Solutions dans le domaine X, gamme de produits etc.

LYRA

An autonomous bridge stays and hangers monitoring solution

Benefits

- Complete solution for cable-stayed bridges condition monitoring
- Wireless design: solar panel, wireless accelerometers, 4G connection
- Autonomous operation
- Advanced mathematical models suitable for long and short cables with supports stiffness integration

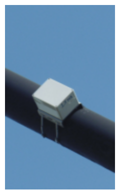
Context

Cable-stayed bridges are widespread all over the world and prone to failure if left unattended. The Lanaye bridge (Belgium) is monitored by the Walloon region once a year and has undergone a loss of tension of 21% in stay 1 between 2001 and 2020. This monitoring is sparse (about once a year), tedious (30 cables to instrument with long cables, etc..) and requires trained staff.

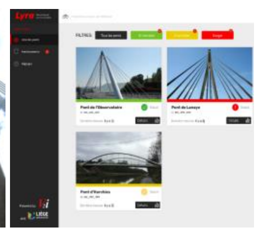
The LYRA has been developed by V2i, the University of Liège and the SPW (public service of Wallonia) to provide a monitoring solution that is more robust and more convenient to use for both spot measurements and long term monitoring. The performance of the system is demonstrated on the Lanaye bridge, whose 30 stays are instrumented since October 2021.

IT Solution

The Lyra consists of 3 main elements that work together to provide the tension in the instrumented cables :



1. Wireless sensors
   - Easy to install
   - 10 years battery life
   - Waterproof casing
   - Acceleration & temperature rec.
2. Wireless central station
   - Solar powered and 4G connection
   - KPIs computation from the acceleration measurements using advanced algorithms
   - The measured KPIs are stored and uploaded on a webserver
3. Web Application
   - Accessed from any device with internet
   - Displays relevant KPIs (e.g. tension variation with time)
   - Automatically sends alarms if KPI values reach used defined thresholds



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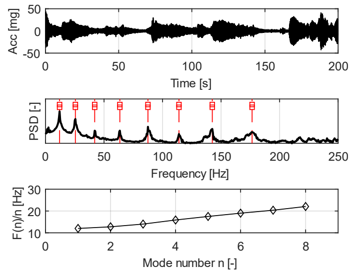
Reference case studies

- Wandre Bridge
- Pont de l'Observatoire, Liège
- Harchies Bridge

Mathematical model

Tension computed from the measured accelerations using an advanced algorithm:

1. Automatic natural frequencies identification
- Acceleration measurements from the wireless nodes
- Tailored pole selection algorithm using stochastic-subspace-identification (SSI) and the PSD of the response
- The resulting natural frequencies are fed to the cable model

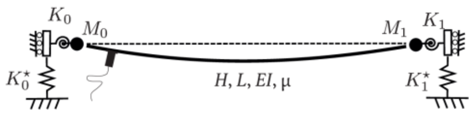


Frequency identification from stay 4 of the Harchies bridge

2. Cable model

Different solutions of the equations of motion are used depending on ε, the cable dimensionless bending stiffness, to link frequencies $F(n)$ and tension H :

- Taut string solution: theoretical solution, no bending effect (ε = 0)
- Asymptotic solution: direct link between the frequencies and the tension, and valid for small ε values.
- Semi-analytic solution: requires an optimization algorithm and valid for all ε values (stiff cables)



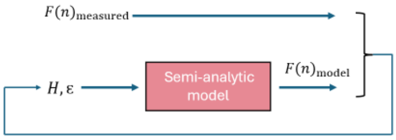
$$F(n) = \frac{n}{2}\sqrt{\frac{H}{\mu L^2}} \qquad \varepsilon = \sqrt{\frac{EI}{HL^2}}$$

L : Cable length
EI : Bending

Cable model and nomenclature

$$F(n) = \frac{1}{2}\sqrt{\frac{H}{\mu L^2}}\left(n + 2np\varepsilon + \left(\frac{\pi^2 n^2}{2} + 4p^2\right)\varepsilon^2\right) + ord(\varepsilon^3)$$

Asymptotic solution



Optimization algorithm: Find H & ε to minimize the difference

Results on 3 bridges

In real conditions, the LYRA automatically choose the computation method thanks to a decision tree based on the bending stiffness and tension variations. It is tested using the 3 solutions on the 3 case bridges:

- Semi-analytic : reference method that always works
- Asymptotic model: overestimation for stiff cables
- Taut string model:
    - slight overestimation for moderately stiff cables
    - completely off for stiff cables

Tension [kN]	Taut string (LSQ)	Taut string F(1)/1	Asymptotic	Semi-analytic
Long stay (Wandre)	4677	4684	4654	4657
Medium stay (Observatoire)	373 (+14%)	343 (+7%)	322	321
Short stay (Harchies)	1498 (+145%)	838 (+40%)	663 (+10%)	600

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Located in the Liege Science Park, V2i is a recognized Belgian player since 2004 and specialized in the development of turnkey monitoring systems and vibrations tests & measurements solutions. To fulfil its objectives, V2i has an experienced team of more than 15 persons and modern facilities. The company has been growing continuously since its foundation and is active in major sec tors of the industry (aeronautics, automotive, transport, civil engineering, etc).

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