Reliability of structures exposed to traffic loads and environmental loading

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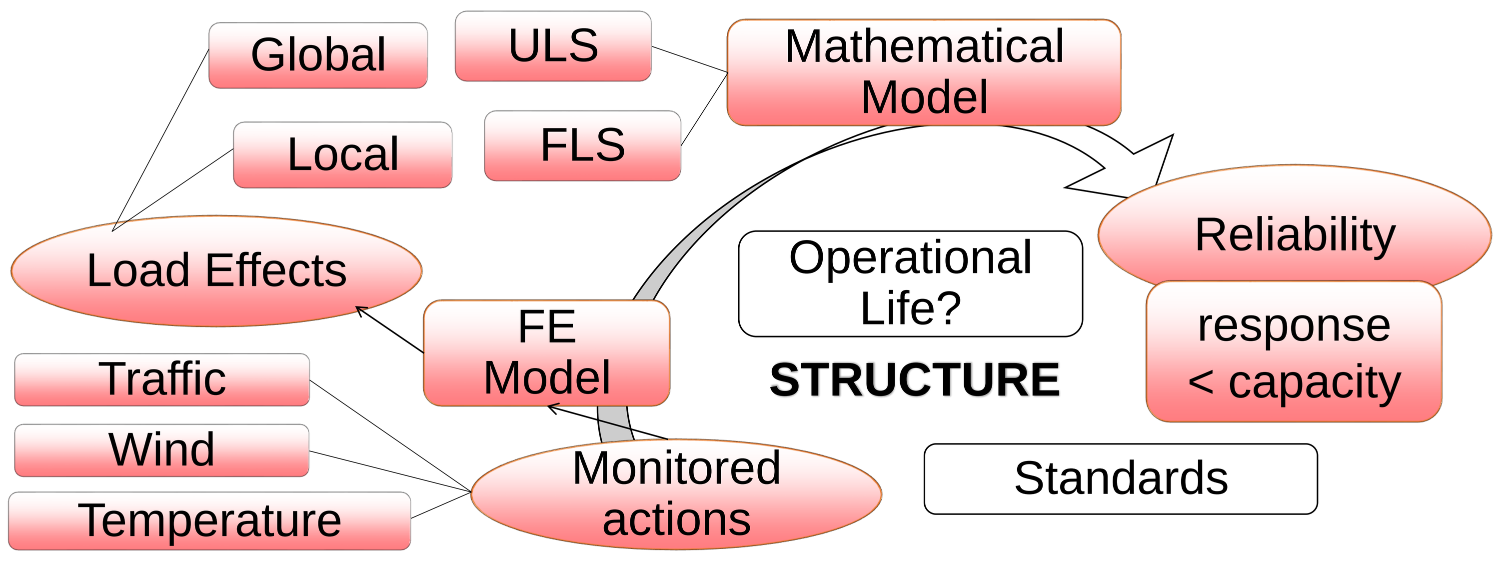
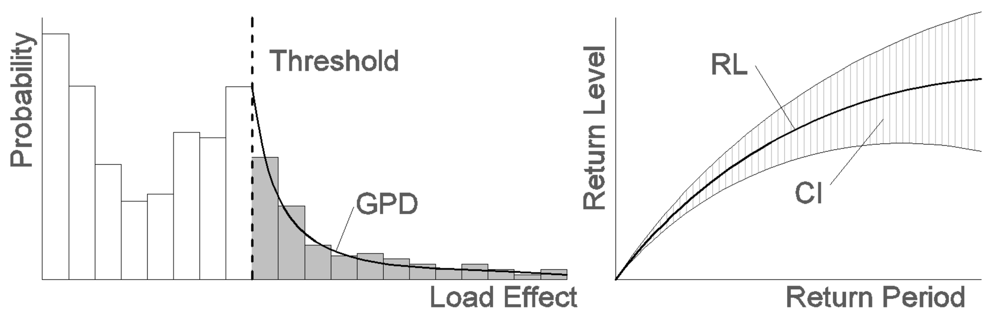
Extending the operational life of structures is an important topic in modern bridge engineering. In order to assess the reliability of objects and their elements at the end of the design life, updated models based on Extreme Value Theory (EVT) predictions and monitoring of actions are performed. The current study is focused on global and local load effects, caused by traffic and wind actions, in the deck of the Millau viaduct, a cable-stayed bridge in the South France.



