Constructionarium footbridge, Norfolk, UK, in association with Harcourt Technologies Limited

minimass footbridge
design and construction options

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1.0 Summary

Minimass is a new design and manufacturing method for low-cost and low-carbon, concrete, structural elements. This document briefly describes how minimass beams can be used for the construction of short bridges, up to 25 m in length.

These bridge options are primarily aimed at the footbridge and cycle bridge markets but the principles can be applied to vehicular bridges under certain circumstances, e.g. for private roads or for temporary construction site access bridges.

At this stage in the evolution of this family of bridge designs, the choice of bridge deck and handrail is intentionally left up to the future owner of the bridge. As we build up a portfolio of completed bridges, it will become clear which choices are more popular and therefore which can become part of the "system", with accompanying cost and programme benefits.

Preliminary cost and carbon comparisons are given at the end of the document.

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by: ARC
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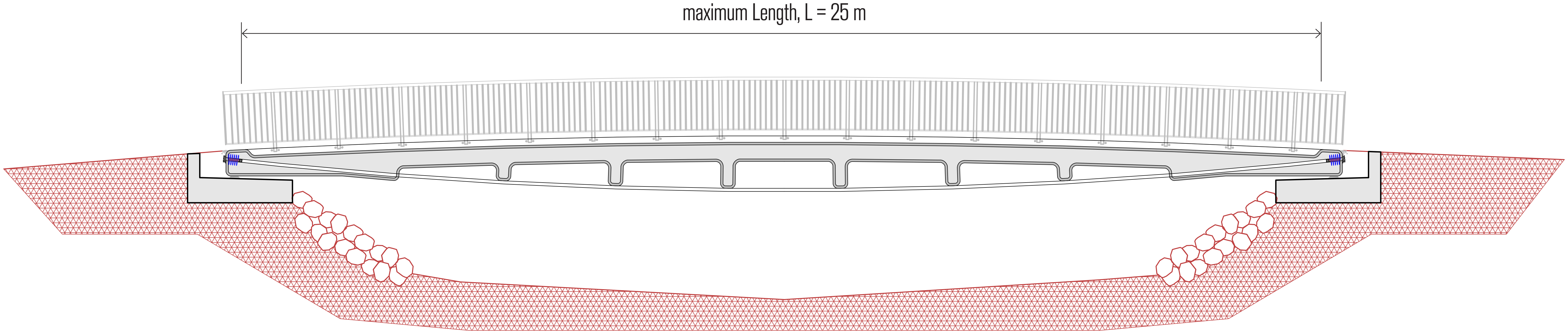
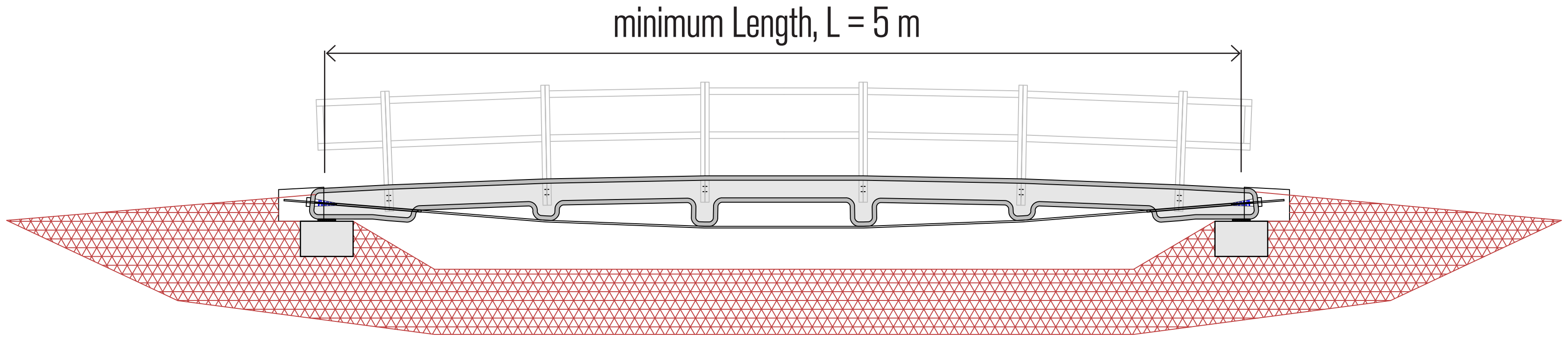
2.0 Length of bridge





