COMPOSITES CONSULTING GROUP

QUALITY, EFFICIENCY & PERFORMANCE

Sandwich - Prestanda och applikationer - Kompositföreningen 2012-10-10

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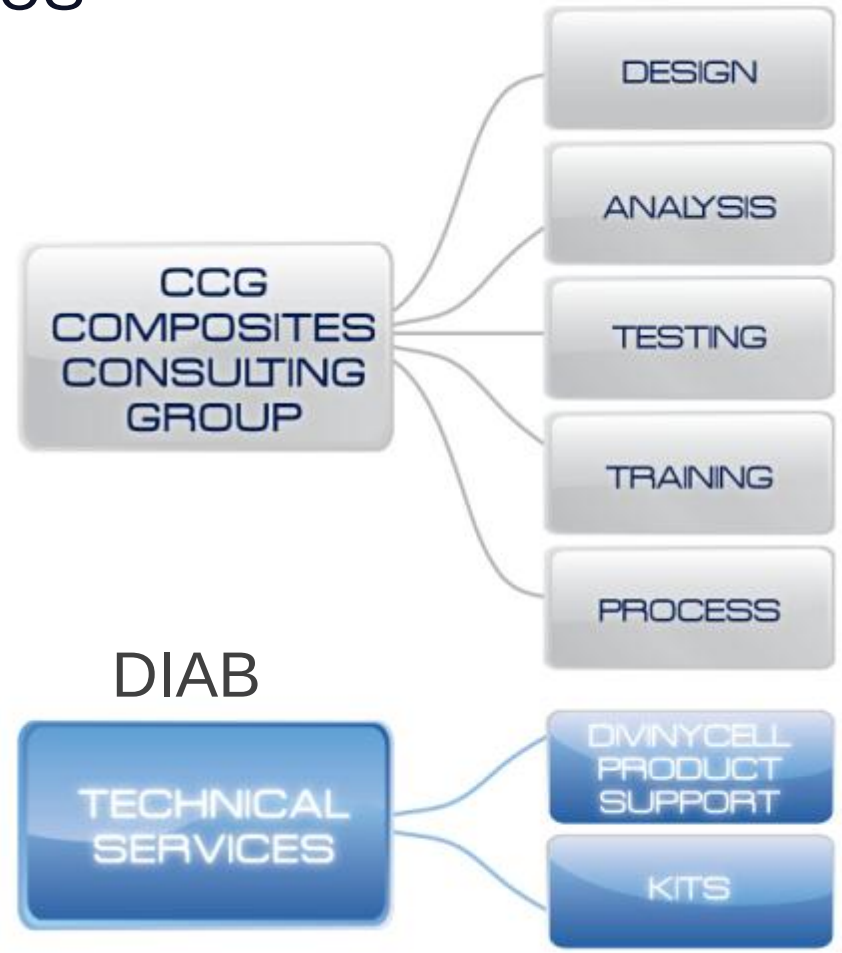
Outline of the presentation

1. **CCG – short presentation**
2. **Sandwich**
   - Material Properties; Creep, Fatigue, Fire (Comparison with steel)
   - Sandwich Theory; Stiffness, Strength (Failure modes)
3. **Calculation Techniques**
   - Analytical and Numerical (FEM)
4. **Composite applications – CCG reference cases**
   - Marine, Wind Turbine, Architectural, Industry
5. **Composite applications – other intersesting composite projects**
   - Architectural, Transportation

THE CUSTOMER IS OUR FOCUS

The CCG business model is to offer the most advanced and complete service and support mechanisms within the composites industry.

CCG, advancing your application through competence, experience and innovation.



Composites Consulting Group, CCG – an independent DIAB company:

- Extensive engineering and manufacturing experience in composites and sandwich products
- Design, Structural calculations and Process support
- 20 employees and seven offices in Europe, USA, Asia Pacific and China
- Offer training in process and manufacturing for all areas of composite materials and applications
- Recommends material and optimize process method

