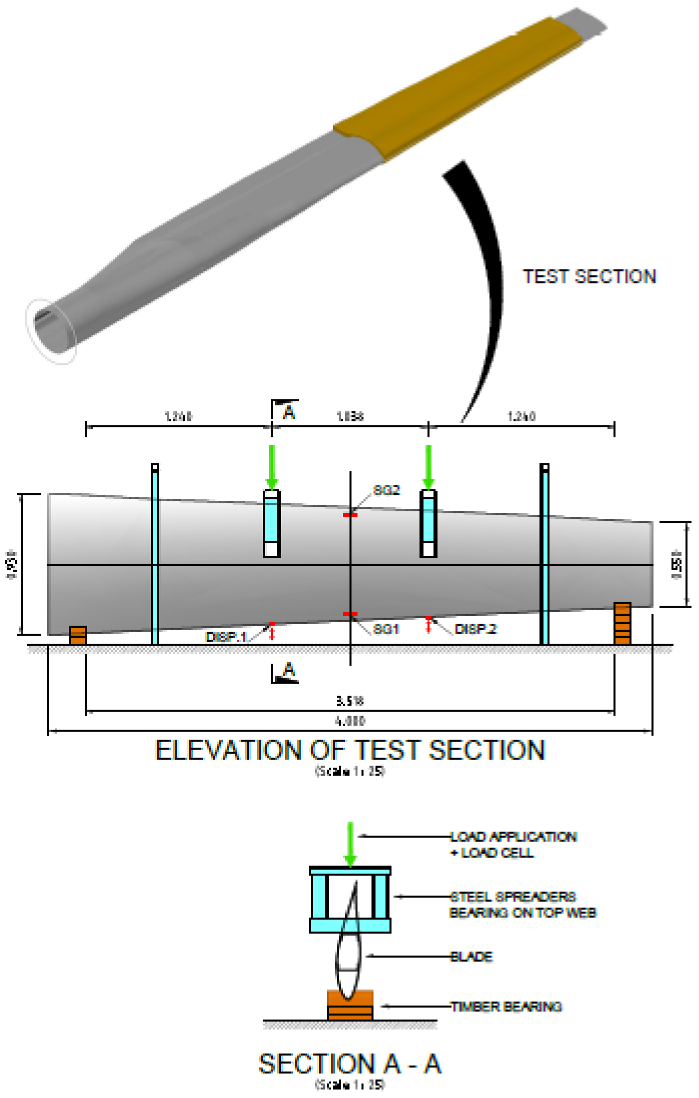
Static loads

Connections

GFRP burn-out



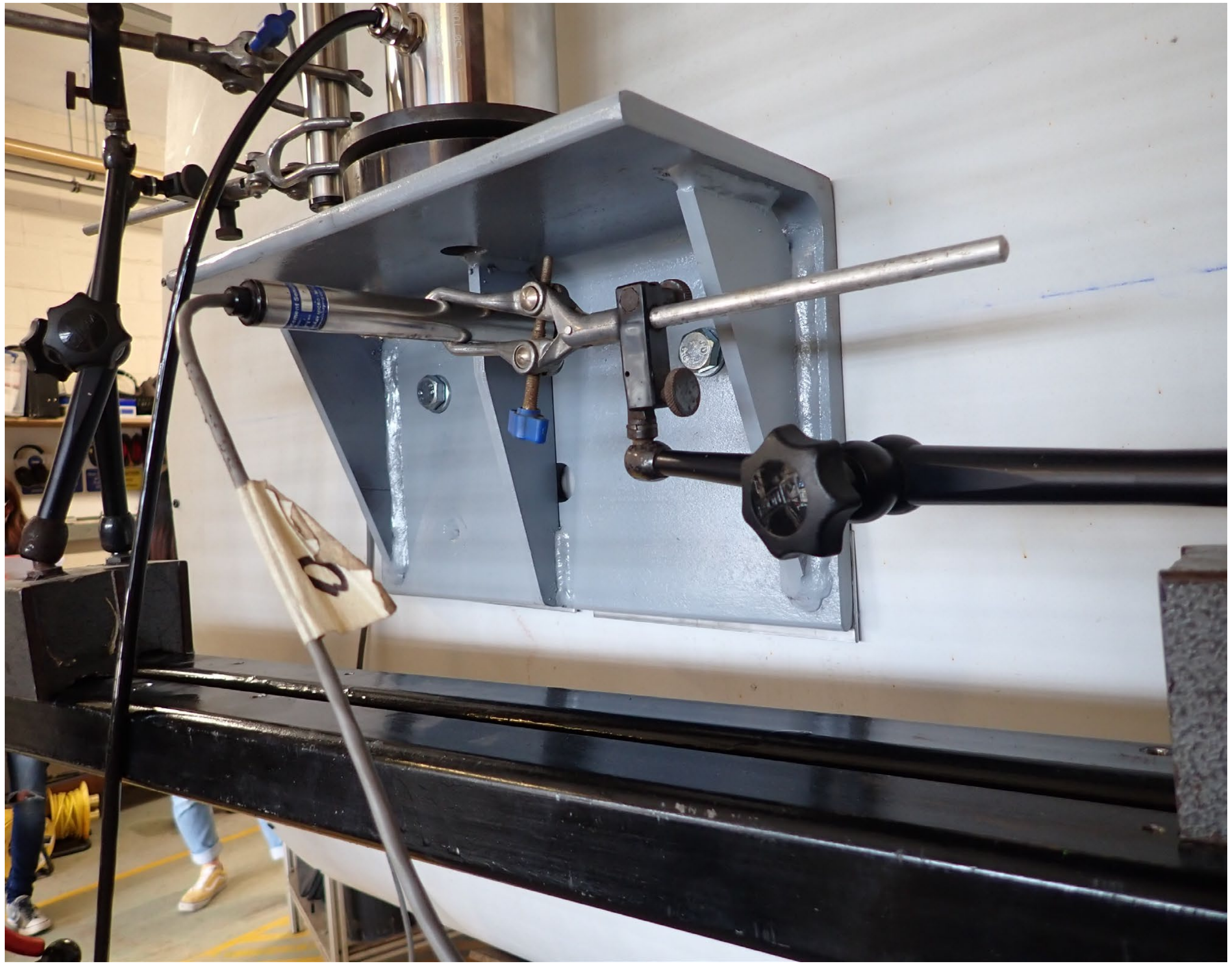
N29 Testing and Investigating – Static Load Tests



N29 Testing and Investigating – Static Load Tests

N29 Testing and Investigating – Static Load Tests

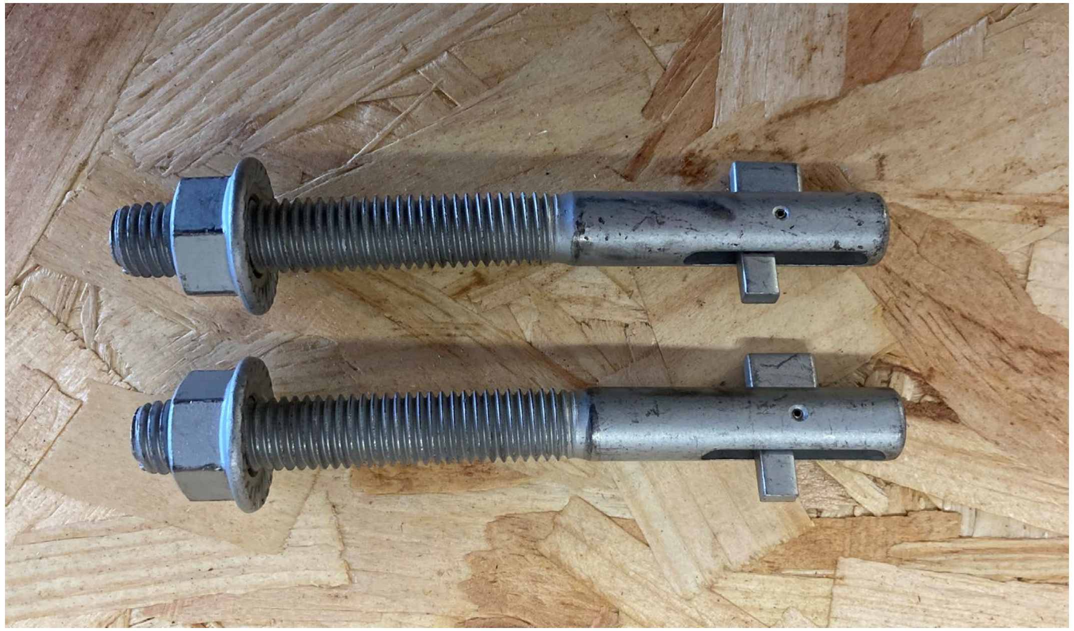
N29 Testing and Investigating – Connection Tests (3 No.)