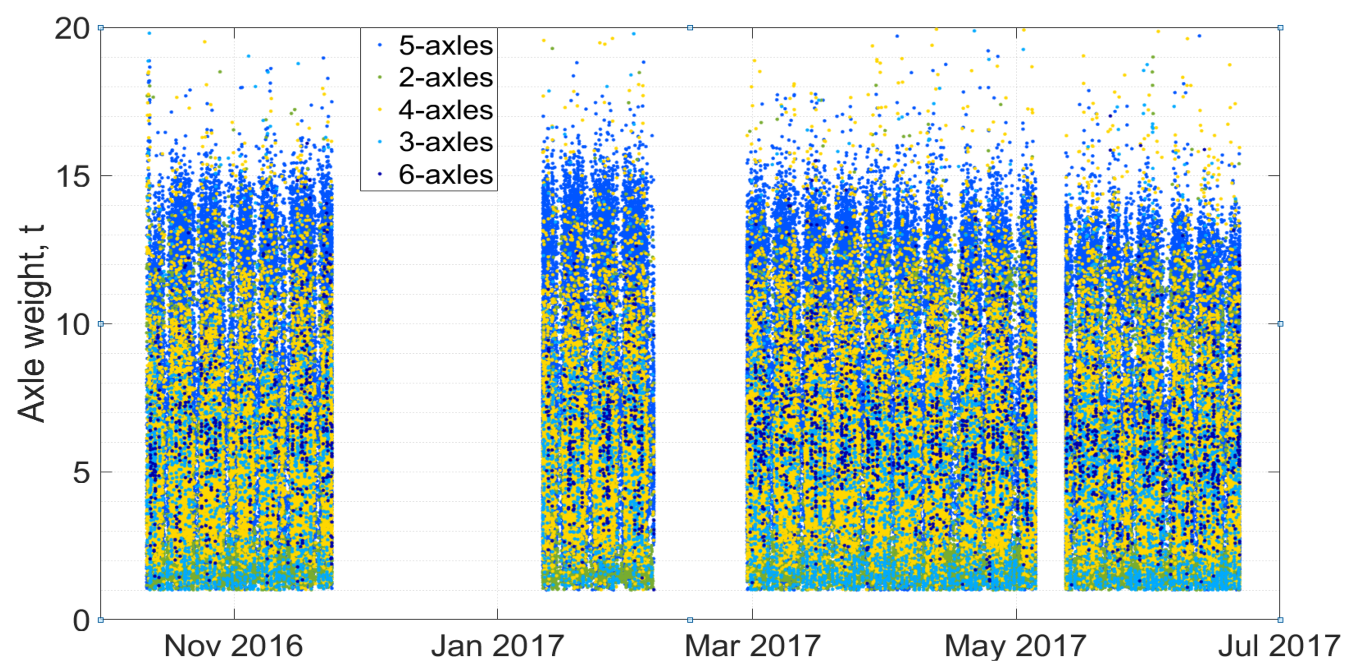
Mathematical modeling based on Extreme Values Theory and monitoring data

Monitoring of loads at any period of the operational life of a bridge allows updating the design **expected life** of the bridge →
Predicting of load effects using:
- EVT distributions parameters
- Limited time measurements of actions

Traffic - the most significant load:
Bridge Weigh In Motion (BWIM) system
→ various types of heavy trucks
→ periods of 43 and 176 days



