PARENT PAVILION

Technical booklet: tests, loads and numbers

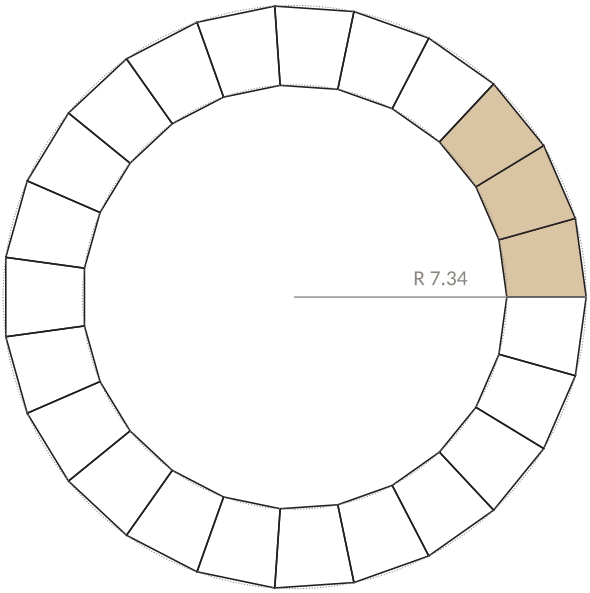
Lazzaretto Nuovo, Venice lagoon · AUD5101 Island of Pavilions · Jean Paul Sapiano

Every figure in this booklet is calculated from the project model and published material values.
They are design-stage hand checks; the structure is to be confirmed by a structural engineer.

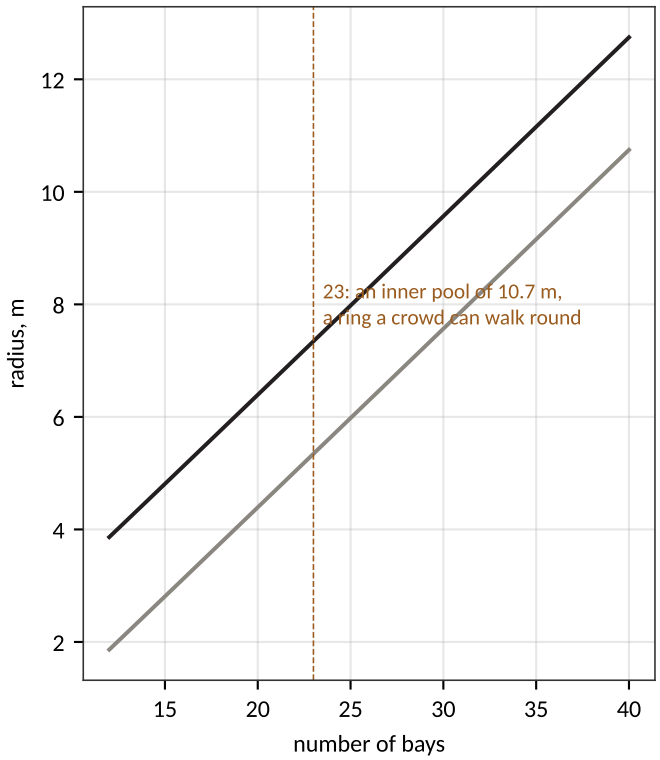
A How the ring is found

A bay two metres deep and two wide, repeated until it closes. The number of bays sets the circle.

23 trapezoid bays: chord 2.0 on the outside, depth 2.0



Bays against radius (outer and inner)

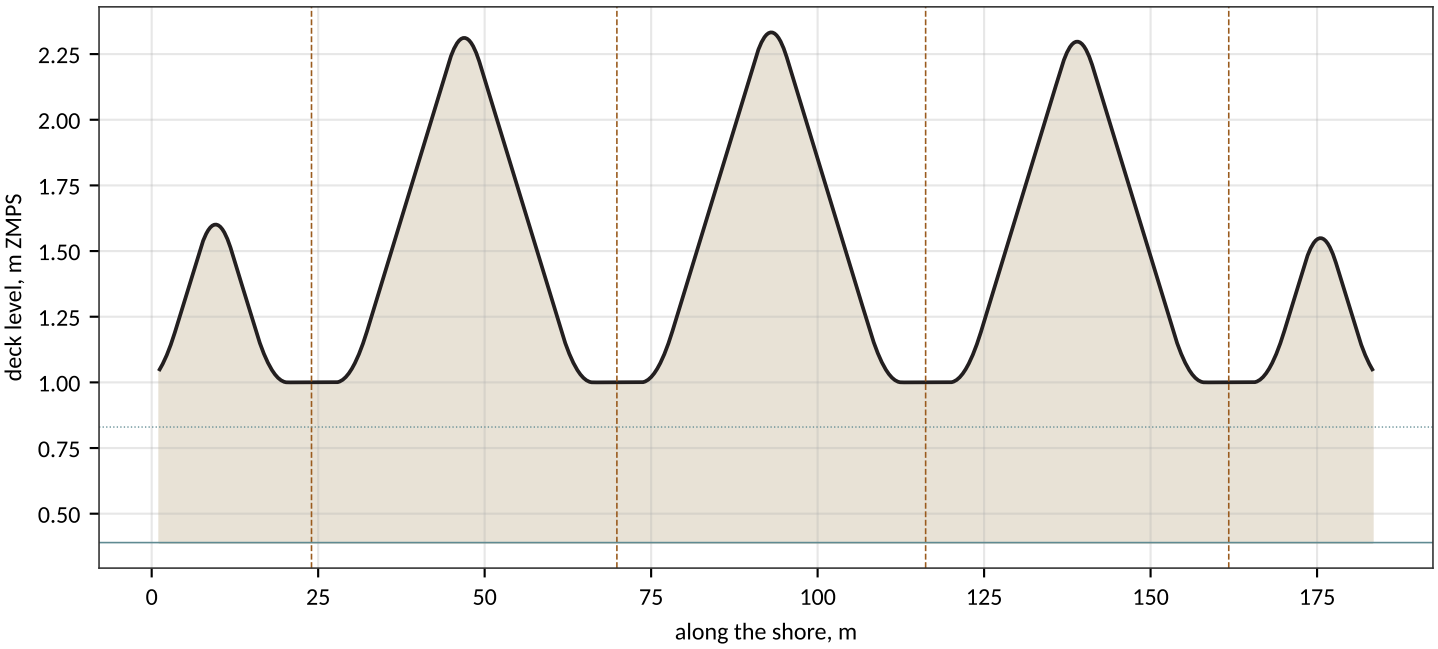


Outer radius = chord / (2 sin(π/n)). With 23 bays the ring is 14.7 m across and its inner pool 10.7 m: wide enough to hold a young marsh, small enough for two people to row the opened chain. Each bay is the same part, so one jig builds all of them; the three shaded bays are the hinge, the gate and the lock.

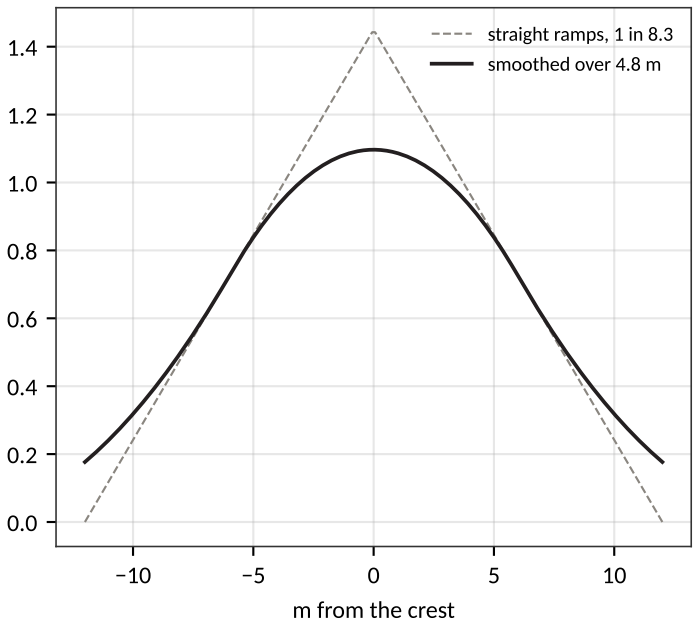
B How the walk rises

Low at every station, where the ring docks; lifted between them, so the tide and the boats pass under.

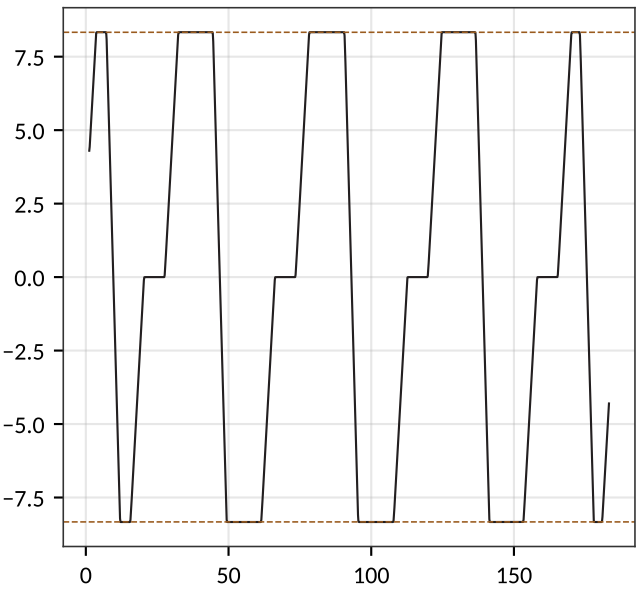
The walk: flat at +1.00 at the four stations, rising to +2.45 between them



The rule: two ramps, then a moving average



Slope, %: steepest 8.3% (an accessible ramp allows 8.3%)

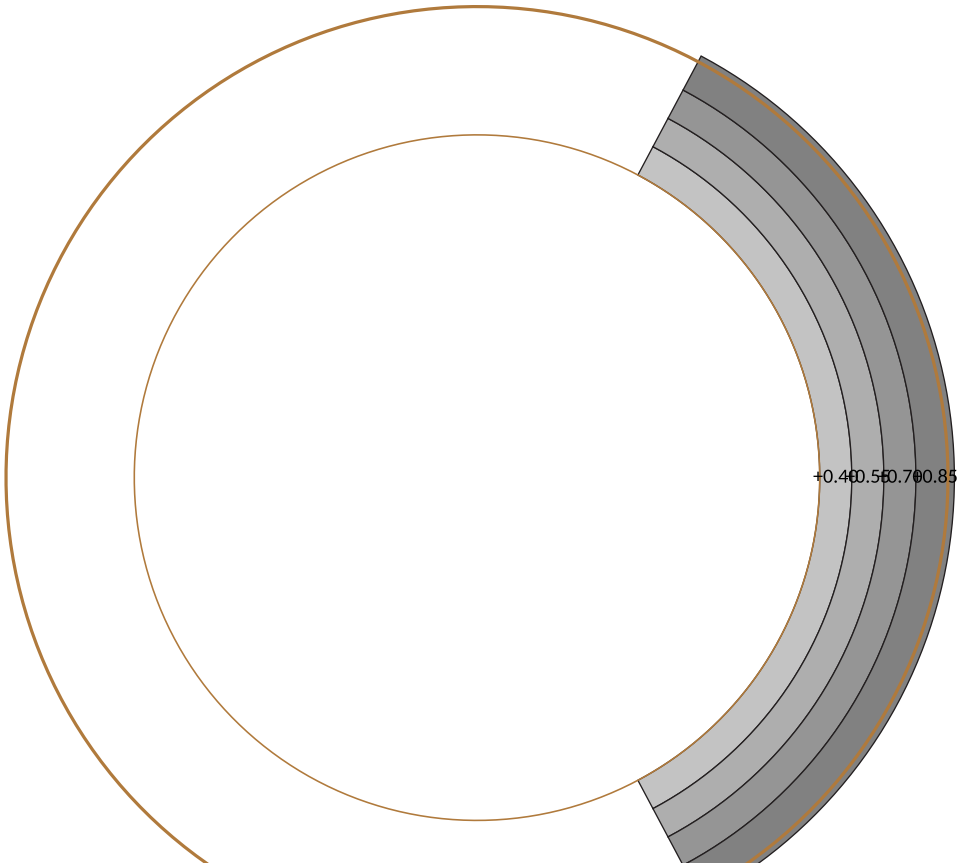


The profile is not drawn by hand: two straight ramps meet at the crest and a 4.8 m moving average turns the corners into the bridge's curve. The same rule gives every span the same shape. Level stone landings give a resting place at every station; between them the walk lifts in one smooth curve so the tide and small boats pass under, with its steepest pitch kept short.

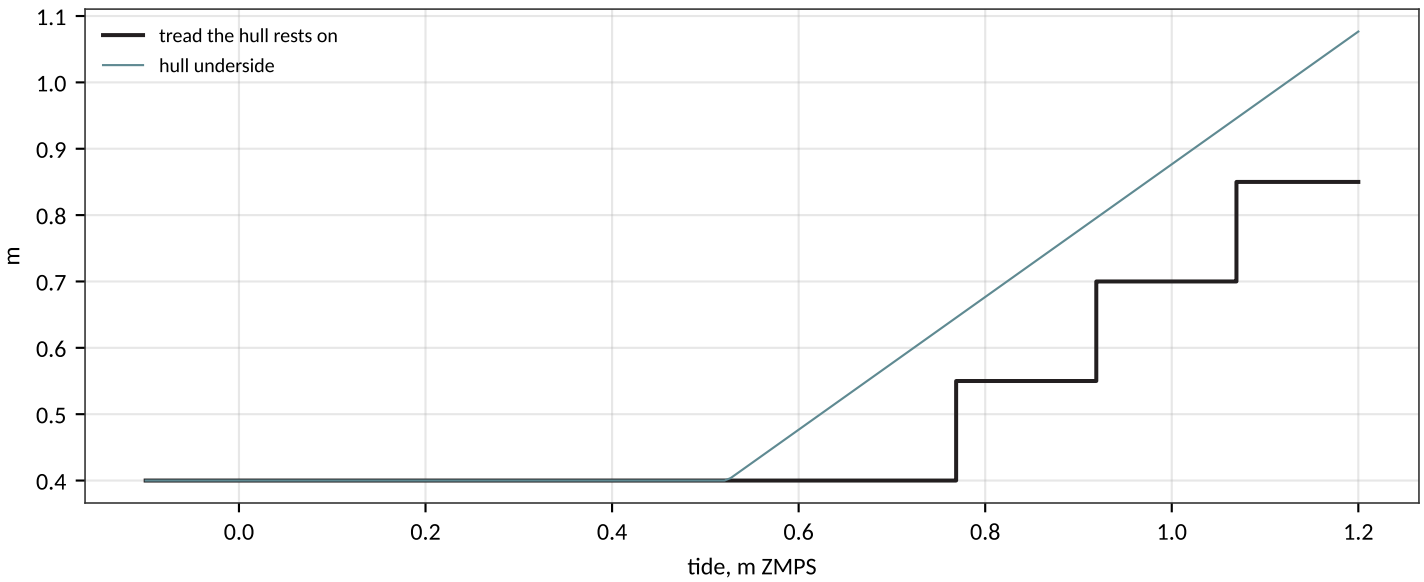
C How the stair is found

Concentric with the ring: every tread is an arc of the same centre, so the ring meets a step at every tide.