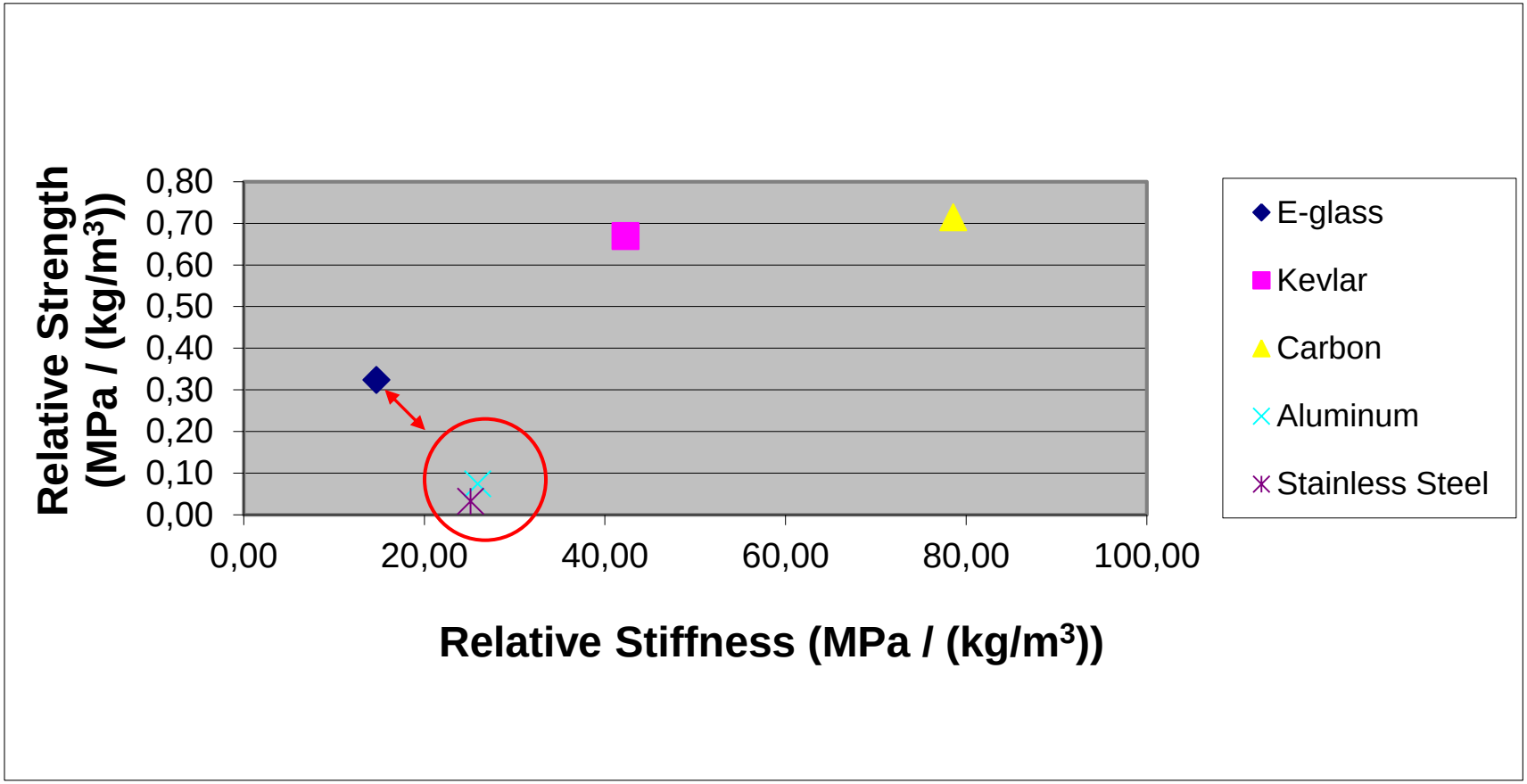
Why Sandwich?

FRP/Metals – Comparison

	Stiffness E-modulus (GPa)	Strength (MPa)		Density (kg/m^3)
E-glass *	25	550 $_T$	350 $_C$	1700
Kevlar *	55	870 $_T$	190 $_C$	1300
Carbon *	110	1000 $_T$	720 $_C$	1400
Aluminum	70	200		2700
Stainless steel	196	250		7800

* Approximate values for hand laid laminates with unidirectional fibers and polyester

FRP/Metals – Comparison



Metals are stiffer than E-glass even you include the weight

FRP/Metals – Comparison

Main positive properties FRP:

High static strength,

Higher fatigue strength compared to Steel

Low weight

Main negative properties FRP:

