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Spanned Flexure -Convertible Roof Systems Using Elastic Kinetic Plates Actuated by Tension Cables

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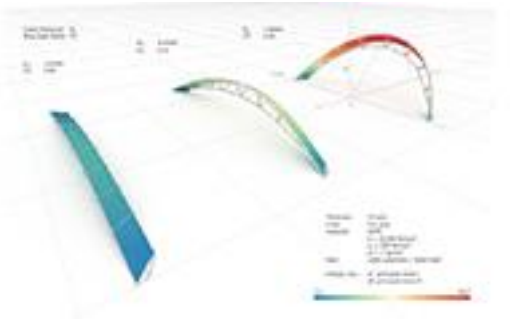
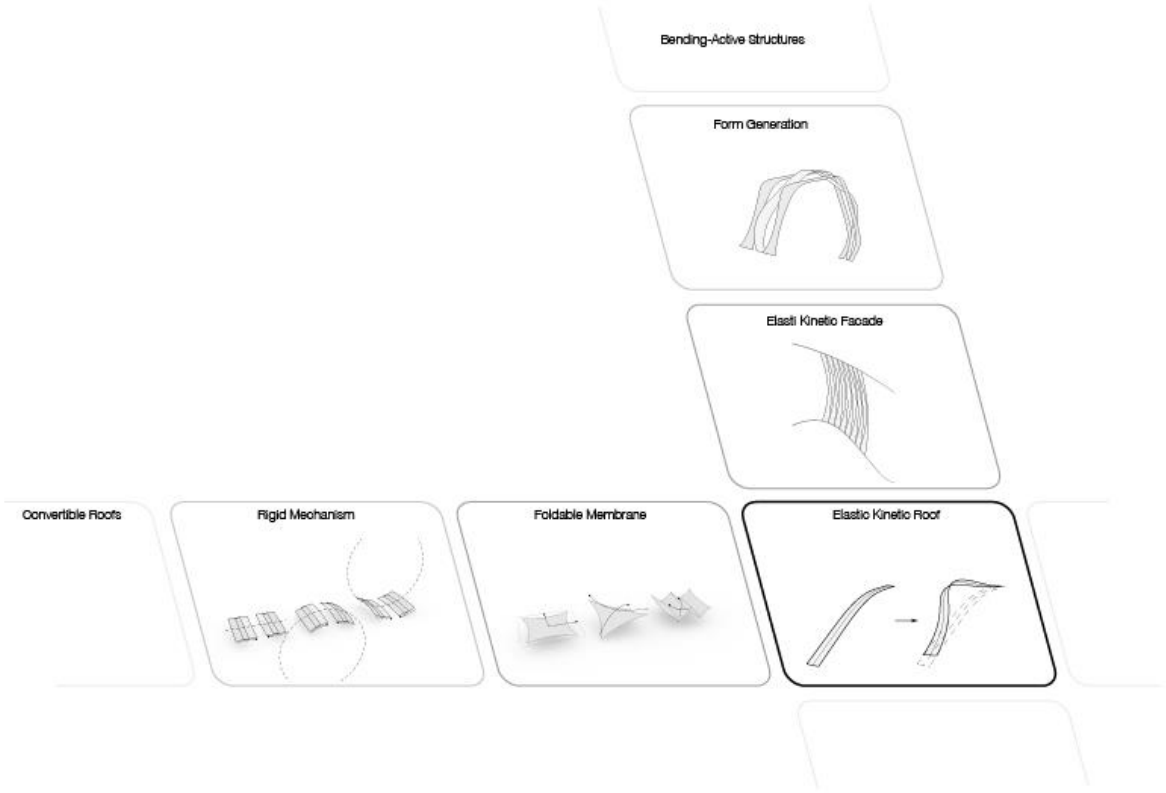
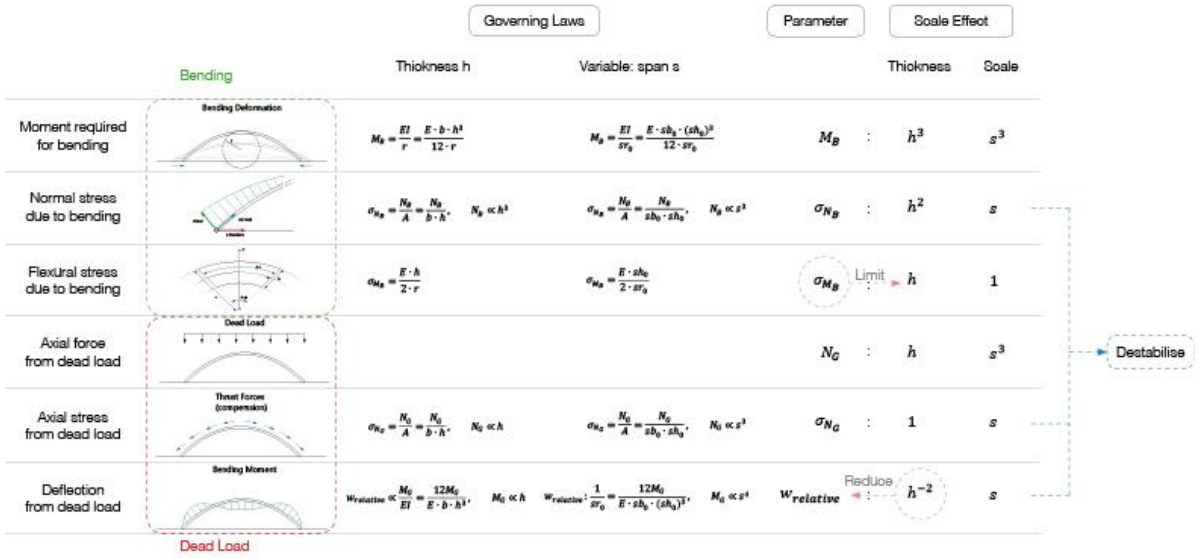
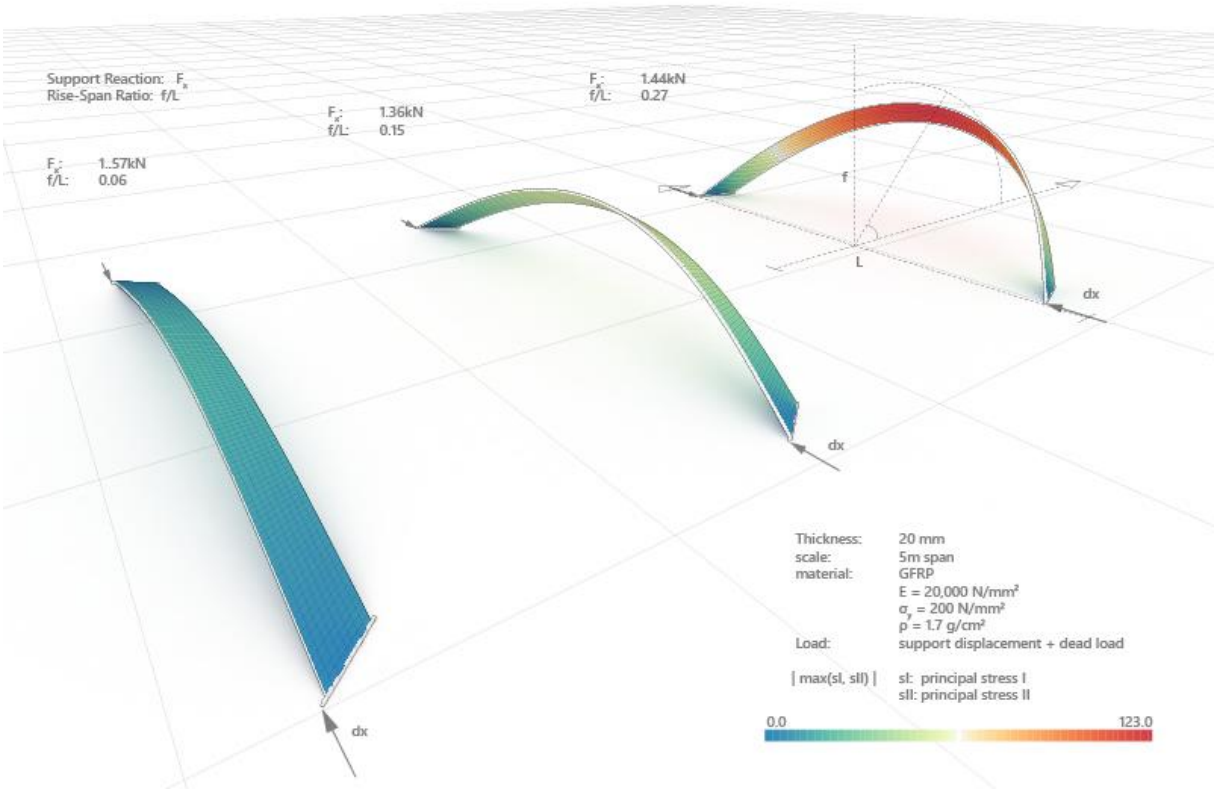
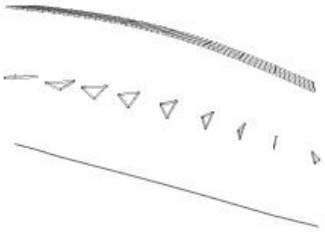
The research aims to expand the potential in convertibility of elastic kinetic structures toward adaptive load-bearing structural system. The study is focused by means of finite element models on the form-finding and the structural analysis of flexible plate structures actuated and supported by cable elements, in order to examine their feasibility in geometry and scalability under severe load conditions. The research results in the scale evaluation of different types of kinetic plates, the proof of the novel structural system and the according design proposals of convertible roof systems on a conceptual level.

