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A low-order analytical model to monitor tension in shallow cables with specific end conditions

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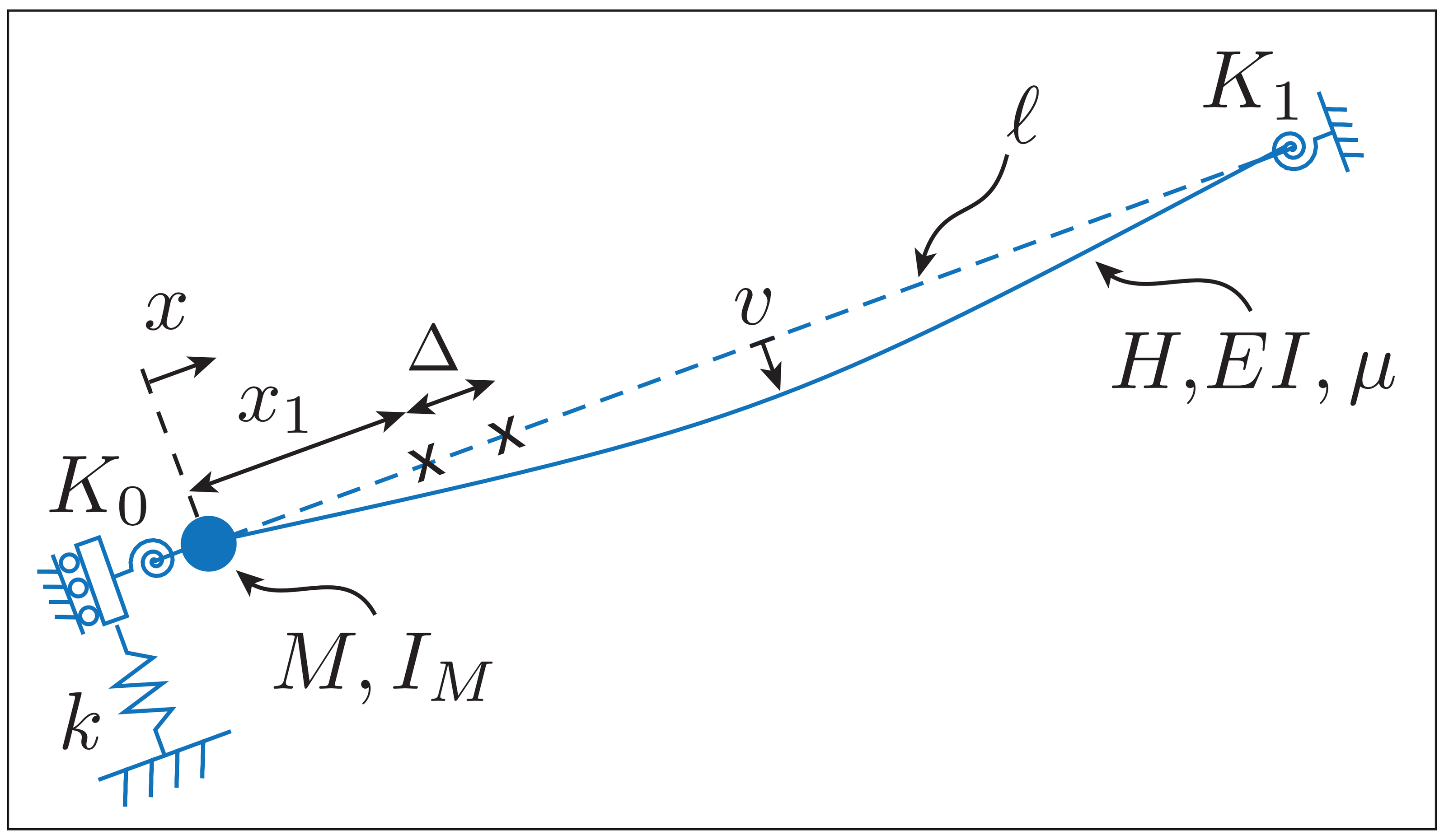
In order to prevent accidents on aging Walloon bridges, the Wallonia Public Service department has launched a research project which aims at remotely keeping track of tension in their cables.

An accurate and non-intrusive method is to identify tension based on the natural frequencies of the cable measured by means of a wireless accelerometer.

Characteristics of cables monitored:

- High levels of tension and/or small axial rigidities
- Flexural rigidities not negligible but small
- Various lengths (short hangers or long stay-cables)
- Arbitrary rotational end restraints
- Bottom anchorage possibly flexible and heavy

The corresponding model is presented hereafter. It provides equations of motion that are solved with a mix of analytical and numerical tools. At first, except μ and Δ, the parameters are not exactly known.



