COMPOSITE EDGE PROFILES FOR BRIDGES

M. Labordus[1*], E. Velds[1], G. Takke[2]

[1]*Infra Composites BV, Rotterdamseweg 380, 2629 HG Delft, The Netherlands*
[2]*Infra Composites BV, Keulschevaart 7, 3621 MX Breukelen, The Netherlands*
**M.Labordus@Infracomposites.com*

Keywords: Edge profiles, infrastructure, vacuum infusion, sandwich composites.

Abstract

Edge profiles for bridges are traditionally made in concrete or metal. Although the concrete profiles are relatively easy to manufacture, they are also very heavy. This implies that the outer concrete girders of the bridge need to be dimensioned on the weight of the edge profiles too, rather than on traffic loads alone. Metal profiles in stainless steel or aluminium are, with increasing metal prices, becoming very expensive. Normal steel, even if galvanized and/or coated, is not durable enough. Composites offer a promising alternative. Several composite profiles have been designed and produced for different bridges in the Netherlands. The profiles are dimensioned on wind, rain and snow loads, and in some cases also for pedestrian loads and aerodynamic actions from passing trains. Designs have been validated with FEM calculations and mechanical tests. During design, producibility aspects are taken into account at a very early stage. Also attachments and transportation and installation requirements need to be considered. This paper describes two composite edge profile projects which have recently been successfully completed.

1. Introduction

Edge elements on bridges mainly have a cosmetic function. They serve to hide the actual concrete structure of the bridge. Most concrete bridges are made by positioning prefab concrete girders on abutments. On top of these girders, a concrete bridge deck is cast, see figure 1.

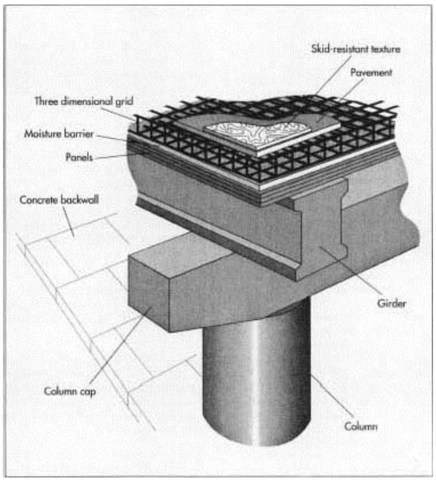


Figure 1. Cutaway view of a typical concrete beam bridge

The resulting edges of the bridges are covered by nice looking edge elements, thus providing the bridge with a more balanced appearance.

Figure 2. Traditional concrete edge elements installed on bridge Slootdorp N240 (picture Holland Scherm)

When these edge elements are made in concrete, a lot of additional load needs to be carried by the outer girders because of the weight of the profiles. Furthermore, installation requires special heavy equipment. Another downside is the high environmental impact associated by the use of concrete, expressed in the carbon footprint which is about 150kg CO2 per ton of concrete (source www.greenrationbook.org.uk). Metal profiles in stainless steel or aluminium are, with increasing metal prices, becoming very expensive. Normal steel, even if galvanized and/or coated, is not durable enough. Composites offer a promising alternative.

2. Project 1: Widening of highway A12 Waterberg/Velperbroek

2.1 Project description

The A12 highway was widened near the towns of Waterberg and Velperbroek. This required the widening of several bridges. The opportunity was taken to also improve the cosmetics of the old bridges, see picture 3 for the old situation.