Treads in plan: four arcs, 0.5 m deep, 0.15 m rise, wrapping 124° of the ring

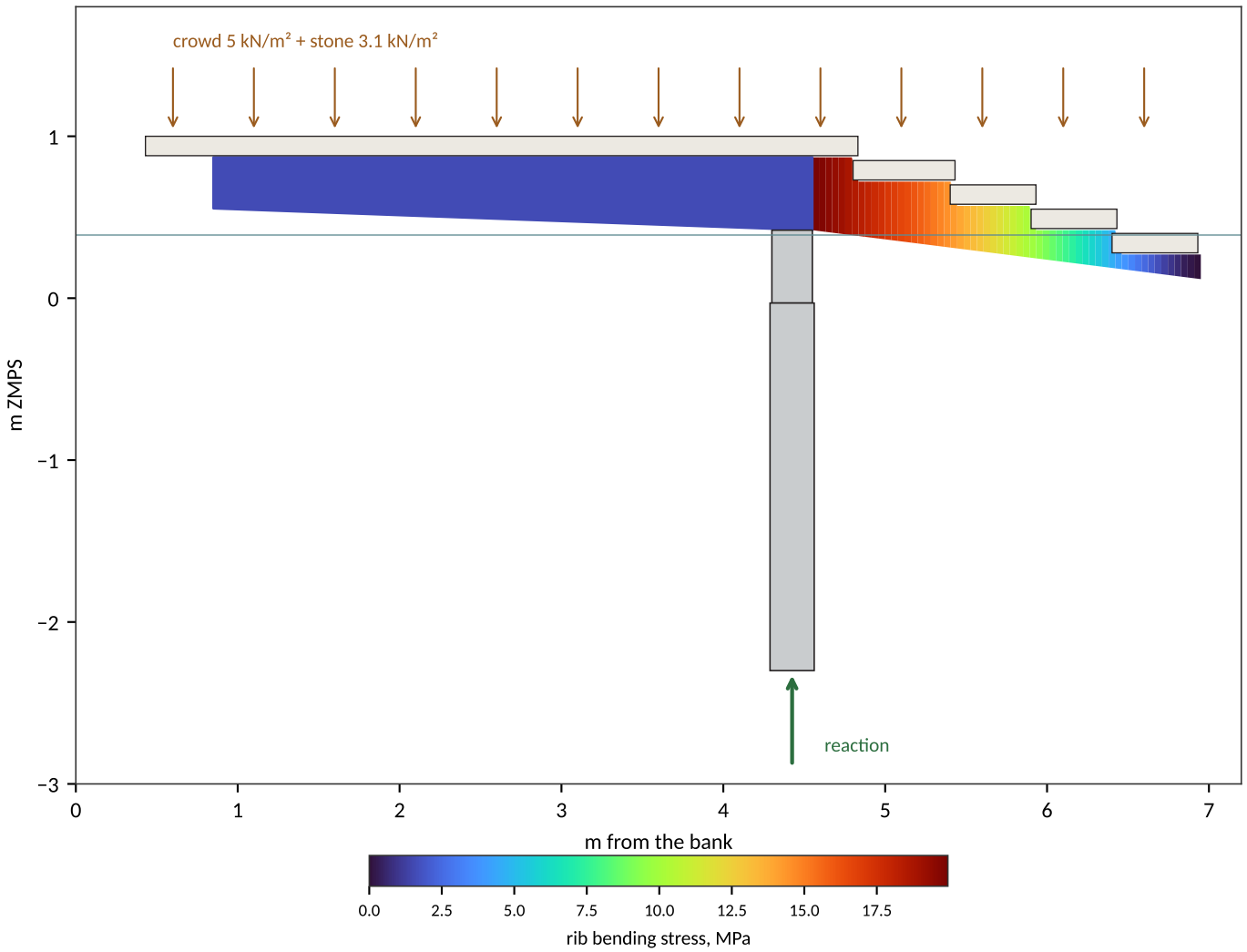


As the tide falls the ring settles step by step

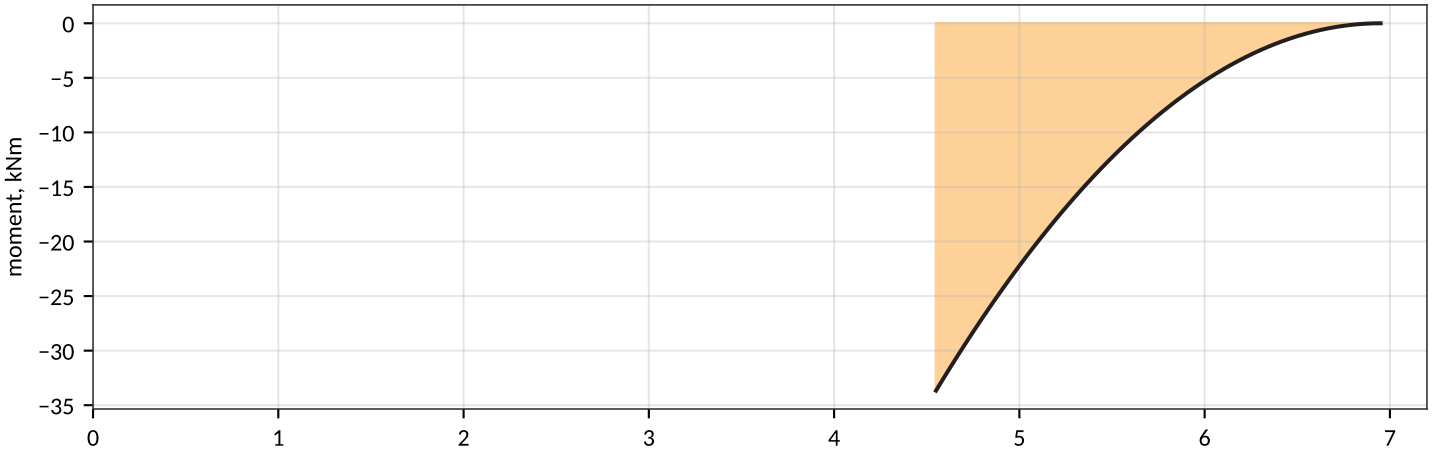


D Where the stair carries its load

The stone is a thin skin. The load goes slab → rib → spine → piles → caranto. Colour: bending stress in the rib.

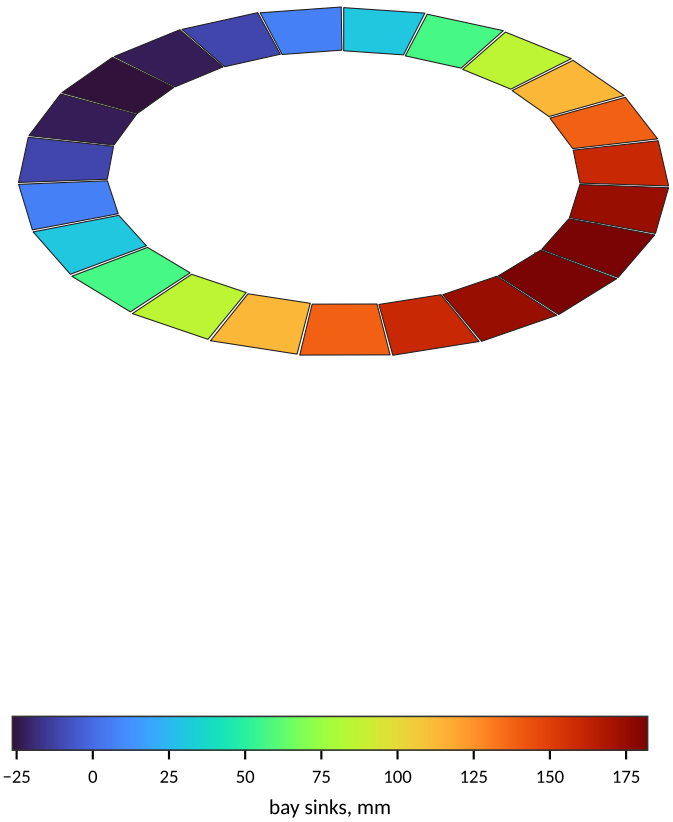


Bending moment along the cantilever: 33.7 kNm at the spine, nothing at the tip



E The ring under a crowd

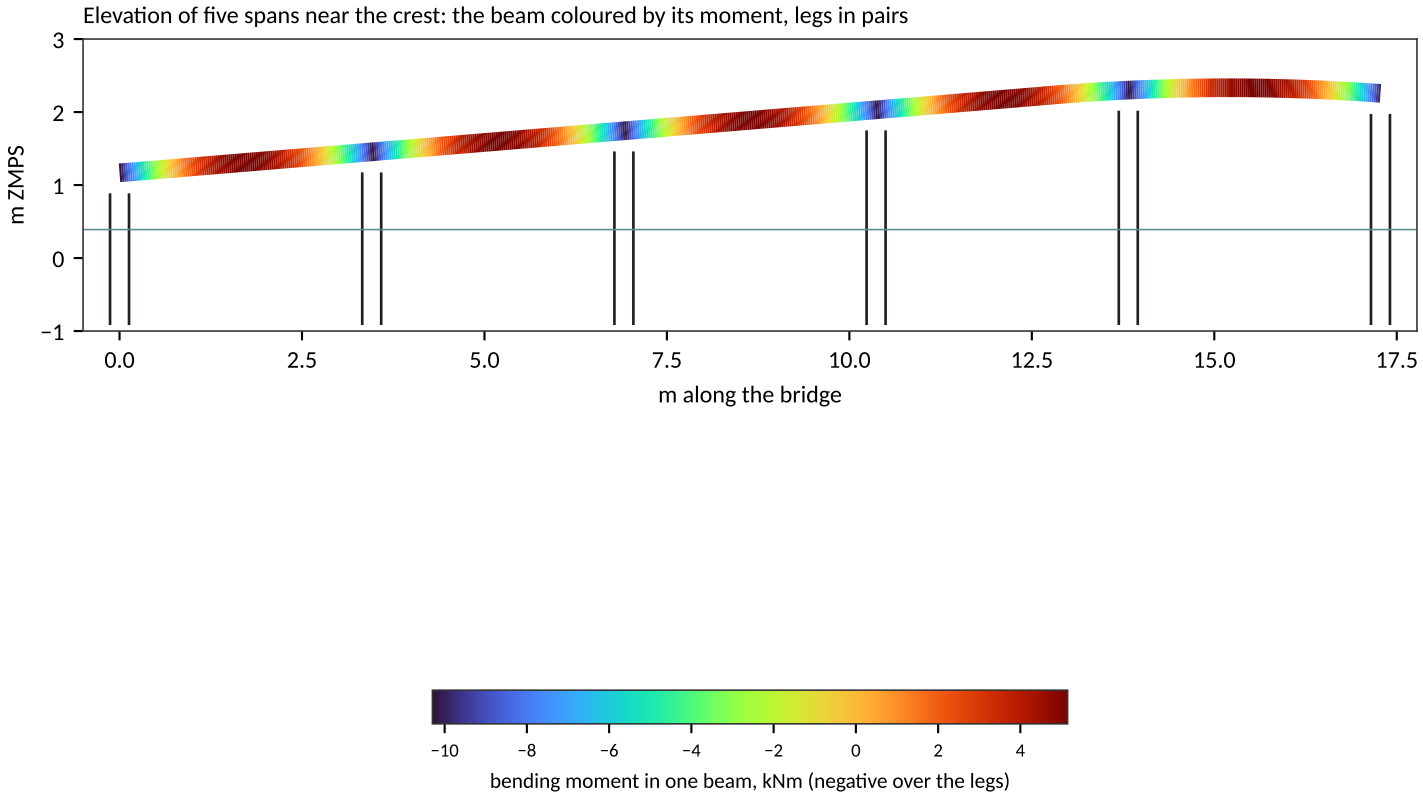
Sixty people gathered at one side. Colour: how far each bay sinks (draft change), from the heel calculation.



Heel 0.95°. The ring is a wide annulus, so its waterplane resists tipping strongly (GM ≈ 122 m): the bays under the crowd sink 182 mm, those opposite -26 mm. Pinned hinges make the ring act as one body; if the pins were loose each bay would sink alone, about four times as much.

F The bridge beams

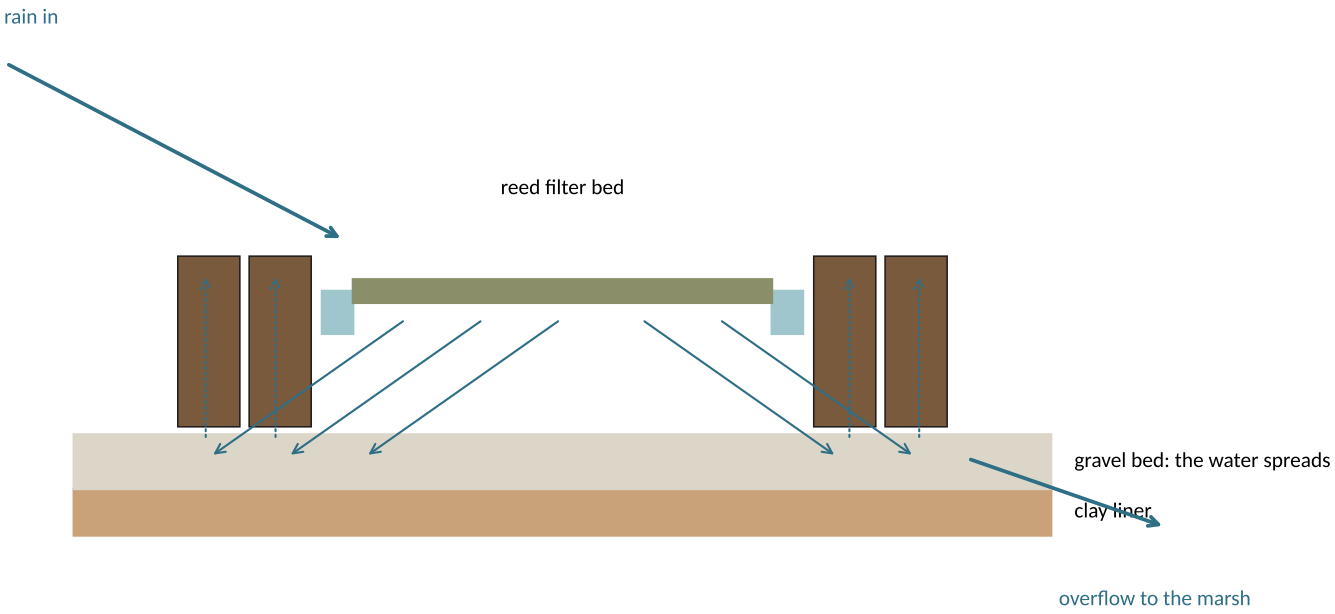
Two oak edge beams, 80 × 300, continuous over leg pairs every 3.46 m. Colour: bending moment under a crowd.