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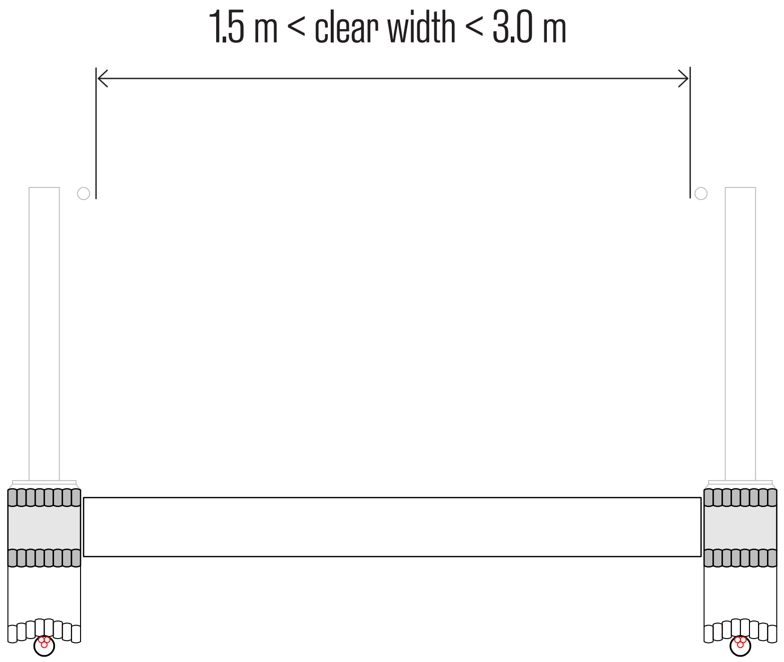
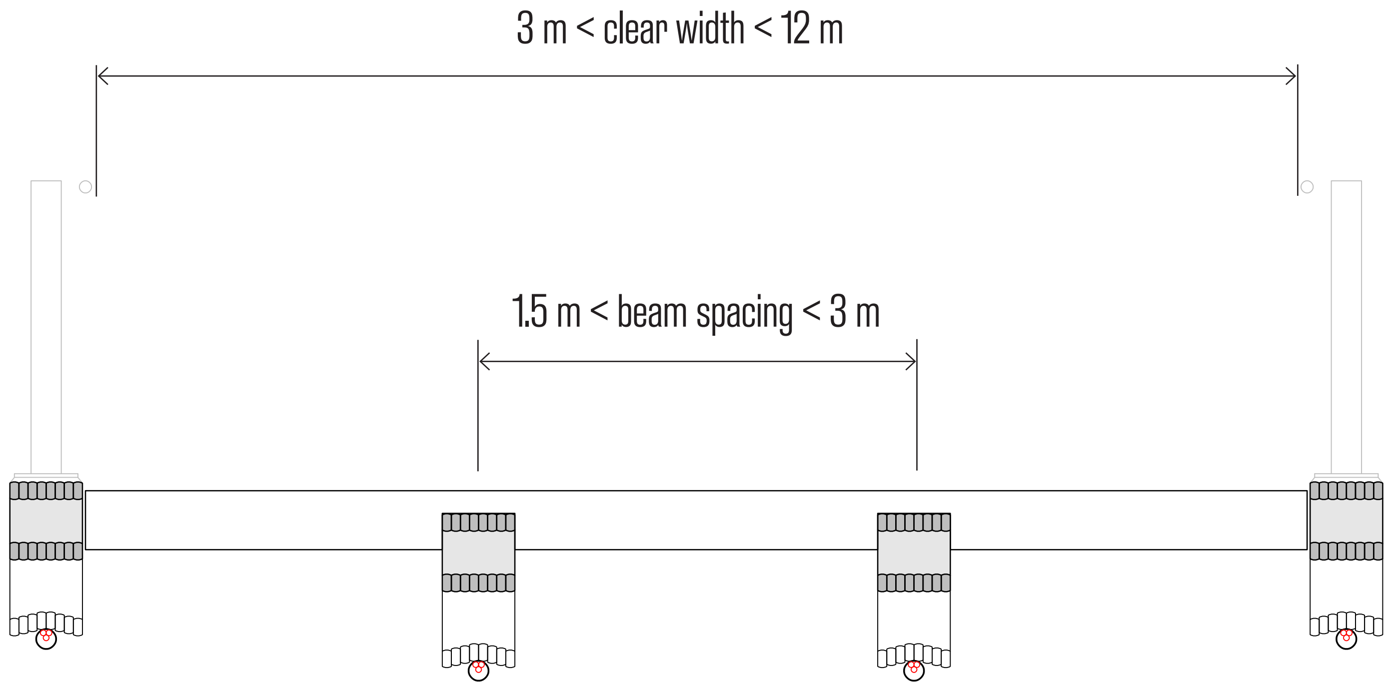
3.0 Width of bridge