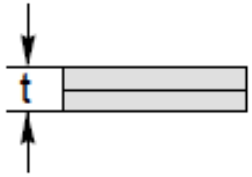
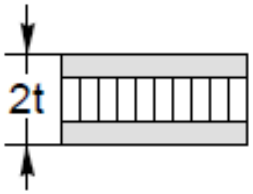
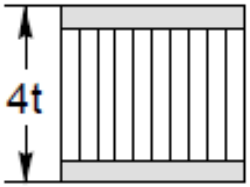
Low stiffness (E-glass)

Carbon & Kevlar much more expensive

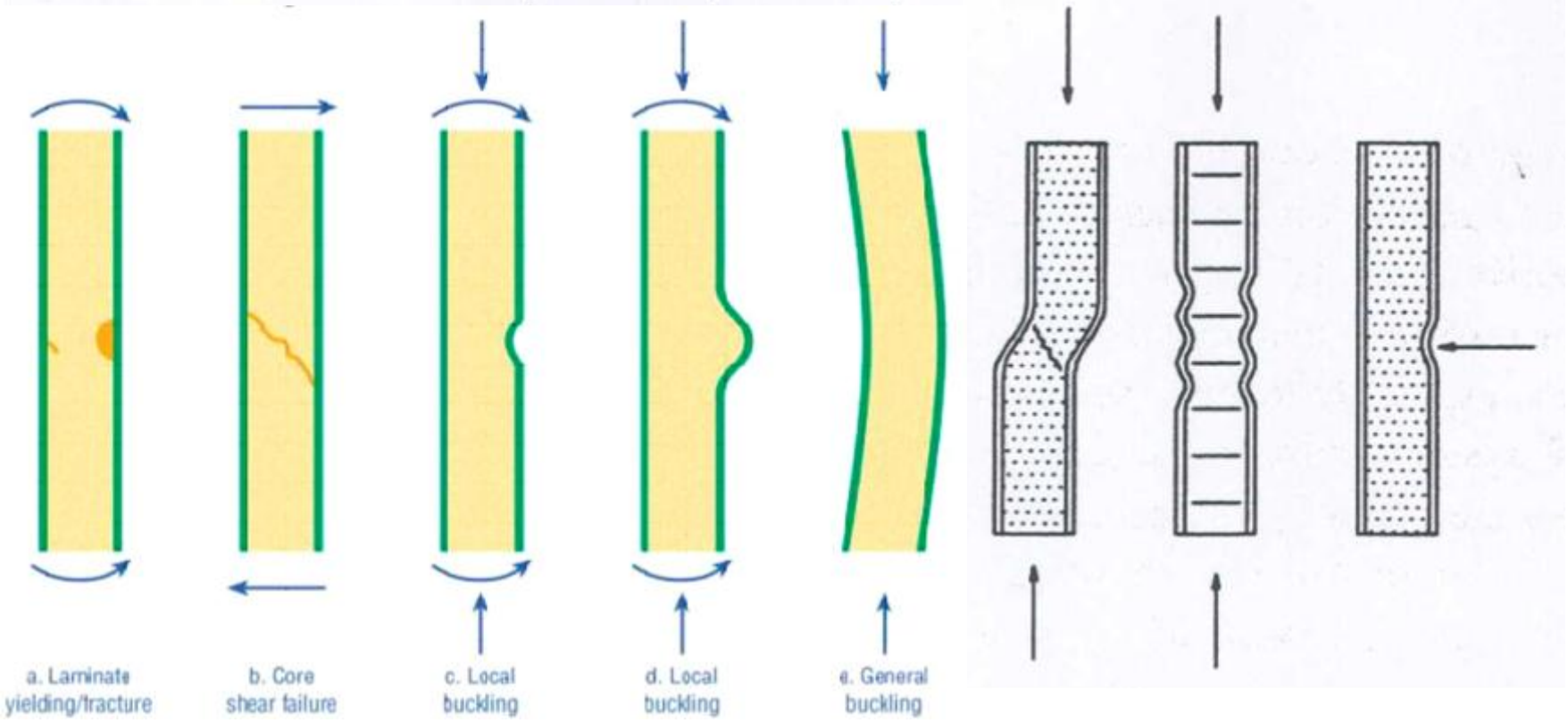
Solution :

To increase stiffness of GFRP - **use Sandwich construction**!

Why Sandwich?