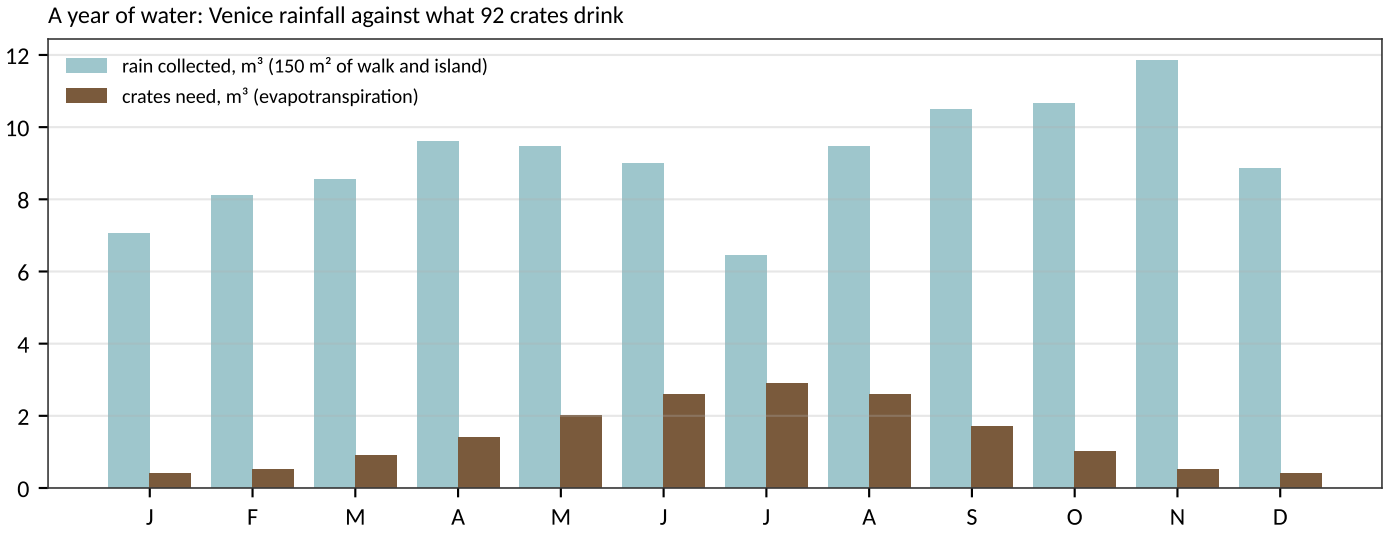
Peak moment 10.30 kNm over the legs; stress 8.6 MPa in an 80 × 300 oak beam against a design strength of about 13 MPa (D24 oak, kmod 0.7). The beams could be slimmer; they are kept at 300 so the deck reads as one thin plane and so the fins can bolt into them.

G How the nursery waters itself

Rain from the walk and the island, filtered through reeds, carried by gravity under the crates, overflowing to the marsh.



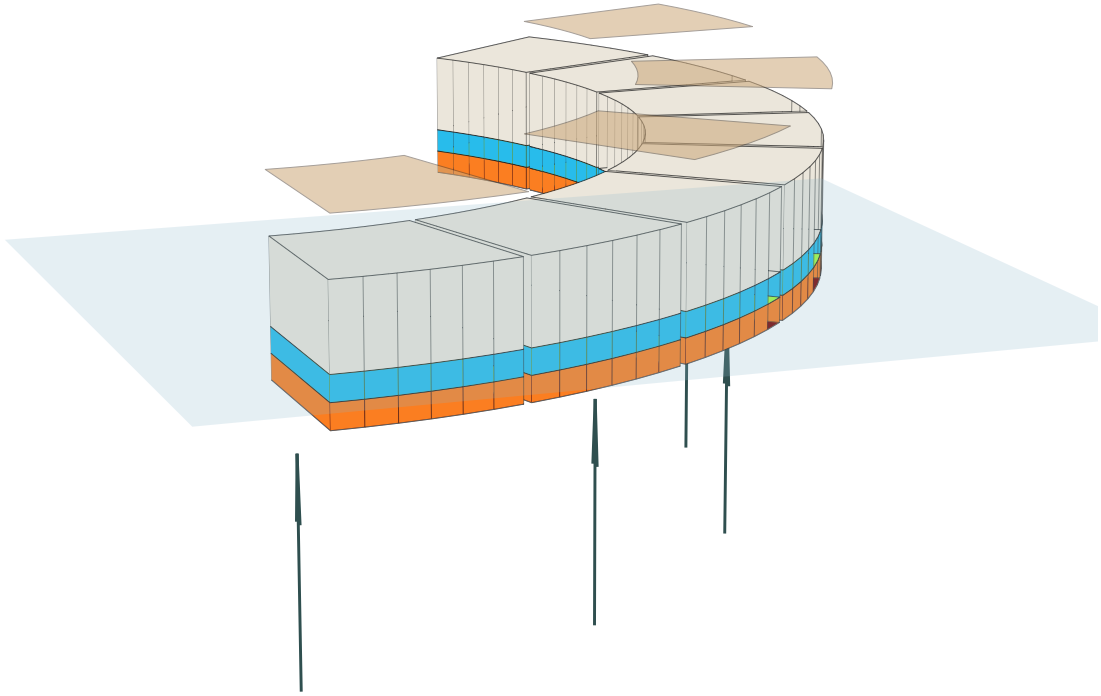
Section through the nursery, heights x6

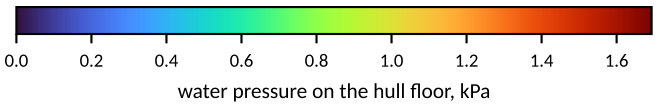


Test: rain alone covers the crates in every month (2.2 times the need at the driest point). Rain is fresh water, and salt-marsh seedlings must be hardened to salt before they go out: in the last month the stewards feed the filter bed with lagoon water carried up by bucket from the sandolo. Surplus rain overflows to the marsh.

H How it floats

A third of the ring, heights drawn three times larger. Colour: water pressure on the wetted hull, kPa; arrows: the water holding it up.



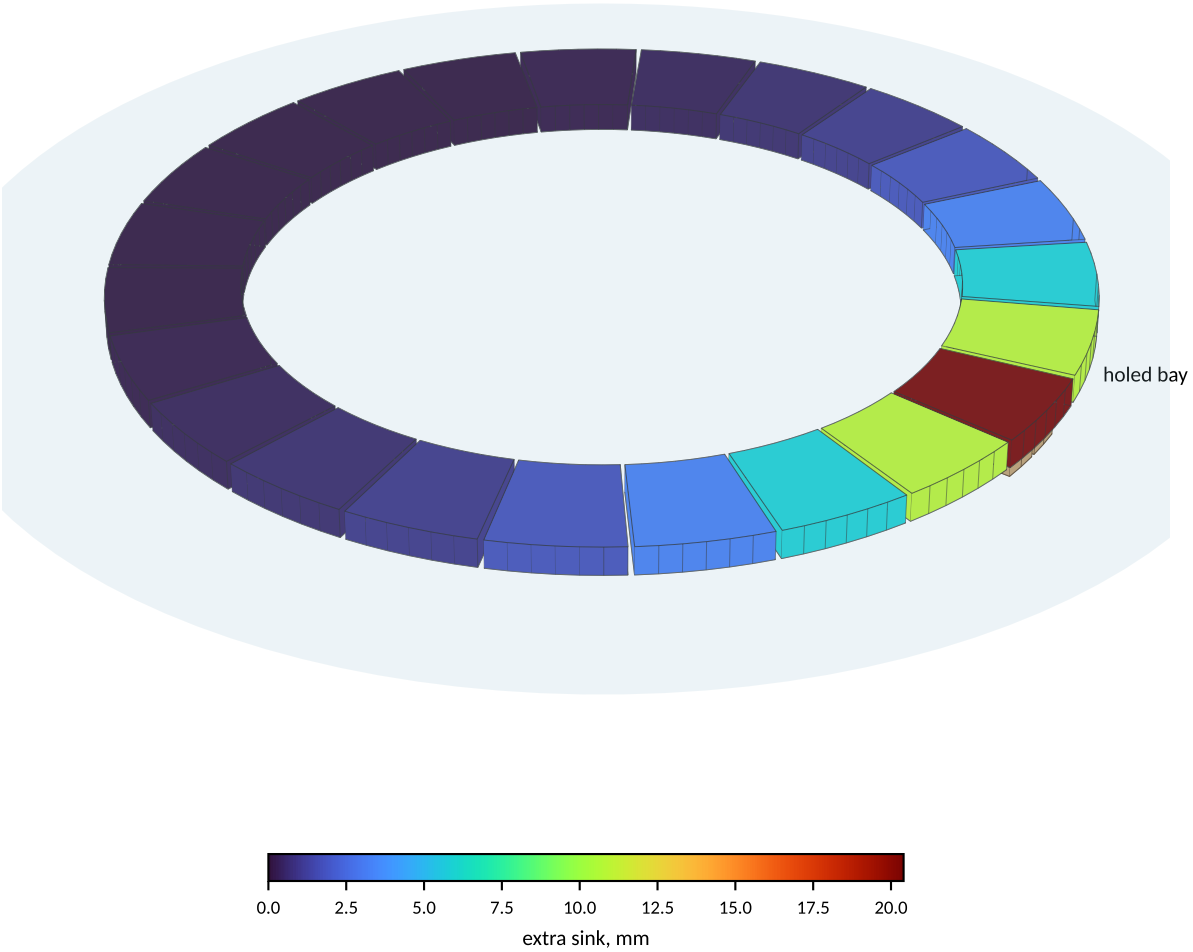


The ring weighs 10.3 t. Water pushes up on 60 m² of hull floor; the ring settles until that push equals its weight, at a draft of 168 mm. The hulls are 450 mm deep, so 282 mm stays dry above the water: room for 139 people before the last 100 mm.

RESULT Draft 168 mm empty; the ring carries a full crowd and keeps its deck level and dry.

I If one hull is holed

One bay flooded. Its cork cores keep it up; the drop pins share its load with its neighbours. Colour: how far each bay sinks, mm.

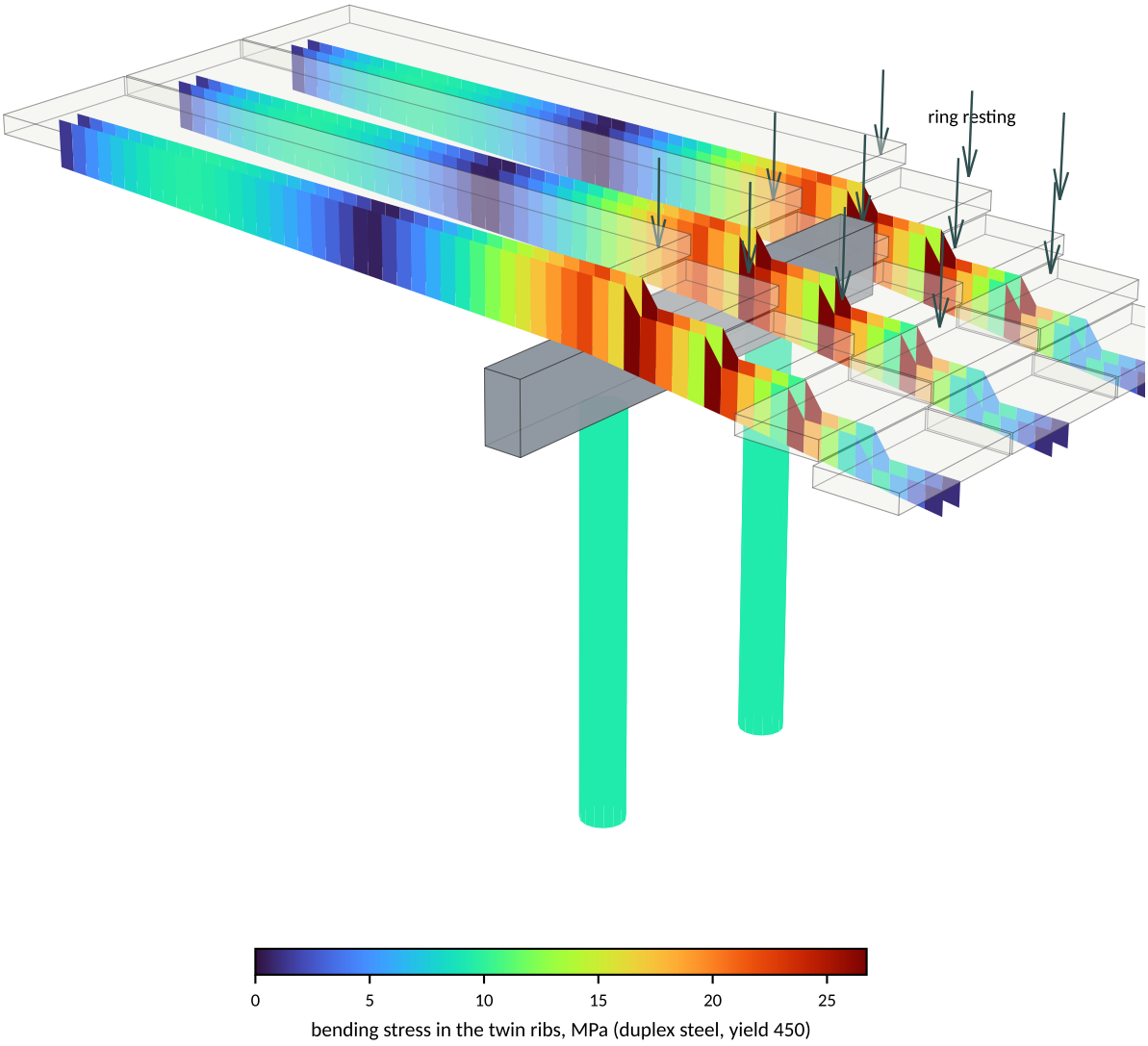


Each bay carries 0.70 m³ of expanded cork, 719 kg of lift on its own against a bay weight of 449 kg. Flooded, the bay sinks only 20 mm, because the pinned neighbours take part of its weight: the dip spreads over three bays each side and fades out.

RESULT A holed hull stays afloat on its cork at 1.6 times its weight; the deck dips 20 mm and the ring keeps working until the bay is swapped.

J The stair, carrying the ring

Three metres of stair: slabs drawn clear, the twin ribs coloured by bending stress, the piles by their load. The ring rests on the treads.