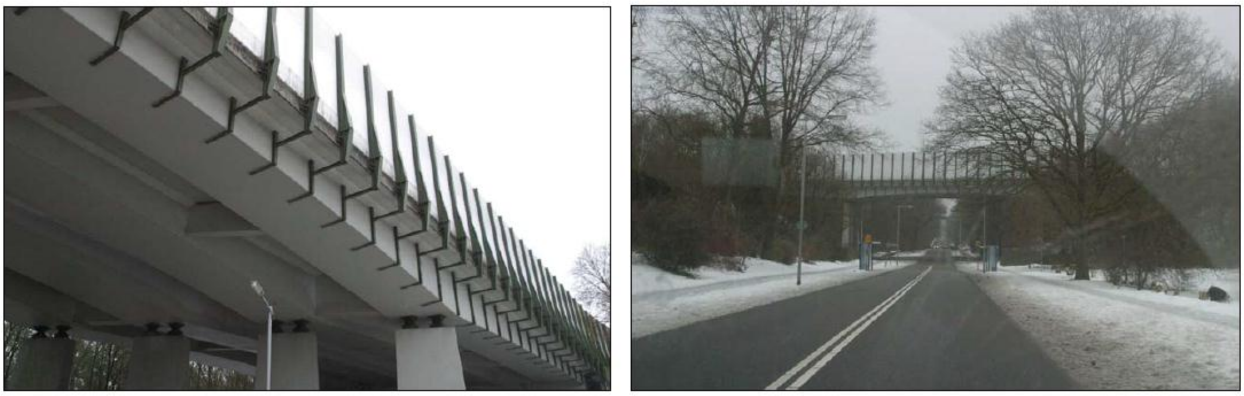


Figure 3. Old situation

Composite edge profiles were prescribed in the public tender, which was won by Heijmans. The design, production and installation of the composite edge profiles was subcontracted to Infra Composites BV.

2.2 Design of edge profiles

The cross section has dimensions as indicated in figure 4. The length of the elements is 3 meter, where both the upper and lower edges are fixed at 4 places, and fixed in its plane at 2 places.

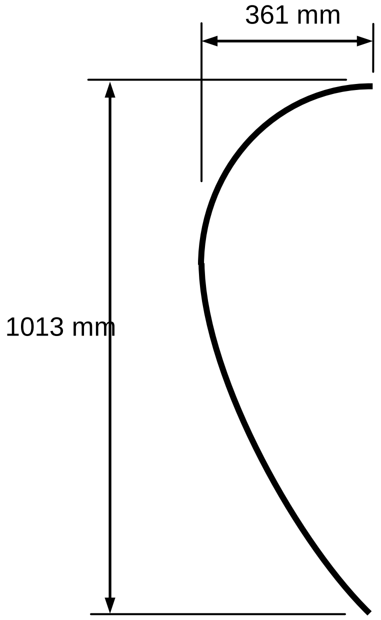


Figure 4. Dimensions of edge element

Loads are determined by paragraph 8.6 from the Dutch standard NEN 6702. A wind load is given by:

$$p_{rep} = C_{dim} C_{index} C_{eq} \phi_1 p_w$$

where C_{eq} and ϕ_1 are equal to 1 for this element. For a width of 3 meter and a height of 1 meter, C_{dim} is 0.991. The wind load p_w follows from a table for a height of 10 meter: 0.73 kN/m^2. For C_{index} the maximum factor for the end pressure is used: 0.8. This gives a total load of:

$$p_{rep} = 0{,}579\ kN/m^2$$

Next to the external wind loads, also the loads resulting from the weight of the elements are taken into account. Part of the elements will be crossing a railway track. The elements are installed 9.5 meter above the tracks. The trains can have a maximum speed of 160 km/hrs. The Dutch standard NEN 6706, paragraph 9.5.3 indicates a vertical thrust of 0,1 kN/m2 for this situation. Since two trains can pass simultaneously from opposite directions, this value needs to be doubled to 0.2 kN/m2. No reduction factor is applied for more aerodynamic shapes of the trains. Because the elements are limited in size, a reduction factor of 0.75 is applicable according to NEN 6706, section 9.5.3.4. This brings the representative load to 0.15 kN/m2. Since this load is much smaller than the loads resulting from the wind, they are not taken in to account separately.

The elements consist of a composite laminate with the composition as listed in table 1. The core is left out along the edges, to prevent exposure of the core after trimming. At two locations, thicker foam cores are applied, so inserts can be installed to accommodate a blind fastening system.

Tabel 1. Composition of laminate

layer	Material	Thickness [mm]
1	1200 gram/m2 quasi-isotropic E-Glass	0.94
2	1200 gram/m2 quasi-isotropic E-Glass	0.94
3	Soric XF 5 mm (levert ~4.5 mm op onder vacuum)	4.5
4	1200 gram/m2 quasi-isotropic E-Glass	0.94
5	1200 gram/m2 quasi-isotropic E-Glass	0.94
		8.3

FEM calculations are performed to validate the structural performance. The composite is modelled as 0/90 lagers which are stacked in 0^o and 45^o orientations, see figure 5.