<u>Edge Beam Bridge</u>

For simple footbridges with a clear width between 1.5 m and 3.0 m, the structure is formed with a pair of edge beams that support a bridge deck.

<u>Wide Bridge</u>

Where a wider clear width is required, such as combined foot and cycle bridges, or for crossings accessible for horses, additional beams can be added that support the bridge deck below the level of the bridge carriageway. This typology is also applicable for vehicle bridges.

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4.0 Bridge deck options

Timber deck

For low load requirements, simple timber decking boards can be used, or for something more substantial, capable of supporting occasional vehicle traffic, e.g. for maintenance, it is possible to use a prefabricated glulam deck (as shown in the image).

Pros & Cons:

- low carbon
- low weight
- simple to install

- can be higher maintenance
- can be higher cost
- can require non-slip finish

Concrete deck

Concrete can be used either as precast sections, or with some element of in-situ pouring, depending on load and span requirements. Hollowcore (as shown in the image), solid slabs and lattice slabs are all feasible solutions.

Pros & Cons:

- low cost
- high load capacity
- low maintenance

- higher weight
- can be higher carbon

Metal deck

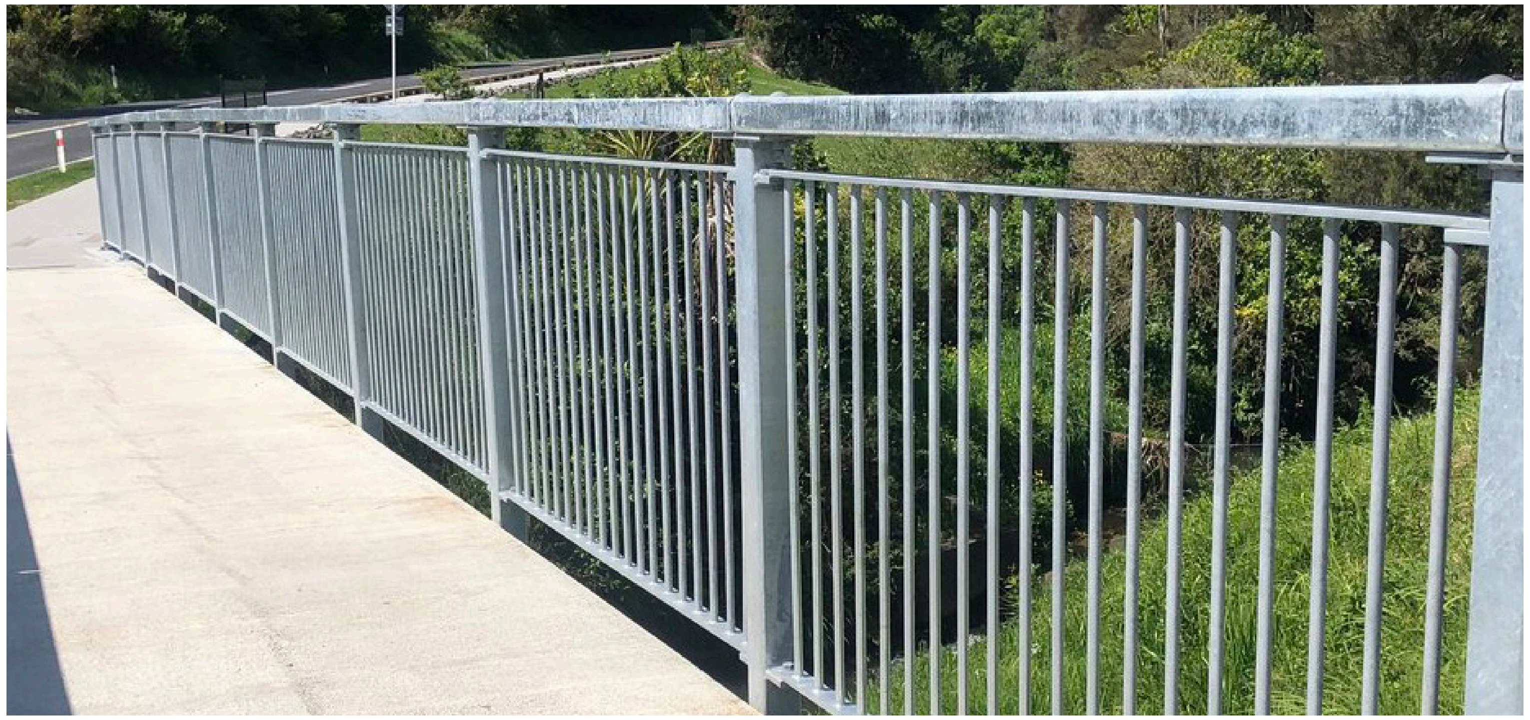
For very lightweight solutions, steel decks can be used, either profiled (as shown in the image), or industrial metal gratings. For some cast in-situ concrete designs, metal decks can be used as permanent formwork to avoid any temporary supports.

Pros & Cons:

- can be very low weight
- light and fast to install

- will require a surface finish if used without in-situ concrete
- can be higher cost

5.0 Handrail options



Timber handrails

For quick, easy and low cost installation, timber handrails provide a good option. These would be painted or treated to provide protection against the weather but would require ongoing maintenance. Handrails can be fixed either to the side of the beams (as shown in the image), or to the top surface of the beam.

Pros & Cons:

- low carbon
- low cost
- fast to install

- regular ongoing maintenance
- larger cross-sections

Metal handrails

For bridges with a higher level of traffic, or for lower maintenance options, a range of metal handrails are possible. From simple, prefabricated sections (such as shown in the image), to more bespoke stainless steel and prestressed wire options, the range of metal handrail designs is very wide. These can be fixed either to the side of the edge beam, or to the top surface.

Pros & Cons:

- more permanent appearance
- lower ongoing maintenance
- fast to install

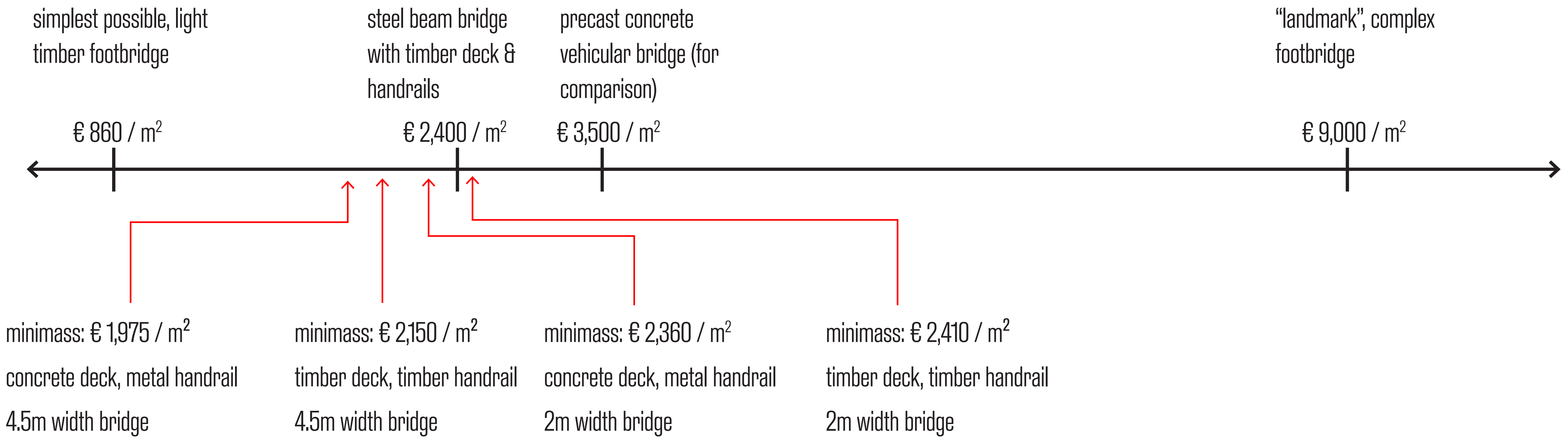
- higher carbon
- can be higher cost, depending on design
- requires longer lead time

6.0 Cost comparisons

Bridges are notoriously difficult to price at an early stage, as there are many elements that can vary significantly in price. For example, the foundations and abutments can make up a large proportion of the overall cost but the extent and requirements will be unknown before the start of the project. However, the diagram below aims to indicate the various range of possible costs for different types of footbridge.

Costs are given on a per sqm basis, as they vary according to the length and width of the required bridge.

All costs are estimates and would require review and approval for any given project.



6.1 Cost assumptions

In the evaluation of minimass bridge costs, the following methodology and assumptions have been used. Minimass beams are priced on the basis of the average costs for materials, average applied loads and assuming minimum 4 beams being produced per printing day. These values can vary and do affect the resulting cost.

Timber deck, timber handrails (€ / m^2)

bridge width (m)	2	4.5
minimass beams	547	487
timber deck	300	300
surfacing and finishes	0	0
timber handrails	115	51
movement joints (if required)	120	120
waterproofing	30	30
bearings (if required)	20	20
subtotal	1132	1008
earthworks, piling, abutments @ 35 %	609	542
preliminaries @ 15 %	307	275
design phase contingency @ 15 %	362	325
Total	2410	2150

Concrete deck, metal handrails (€ / m^2)