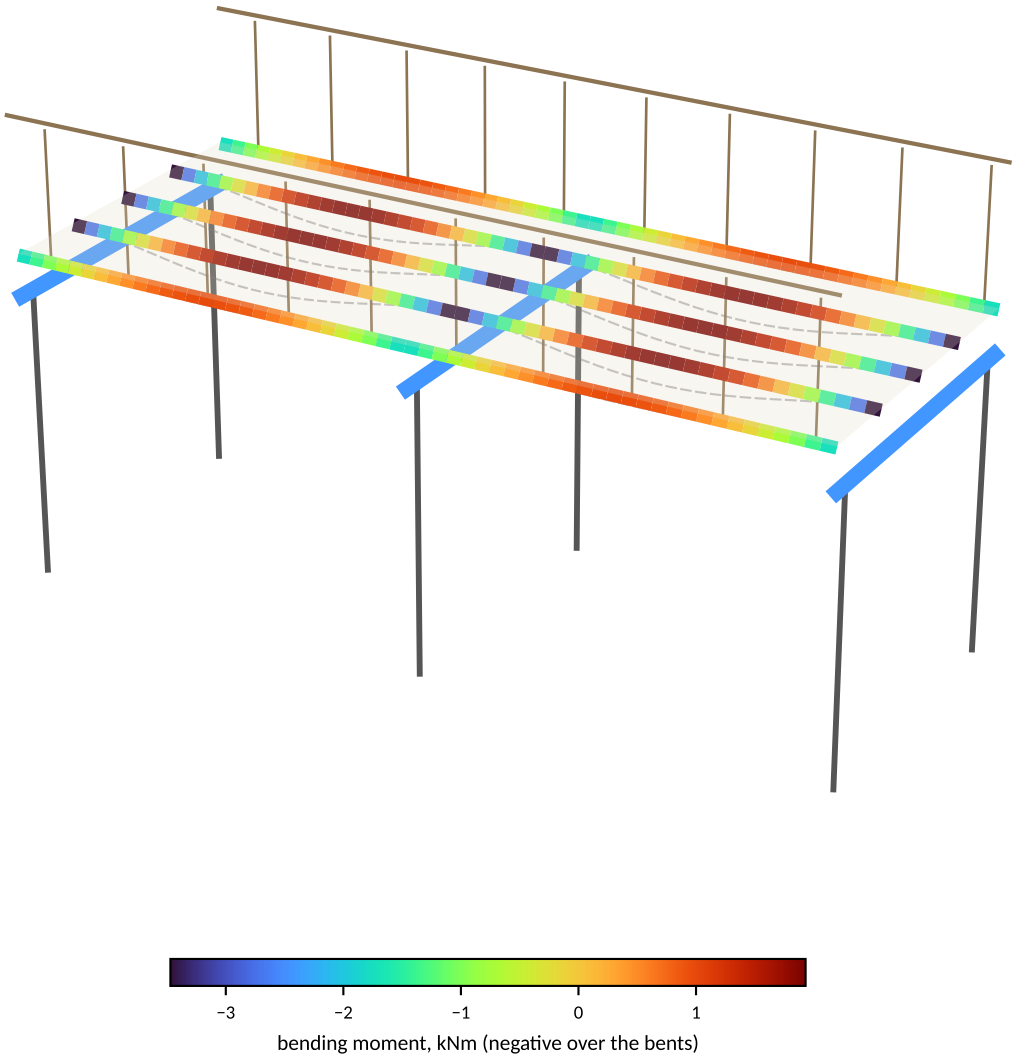


The stone is a thin skin. Load goes slab → pad → rib → spine → pile → caranto. The ribs are deepest over the spine, where the moment peaks at 37.9 kNm, and taper to the tip where it falls to zero: the shape follows the force. Peak stress 27 MPa; each pile takes about 121 kN.

RESULT The ribs work at 6% of yield with the ring resting on the treads; the piles carry the stair and the ring into the caranto.

K The bridge as a frame

Two spans between pile bents: edge beams and joists coloured by bending moment under a crowd, the deflected shape drawn 150 tim

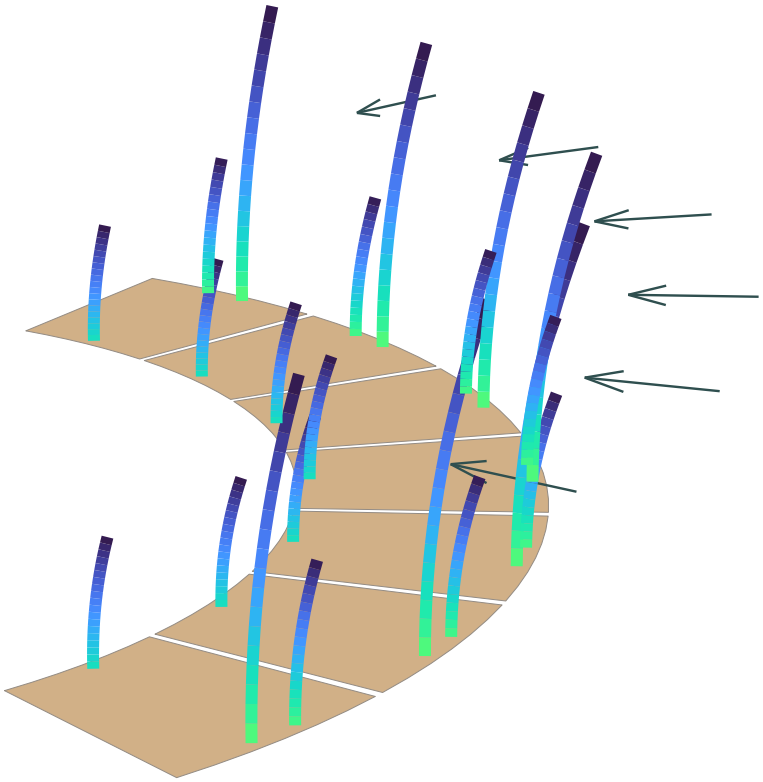


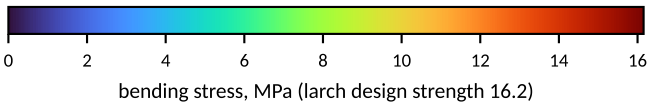
The deck boards span 620 mm between joists; the joists and the oak edge beams span 3 m between bents and run on, continuous, so the moment changes sign over each crossbeam. Under a full crowd (5 kN/m²) the peak moment is 3.47 kNm, the stress 4.8 MPa, and mid-span sags 1.1 mm, under L/500.

RESULT The frame carries a packed bridge at 37% of the timber's design strength and sags 1.1 mm: firm underfoot.

L The posts in the wind

A quarter of the ring with its tall and short posts. Colour: bending stress in each post at a gust of 1 kN/m² with people leaning on the rai



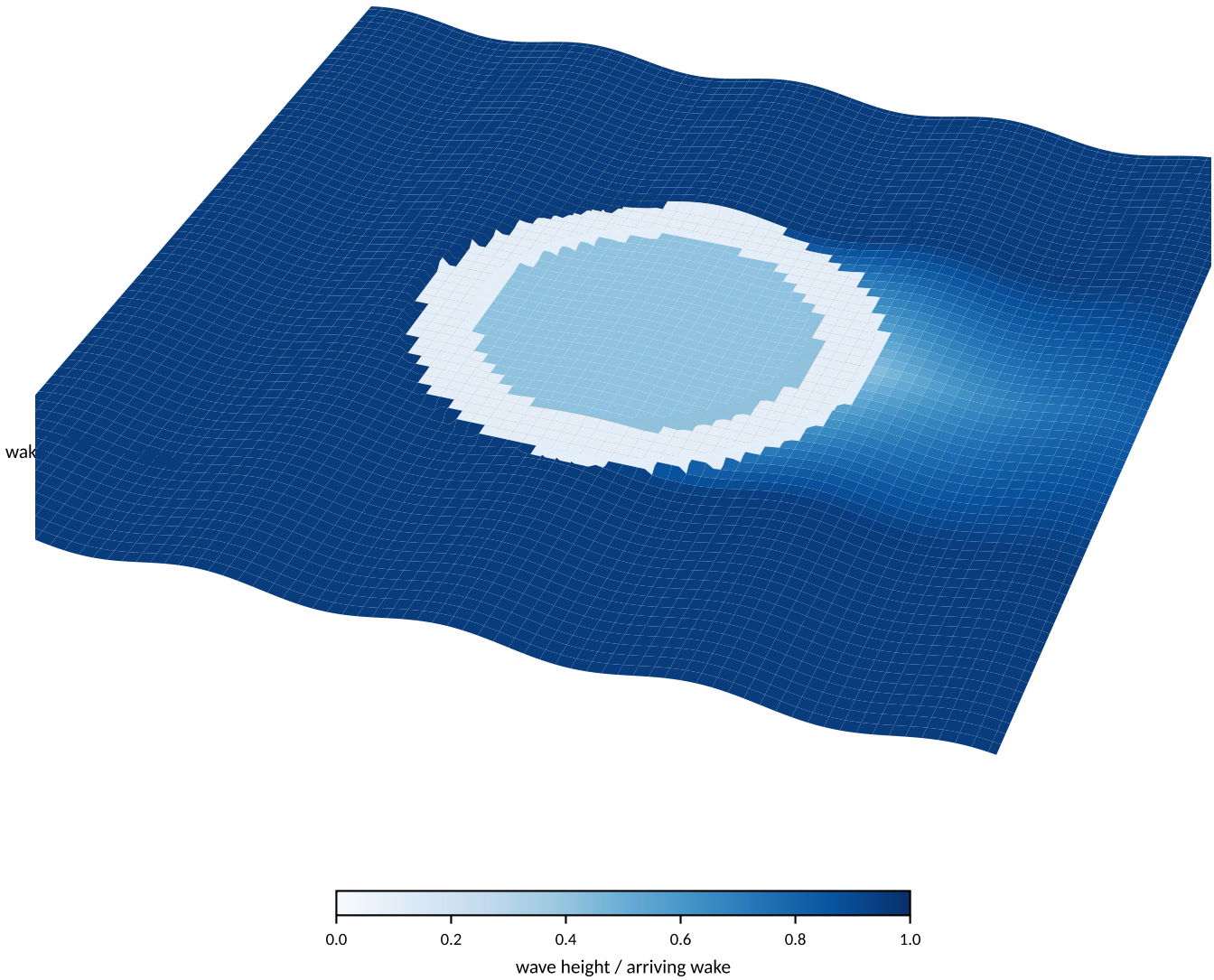


Each post is a cantilever from its steel shoe. The 140 mm tall posts reach 6.6 MPa at the shoe, the short and inner posts far less. Sway at the top of a tall post is drawn 10 times larger; the rope rail ties the posts together so a crowd leaning on it spreads its push along the ring.

RESULT Every post stays within its strength in a gale with people leaning on the rail, the tall posts at 41%.

M The wake, calmed

A 2.5 s boat wake running at the ring from the channel. Colour: wave height relative to the wake arriving. Inside, the water settles.

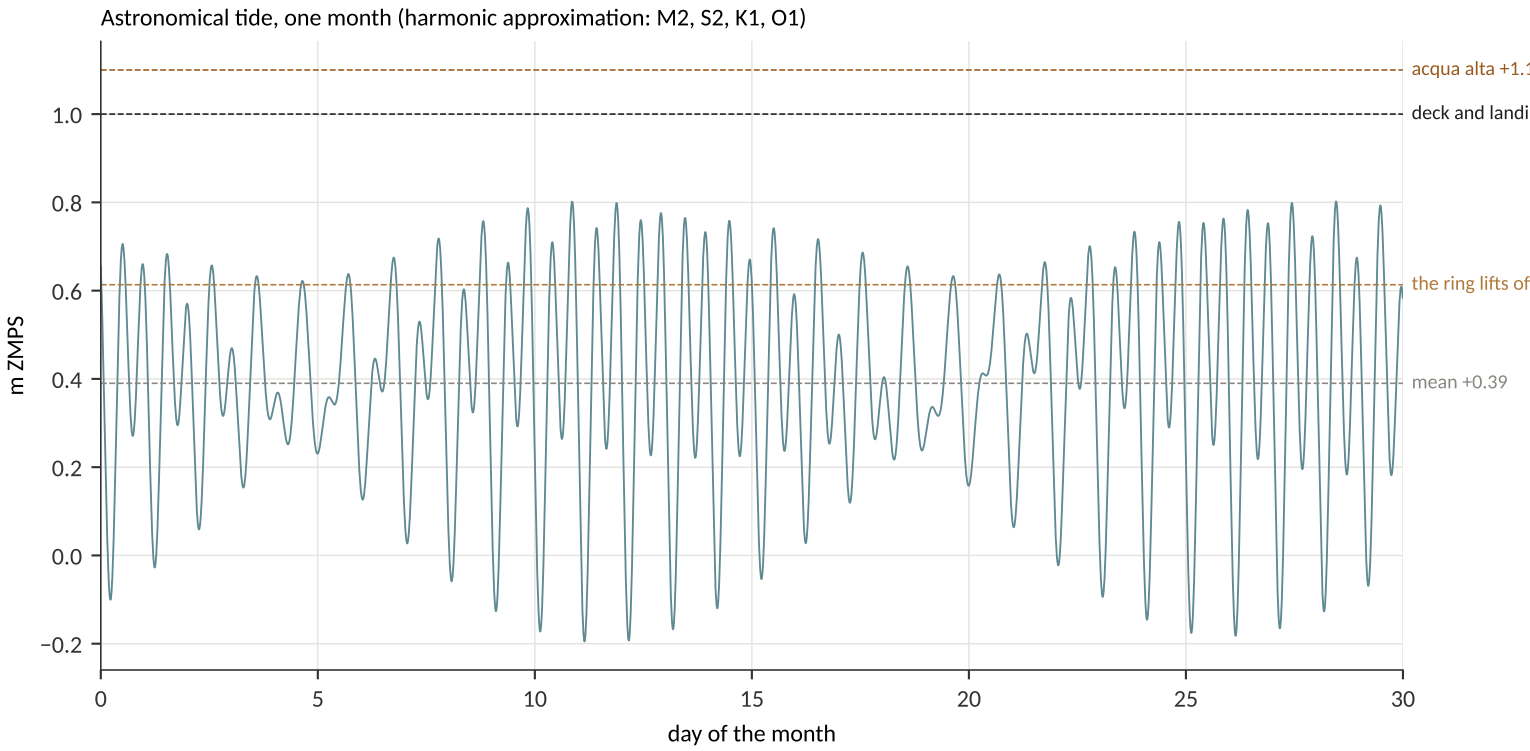


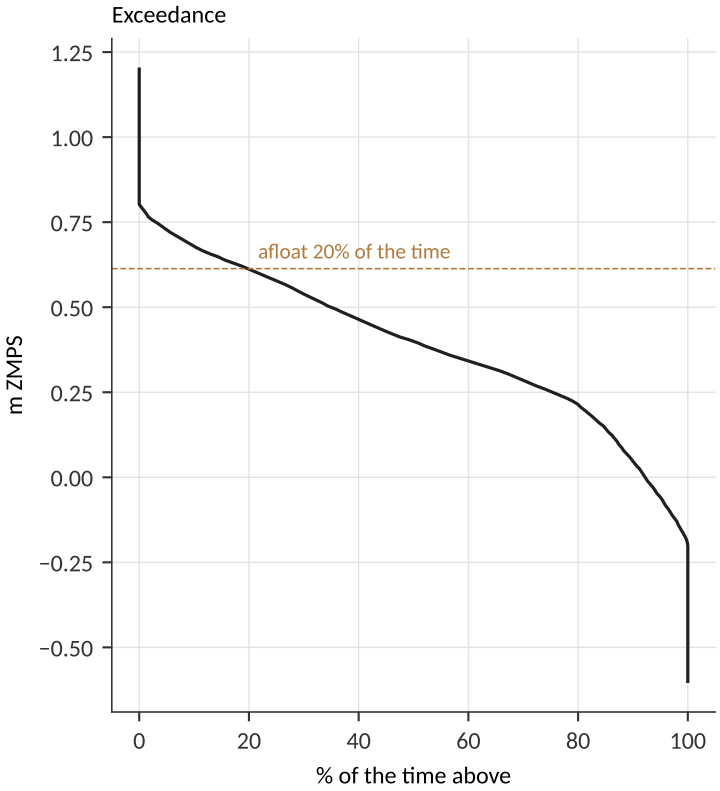
The hull alone passes about 82% of a 2.5 s wake's height; the brushwood skirt hanging below the rim breaks most of what gets under it. Inside the ring the wave is about 37% of what arrives, 14% of its energy, and the lee behind the ring is calmer for several metres. Silt held in the water drops where it is calm: inside the ring.