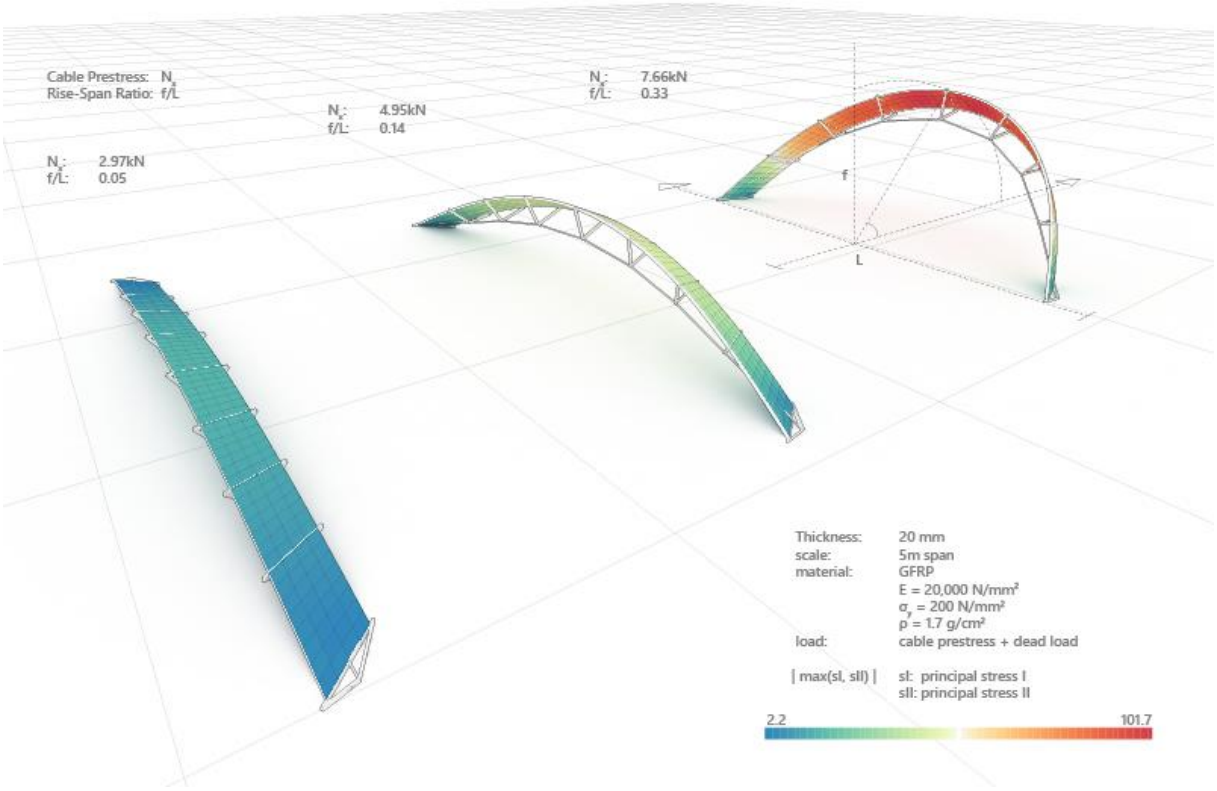


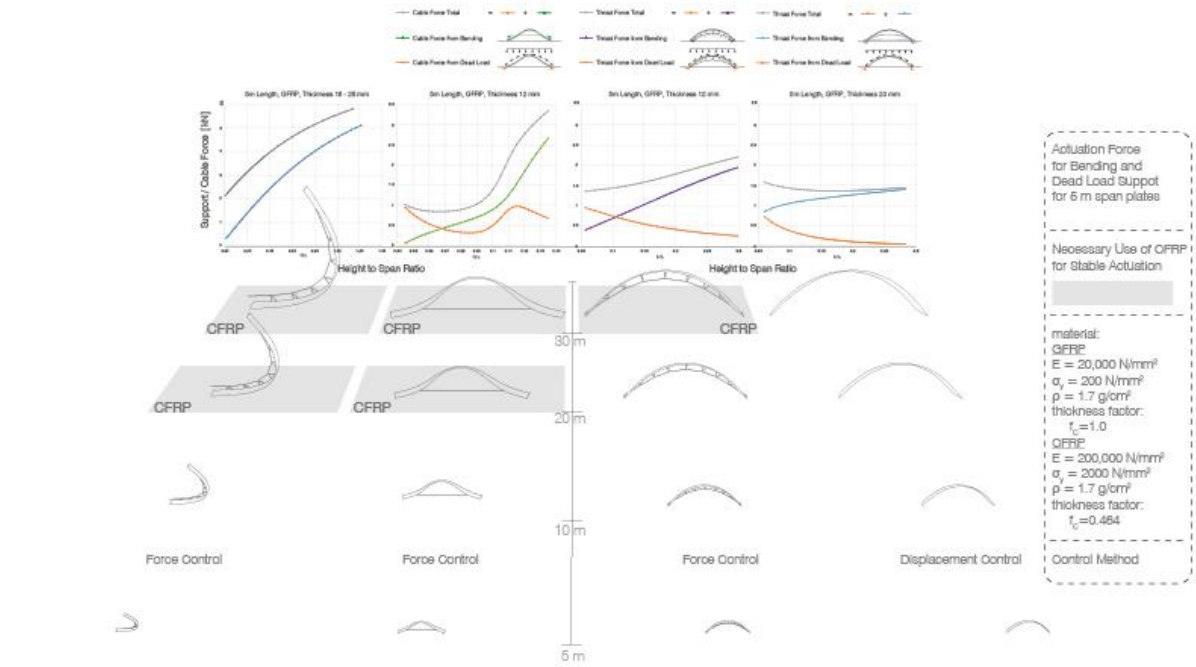



Governing Laws
Parameter
Scale Effect
Bending
Thickness h
Variable: span s
Thickness
Scale
Moment required for bending
Bending Deformation
$M_B = \frac{EI}{r} = \frac{E \cdot b \cdot h^3}{12 \cdot r}$
$M_B = \frac{EI}{sr_0} = \frac{E \cdot sb_0 \cdot (sh_0)^3}{12 \cdot sr_0}$
M_B : h^3 s^3
Normal stress due to bending
$\sigma_{N_B} = \frac{N_B}{A} = \frac{N_B}{b \cdot h}$, $N_B \propto h^3$
$\sigma_{N_B} = \frac{N_B}{A} = \frac{N_B}{sb_0 \cdot sh_0}$, $N_B \propto s^3$
σ_{N_B} : h^2 s
Flexural stress due to bending
$\sigma_{M_B} = \frac{E \cdot h}{2 \cdot r}$
$\sigma_{M_B} = \frac{E \cdot sh_0}{2 \cdot sr_0}$
σ_{M_B} Limit : h 1
Axial force from dead load
Dead Load
N_G : h s^3
Destabilise
Axial stress from dead load
Thrust Force (compression)
$\sigma_{N_G} = \frac{N_G}{A} = \frac{N_G}{b \cdot h}$, $N_G \propto h$
$\sigma_{N_G} = \frac{N_G}{A} = \frac{N_G}{sb_0 \cdot sh_0}$, $N_G \propto s^3$
σ_{N_G} : 1 s
Deflection from dead load
Bending Moment
$w_{relative} \propto \frac{M_G}{EI} = \frac{12M_G}{E \cdot b \cdot h^3}$, $M_G \propto h$
$w_{relative} : \frac{1}{sr_0} = \frac{12M_G}{E \cdot sb_0 \cdot (sh_0)^3}$, $M_G \propto s^4$
$w_{relative}$ Reduce : h^{-2} s
Dead Load

