Extensive wind tunnel measurements to explore the conditional expected load method

Nicolas Blaise, Thomas Andrianne, Vincent Denoël

University of Liège (Belgium)

7th European-African Conference on Wind Engineering

EACWE 2017
4-7 July 2017, Liège

Context

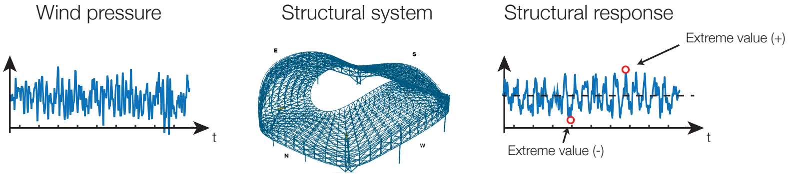
Le Nouveau Vélodrome Marseille

Stade de Lille Métropole

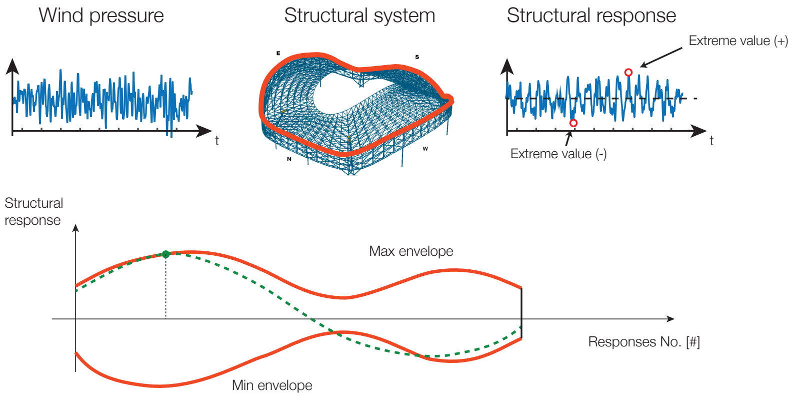
→ Equivalent Static Wind Loads?