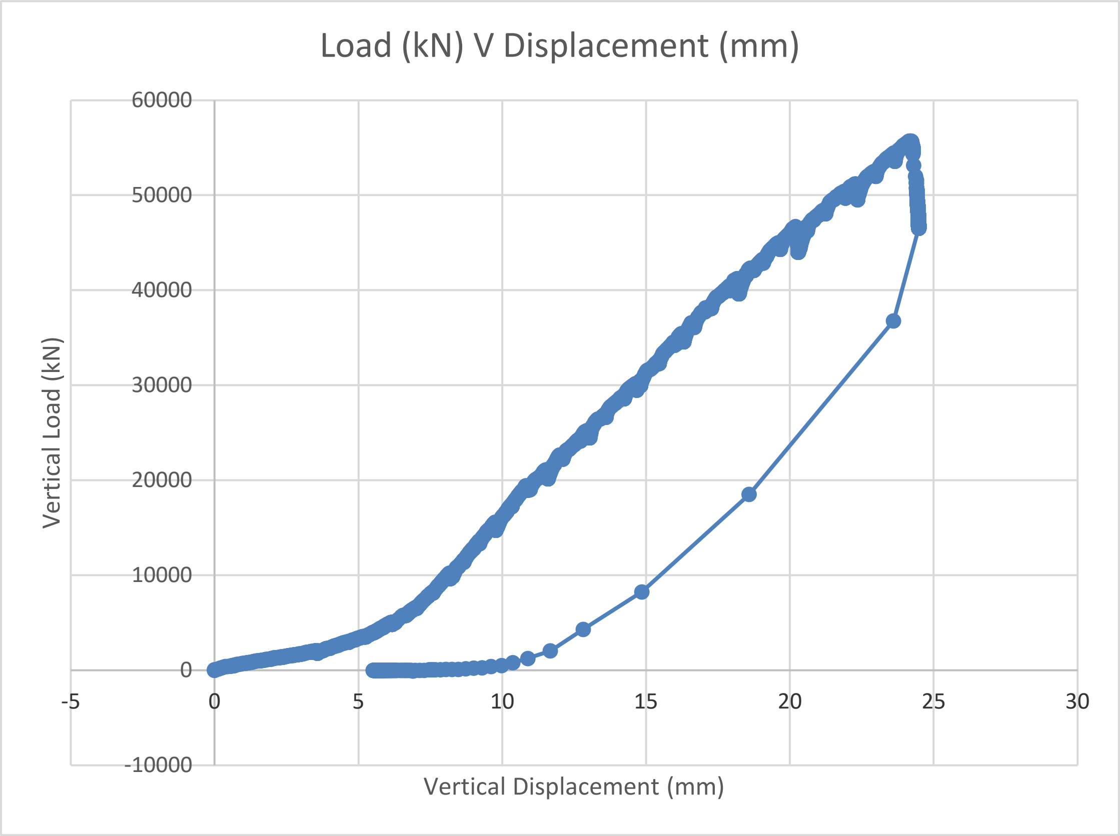


- M12 Grade 8.8 Bolts
- M12 Grade 8.8 BlindBolts
- 12 dia Threaded Bar

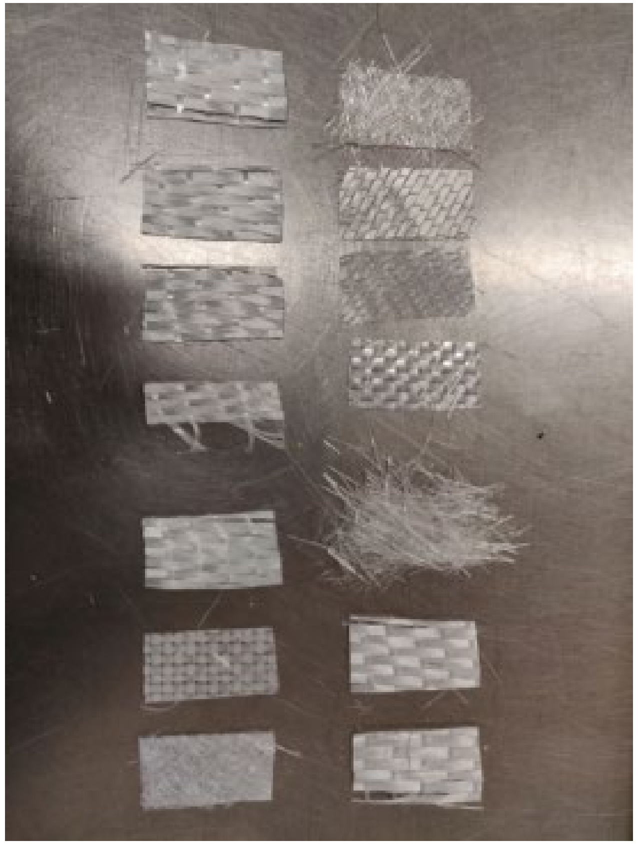
N29 Testing and Investigating – Connection Tests (3 No.)

N29 Testing and Investigating – Connection Tests (3 No.)





N29 Testing and Investigating – GFRP Burnout & LS-DYNA FEA (GT)

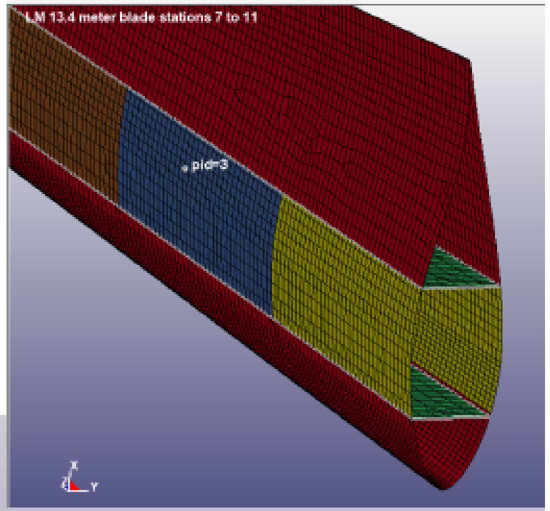


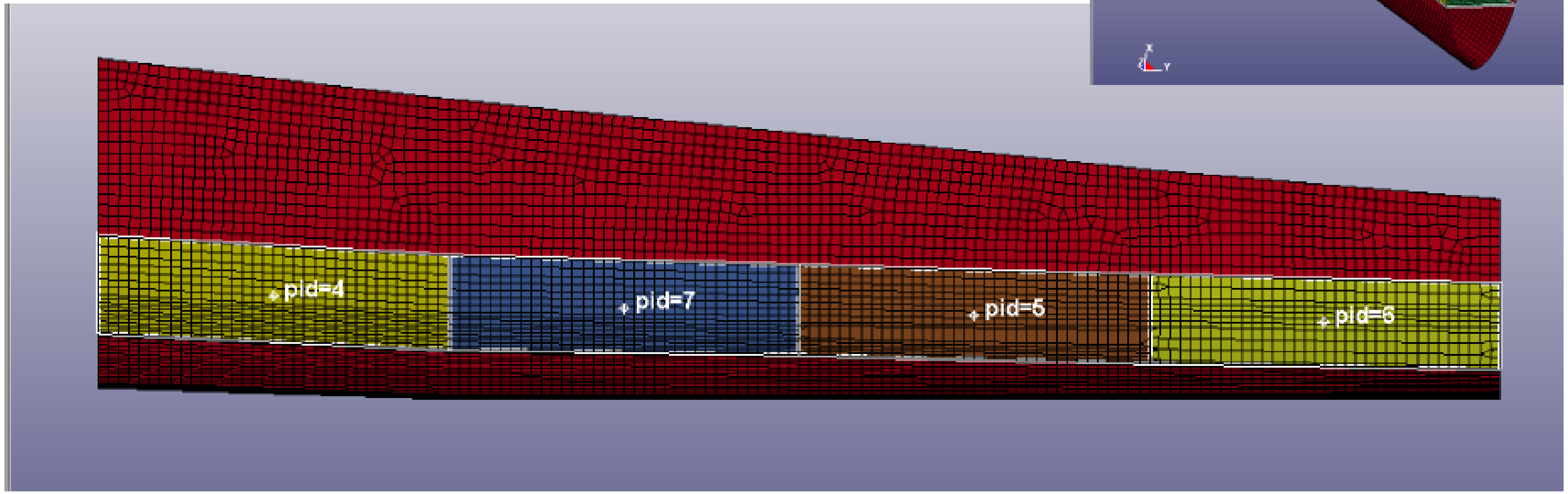
N29 Testing and Investigating – GFRP Burnout & LS-DYNA FEA (GT)