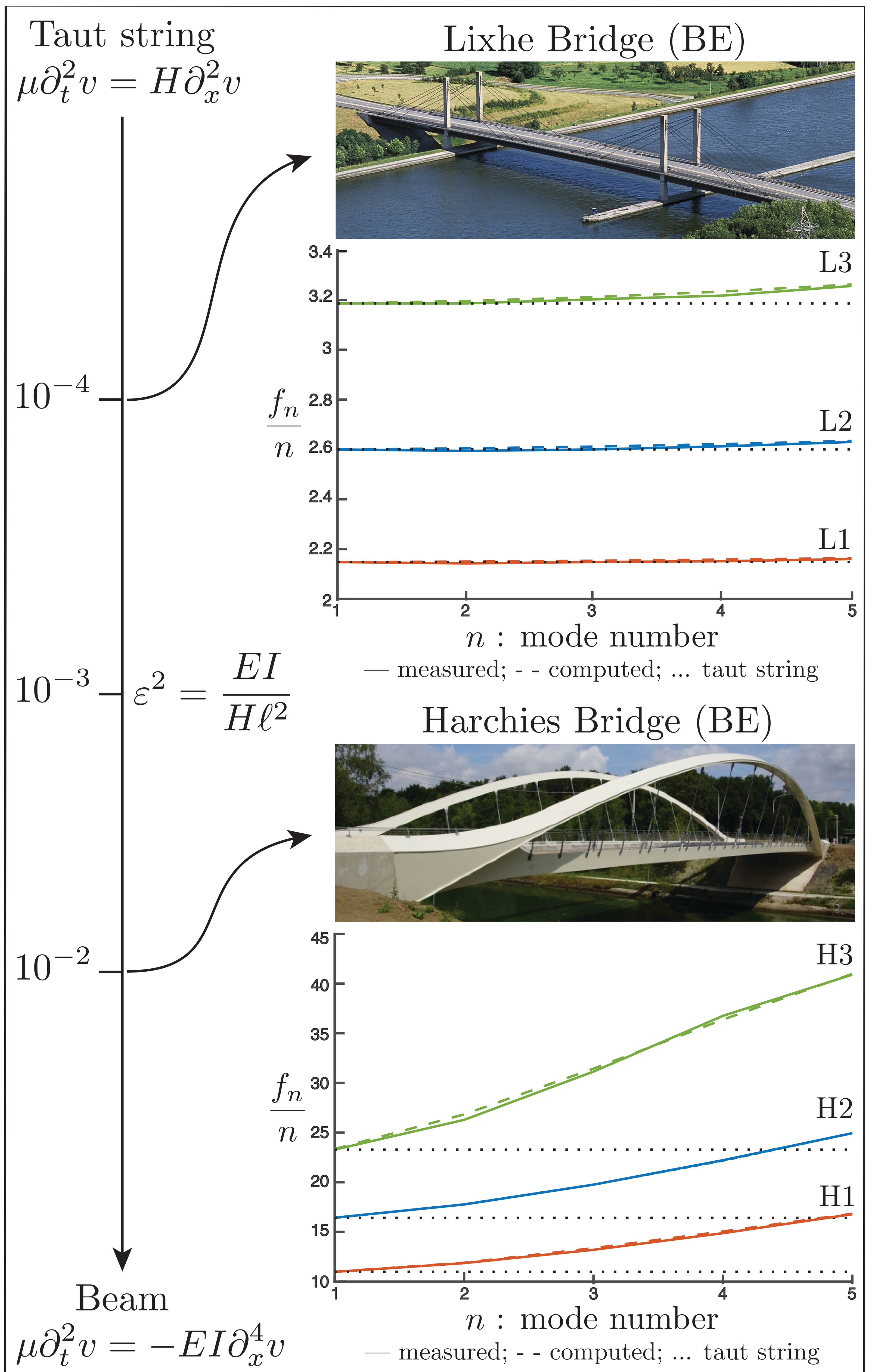
Cable model with specific end conditions (x = sensors)

Parameters of the low-order cable model

H	[kN]	Cable tension, parallel to the chord
ℓ	[m]	Length between anchorages
μ	[kg/m]	Mass per unit length of the cable
EI	[kN.m^2]	Flexural rigidity of the cable
M	[kg]	Mass of bottom anchorage device
I_M	[kg.m^2]	Rotational inertia of M
k	[kN/m]	Transverse stiffness at bottom
K_0	[kN/m]	Rotational stiffness at bottom
K_1	[kN/m]	Rotational stiffness at top
x_1	[m]	Distance from bottom to first sensor
Δ	[m]	Distance between consecutive sensors

Thus, the identification procedure is the following:

1. Accurate on site measurements, several sensors
   - Natural frequencies f [Hz] → H, EI, M, I_M, k
   - Mode shape ratios → ℓ, x_1, K_0, K_1
2. Light remote measurements, one wireless sensor
   - Natural frequencies f [Hz] → $H(t)$



	Lixhe Bridge						Harchies Bridge				
	μ	ℓ	H	EI	ε^2		μ	ℓ	H	EI	ε^2
L1	75.6	51	3587	736	7.8E-5	H1	25.3	7.1	621	172	5.5E-3
L2	75.6	43	3712	1069	1.5E-4	H2	25.3	5.8	957	182	5.6E-3
L3	75.6	35	3829	1092	2.3E-4	H3	25.3	4.4	1088	180	8.5E-3

Identification procedure applied to hangers and stay-cables