`<complex structure, load combination, codification, simplicity>`

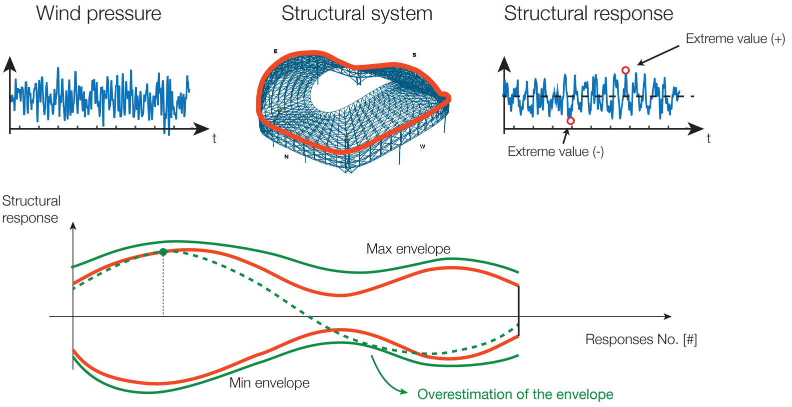
Equivalent Static Wind Loads



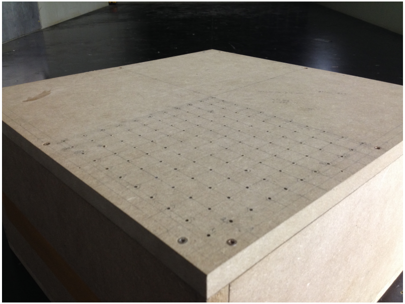
Equivalent Static Wind Loads



Equivalent Static Wind Loads



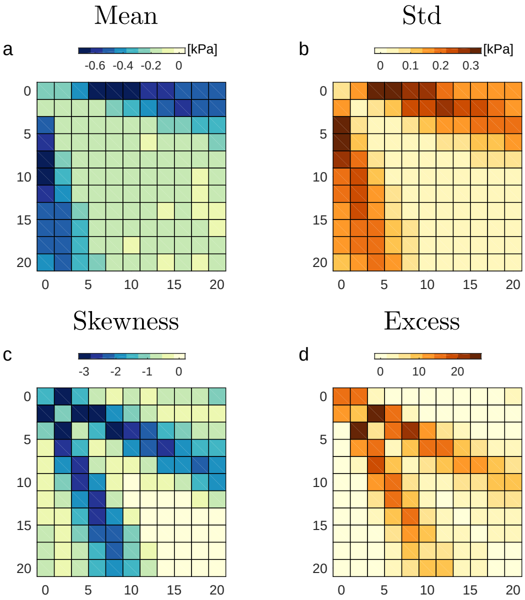
Academic Example



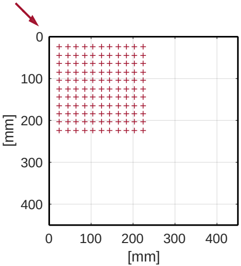
- ▷ Well-known wind pressure field
- ▷ Limitations of existing ESWLs
- ▷ Linear & static structural behaviour <simple enough>

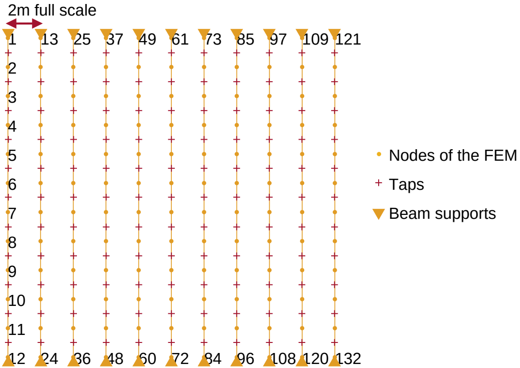
Non Gaussian pressure field !