Part and Material Identification

Part 1 – Shell
Part 3 – Webs

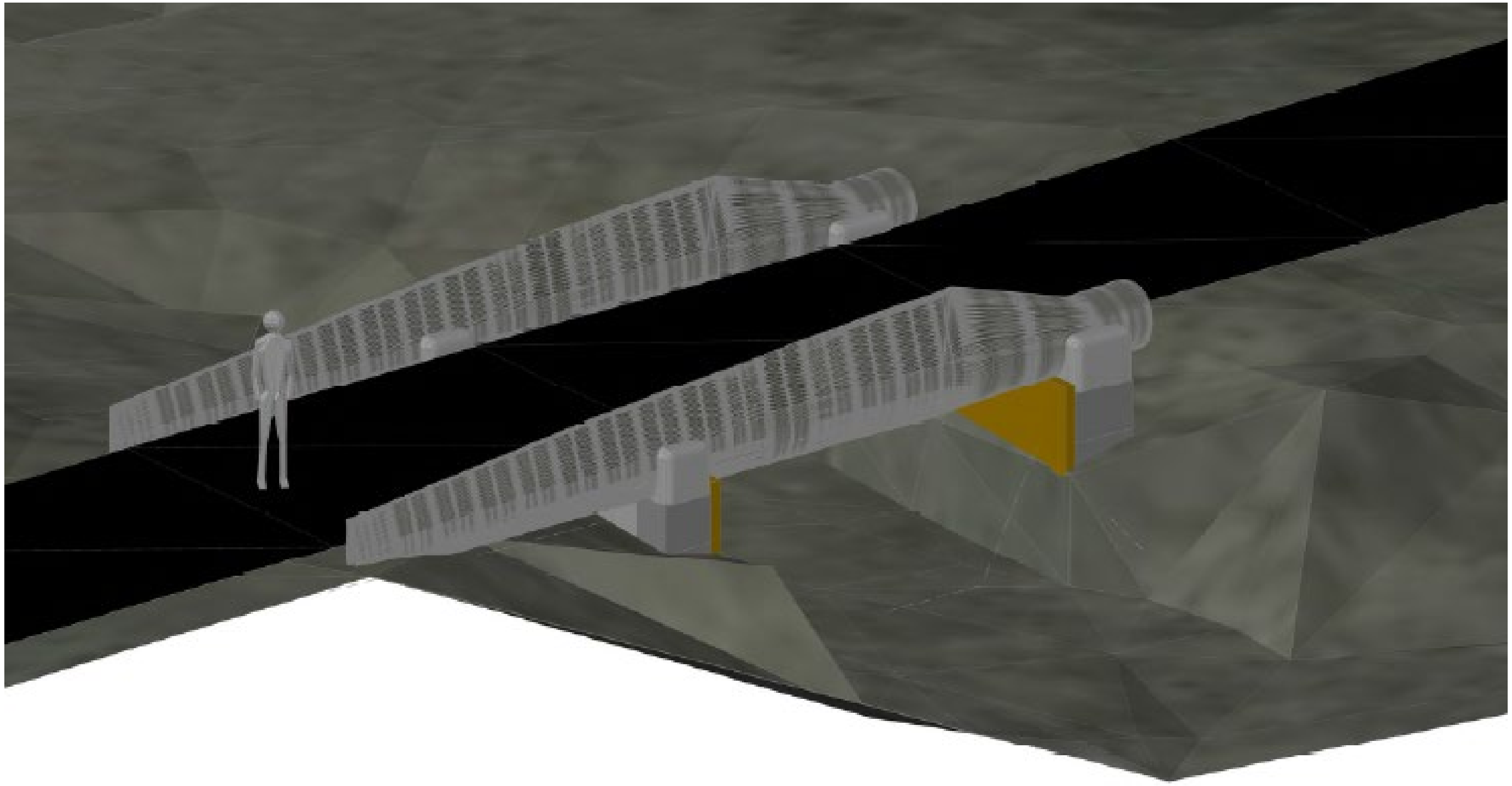
Part 4 – Spar cap from 7m to 8m
Part 7 – Spar cap from 8m to 9m
Part 5 – Spar cap from 9m to 10m
Part 6 – Spar cap from 10m to 11m