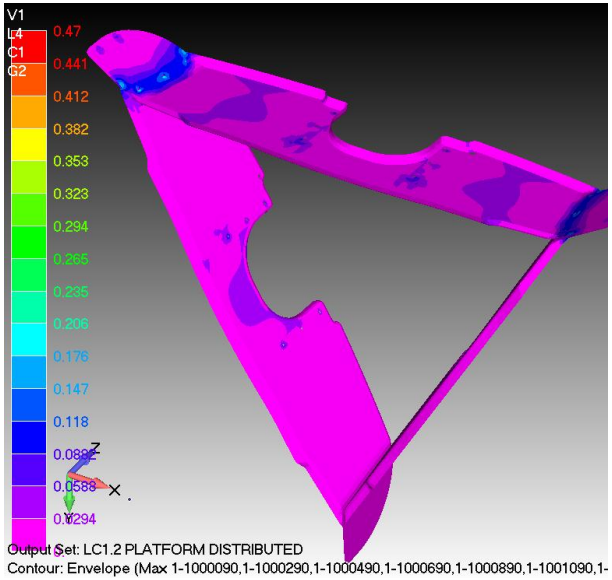
	Solid material	Core thickness t	Core thickness 3t
			
Stiffness	1.0	7.0	37.0
Flexural strength	1.0	3.5	9.2
Weight	1.0	1.03	1.06

Failure modes



Structural Calculation - Techniques

Todays software makes it possible to get an accurate understanding of the structural behavior of composites



Analytical

Corela – excel based tool

R.O.M, Lamina Theory

ESAComp, CompositePRO etc.

FEM

FEMAP/NeiNastran, Ansys, Abaqus, NISA, CATIA, NX

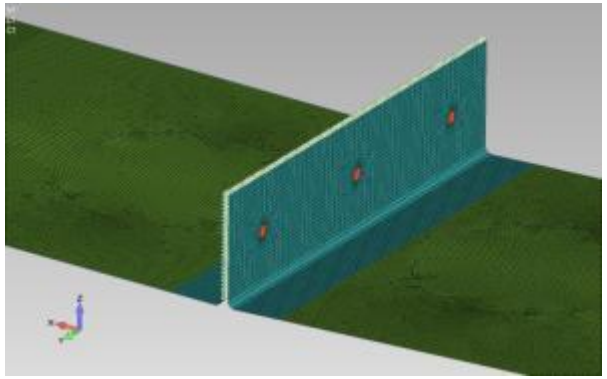
Possible to do both statically and dynamic calculations on composites. Crash analyses are very difficult.

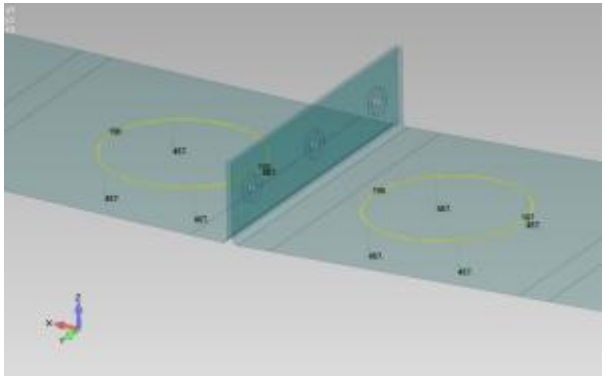
Always make an Analytical Comparison!

Structural Calculation – Empirical comparison

Example: Bolted Flanges Between Composite Parts

An empirical test is carried out in order to calibrate the FE model and also gather material properties.

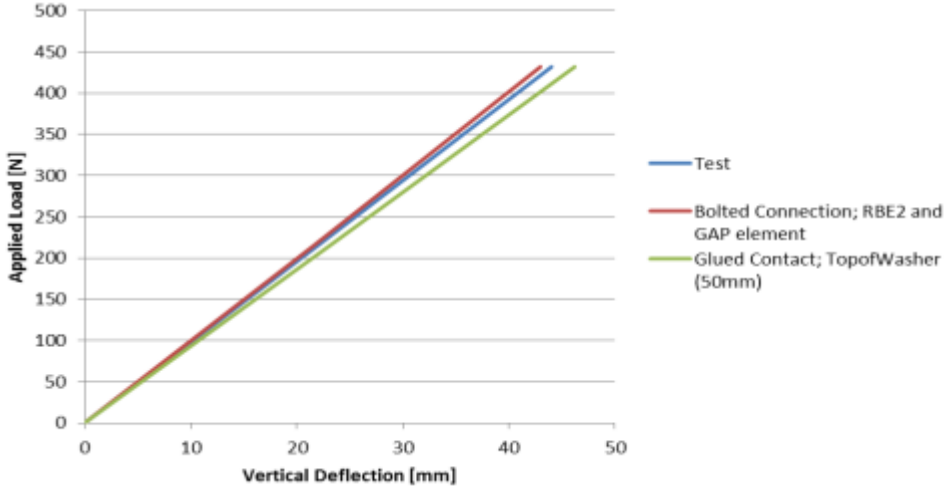




Structural Calculation – Empirical comparison cont.