RESULT Inside the ring the wake arrives at 37% of its height and 14% of its energy: still water where the young marsh can root.

1 The tide

Venice levels in metres above ZMPS. When the ring rests, when it floats, how often.



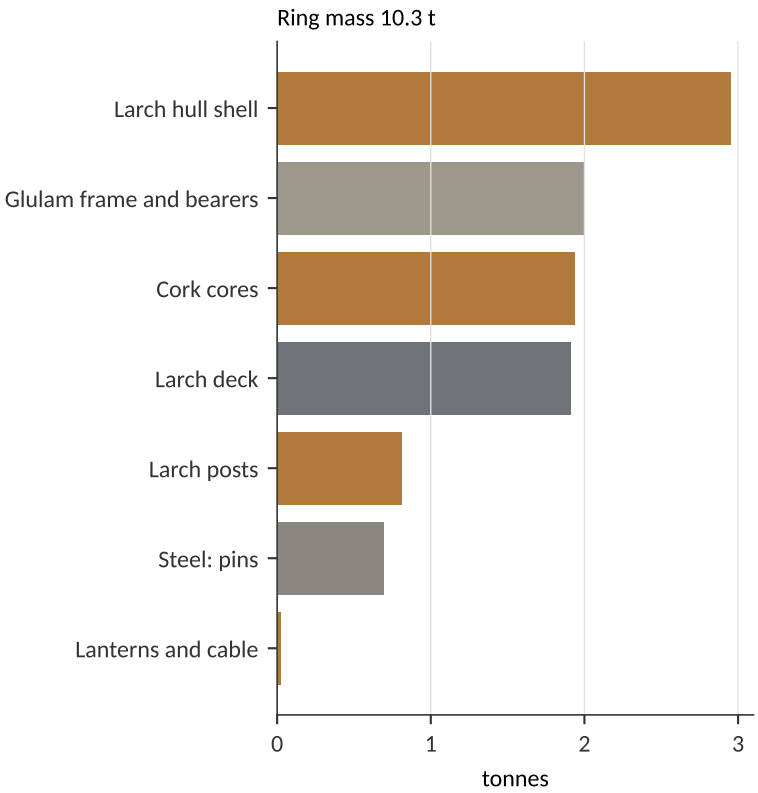


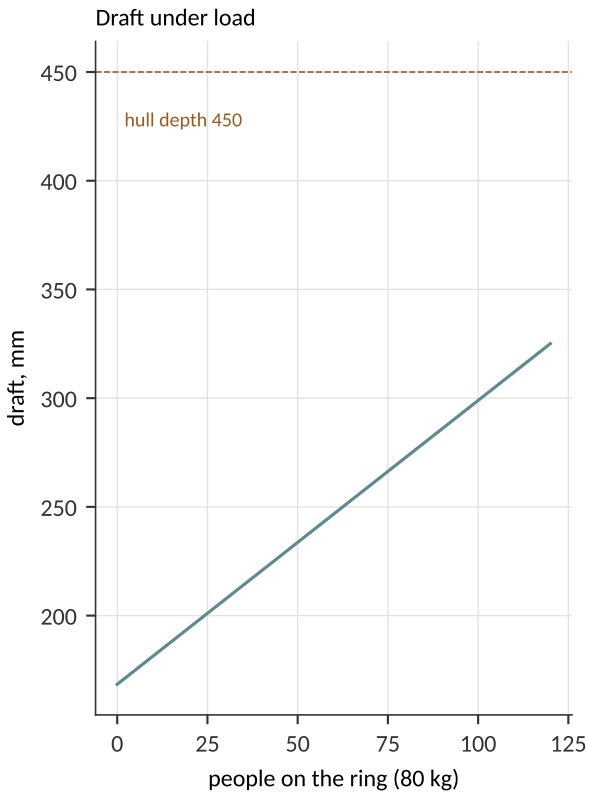
Level	m ZMPS
Acqua alta (city alarm)	+1.10
Landing and resting deck	+1.00
High water (spring)	+0.83
Ring lifts off (empty)	+0.61
Mean sea, now	+0.39
Low water	−0.05
Caranto, stiff clay	about −2.30
Sea level rise	4.8 mm a year

RESULT Afloat 20% of a month, resting on the stair the rest: it lifts on most high tides. Lift-off computed at +0.61.

2 Does it float?

Mass of the 23-bay ring, buoyancy of the sealed hull, the tide at which it lifts off.



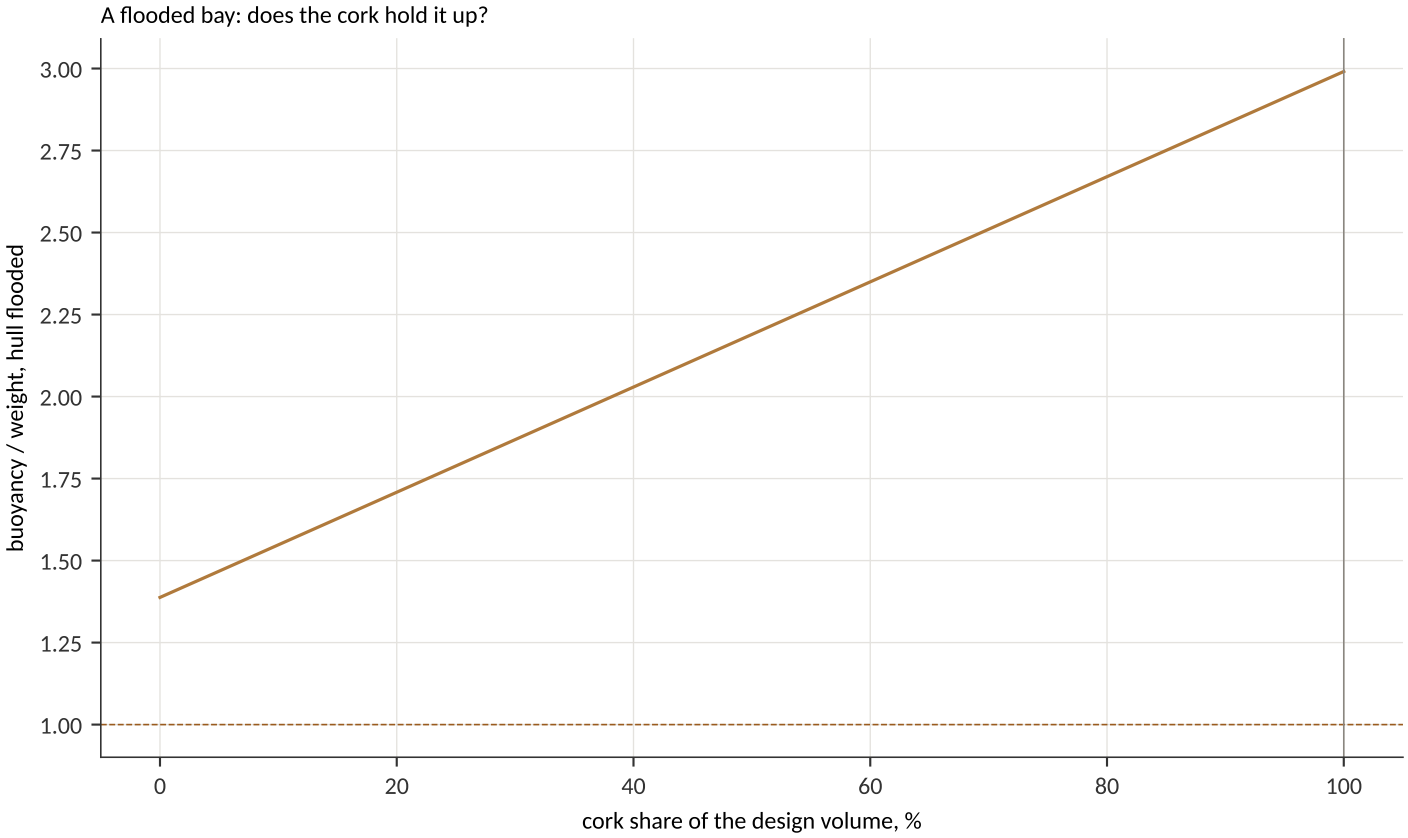


Item	Value
Deck area, 23 bays	79.7 m²
Hull plan (75% of deck)	59.8 m²
Hull volume (450 deep)	26.9 m³
Displacement available	27.6 t
Ring mass	10.32 t
Draft, empty	168 mm
Draft, 120 people	325 mm
Freeboard of hull, 120 people	125 mm
Lift-off level, empty	+0.61
Lift-off level, 30 people	+0.65
Reserve buoyancy, empty	2.7 x its weight

RESULT Floats with 2.7 times its own weight in reserve; even 120 people leave 125 mm of hull dry.

3 If a hull floods

Each bay carries cork cores, so a holed hull still floats. Test: one bay flooded, the cork alone.

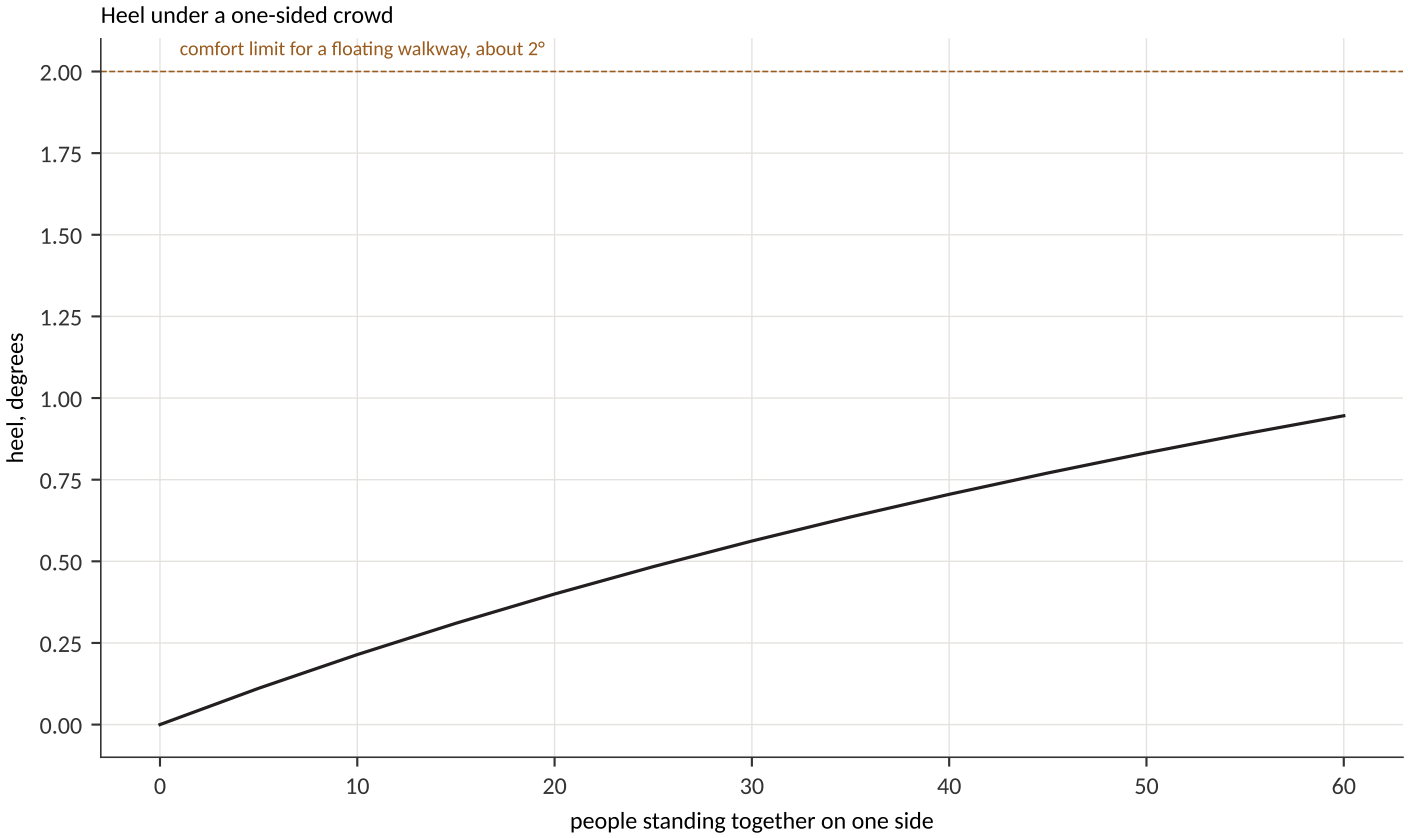


Item	Value
Bay mass	449 kg
Cork per bay	0.70 m^3 at 120 kg/m^3
Cork lift, flooded	719 kg
Larch buoyancy of its own volume	623 kg
Buoyancy / weight, flooded	3.0
Neighbour bays share the load through the pins	yes

RESULT A fully flooded bay still floats on its cork at 3.0 times its weight; the ring cannot sink.

4 Does it tip?

A crowd gathered on one side of the ring. The ring is a wide annulus, so it barely heels.