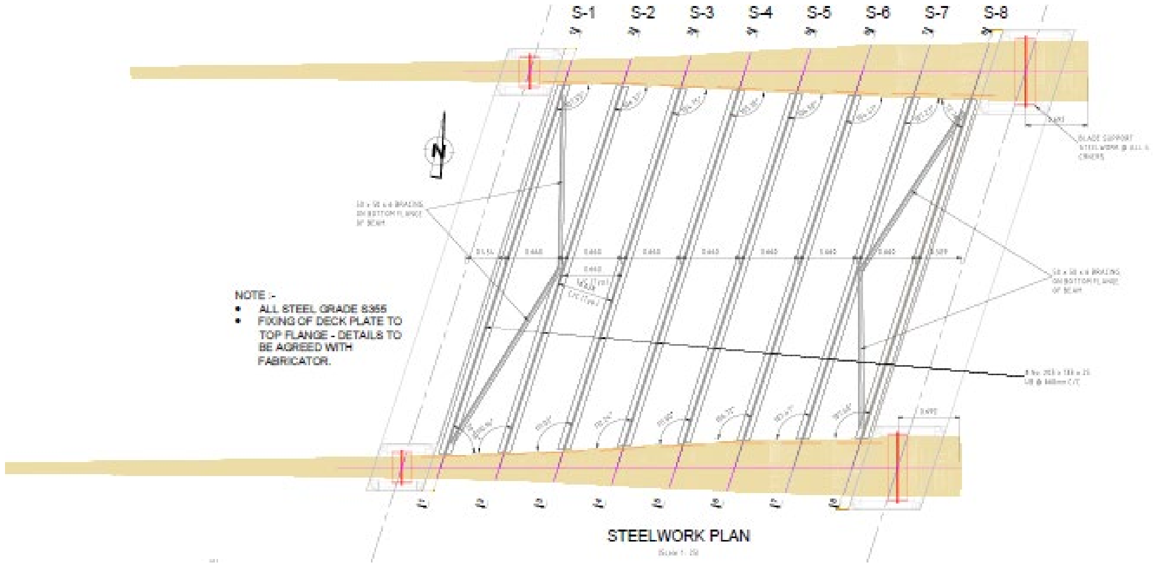


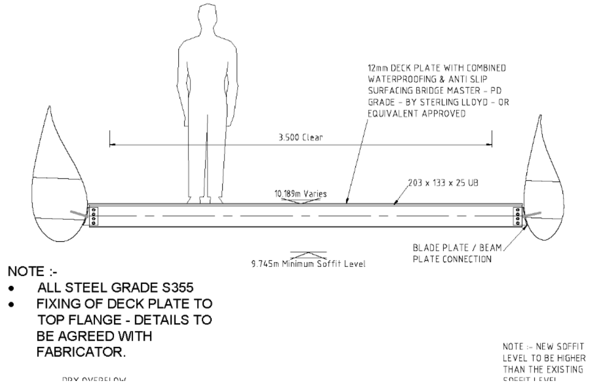
Dr. Russell Gentry, GT

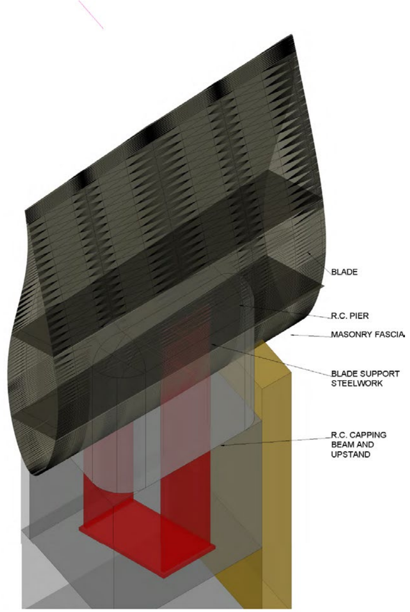
Blade Bridge – Design Development



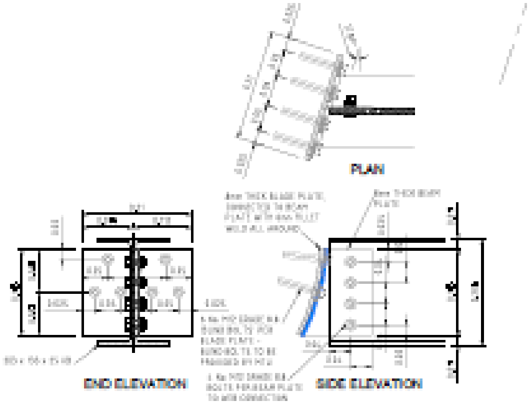
Blade Bridge – Design Development



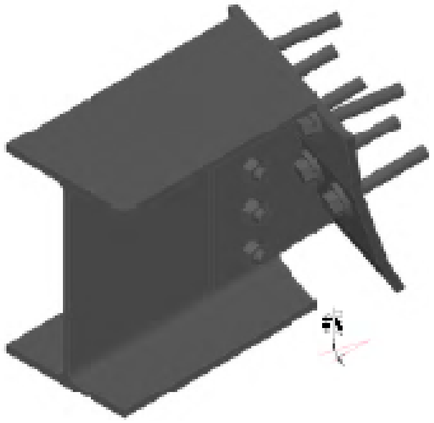




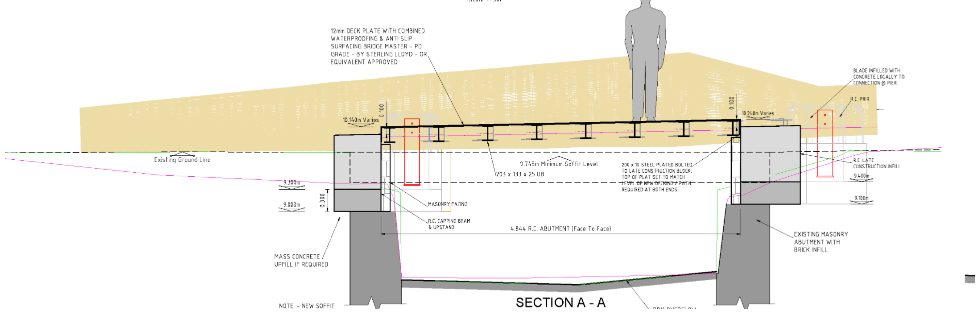
PROPOSED SUPPORT STEELWORK



TYPICAL BLADE PLATE / BEAM PLATE CONNECTION DETAIL

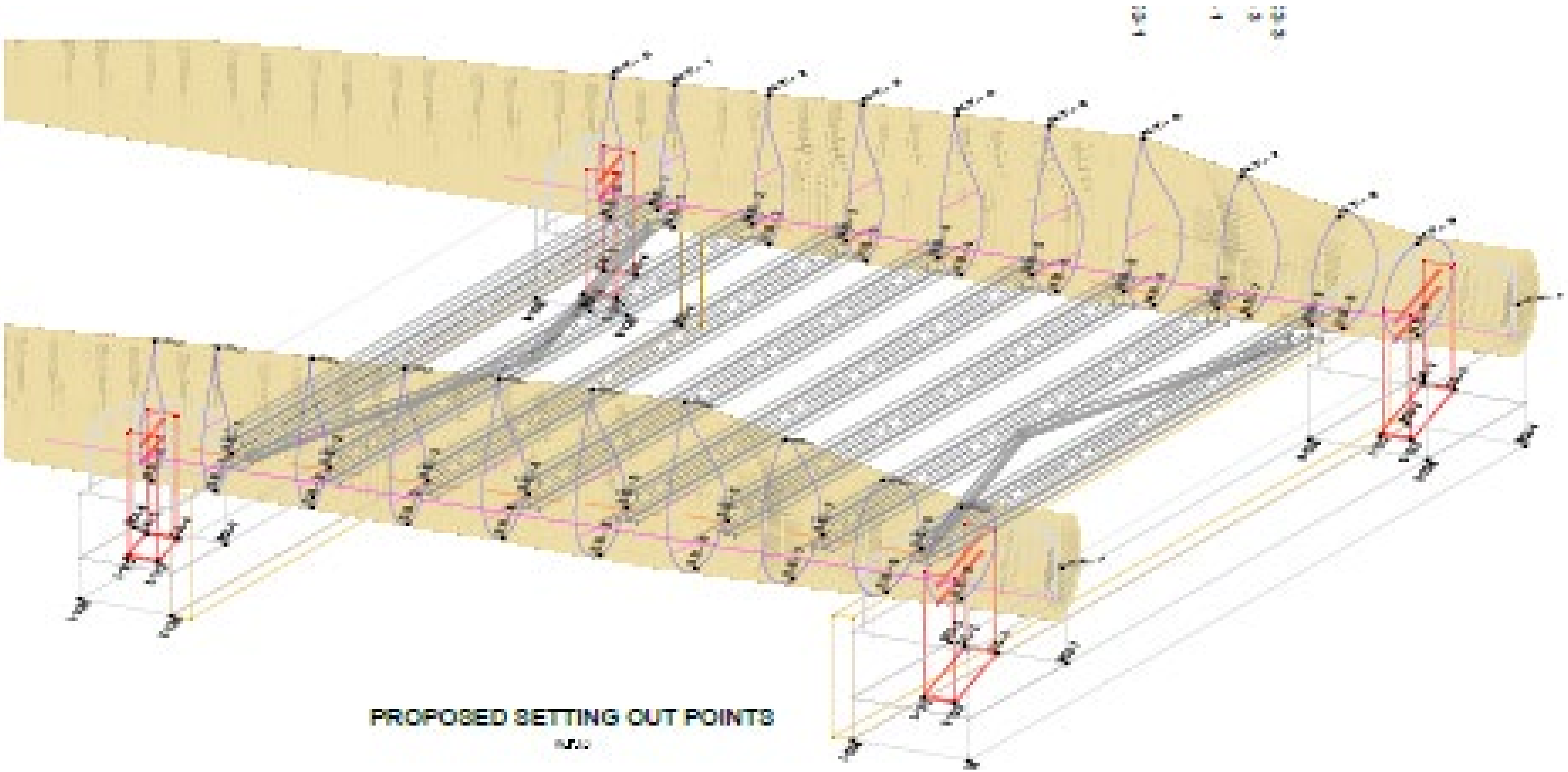


PLAN LAYOUT

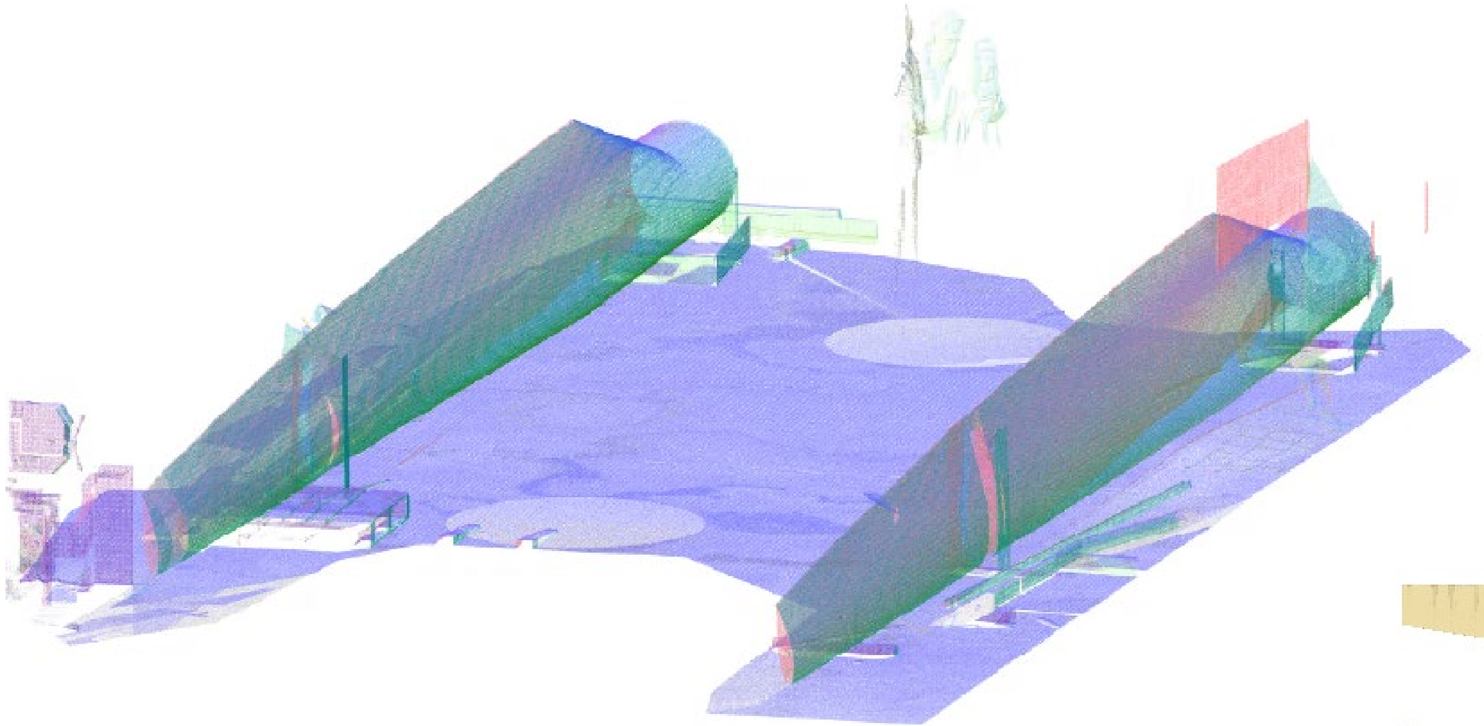


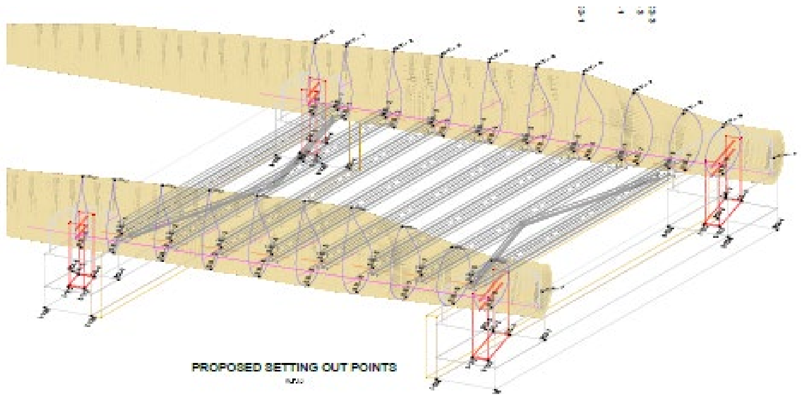
SECTION A - A

Blade Bridge – Design Development



Blade Bridge – Fabrication Stage – AR Brownlow Ltd. Carrigaline





Blade Bridge – Fabrication Stage – AR Brownlow Ltd. Carrigaline

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Blade Bridge – Fabrication Stage – AR Brownlow Ltd. Carrigaline