Pressure Field

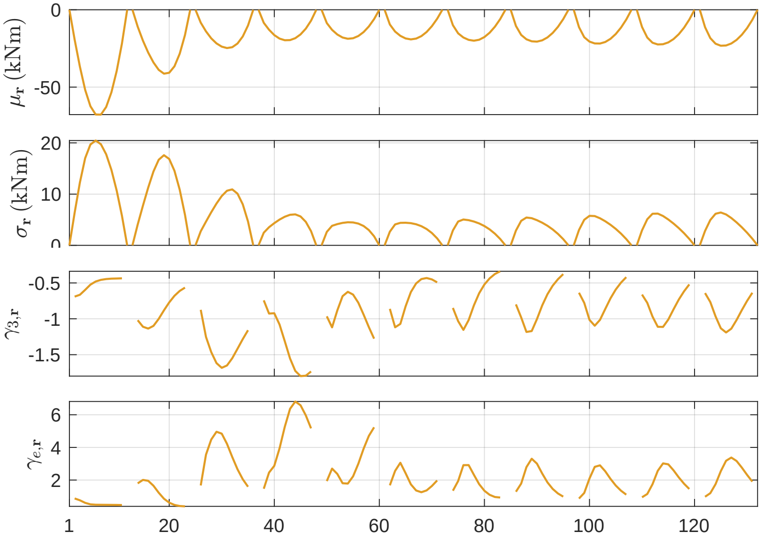


Structural System



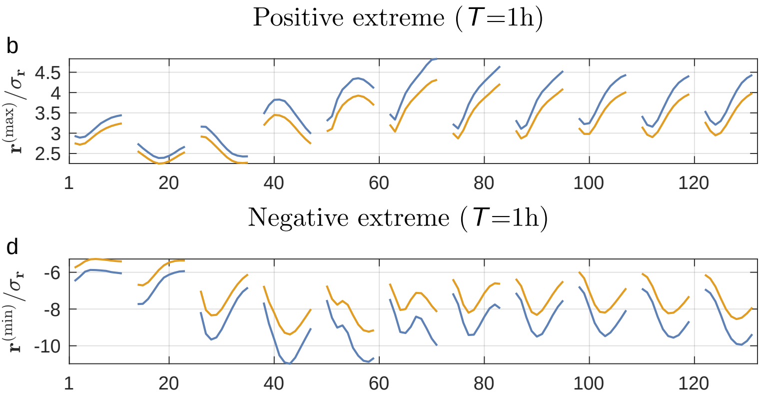


Structural System: Bending Moments



Non Gaussian structural responses!

Structural System: Bending Moments



Extreme values (Kareem-Zhao formula)

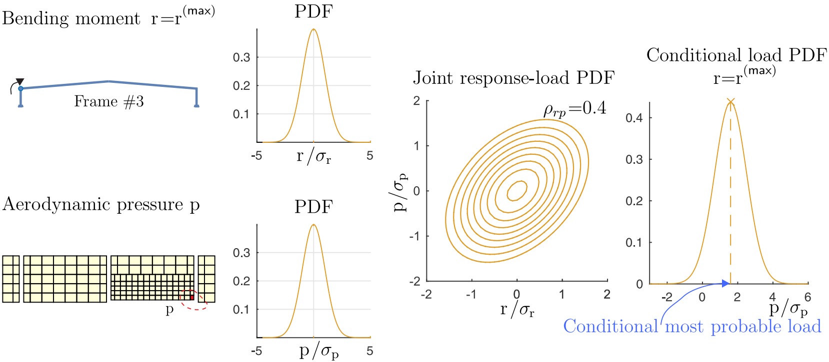
Mean extreme, 86% quantile for T =1hour

Equivalent Static Wind Load

▷ Load-Response Correlation (LRC) [Kasperski 1992]

$$p = g\boldsymbol{\rho}_{pr}\boldsymbol{\sigma}_p$$

Gaussian context: Most probable extreme load pattern



Equivalent Static Wind Load

▷ Load-Response Correlation (LRC) [Kasperski 1992]

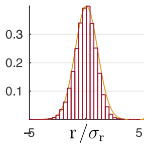
$$p = g\rho_{pr}\sigma_p$$

Non-Gaussian context: No interpretation

Bending moment $r = r^{(max)}$

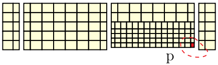
γ_3=-0.16, γ_e=0.36

PDF

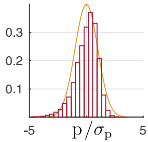


Aerodynamic pressure p

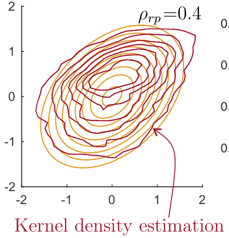
γ_3=-1, γ_e=2



PDF

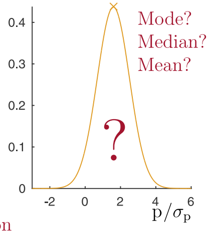


Joint response-load PDF



Conditional load PDF

$r = r^{(max)}$



Equivalent Static Wind Load

▷ Conditional expected static wind load [Blaise et al., 2016]

$$\mathrm{p} = \mathbb{E}\left[\mathrm{p}|\mathrm{r} = \mathrm{r}^{(\max)}\right] = \int_{\mathbb{R}} \mathrm{p}\,\psi_{\mathrm{p}|\mathrm{r}}\left(\mathrm{p}, \mathrm{r}^{(\max)}\right) \mathrm{dp}$$

Non-Gaussian context: conditional average of the pressures

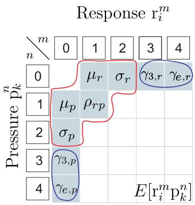
▷ Bicubic Model (7-parameter)

$$\mathrm{p} = g(u) = \frac{\alpha_u}{b_u}\left(\frac{u^3}{3} + a_u u^2 + (b_u - 1)u - a_u\right) \qquad \mathrm{r} = h(v) = \frac{\alpha_v}{b_v}\left(\frac{v^3}{3} + a_v v^2 + (b_v - 1)v - a_v\right)$$