ID	Analysis Type	Applied Load [N]	T_z Deflection [mm]	Deviation from Test
	Test	0	0	-
		216	22.0	-
		432	44.0	-
1	Beam element rigid with RBE2 to bolt hole edge +GAP element	0	0	-
		216	21.6	-1.82 %
		432	43.1	-2.27 %
2	Glued Contact; TopOfWasher (50mm)	0	0	-
		216	23.1	5.00 %
		432	46.2	5.00 %

Vertical deflection T_z, measured from the test and for the different finite element analyses.



REFERENCE PROJECTS

Reference project – Civil Engineering & Construction

Horten Lawfirm headquater in Copenhagen

Scope Of Work Structure analyzing, composite processing and materials specification.

Client Skandinaviska Glassystem

Facts CCG carried out FEA (finite element analysis) to evaluate the global behavior of each cladding module and its reaction forces into the concrete. CCG also did engineering and manufacture processing of the new light Façade for buildings.

Reference project – Civil Engineering & Construction

Euskalduna Palace Expansion – Bilbao (Spain) - Composite/stainless steel roof

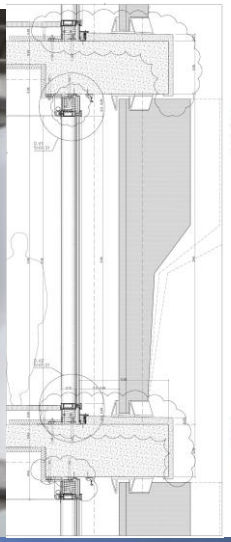
Scope Of Work
CCG performed design (fastening and laminate setup) and structural engineering of the composite/stainless steel roof. CCG also suggested manufacturing methods. Prototypes of the concept is produced in autumn 2011.

Client
Façade architects ENAR

Facts
- New expansion area for the Euskalduna Palace Museum,
- Light composite elements as a modular enclosure.
- Roof modules feature outer stainless steel surface integrated with a composite lightweight sandwich composite structure.
- “Easy assembling” concept for roof setting. No secondary finishing operations,
- Roof to satisfy the highest requirements for stifness, joint watertightness, thermal and sound insulation .

Reference project – Civil Engineering & Construction

BBVA main offices in Madrid (Spain)



Scope Of Work

CCG performed design (fastening and laminate setup) and structural engineering of the composite fins. CCG also suggested manufacturing methods. The project is in tender phase (2011).

Client

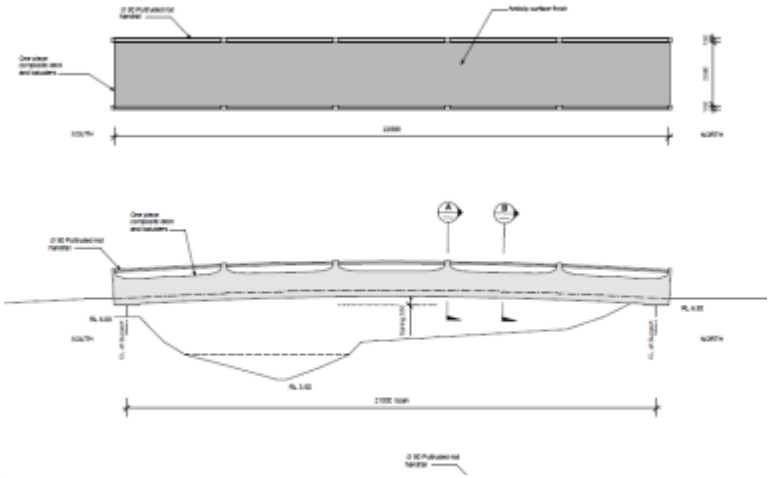
Enar-Envolventes Arquitectonicas, S.L. (Madrid)

Facts

- Building includes about 3.000 façade sun protection “fins”.
- Fins featuring characteristic geometry with more than 20 different dimensions, ranging from 4 to 10 meters.
- Fins to withstand blast and wind loads designed with an hybrid sandwich composite-steel structure.
- Highest esthetical specifications paramount as obvious for an emblematic building.