POT approach: GPD fitting to assess RL with CI

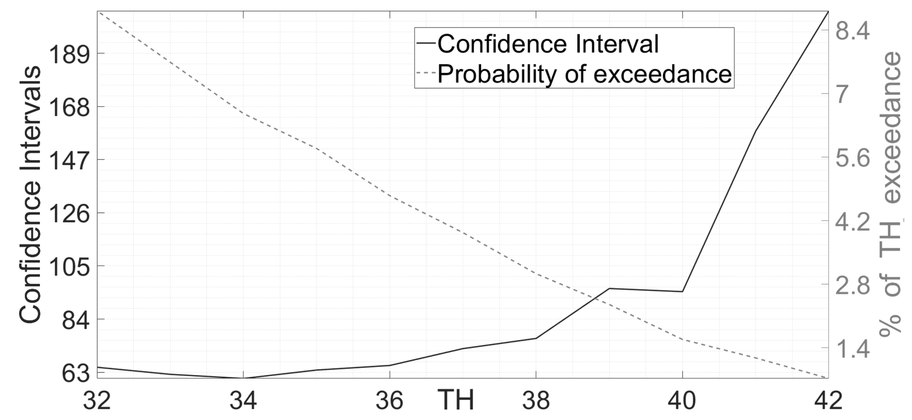


BWIM data recorded at the deck of the Millau viaduct

Return Levels (RL) of load effects in each studied case are assessed by fitting recorded data that cross a certain threshold to Generalized Pareto Distribution (GPD) as a principal of the Peaks Over Threshold (POT) approach of EVT. **Confidence Intervals** (CI) of RL are studied for different duration of monitoring.

Performed here algorithm is based on POT that is **mathematically simple**, Assumptions:
- stationarity of loading,
- independency of events,

Main drawback → threshold estimation.
One of interests of the current study is the updated method for a **threshold choice** based on values of CI and the probability of exceedance.



Updated Threshold choice, example

Extreme effects + Fatigue

To observe the influence of extreme events such as highly overweighed trucks on fatigue ($D=\Sigma\, d_i$) of critical details, the **statistical model** is made, that accounts for the location of the studied element (L), axle types of vehicles (V), the amplitude of the load (A), overall loading of the viaduct at the moment (G).

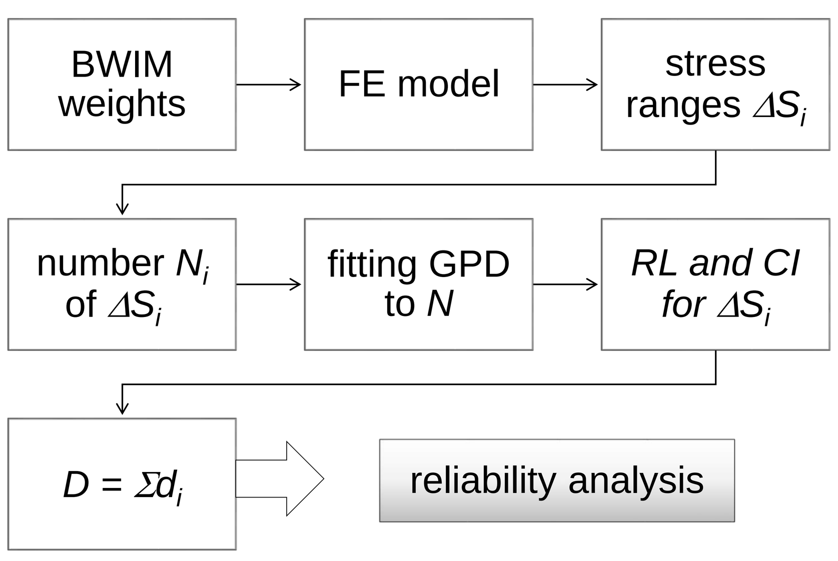
$$P_D(\mathrm{d}) = \int_A \int_V \int_G \int_L P_D(d|A,V,G,L) \times p(A,V,L,G)\, dA\, dV\, dL\, dG$$