Blade Bridge – Programme

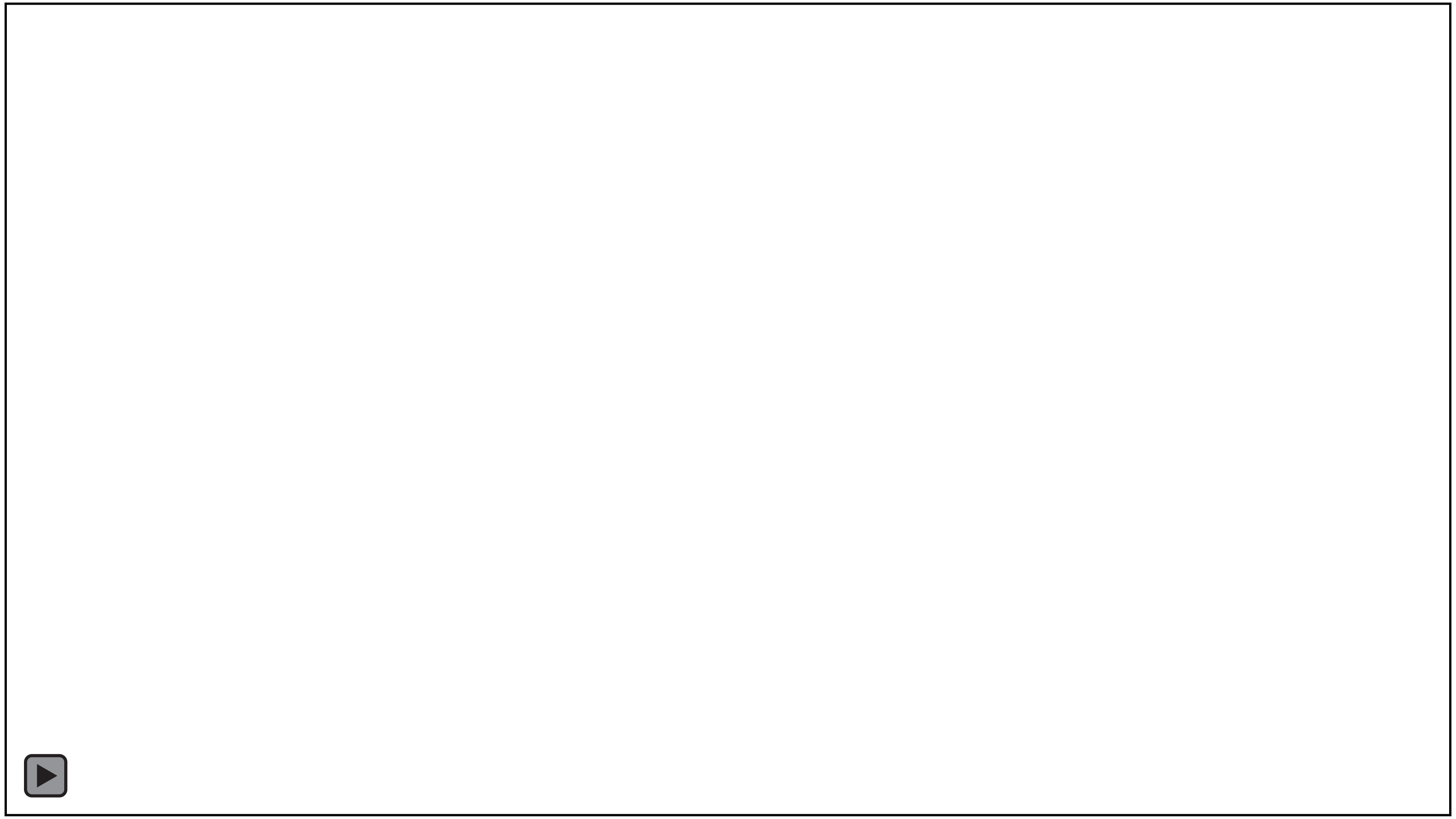
Complete Fabrication: December 2021

Galvanising: January 2022

Yard Assembly and Load Testing: January 2022

Deployment: January 2022

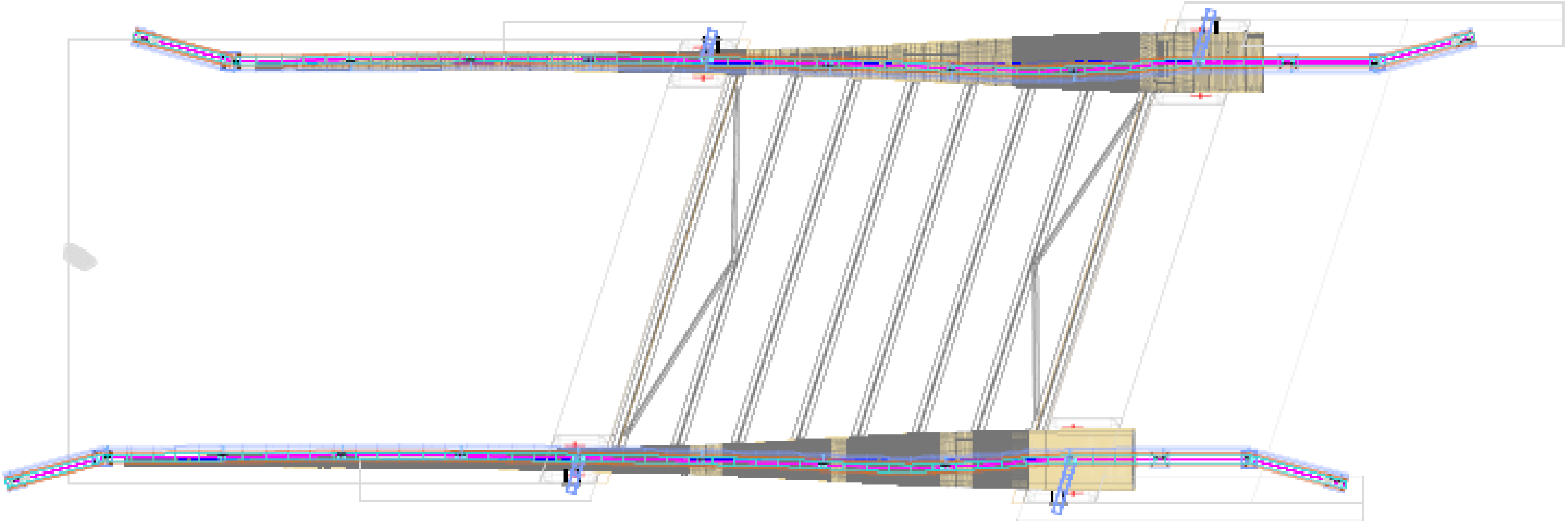
Finishing Works: February to July 2022



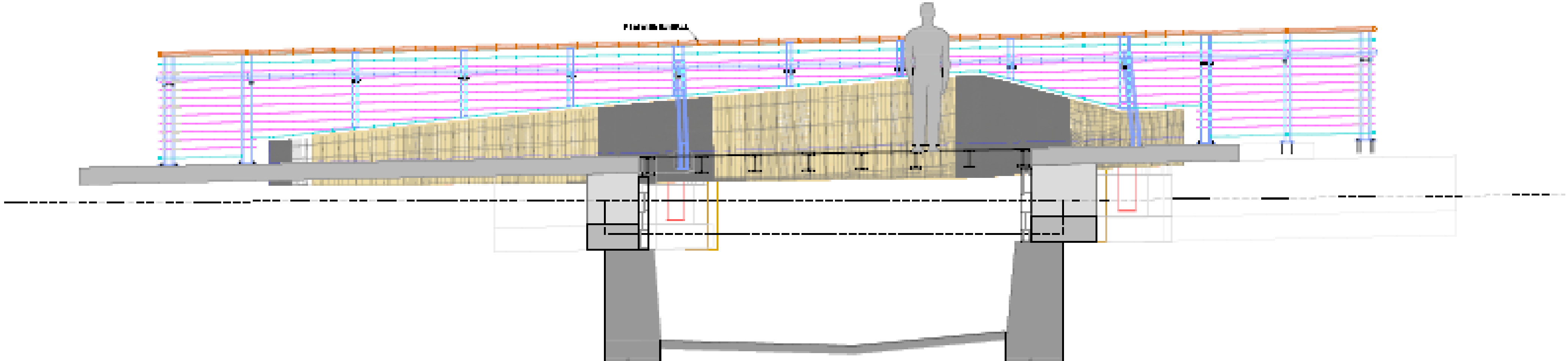
Jan 26th, 2022

Summer 2022

Summer 2022



PLAN LAYOUT



LONG SECTION

RE-WIND NETWORK
BLADE REPURPOSING SOLUTIONS
WWW.RE-WIND.INFO

Life Cycle Sustainability Assessment of a Pedestrian Bridge Made from Repurposed Wind Turbine Blades (BladeBridge)

Presenter: Angela J. Nagle

Research Team: Kieran Ruane, Russell Gentry, Lawrence C. Bank,
Niall Dunphy, Ger Mullally, Paul G. Leahy, Zoe Zhang, Asha McDonald, Emma Delaney