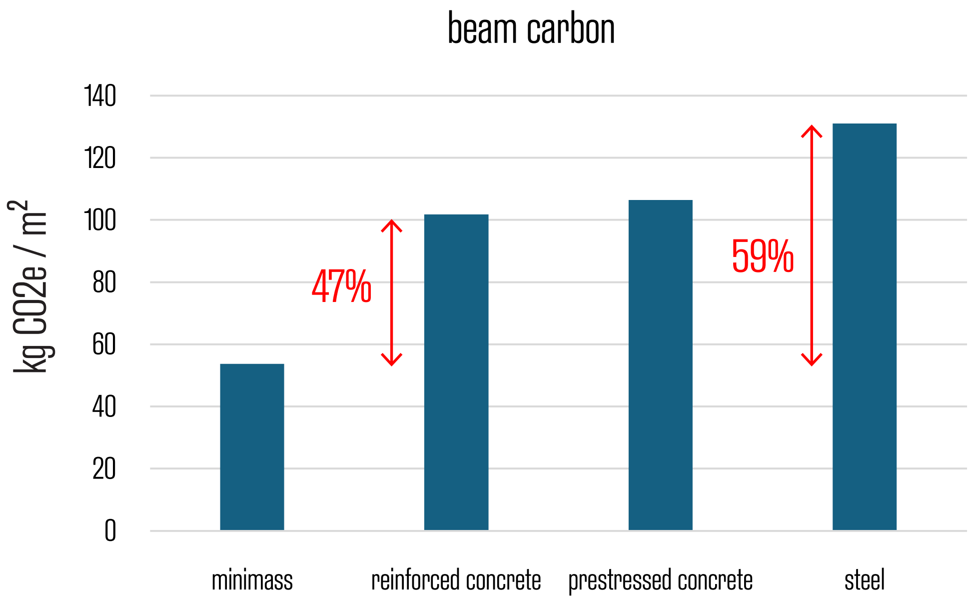
bridge width (m)	2	4.5
minimass beams	547	491
concrete deck	100	100
surfacing and finishes	70	70
metal handrails	225	100
movement joints (if required)	120	120
waterproofing	30	30
bearings (if required)	20	20
subtotal	1112	931
earthworks, piling, abutments @ 35 %	598	498
preliminaries @ 15 %	300	250
design phase contingency @ 15 %	350	296
Total	2360	1975