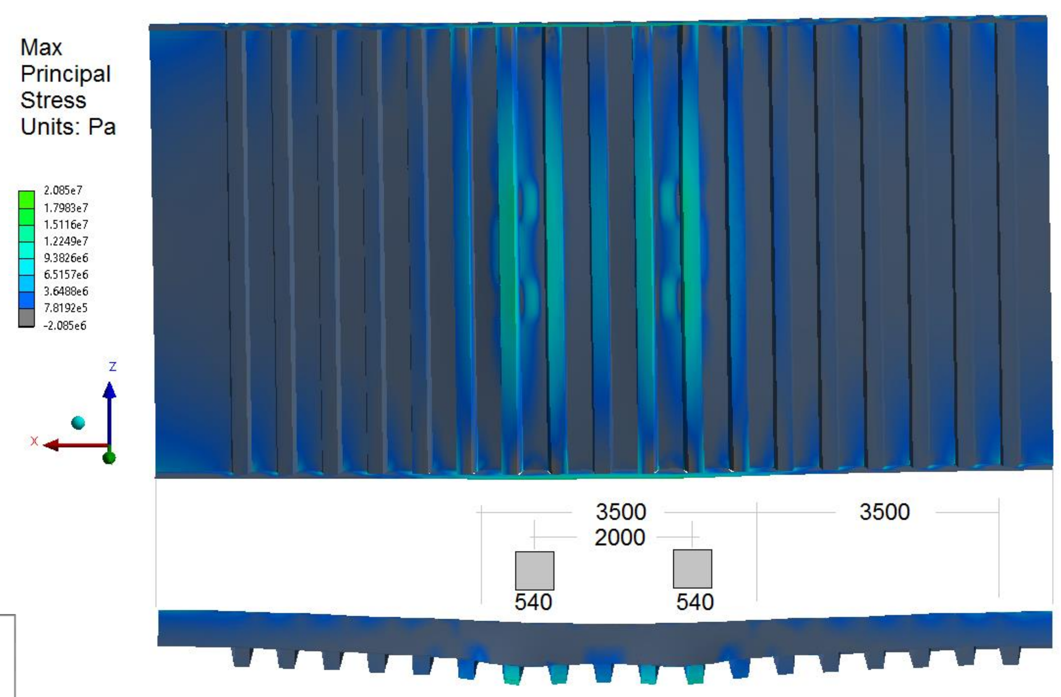
Actual stresses in welded joints between stiffeners and plates of the orthotropic deck:

local + global

FE model: stresses from trucks axle loads

Statistically: traffic composition on the deck



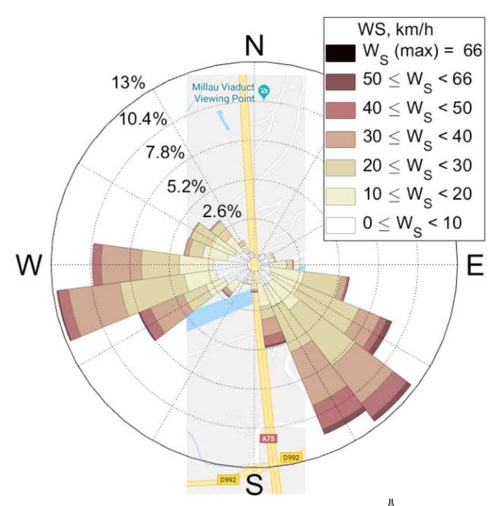


FE model of the 6-meters element of the deck

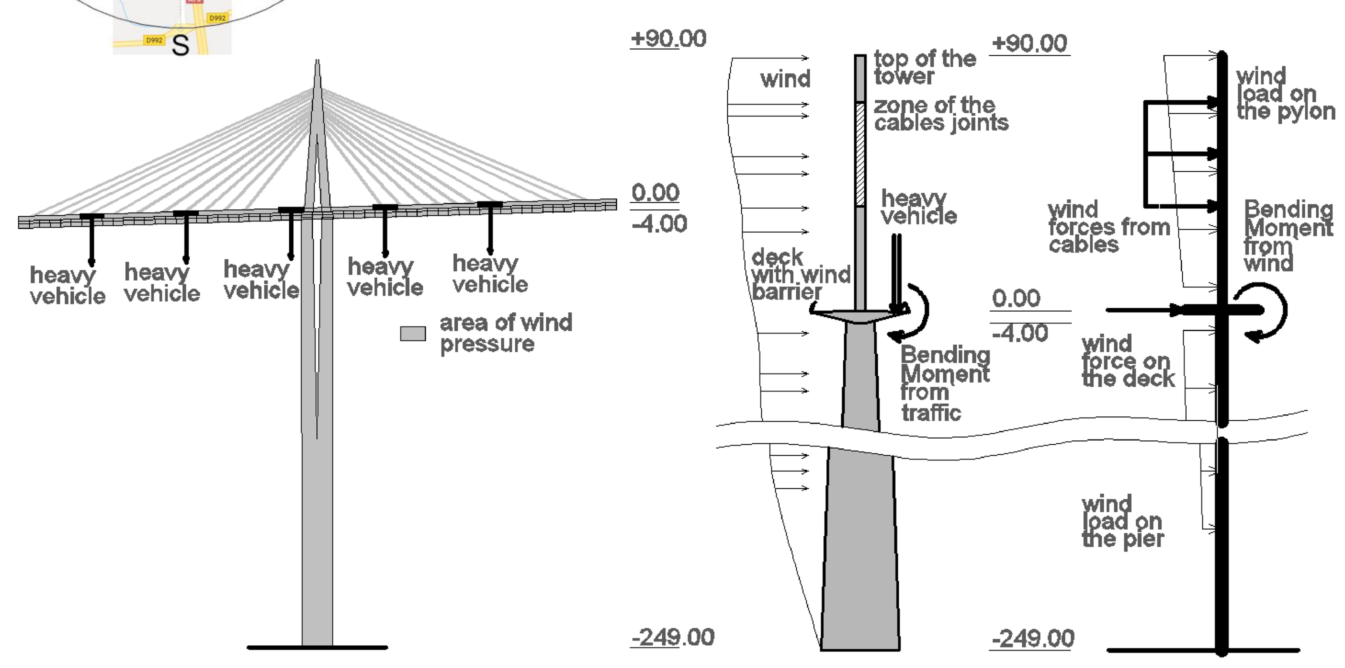
Prediction for fatigue using EVT:
- numbers of cycles, N
- high amplitudes cycles, A

→ GPD fitted to monitored load effects caused by traffic
→ RL with CI for N and A

Traffic + Wind



Monitoring of the **wind**:
- wind velocities in the most unfavorable direction
- the same period as BWIM data
- data recorded by the nearest weather station
- calibrated with the bridge management system



Combination of traffic and wind actions at the deck of Millau Viaduct

Probability of global Bending Moment (M)	Traffic only		Wind only		Combination	
	M, kNm	Pr(M)	M, kNm	Pr(M)	M, kNm	Pr(M)
Weekly max	8661	$8{,}3\times10^{-2}$	12715	$5{,}9\times10^{-3}$	21376	$4{,}8\times10^{-4}$
Return level, 120	12450	$9{,}5\times10^{-7}$	158470	$9{,}5\times10^{-7}$	183368	$9{,}1\times10^{-13}$
Queue of lorries	12099	$8{,}0\times10^{-2}$	30837	$3{,}5\times10^{-4}$	42936	$2{,}8\times10^{-5}$

Main objectives and achievements

- Influence of monitoring duration and the type of available data on the confidence of statistical predictions.
- Contribution of wind actions into the global behavior of a bridge and on return levels for global load effects.
- Combination of high amplitude cycles (extreme events) with the fatigue of deck details.

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