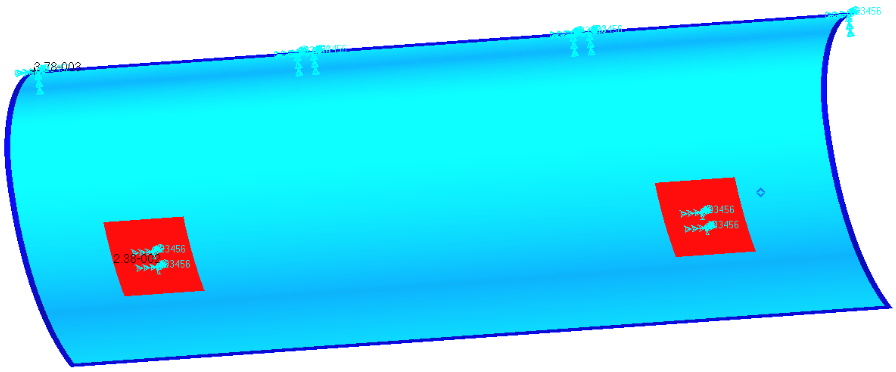


Figure 5. FE model of edge profile

For the working loads, both wind and weight are applied. The deformed situation is depicted in figure 5. The maximum deformation is 5.9 mm.

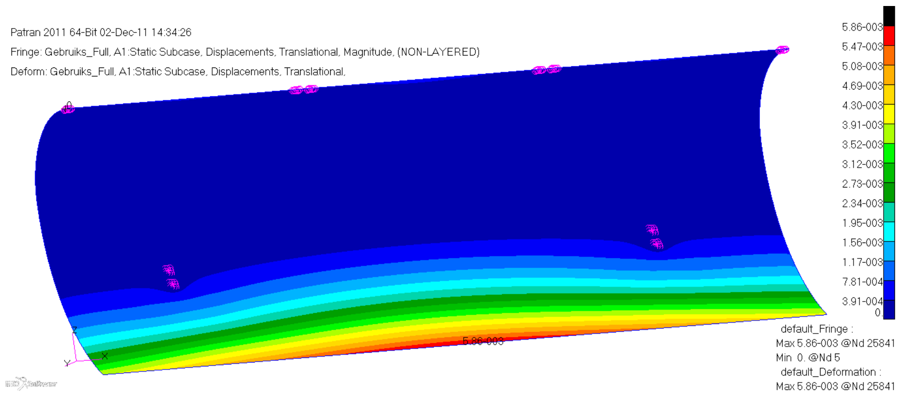
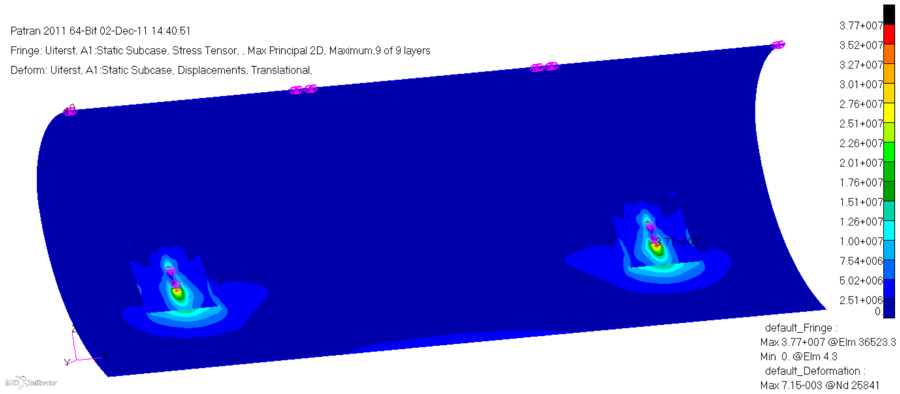