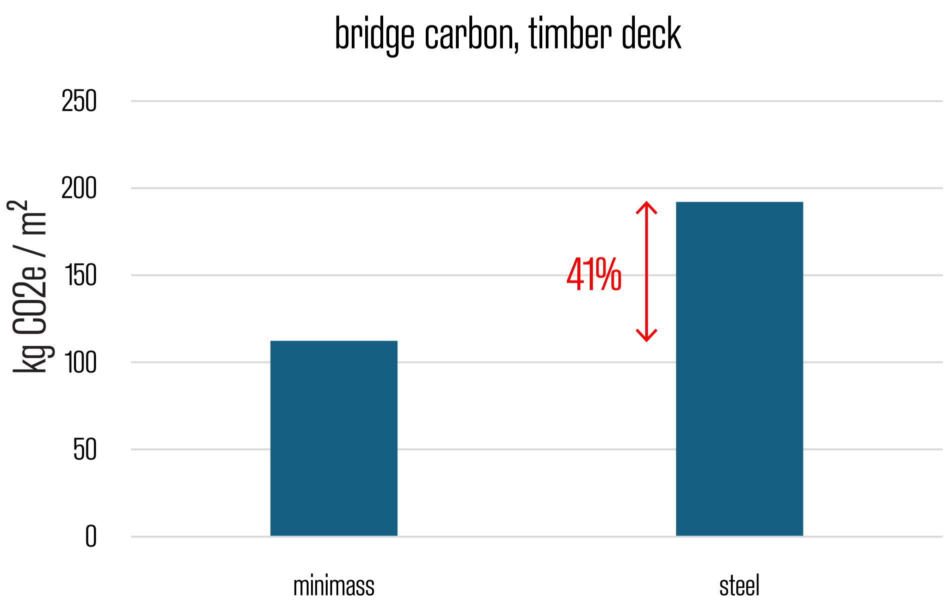
7.0 Carbon comparisons

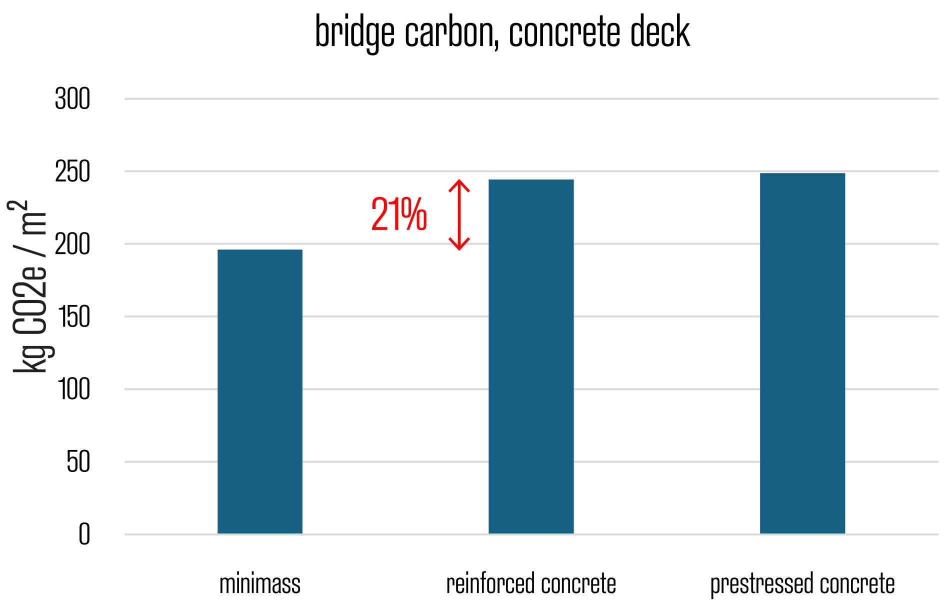
The calculation of embodied carbon for a bridge must include all the components. As such, the resulting figures are subject to design choices. Similar to the cost comparison, the best way to demonstrate the carbon performance of a minimass structure is by describing several different design types and calculating the embodied carbon for each.

This assessment compares bridge design options for a simple footbridge, with a clear width of 2 m and length of 10.8m.

However, foundations and abutments are excluded from this comparison, as the requirements for these will be project specific.







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Appendix: carbon calculations

CONSTRUCTIONARIUM BRIDGE

CARBON COMPARISON
4th December 2024

- The following is a comparison of the estimated carbon content of the Constructionarium bridge, where the primary structural beams are designed using different alternatives. Each alternative assumes different options for bridge deck, handrails etc etc, so that the camparison can highlight the difference caused by the choice of primary structure. We do not make any claims regarding this being the most efficient possible bridge design to span this distance, only that if the assumptions relevant to this bridge design are made then the following approximate carbon calculation is the result.
- Values are given as stages A1 - A3 (cradle to gate), but if recycled content or other factors are included these are noted individually.