α_u, b_u, a_u: Match σ_{p}, $\gamma_{3,\mathrm{p}}$ and $\gamma_{e,\mathrm{p}}$

α_v, b_v, a_v: Match σ_{r}, $\gamma_{3,\mathrm{r}}$ and $\gamma_{e,\mathrm{r}}$

ρ_{uv}: Match correlation coefficient ρ_{rp}

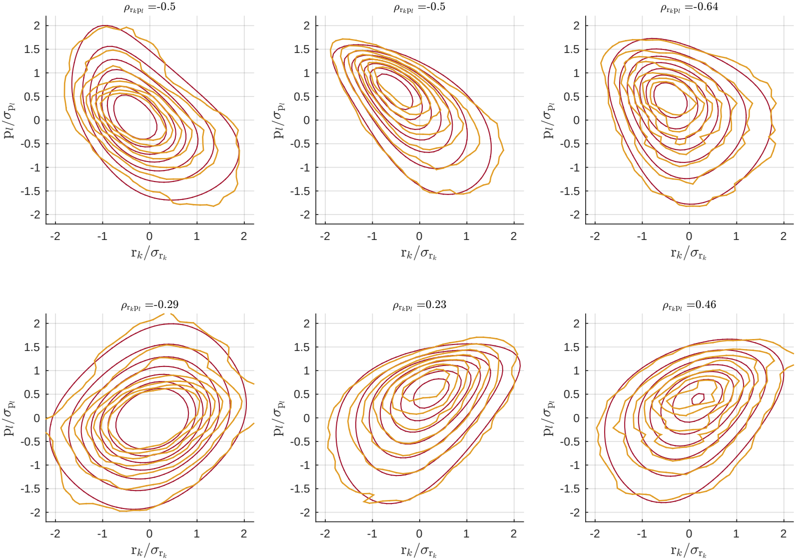


Gaussian assumption

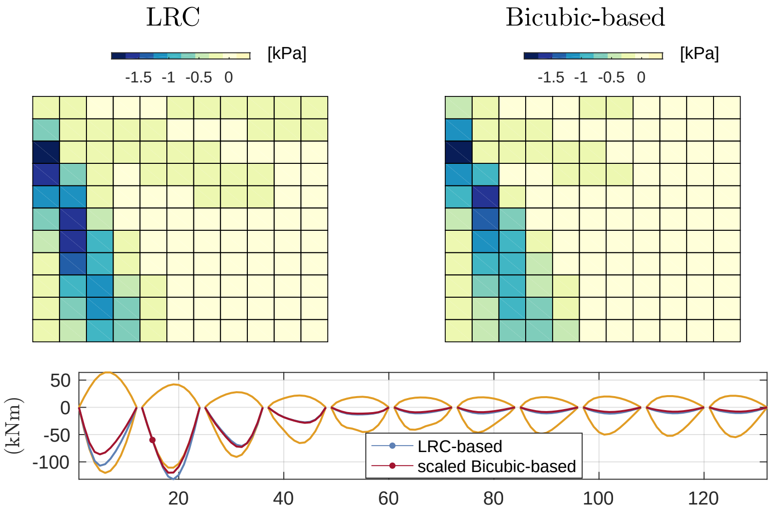
Bicubic Model

Equivalent Static Wind Load

▷ Bicubic Model (7-parameter)