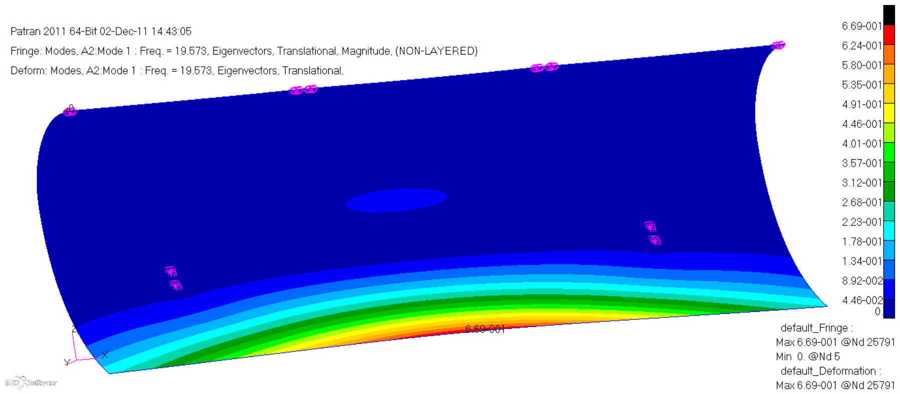
Figure 6. Deformation plot

For ultimate load, again wind and weight are applied, but multiplied by a load factor of 1.2. The structure needs to be able to withstand this load. The maximum stresses are given in figure 7, and occur in the situation where suction at the lower side is applied. The highest stress is 37.7 MPa. According to the CUR 96 guideline [2], the allowable stresses in a 0/90 laminate are 327 MPa. With the safety factors from the CUR 96 guidelines, the maximum stresses become 142 MPa, which is still within the strength margins.



Figuur 7. Maximum stresses in composite layers at ultimate load

The natural frequency is also determined. The lowest natural frequency is 19.6 Hz. The corresponding vibration mode is given in figure 8. For a structure of this size, the frequency is high enough.



Figuur 8. First natural frequency of element

Local stresses at the load introductions are also verified, both in plane and out of plane. For a single lap joint in the plane of the laminate, the following stress calculation is used:

$$\sigma_b = 2 \cdot 1.25 \cdot \frac{F}{Dt} \cdot \gamma_s$$

with

σ_b	Tensile strength of total laminate, 273 MPa.
F	Load on edge of load introduction hole.
D	Hole diameter, 10 mm for a M10 bolt.
t	Thickness of laminate, 4x 0,94 mm = 3,76 mm.
γ_s	Safety factor; 1.

With these parameters, the load on the edge of the load introduction hole can be calculated, 4106 N.

In case of loads out of the plane, the interlaminar strength is valid. Cur 96 indicates an interlaminar strength for these laminates of 20 MPa. This implies that along the circumference of the hole, the following load can be transferred:

$$F = \pi D t \cdot \tau = \pi \cdot 10 \cdot 3.76 \cdot 20 = 2362N$$

In figure 9, the bolt loads are depicted as they are determined with the FE calculations. With a maximum load of 1560 N, a safety factor of at least 1.5 is valid when it’s assumed the load can occur in any direction. Therefore, no additional measures are needed for this application

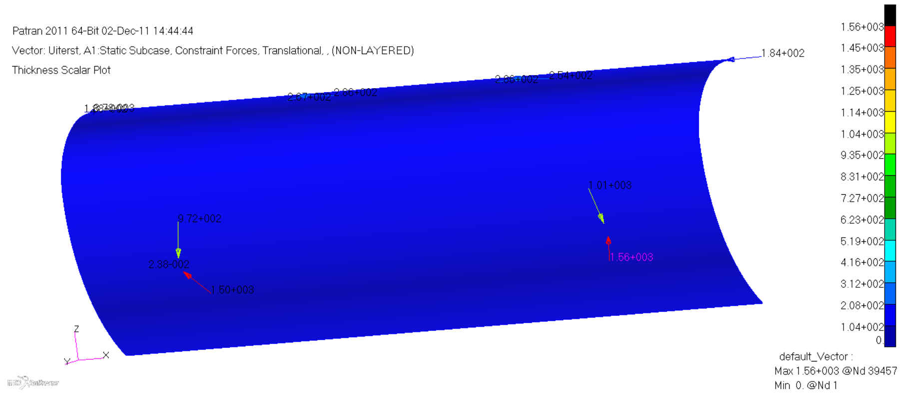


Figure 9. Bolt loads in ultimate load condition

2.3 Production

With the structural design ready and validated, tooling was designed and produced. First a rough master mould was milled from polystyrene foam. Then, an epoxy paste is applied over the surface, which is, after curing, milled down to the final dimensions, see figure 10. Finally, a polyurethane coating is applied. Over this master mould, a composite mould is laminated.