- The carbon storage ability of timber is not included.

bridge usable area (m2) 21,6

Timber deck, timber handrails

element	material	description	no. elements	volume m3	mass kg	carbon intensity kg/kg	total carbon kgCO2e	notes
bridge deck panels	C16+ softwood	140mm thick glulam decks	-	2,89	1357	0,28	380	IStructE Carbon Tool v2, UK Glulam 100% FSC/PEFC
handrails, verticals	C24 softwood	2x50x150	12	0,02	115,48	0,263	30	ICE DB v3.0, no account for carbon storage
handrails, horizontals	C24 softwood	50x75	4	0,04	76,14	0,263	20	ICE DB v3.0, no account for carbon storage
shelf angle	S355 steel	150x150x12 EQA on both sides	-	0,07	566,4	1,44	816	ICE DB v3.0, hot dip galvanised steel, including 85% recovery rate (module D)
bearings	natural rubber	200x200x25 elastomeric	4	N/A	N/A	N/A	20	estimated
bolts, screws etc	misc	deck & handrail fixing components	N/A	N/A	N/A	N/A	50	estimated
total							1316	kg
total / sqm							61	kg/sqm

Concrete deck, metal handrails

element	material	description	no. elements	volume m3	mass kg	carbon intensity kg/kg	total carbon kgCO2e	notes
concrete slab	C25/30	200mm thick	-	4,32	10368	0,1	1037	IStructE Carbon Tool v2, UK C25/30 25% GGBS
rebar	mild steel	assumed 200kg/m^3	-	-	864	1,2	1037	ICE DB v3.0, mild steel rebar, including 85% recovery rate (module D)
metal handrails	galvanised steel	30kg/m	-	-	648	1,44	933	ICE DB v3.0, hot dip galvanised steel, including 85% recovery rate (module D)
bearings	natural rubber	200x200x25 elastomeric	4	N/A	N/A	N/A	20	estimated
bolts, screws etc	misc	deck & handrail fixing components	N/A	N/A	N/A	N/A	50	estimated
total							3077	kg
total / sqm							142	kg/sqm