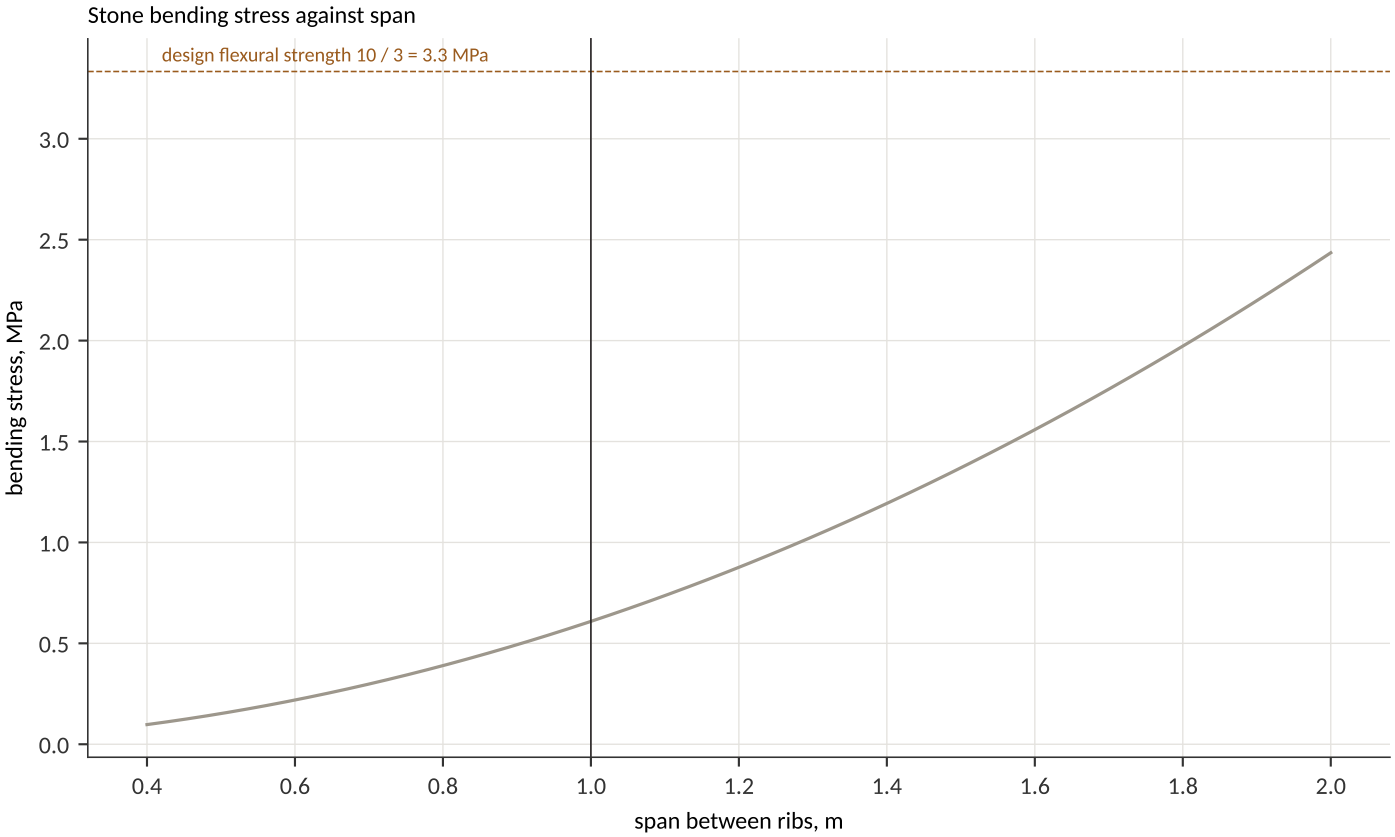


Item	Value
Waterplane second moment	1233 m^4
Displaced volume	10.1 m^3
BM = I / V	122.5 m
KB, KG (assumed)	0.08, 0.55 m
Metacentric height GM	122.0 m
Heel, 60 people at one side	0.95°

RESULT GM of 122 m: 60 people at one side heel it 0.95°. Treated as a rigid ring; the hinges are pinned in service.

5 The stone slab

Istrian stone, 120 mm, spanning 1.0 m between rib pairs. Crowd load 5 kN/m² (EN 1991-2, footbridges).

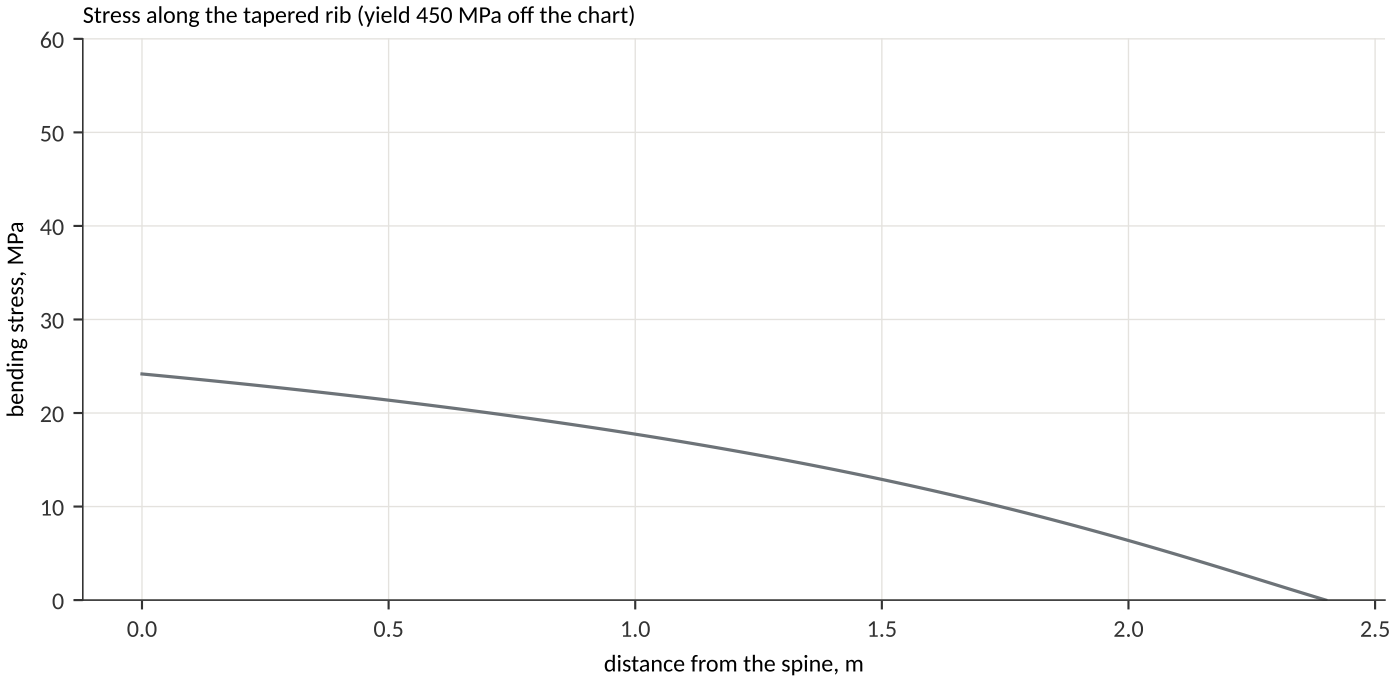


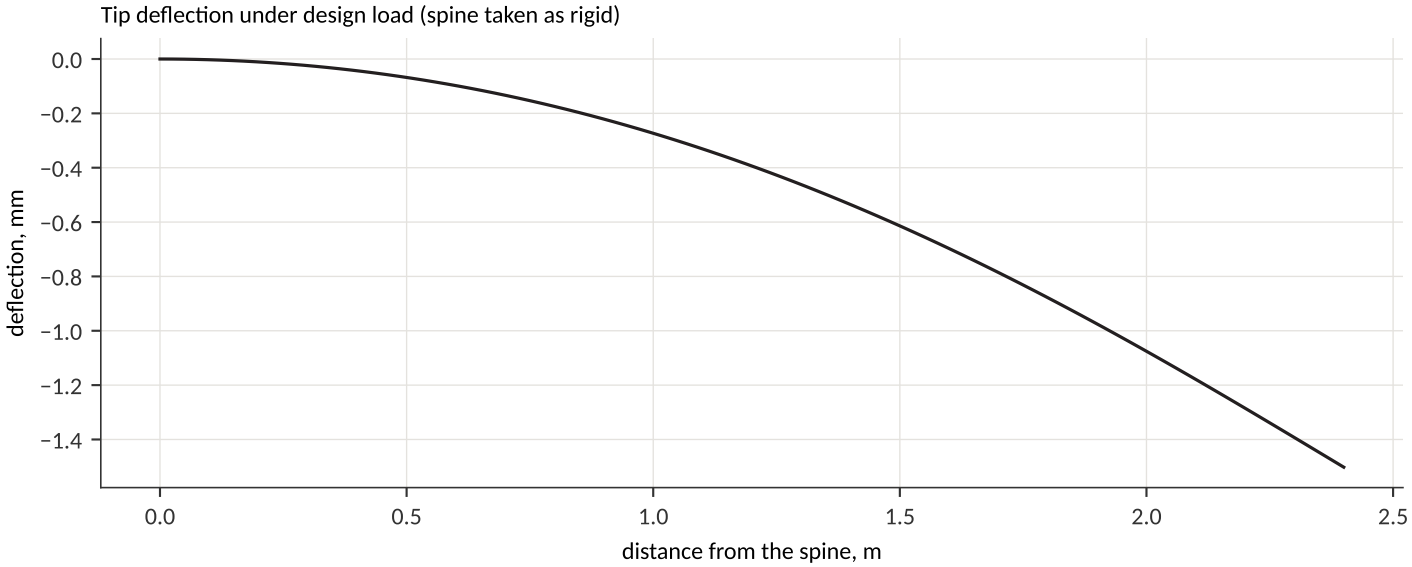
Item	Value
Density, Istrian limestone (supplier, unverified)	2636 kg/m³
Self weight	3.10 kN/m²
Crowd load	5.0 kN/m²
Design load 1.35g + 1.5q	11.7 kN/m²
Stress at 1.0 m span	0.61 MPa
Stress, 10 kN service vehicle over 0.5 m	3.13 MPa
Flexural strength assumed (published 10 to 15)	10.0 MPa, factor 3.0
Utilisation, crowd	18%

RESULT 120 mm slabs at 1.0 m spans: 0.61 MPa under a crowd, 18% of the design strength.

6 The rib cantilever

Twin stainless plates 2 x 25 mm, 450 deep at the spine tapering to 150, every 1.0 m. Back span 4.0 m, cantilever 2.4 m.



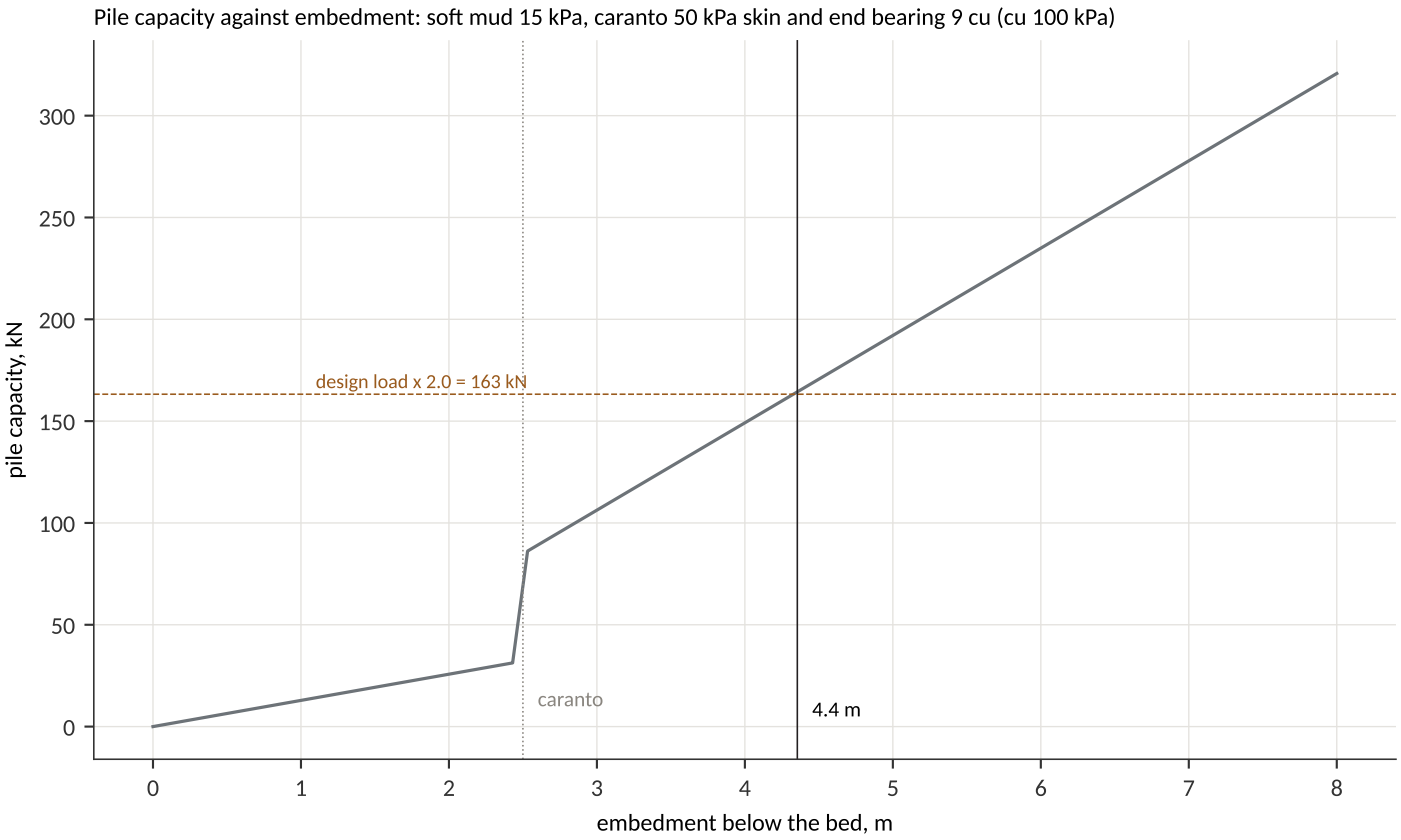


Item	Value
Line load on a rib pair	11.7 kN/m
Resting ring at the tip	2.97 kN/m
Moment at the spine	40.8 kNm
Peak stress	24 MPa (5% of yield, duplex 1.4462)
Tip deflection	1.5 mm (L/1598)

RESULT Peak 24 MPa, tip 1.5 mm: the ribs are strong and stiff enough; cross-bolts every 600 mm hold the twin plates together against buckling.

7 Spine and piles

The spine carries the ribs to paired 273 mm tubes driven to the caranto.

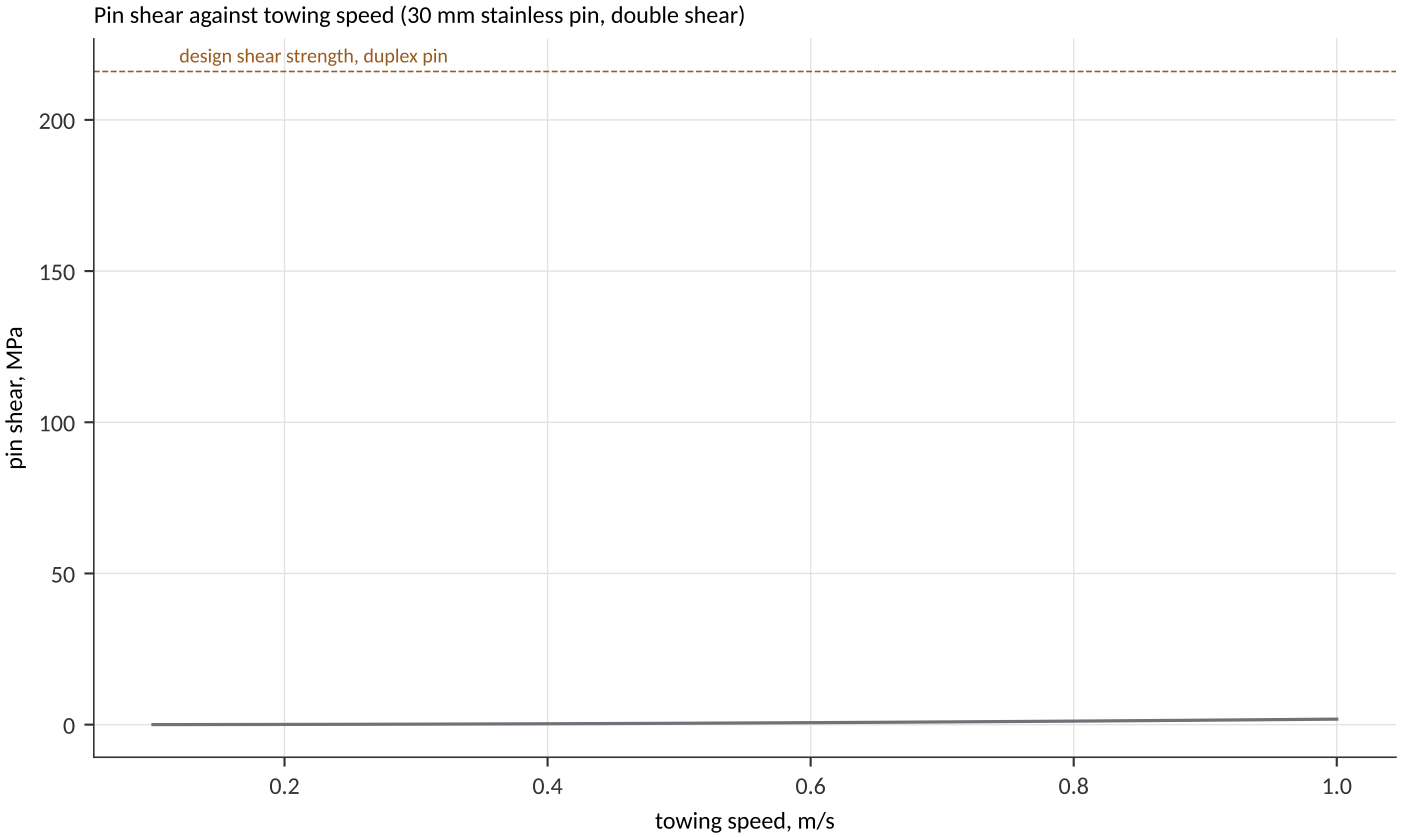


Item	Value
Reaction at the spine, per metre	54.4 kN/m
Load per pile (pairs every 3 m)	82 kN
Pile section	CHS 273 x 10, stainless
Axial stress	10 MPa
Euler buckling (free length 3.7 m, cantilever)	2551 kN
Embedment needed, factor 2	4.4 m below the bed: tips at about -4.2

RESULT 82 kN a pile, buckling capacity 2551 kN. Driven 4.4 m into the bed, through the soft mud into the caranto. Bearing taken in the stiff caranto clay.