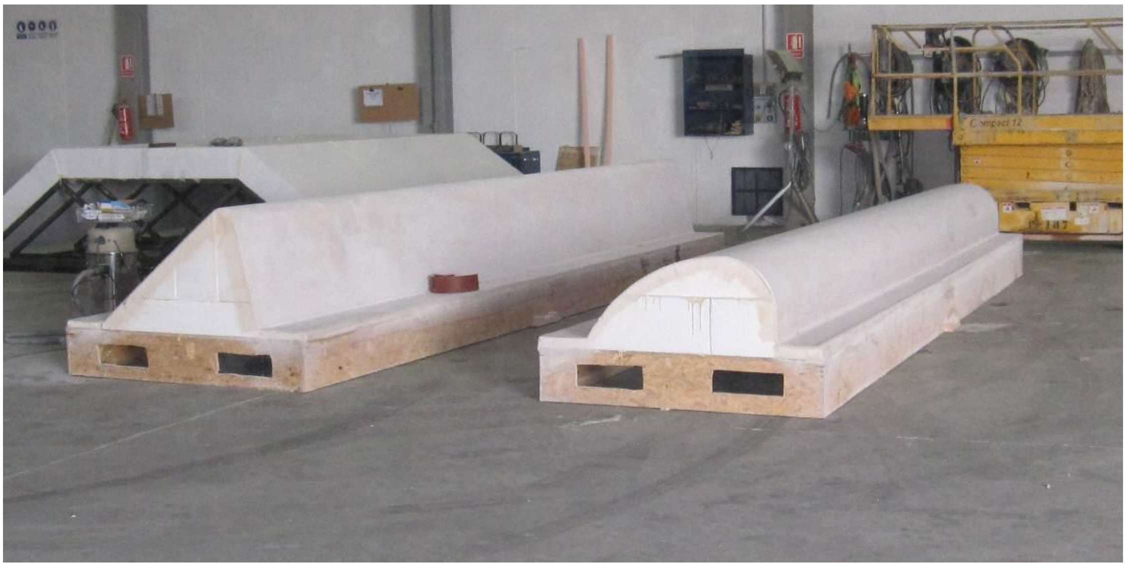


Figure 10. Milled master moulds for two types of edge profiles

After a proper application of mould sealer and release agent system, the mould is ready for production. First, a gelcoat is sprayed into the mould. Then, the layup as specified in table 1 is laid up in the mould. A layer of flow material is put over surface of the laminate and a runner channel is positioned in lengthwise direction. Everything is then covered with a nylon vacuum bag which is sealed to the mould flanges, see figure 11.

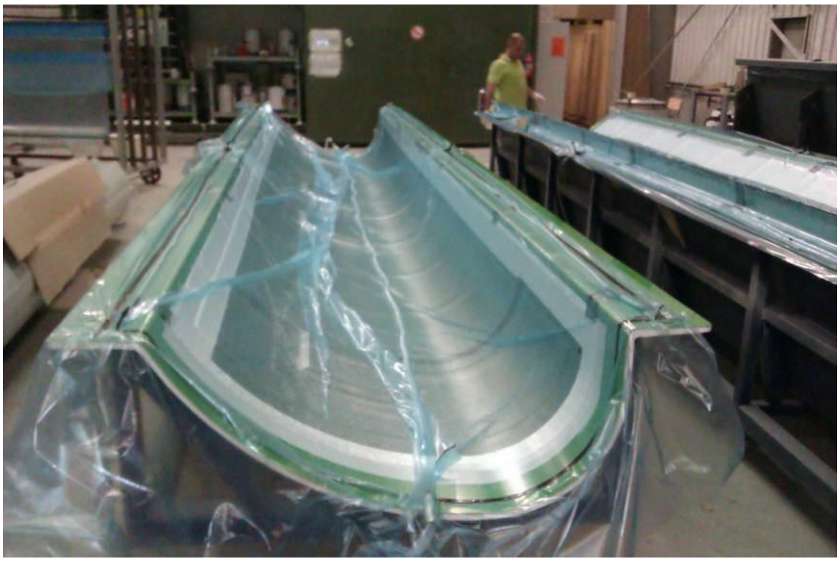


Figure 11. Laminate in mould, ready for infusion

Resin is introduced from both ends, while vacuum is applied along the two upper sides of the laminate. After infusion and curing, the elements are demoulded, trimmed to the correct dimensions and holes are drilled. In figure 12, the resulting elements are shown after installation.