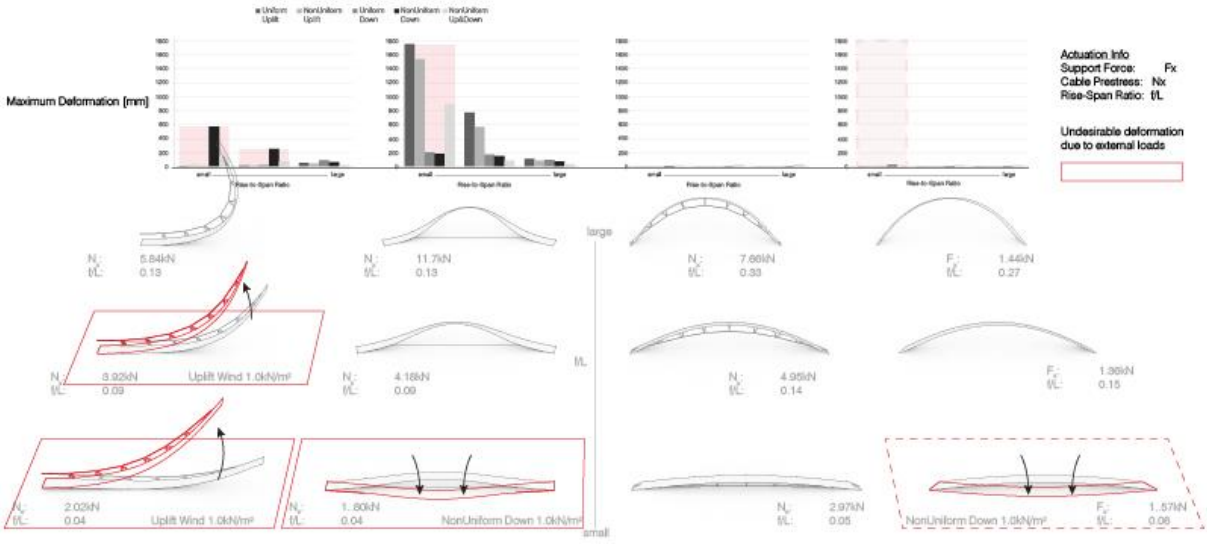

Support Reaction: F_x
Rise-Span Ratio: f/L
F_x: 1.57kN
f/L: 0.06
F_x: 1.36kN
f/L: 0.15
F_x: 1.44kN
f/L: 0.27
f
L
dx
dx
dx
Thickness: 20 mm
scale: 5m span
material: GFRP
E = 20,000 N/mm²
σ_y = 200 N/mm²
ρ = 1.7 g/cm³
Load: support displacement + dead load
| max(sI, sII) | sI: principal stress I
sII: principal stress II
0.0
123.0




Cable Prestress: N
Rise-Span Ratio: f/L
N: 2.97kN
f/L: 0.05
N: 4.95kN
f/L: 0.14
N: 7.66kN
f/L: 0.33
f
L
Thickness: 20 mm
scale: 5m span
material: GFRP
E = 20,000 N/mm²
σ = 200 N/mm²
ρ = 1.7 g/cm²
load: cable prestress + dead load
| max(sI, sII) | sI: principal stress I
sII: principal stress II
2.2
101.7



Cable-Cantilevered Plate		Torsional Plate		Cable Supported Arched Plate		Single Curved Arched Plate	
Thickness:	16-28*8*t_c mm, (8:1,2,4,6)	Thickness:	20*8*t_c mm, (8:1,2,4,6)	Thickness:	20*8*t_c mm, (8:1,2,4,6)	Thickness:	20*8*t_c mm, (8:1,2,4,6)
scale:	5, 10, 20, 30m span	scale:	5, 10, 20, 30m span	scale:	5, 10, 20, 30m span	scale:	5, 10, 20, 30m span
material:	GFRP -> CFRP	material:	GFRP -> CFRP	material:	GFRP -> CFRP	material:	GFRP -> CFRP
Actuation Load:	cable prestress + dead load	Actuation Load:	cable prestress + dead load	Actuation Load:	cable prestress + dead load	Actuation Load:	support displacement + dead load



Single Curved Arched Plate		Torioned Plate		Cable Supported Arched Plate		Single Curved Arched Plate	
Thickness:	16 - 28 mm	Thickness:	20 mm	Thickness:	20 mm	Thickness:	20 mm
scale:	6m span	scale:	6m span	scale:	6m span	scale:	6m span
material:	GFRP E = 20,000 N/mm² σ_y = 200 N/mm² ρ = 1.7 g/cm³	material:	GFRP E = 20,000 N/mm² σ_y = 200 N/mm² ρ = 1.7 g/cm³	material:	GFRP E = 20,000 N/mm² σ_y = 200 N/mm² ρ = 1.7 g/cm³	material:	GFRP E = 20,000 N/mm² σ_y = 200 N/mm² ρ = 1.7 g/cm³
Load:	cable prestress + dead load	Load:	cable prestress + dead load	load:	cable prestress + dead load	Load:	support displacement + dead load