Reference project – Civil Engineering & Construction

22m Gosnell Foot Bridge - Australia



Scope Of Work

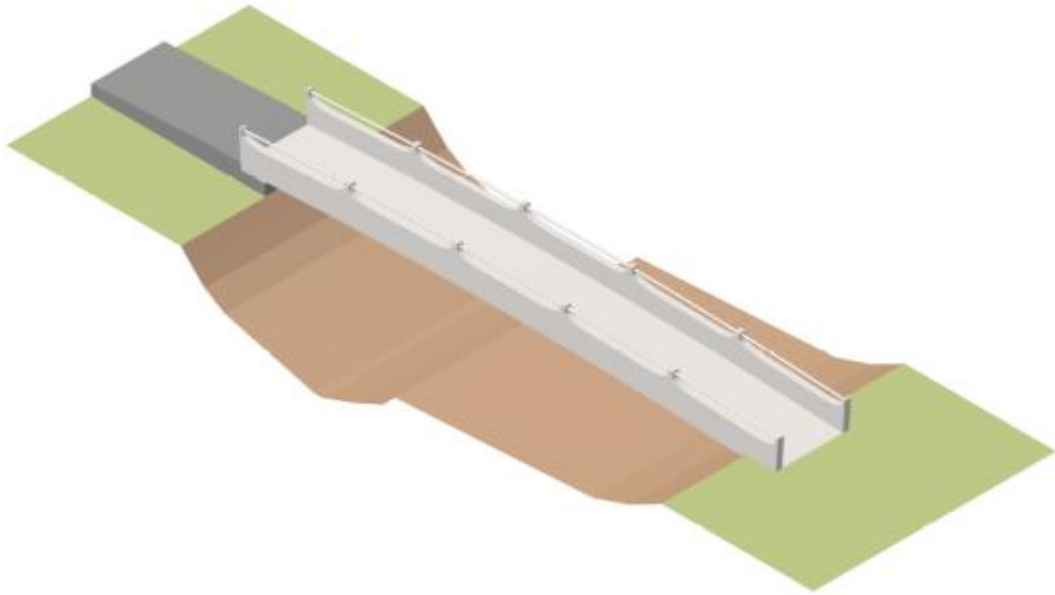
CCG performed design (fastening and laminate setup) and structural engineering of the composite parts.

Client

Local council - Western Australia

Facts

- Low environmental impact bridge for Western Australia.
- Public land, project for local council.
- Delivered to the site as one piece ready to be assembled



MARINE - Reference project:

Rescue boat for Scat harding

Scope of work

Rescue Boats
Structural laminate design, infusion process and FEA analysis of rescue boats.

Client

Scat Harding

Facts

Rescue boats for oil rigs, ferries, commercial ships etc. CCG has done several projects for Scat Harding. One of the rescue boats holds the world record of dropping height – 53m!

MARINE - Reference project:

Delta 54

Scope of work

Laminate design of whole vessel.

Assist in vacuum infusion on site for hull and deck.

All **carbon sandwich**

Client

Delta Yachts

Others

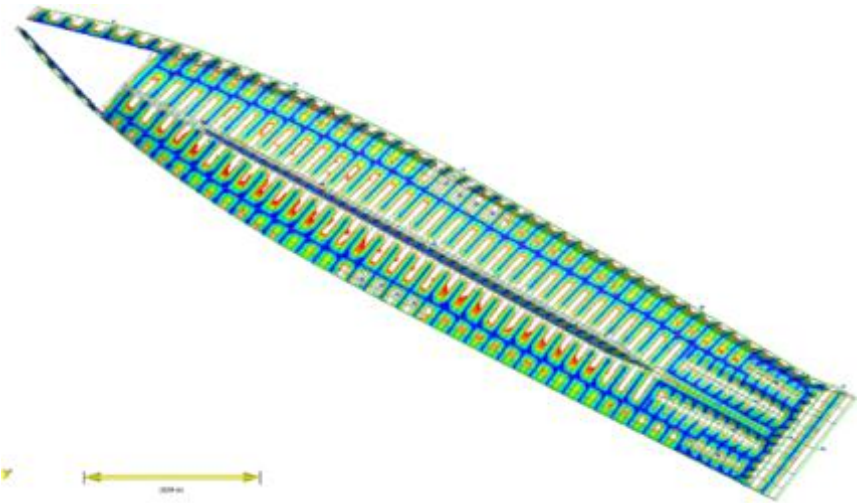
CCG setup the whole infusion process and performed the infusion at the clients premises. The workers were also trained during the process.