RE-WIND NETWORK
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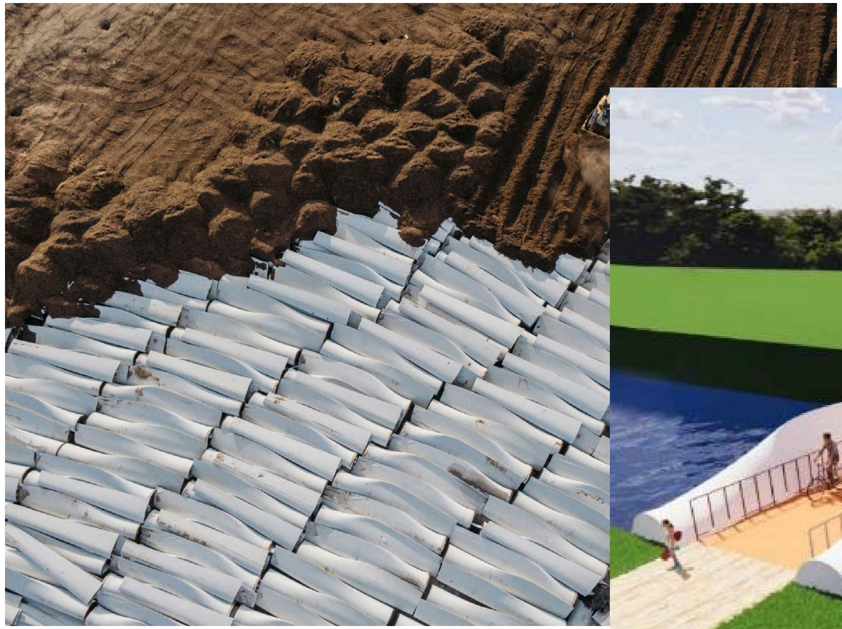
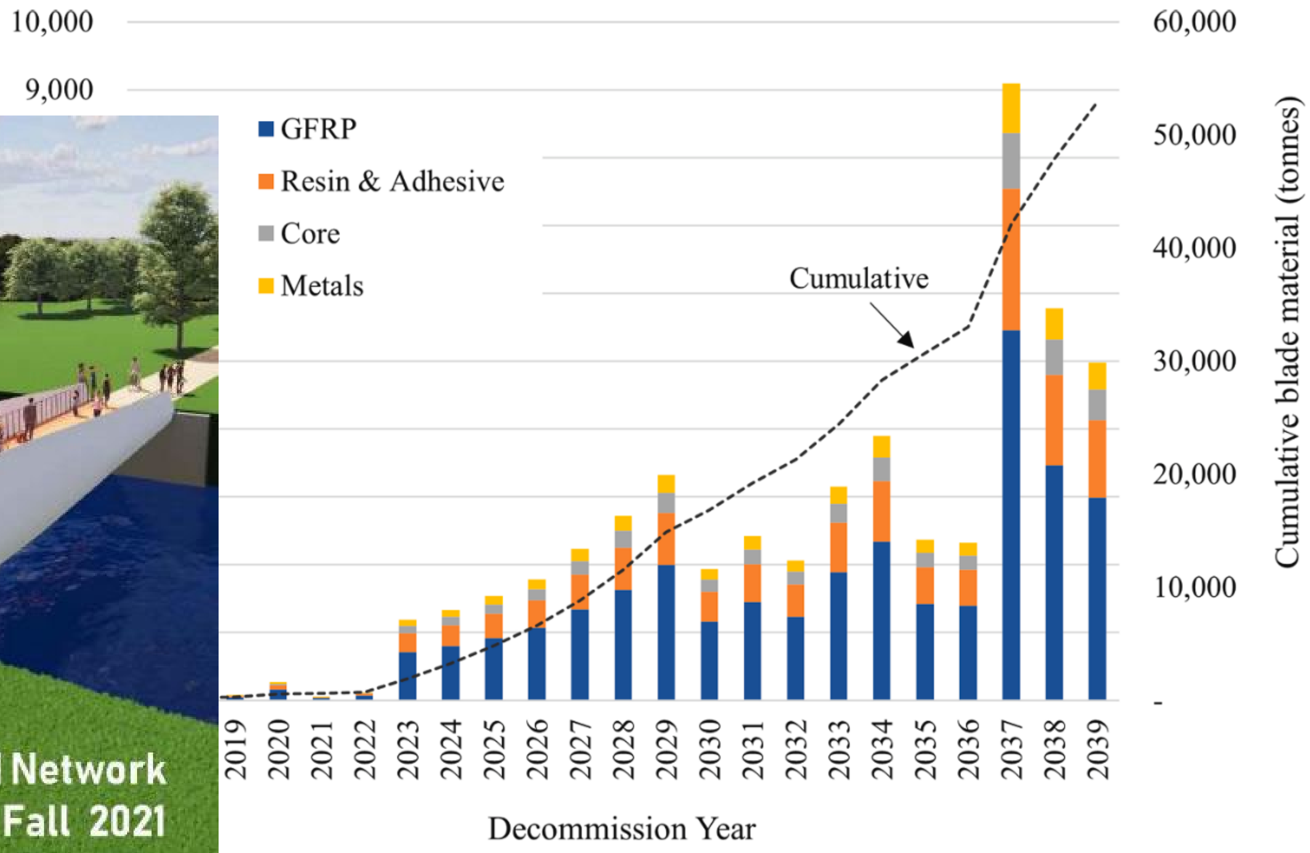
QUEEN'S UNIVERSITY BELFAST
CUNY THE CITY UNIVERSITY OF NEW YORK
UCC University College Cork, Ireland
Coláiste na hOllscoile Corcaigh
MTU Ollscoil Teicneolaíochta na Mumhan
Munster Technological University

Wind Blade Waste Problem & Opportunity



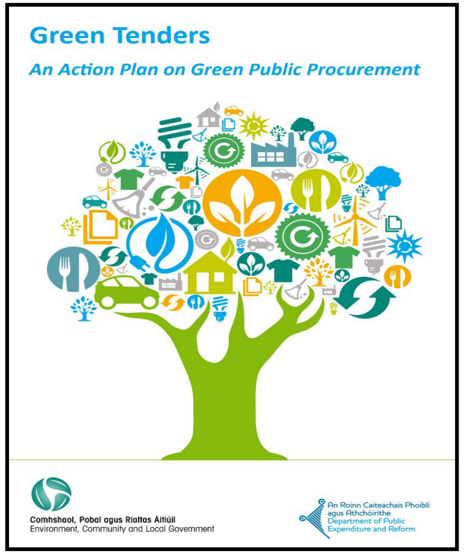


Double Opportunity & 2-sided Customer Base

Few sustainable and acceptable End-of-Life options exist for discarded GFRP blade material

+

EU Green Deal pushing Ireland to focus on sustainable procurement, SDG 12, and SDG 17



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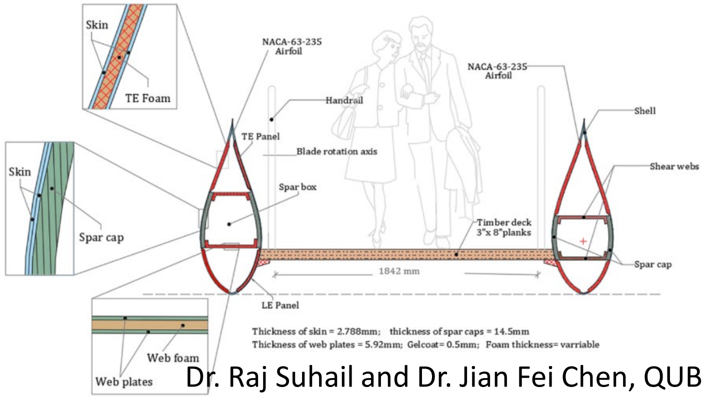
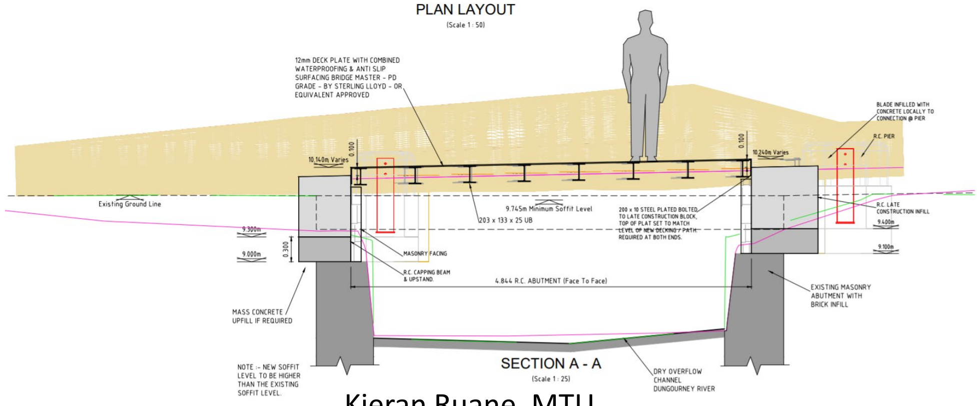
Considering the €1 million/day pledged for pedestrian infrastructure, a huge opportunity exists in Ireland to repurpose wind blades into publicly procured cycleway bridges