8 The hinge

Drop pins join the bays. The worst case is towing the opened ring, 20 bays in a line, on the November move.

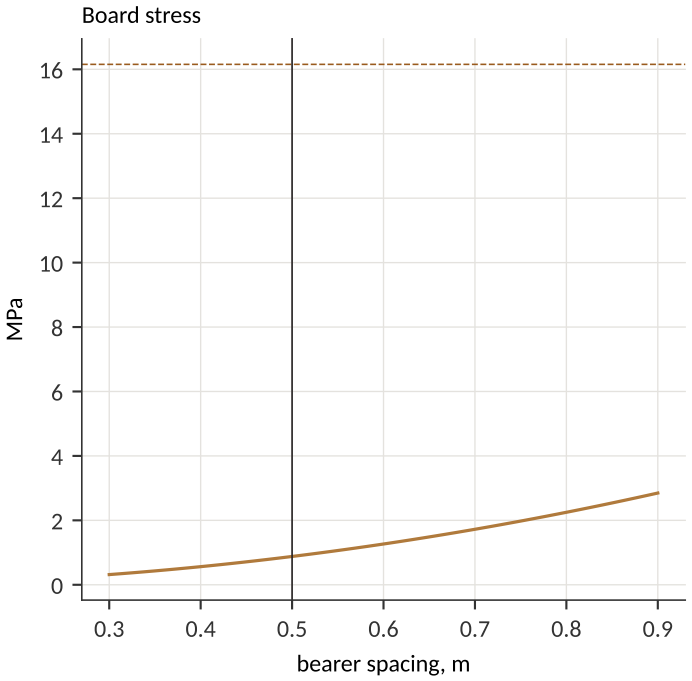


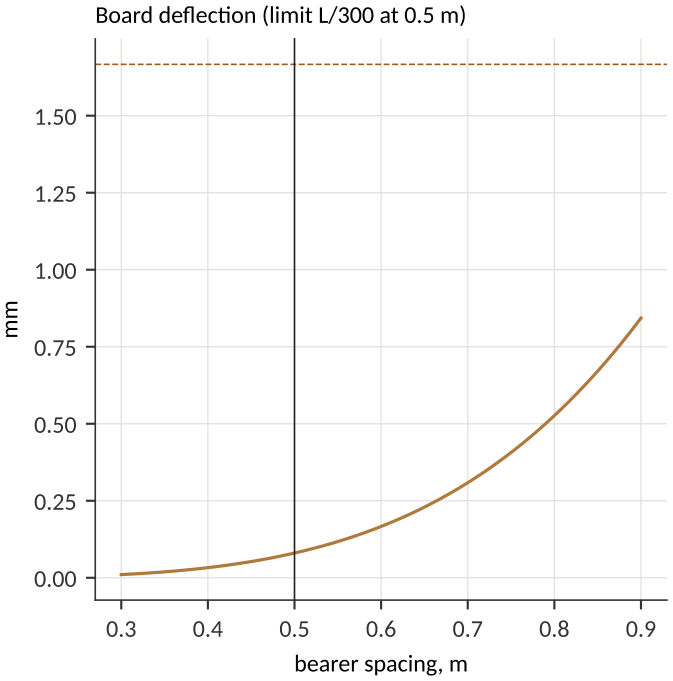
Item	Value
Towing speed planned	0.5 m/s (1 knot), on the slack of a spring tide
Drag on the line of 20 bays	0.6 kN
Pin	30 mm duplex stainless, double shear
Shear at 0.5 m/s	0.5 MPa
Shear at 1.0 m/s	1.8 MPa

RESULT Towing loads are a small fraction of a 30 mm duplex pin; in storms the ring stays pinned and docked on its stair.

9 Deck boards and posts

Larch D30 boards, 40 mm, on bearers at 500 mm. Posts larch, the tall one 140 mm and 2.7 m above the deck.



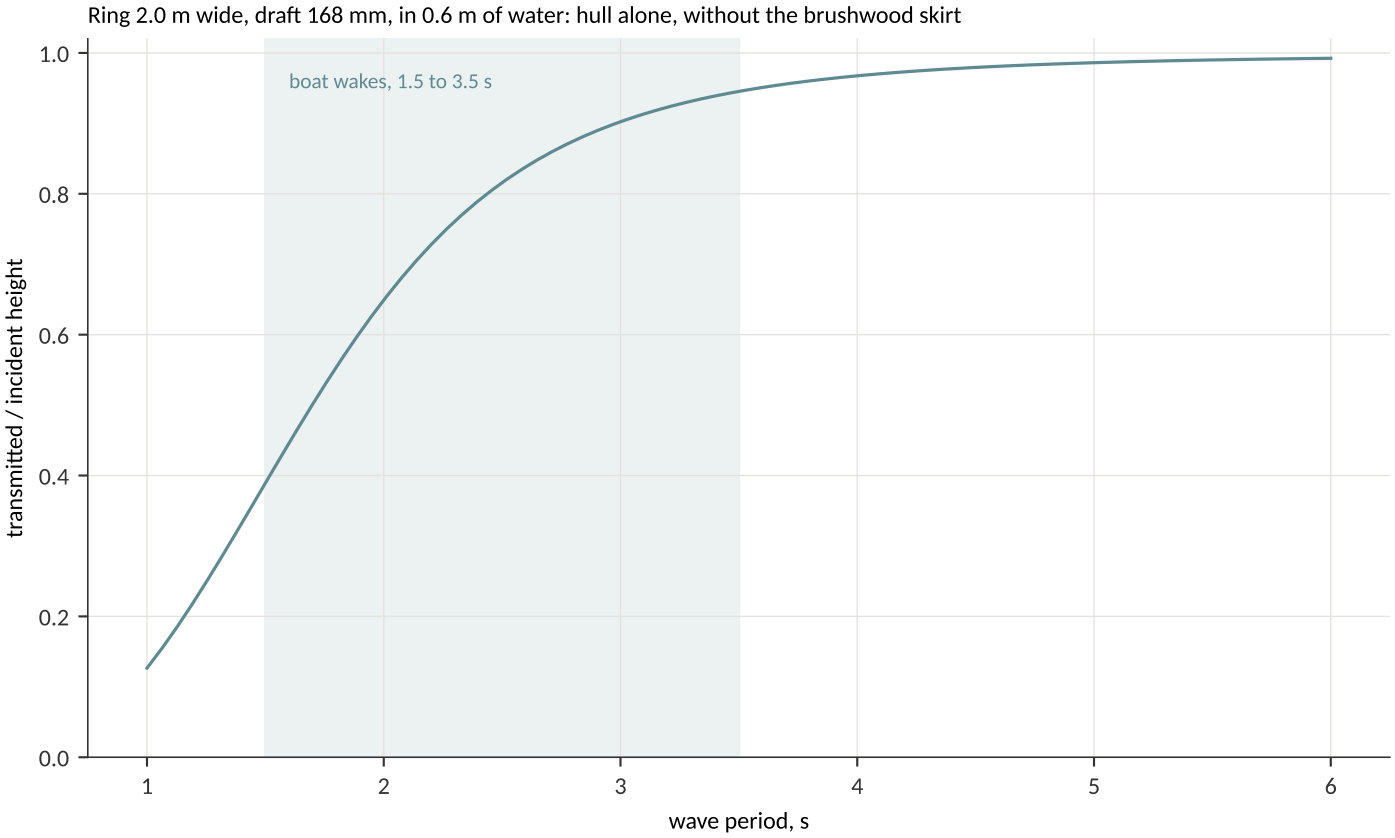


Item	Value
Board design strength, D30, kmod 0.7	16.2 MPa
Board stress at 0.5 m	0.9 MPa
Board deflection at 0.5 m	0.08 mm
Tall post, wind 1 kN/m² + 0.5 kN lean at the top	2.79 kNm at the shoe
Tall post stress, 140 mm round	10.4 MPa

RESULT Boards work at 0.9 MPa against 16.2; the 140 mm tall post carries wind and a leaning crowd at 64% of its strength.

10 Does it calm the water?

Boat wakes are short waves. A floating box breakwater passes long waves and stops short ones (Macagno).

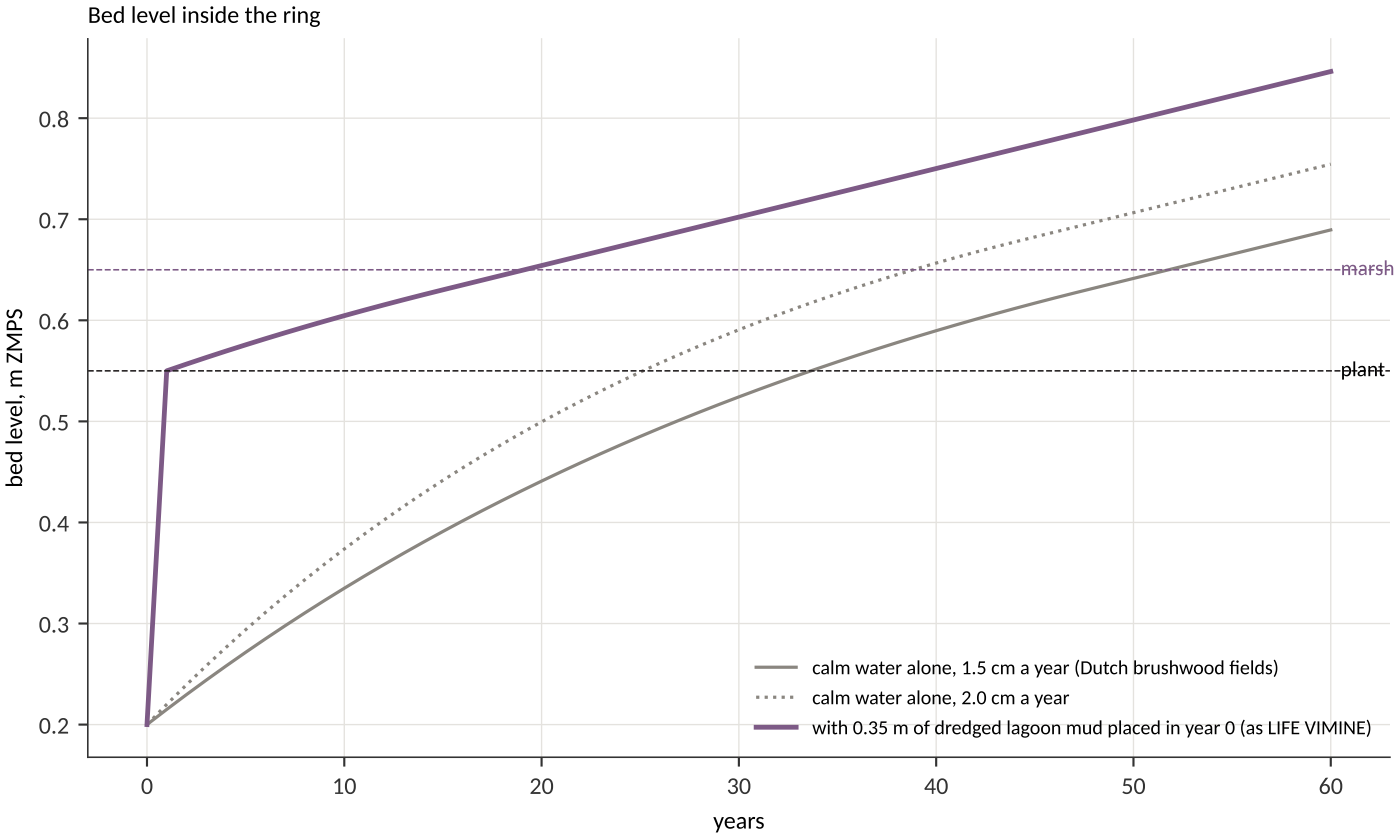


Item	Value
Transmission, 2.0 s wake	65%
Transmission, 2.5 s wake	82%
Transmission, 5 s swell	99%
Energy passed at 2.5 s	67%
The brushwood skirt under the rim	cuts the remainder further: not counted here

RESULT The hull takes the top off every wake, down to 67% of its energy from the hull alone; the brushwood skirt below the rim breaks the rest, so the water inside is calm enough for silt to settle.

11 How fast does the marsh rise?

Silt settles in the calm water. Test: from the bed (+0.20) to the planting level (+0.55), with and without help.