Figure 12. Edge elements installed on the bridge

3. Project 2: Fly-over Waarderpolder

3.1 Introduction

A new fly-over has been designed near the city of Haarlem over the Waarderpolder, see figure 13 by Royal Haskoning Architects. The tender was won by Ballast Nedam, who subcontracted the design, production and installation of the edge profiles to Infra Composites BV.

Figure 13. Artist impression of fly-over Waarderpolder (picture Royal Haskoning)

The concrete bridge structure is covered allong both sides with large composite edge profile elements, see figure 14.

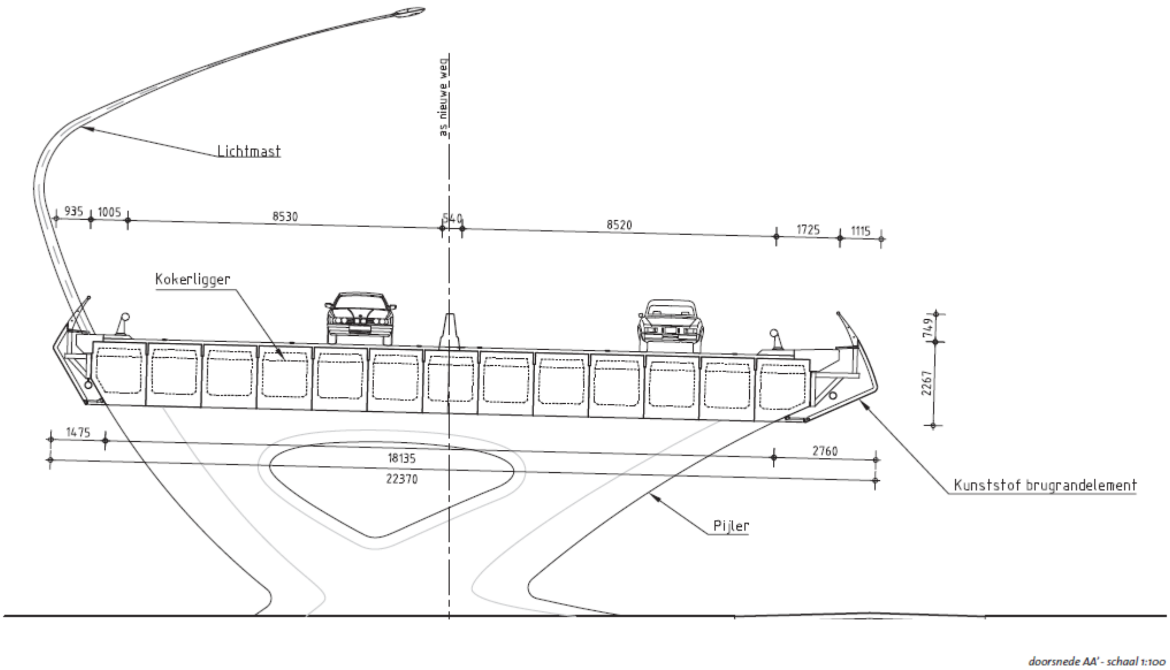


Figure 14. Cross-section of fly-over

3.2 Design of edge profiles

The edge elements are much larger now than in the previous example. Loads are therefore also higher. Furthermore, the top section of the elements now also functions as part of the pedestrian path for maintanance purposes. FE calculations, following a similar approach as decribed previously, have let to the following designs for inner and outer edege profiles for the fly-over, see figure 15. The laminates are the same, only the types and thicknesses of the cores vary. Where pedestrian loads are foreseen, a 25 mm balsawood core is applied. For the large shell sections, PET foam of 80 kg/m3is applied with thicknesses varying from 15 to 25 mm.