minimass + timber deck, timber handrails								
3DCP	C30/37 + additives	3D printed concrete	2	0,25	590	0,125	148	Roadstone EPD plus Masterseries additives
infill concrete	C30/37	ready mix concrete	2	0,53	1266	0,123	311	Roadstone EPD
rebar	mild steel	beam reinforcement	2	0,02	183	1,2	439	ICE DB v3.0, mild steel rebar, including 85% recovery rate (module D)
PT tendons	Y1860 steel	beam tendons	2	0,01	40	1,58	126	30% premium for carbon compared to rebar, as suggested by Concrete Centre carbon calculation
PT anchors + misc PT	mild steel	anchorages	2	0,00	8	1,2	19	estimated
HDPE sheathing	HDPE	strand sheathing, 16mm ID, 2mm wall thickness	2	-	7	1,9	27	estimated
grout for shelf angles	HSNS grout	thickness varied from 0mm to 50mm	-	0,05	100	0,407	41	Fosroc Conbextra GP EPD
total							1111	kg
total / sqm							51	kg/sqm
minimass + concrete deck, metal handrails								
3DCP	C30/37 + additives	3D printed concrete	2	0,27	649	0,125	162	Roadstone EPD plus Masterseries additives
infill concrete	C30/37	ready mix concrete	2	0,58	1392,6	0,123	343	Roadstone EPD
rebar	mild steel	beam reinforcement	2	0,03	201,3	1,2	483	ICE DB v3.0, mild steel rebar, including 85% recovery rate (module D)
PT tendons	Y1860 steel	beam tendons	2	0,01	40	1,58	126	30% premium for carbon compared to rebar, as suggested by Concrete Centre carbon calculation
PT anchors + misc PT	mild steel	anchorages	2	0,00	8	1,2	19	estimated
HDPE sheathing	HDPE	strand sheathing, 16mm ID, 2mm wall thickness	2	-	7	1,9	27	estimated
total							1160	kg
total / sqm							54	kg/sqm
steel design								
edge beam	S355	400x200x10 RHS	2	0,124097	974,16	1,44	2806	ICE DB v3.0, hot dip galvanised steel, including 85% recovery rate (module D)
bolts and fixings	misc	fixings for steel angles	N/A	N/A	N/A	N/A	25	estimated
total							2831	kg
total / sqm							131	kg/sqm
prestressed concrete design								
edge beam	RC45/55	Spæncom KBE 58/18	2	2,13125	5115	0,178	1821	ICE DB v3.0, precast model, RC40/50 using UK average
prestress	HS steel	9x12.5mm	2	0,009554	75	1,58	237	30% premium for carbon compared to rebar, as suggested by Concrete Centre carbon calculation
rebar	mild steel	shear rebar and minimum longitudinal	2	0,012739	100	1,2	240	estimated allowance
total							2298	kg
total / sqm							106	kg/sqm
reinforced concrete design								
concrete	RC40/50	ready mix concrete, 300x600	2	1,875	4500	0,159	1431	ICE DB v3.0, 15% cement replacement with PFA
rebar	mild steel	beam reinforcement	2	0,040764	320	1,2	768	ICE DB v3.0, mild steel rebar, including 85% recovery rate (module D)
total							2199	kg
total / sqm							102	kg/sqm

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summary, beams only

bridge type	total / sqm kg/sqm	saving with minimass %
minimass	54	-
reinforced concrete	102	**47%**
prestressed concrete	106	**50%**
steel	131	**59%**

summary, full bridge calculation

beam type	deck type	total / sqm kg/sqm	saving %
minimass	timber	112	-
steel	timber	192	**41%**
minimass	concrete	196	-
reinforced concrete	concrete	244	**21%**
prestressed concrete	concrete	249	**23%**