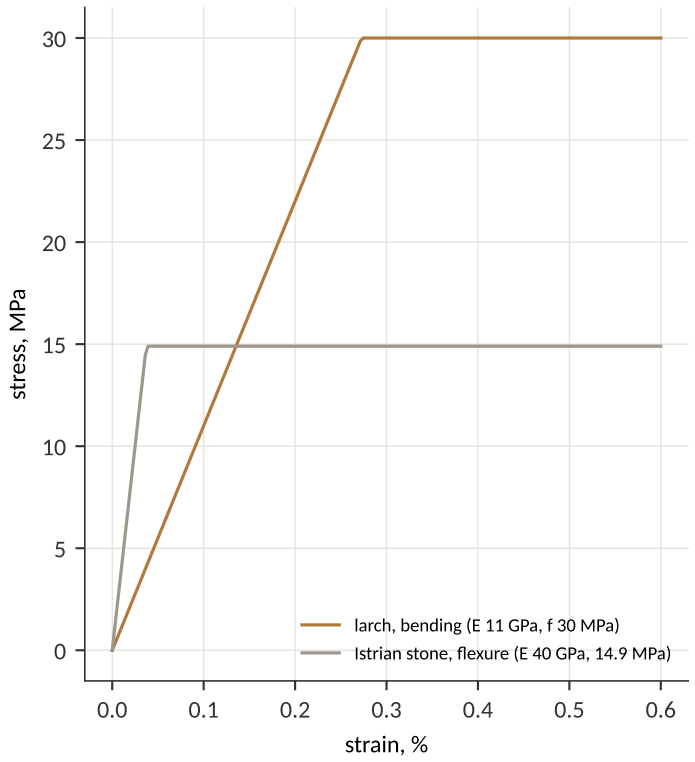
Item	Value
Planting level	+0.55 (glasswort pioneers)
Years to plant, calm water alone	34
Years to plant, with placed mud	1
Settling of 20 µm silt (Stokes)	1159 mm an hour
Sea level rise, kept up with by a living marsh	4.8 mm a year

RESULT Each station starts with 0.35 m of dredged lagoon mud placed inside the ring, as LIFE VIMINE does, so planting begins in the first year; the calm water then keeps feeding the marsh with silt.

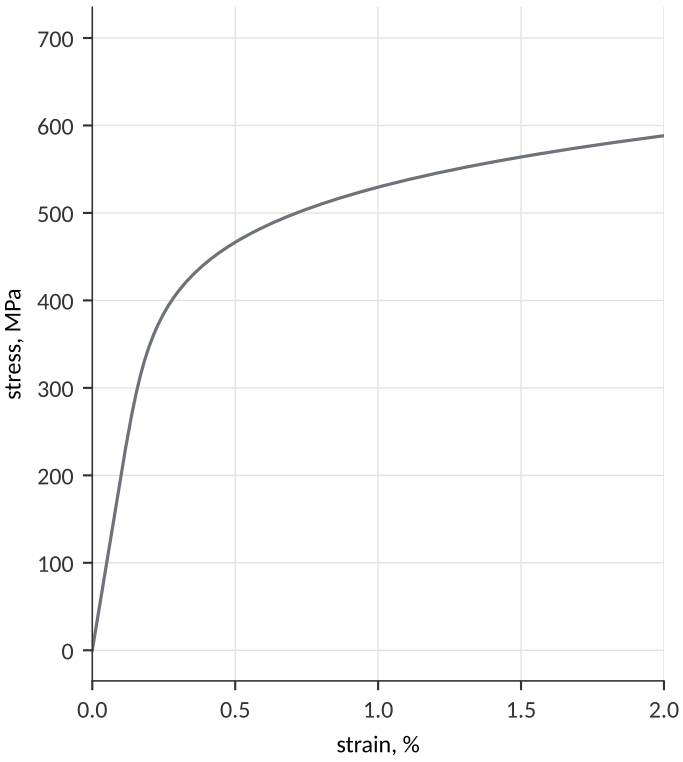
12 The materials

Stress against strain for the four materials the pavilion is made of (typical published values).

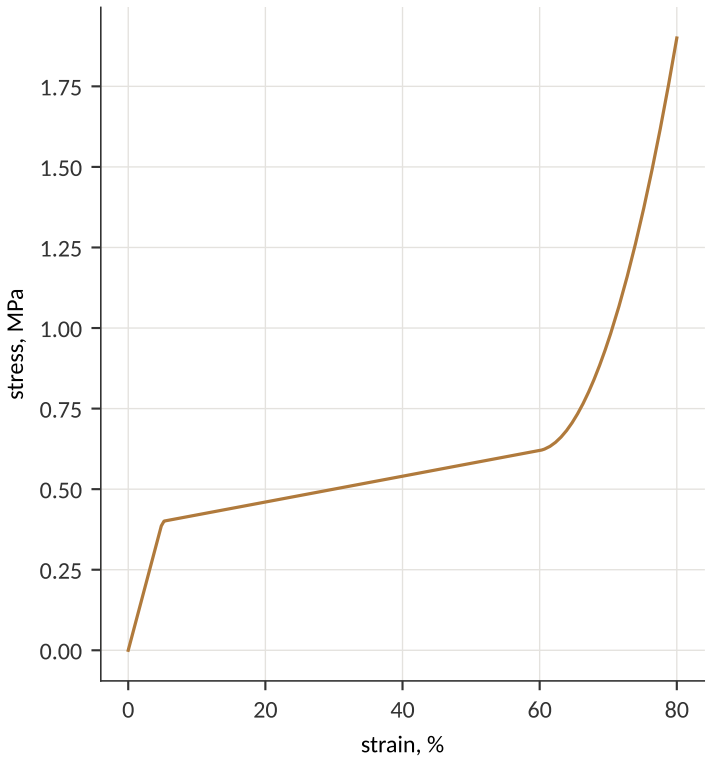
Timber and stone: brittle and elastic



Duplex stainless 1.4462 (Ramberg-Osgood)



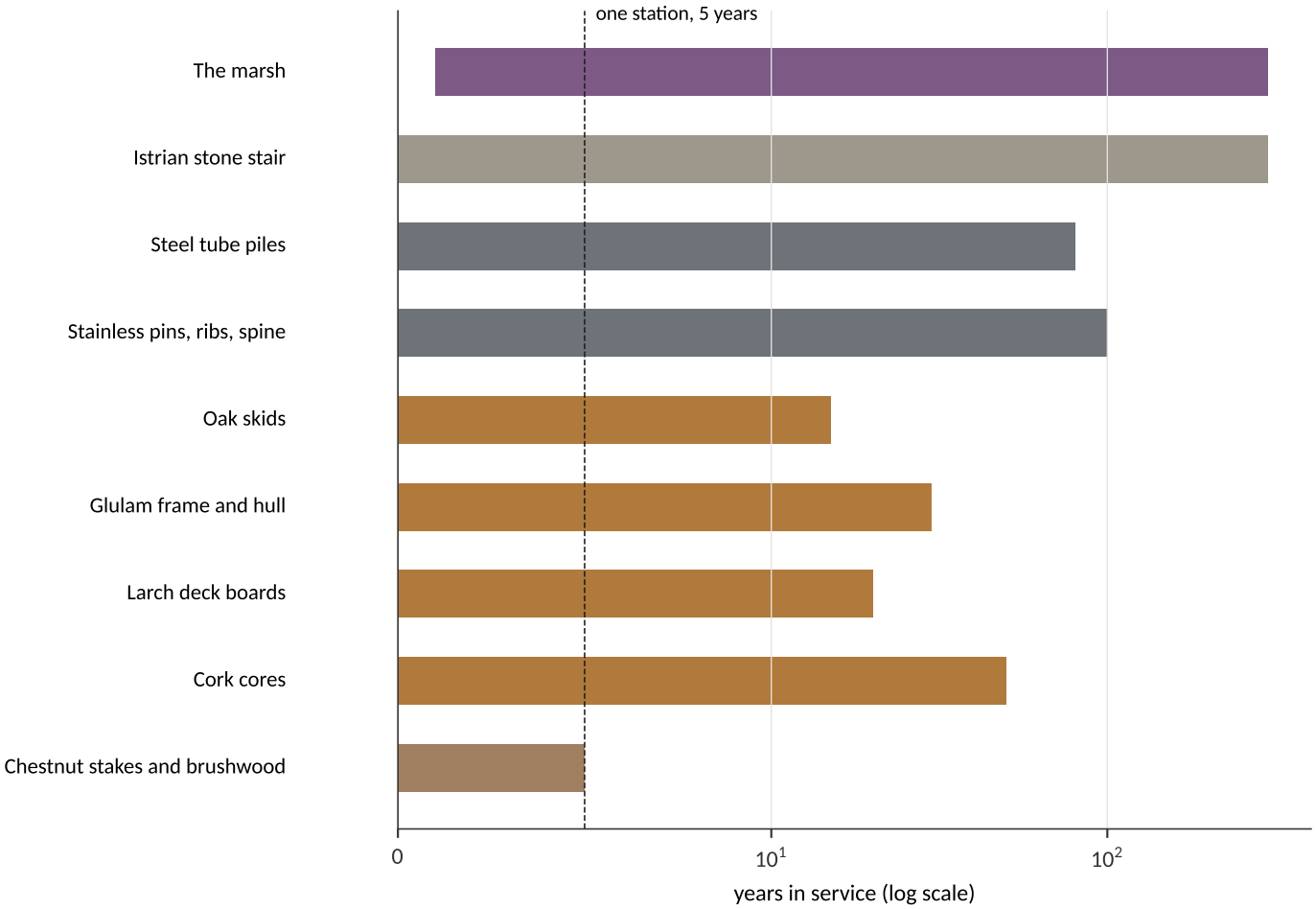
Cork agglomerate in compression



Material	Value
Larch D30	600 kg/m³, f 30 MPa
Istrian stone	2636 kg/m³, 133 MPa crushing
Duplex 1.4462	7800 kg/m³, fy 450 MPa
Cork	120 kg/m³, never rots, floats
Oak skids	700 kg/m³, wet-dry tolerant
Chestnut stakes	rot in 3 to 5 years, as meant

13 What lasts, what goes

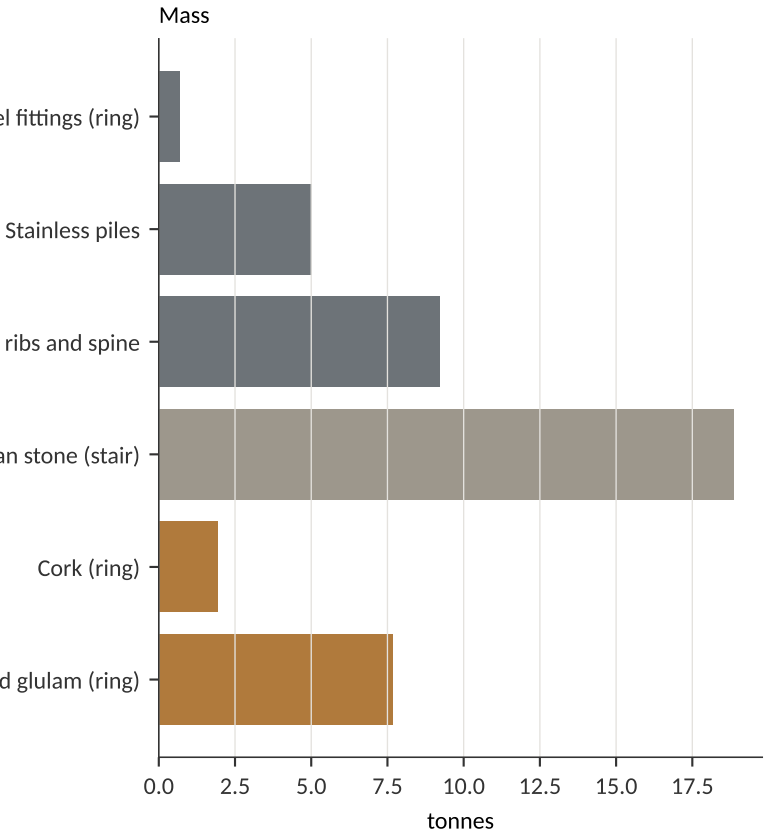
The building is designed to leave. Each part has the life it needs, and no more.

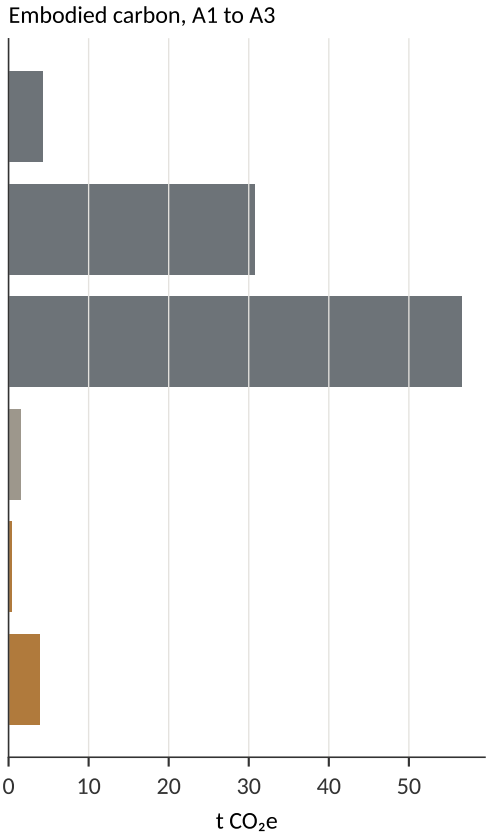


The stakes rot by design once the marsh holds. The ring moves on every five years, so its timber serves four stations in about twenty yea
The stone and the marsh are what stay.

14 How much, and its carbon

Material quantities for one station and the ring, and embodied carbon to the factory gate (ICE v3 factors).





Material	Mass	Carbon
Larch and glulam (ring)	7.7 t	3.9 t CO_2e
Cork (ring)	1.9 t	0.4 t CO_2e
Istrian stone (stair)	18.9 t	1.5 t CO_2e
Stainless ribs and spine	9.2 t	56.7 t CO_2e
Stainless piles	5.0 t	30.8 t CO_2e
Steel fittings (ring)	0.7 t	4.2 t CO_2e
Total, one station	43.4 t	97.5 t CO_2e

RESULT Stone and timber make up the bulk of the pavilion; the stainless steel is held to the joints and ribs that must last a century in salt water, and it is reused at every move.

15 Summary of the tests

What passed, and what still needs work before the final review.

PASS	Afloat 20% of a month, resting on the stair the rest: it lifts on most high tides. Lift-off computed at +0.61.
PASS	Floats with 2.7 times its own weight in reserve; even 120 people leave 125 mm of hull dry.
PASS	A fully flooded bay still floats on its cork at 3.0 times its weight; the ring cannot sink.
PASS	GM of 122 m: 60 people at one side heel it 0.95°. Treated as a rigid ring; the hinges are pinned in service.
PASS	120 mm slabs at 1.0 m spans: 0.61 MPa under a crowd, 18% of the design strength.
PASS	Peak 24 MPa, tip 1.5 mm: the ribs are strong and stiff enough; cross-bolts every 600 mm hold the twin plates together against buckling.
PASS	82 kN a pile, buckling capacity 2551 kN. Driven 4.4 m into the bed, through the soft mud into the caranto. Bearing taken in the stiff caranto clay.
PASS	Towing loads are a small fraction of a 30 mm duplex pin; in storms the ring stays pinned and docked on its stair.
PASS	Boards work at 0.9 MPa against 16.2; the 140 mm tall post carries wind and a leaning crowd at 64% of its strength.
PASS	The hull takes the top off every wake, down to 67% of its energy from the hull alone; the brushwood skirt below the rim breaks the rest, so the water inside is calm enough for silt to settle.
PASS	Each station starts with 0.35 m of dredged lagoon mud placed inside the ring, as LIFE VIMINE does, so planting begins in the first year; the calm water then keeps feeding the marsh with silt.
PASS	Stone and timber make up the bulk of the pavilion; the stainless steel is held to the joints and ribs that must last a century in salt water, and it is reused at every move.