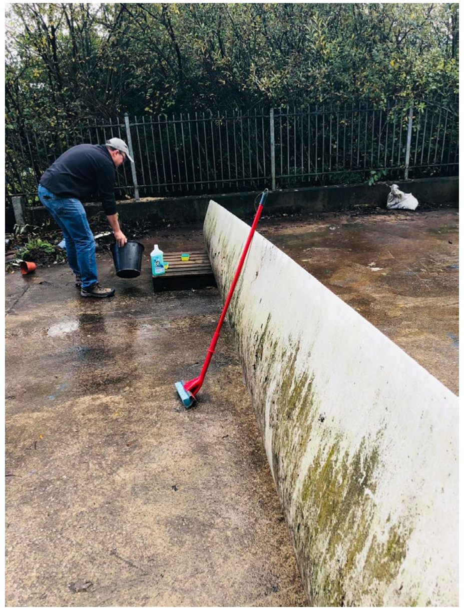
Blade Bridge: from Concept to Installation



Dr. Raj Suhail and Dr. Jian Fei Chen, QUB



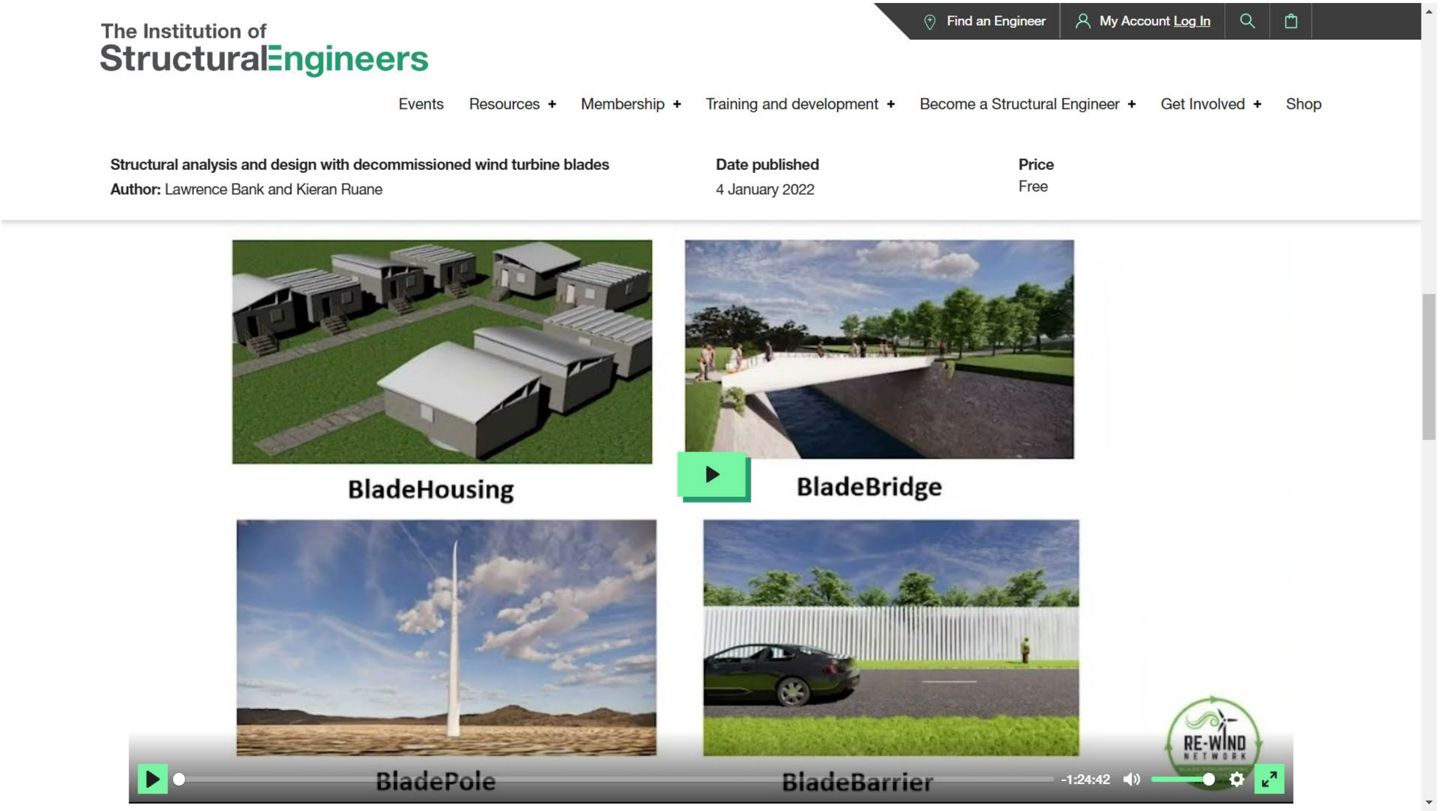
Kieran Ruane, MTU



[Watch video of installation here]

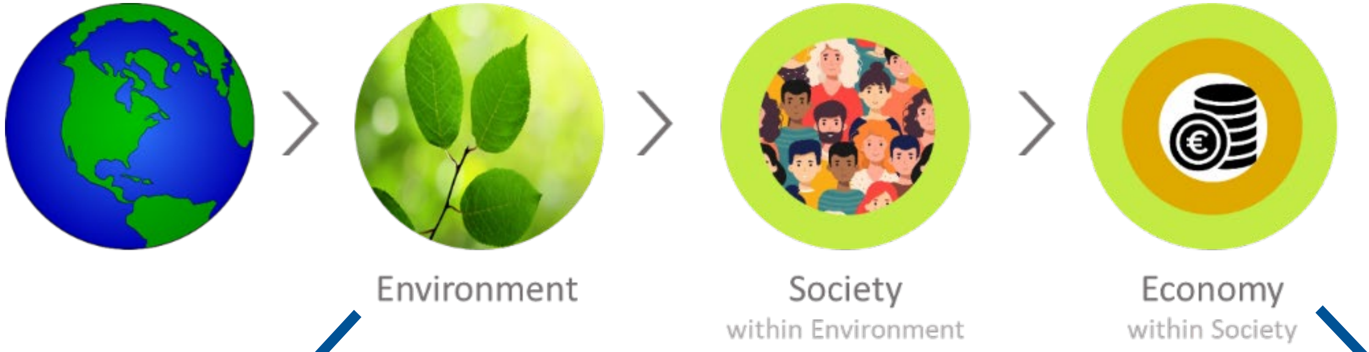
Demonstrating BladeBridge Technical Feasibility

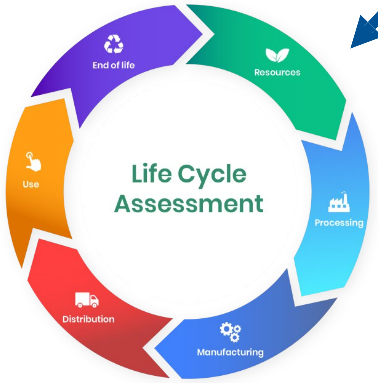
K. Ruane et al., (2022) "Experimental Investigation of an FRP Wind Turbine Blade for use as a Bridge Girder"



Life Cycle Sustainability Assessment (LCSA)

Can BladeBridge offer overall gains in sustainability?