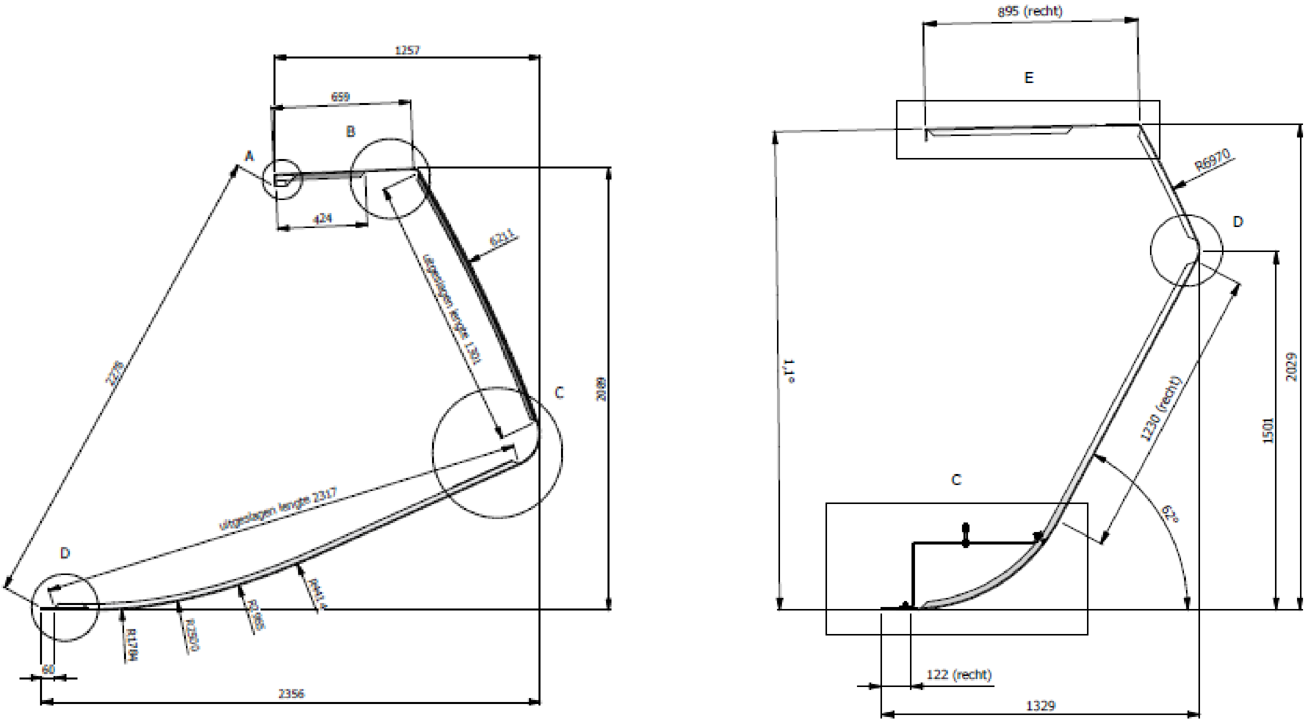


Figure 15. Designs of edge elements

Special testing was performed to validate the performance of the attachment points under fatigue loading, both in-plane as out-of-plane, see figure 16.

Figure 16. In-plane (left) and out-of-plane (right) testing of attachment points

3.3 Production

Composite tooling, produced in the way described in section 2.3, would become very expensive. Therefore it was decided to produce, in-house, metal tooling and achieve the required surface finish by applying a filler and a durable coating system on the tool surface. The requirements stated that the laminates needed to be coloured through-and-through, so a pigmented resin was required. Because of the size of the panels, a special infusion strategy needed to be developed. The laminates was covered with a flownet and a central inlet runner chanel over the length of the panel was used, with side brances every 1.5 meter, see figure 17.

Figure 17. Infusion of edge element

The fly-over with the edge profiles installed, is depicted in figure 18.

Figure 18. Edge profiles installed on the fly-over

Acknowledgements

The authors which to acknowledge the support of their clients Ballast Nedam N.V. and Heijmans N.V.

References

[1] NEN 6706: 2007 NL Technische grondslagen voor bouwconstructies - TGB 1990 - Verkeersbelastingen op bruggen

[2] CUR 96 Vezelversterkte kunststoffen in civiele draagconstructies. 2003