MARINE - Reference project:

155’ Composite sandwich YACHT

Scope of work

CCG gave Design support and infusion process analyzing (flow modelling), training of production personnel, responsible for infusion set up and implementation.



Renewable - Reference project:

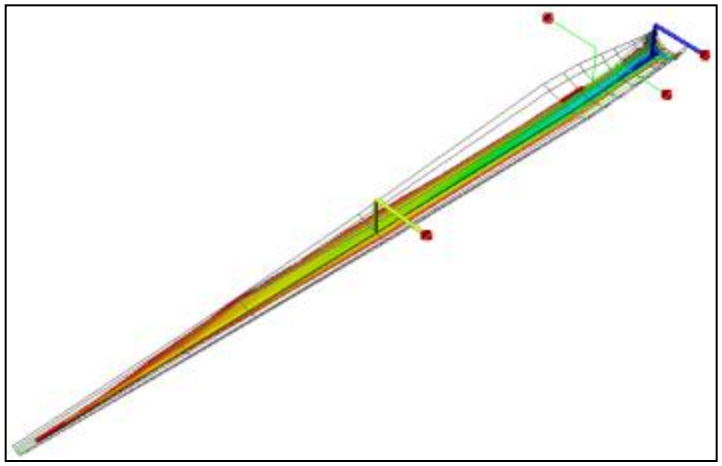
Flow modelling

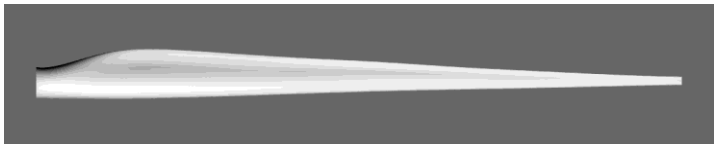
Scope Of Work: Flow Modeling of resin in vacuum infusion

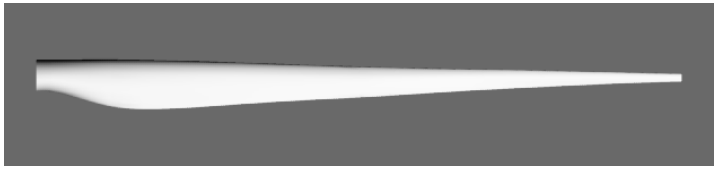
Client: Not disclosed

Facts: The wind blade pressure side and suction side of this 2 megawatt wind turbine was modeled using Polyworx flow model soft ware in order to improve the flow path and fill time eliminating close outs controlling the flow path.

Not only does blade geometry represent challenges for close molding but the variation in laminate thickness from root end to tip and the mix of cored and single skin area along with inserted pre fabricated sections such as spar caps means feed strategies and control need to be well though out to ensure a high quality part is produced with no void content and weight control Accurate 3D models are used to create the flow model simulation in Polyworx in order to create an actuate computer run simulation in order to optimize the infusion process .







Other composite projects

Reference project - DIAB

Train station tunnel entrance arch Malmö city, Sweden

DIAB Divinycell P core CNC machined to chape and laminated – built 2009/2010

Free form – one off project with advanced shape give composite fast and economic solution.

Reference project - DIAB

Nuovo Rifugio Gervasutti at Monte Bianco

Light, stiff and insulated sandwich structure.

Off site construction and lifted in place.

DIAB H core

Reference project - DIAB

Walking bridge in Brisbane, Australia

Cladding with DIAB P core

Sandwich composites are often used in walking bridges. Due to the light weight a fast installation can be done with minimum of traffic interruption. No maintanance.
Also a light esthetic cladding can be achieved by using sandwich composite.

Cultural Center, Baku Azerbaijan

- Cultural Center, Baku Azerbaijan
- Architect - Zaha Hadid

- Single skin GRP laminate. 18000 unique composite panels

Makkah (Mecca) Clock

- Top 200 m of facade is made of 60,000m^2 of sandwich composite
- PET core used
- 601 m tall

THANK YOU