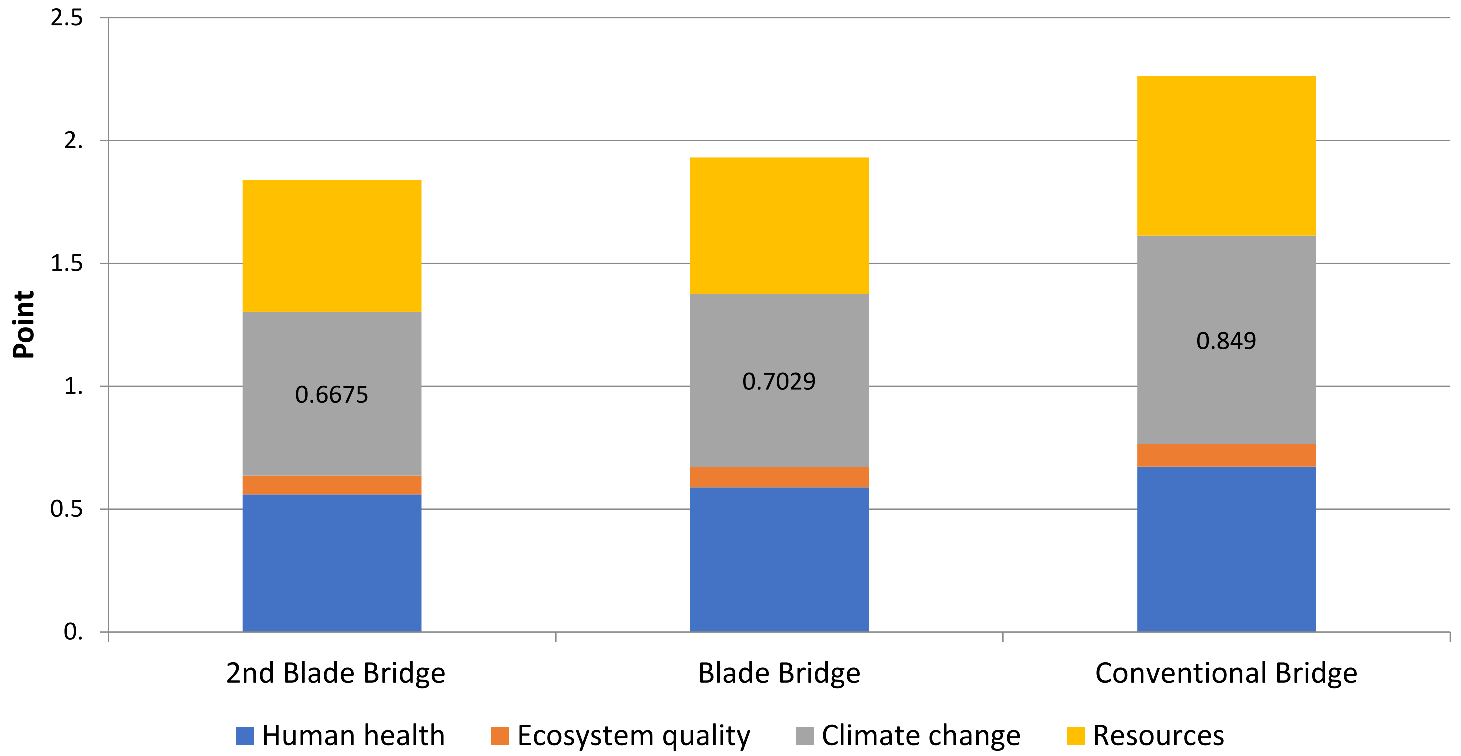


1. Life Cycle Assessment (LCA) was used to compare impacts of Blade Bridge to a conventional bridge

2. Shortfalls in Irish performance of socially aligned SDGs were used to develop s-LCA indicators.

3. Life Cycle Costings was used to compare costs. The NSF I-Corps customer discovery process was used to explore business models & economic value creation

Results Step 1: Environmental (Life Cycle Assessment)



Blade Bridge showed a **14% lower overall environmental impact** as compared to a conventional steel bridge, and **17% lower CO^2** due, to steel substitution & reduced maintenance.

The functional unit was 'A 22m^2 pedestrian bridge with emergency vehicle load capacity of 12 tonnes, over 60 years.'

(Assessment followed ISO 21931-2:2019. SimaPro LCA software was used with IMPACT2002+ impact assessment)

IMPACT2002+ single score impact assessment Humbert, S., De Schryver, A., Bengoa, X., Margni, M., Jolliet, O., 2014. IMPACT 2002+: User Guide. https://doi.org/10.1007/BF02978505

Using ISO 21931-2:2019 ISO, 2019. ISO 21931-2:2019(en), Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 2: Civil engine.

Results Step 2: Social (social-Life Cycle Assessment)

Can BladeBridge improve Irish performance on socially aligned SDGs?

Scale level	Description
+2	Ideal Performance. Best in class
+1	Beyond Compliance
0	Compliant with local and international laws and/or basic societal expectations
-1	Slightly below compliance level
-2	Starkly below compliance level

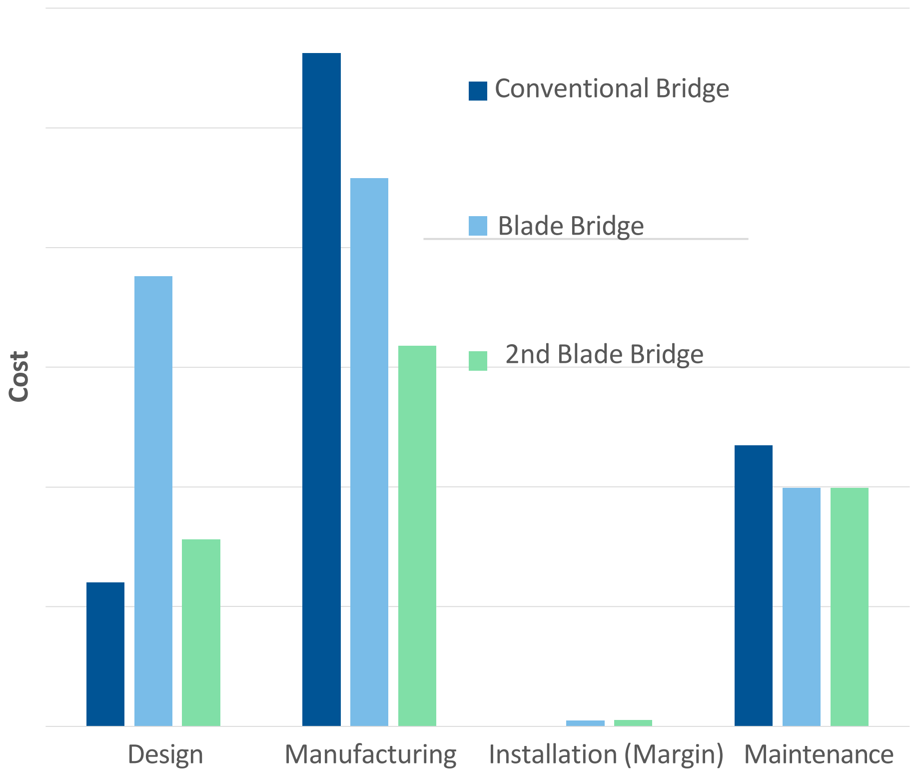
12.7 Promote public procurement practices that are sustainable, in accordance with national policies & priorities

Result: +1 'BladeBridges include circular material use and reduced environmental impacts, which is beyond current compliance for public procurement.'

17.14 Enhance policy coherence for sustainable development

Result: +2 BladeBridge allows renewable energy to become cleaner and more circular, thereby improving SDG 7 while preventing a negative knock-on effect on SDG 12.

Results Step 3: Cost (Life Cycle Costing)



Design of the 1st BladeBridge was more expensive than a conventional bridge due to the extensive blade testing & design work. 2nd + BladeBridges are expected to be only slightly more expensive

Manufacturing of the 1st BladeBridge was cheaper due to the substitution of the steel girder and some handrail material. 2nd + BladeBridges are expected to be cheaper still due to streamlining the design

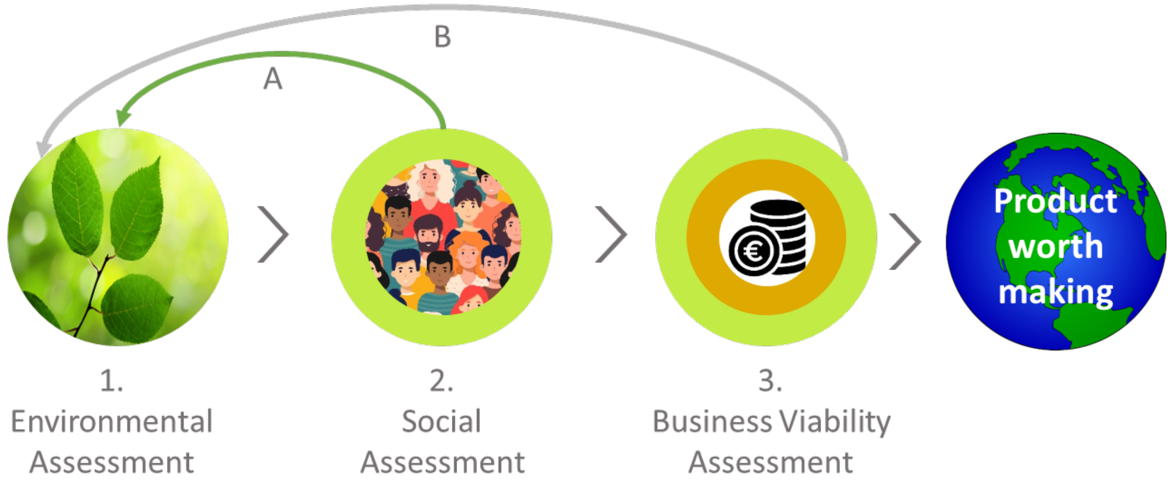
Installation (margin) included the abutment cradle installation, which was the only additional item to a conventional installation

Maintenance estimates indicate less lifetime costs due to reduced maintenance for the girder.

The first BladeBridge was more expensive than a conventional bridge. However, 2nd and subsequent Bridges made from the same blade type are expected to have a **10% less overall lifetime cost** than a conventional bridge due to steel substitution & reduced maintenance.

Conclusions

- The BladeBridge can support **Green Procurement** efforts, offering circular material use and quantified environmental impacts
- Blade Bridge can help **decouple** renewable energy generation from the production of waste
- The BladeBridge can be made at **equivalent cost** to a conventional bridge



Next Steps

New Frontiers Incubation program September 2022 to work on commercialisation of BladeBridge. This includes:

- Interviewing of County Council/TII employees overseeing development of greenways
- BladeBridge environmental impact quantification for use in GPP efforts
- Determining value to wind farm owners in repurposing unwanted blades
- Commencing TII Technical Approval Process on BladeBridge

Please get in touch if you are interested in this effort. Thank you!

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