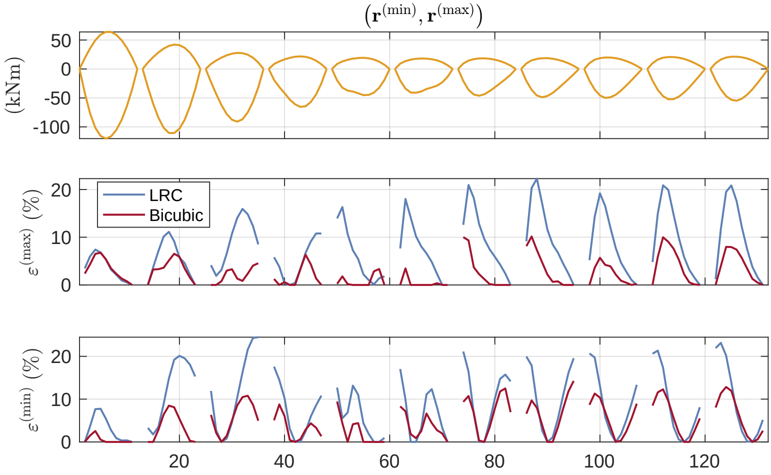
Equivalent Static Wind Load: Comparison



- LRC: Severe 20% over-estimation of the envelope
- Bicubic-based ESWL: Slight 5% over-estimation of the envelope

Envelope Reconstruction

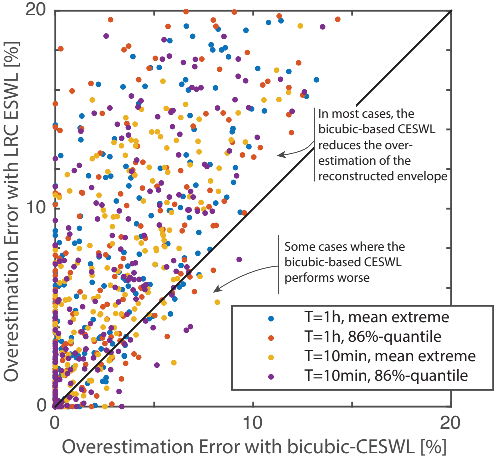
▷ Reconstruction of the 86%-quantiles extremes envelope for a reference period of 1 hour.



Overestimations up to 25% with the LRC method and up to 15% for the bicubic model

Envelope Reconstruction

▷ General comparison between LRC ESWL and Bicubic-based ESWL



bicubic-based CESWLs generally perform better, but not always.

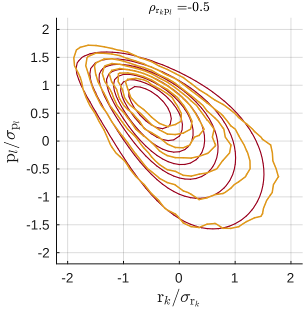
Perspectives & Conclusions

Proposition of a Non-Gaussian version of the LRC

▷ bi-cubic model

▷ regularly extends the LRC for non Gaussian pressure field/responses

▷ 7 degrees-of-freedom: fairly good match the non Gaussian joint PDF



Thank you ...

Vincent Denoël, Université de Liège
Structural & Stochastic Dynamics
`www.ssd.ulg.ac.be`

Read more about this topic:

- Blaise N., Andrianne T., Denoël V. (2017) *Assessment of extreme value overestimations with equivalent static wind loads.* Journal of Wind Engineering and Industrial Aerodynamics 168, 123-133.
- Blaise N., Canor T., Denoël V. (2016). *Reconstruction of the envelope of non-Gaussian structural responses with principal static wind loads*. Journal of Wind Engineering and Industrial Aerodynamics 149, 59-76.
- Blaise N., Denoël V. (2013). *Principal static wind loads*. Journal of Wind Engineering and Industrial Aerodynamics 113, 29-39.
- Kasperski M., (1992). *Extreme wind load distributions for linear and nonlinear design*. Engineering Structures 14, 27-34
- Holmes J.D., (1988). *Distribution of peak wind loads on a low-rise building.* Journal Of Wind Engineering and Industrial Aerodynamics 29, 59-67

Available @ `www.orbi.ulg.ac.be`