Coastal Highway E39
Teknologidagene 2018 – Trondheim

New generation of long-span suspension bridges

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New generation of long-span suspension bridges

Our involvement with Coastal Highway Route E39 so far

- Wind field descriptions
- Wind tunnel testing
- Wind load calculations
- Full-scale measurements
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Spans above 2000 m challenge the existing technologies and methods

Q: How to design a long-span suspension bridge with “optimal” aerodynamic behavior?

A: Develop new technology to improve the understanding of wind loads and responses.
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Development of new technology

From wind climate to design criteria

- Terrain: Wind at low height
- Mechanical response: Wind pressure to structural response
- Wind climate: Global wind
- Aerodynamic response: Wind flow to pressure
- Design criteria
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Development of new technology

From wind climate to design criteria

Wind field description

- Terrain: Wind at low height
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Experimental methods
Calculation format
Development of new technology - Wind field descriptions

Basic models and parameters in the description of the wind field

• For calculating wind loads

New possibilities to measure and model wind

• Ultrasonic anemometers, LIDAR, SIMRA, ...

Probabilistic wind data format

• Physical understanding → Probabilistic models
• Probabilistic quantification of response*

*See paper from COTech 2017
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Development of new technology - Wind tunnel testing

Understand the wind loading mechanisms and magnitudes
• Section model tests: Spring-supported, forced-motion rig

Along-span characteristics are important
• Pressure taps: Along-span load correlation

Effect of additional elements
• Railing, windshields, traffic barriers, etc.

For other E39 bridge concepts
• Submerged floating tube bridge – Hydrodynamics, VIV*  
• Floating bridge – Wave-induced vertical wind components

*See paper from Experimental Fluid Mechanics 2015
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Development of new technology – Calculation methodologies

The prediction of flutter

- Basic theory is derived from flat-plate considerations
- Aerodynamic derivatives (Reformulation?)

Buffeting loads

- Aerodynamic admittance*

Multi-segment flat-plate theory**

- Flat-plate representation of split-box girder

\[ \Lambda = \frac{1}{2\pi} \begin{pmatrix} \frac{1}{x_{C_1}^2 \Gamma_1} & \ldots & \frac{1}{x_{C_N}^2 \Gamma_N} & V_w(K(\ddot{x}_{C_1} - \ddot{x}_w)) \\ \vdots & \ddots & \vdots & \vdots \\ \frac{1}{x_{C_1}^2 \Gamma_1} & \ldots & \frac{1}{x_{C_N}^2 \Gamma_N} & V_w(K(\ddot{x}_{C_N} - \ddot{x}_w)) \end{pmatrix} \]

\[ \Gamma = \begin{pmatrix} \tilde{\Gamma}_1 \\ \vdots \\ \tilde{\Gamma}_N \\ \tilde{\gamma}_0 \end{pmatrix}, \quad \mathbf{v} = \begin{pmatrix} \dot{y} - K^{-1} \alpha - \ddot{x}_{C_1} \dot{\alpha} \\ \vdots \\ \dot{y} - K^{-1} \alpha - \ddot{x}_{C_N} \dot{\alpha} \\ 0 - \ddot{x}_w \dot{\alpha} \end{pmatrix} \]

*See paper from Bluff Body Aerodynamics and Applications 2016
**Submitted to "Journal of Wind Engineering and Industrial Aerodynamics"

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Svend Ole Hansen ApS
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Development of new technology – Full-scale measurements

Further understand and verify the generation of wind loads and responses

• Undisturbed wind
• Wind-induced surface pressure
• Structural response

See paper from AAWE Workshop, August 2018
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Technology is a key factor for the new generation of long-span suspension bridges

Development in all parts of the wind load chain
  • Wind field
  • Calculation methods
  • Experimental methods

For the design of girder cross section

Norway leads the field in the technological development for suspension bridges
  • Perspective: In 20-40 years - Top 3 of world’s longest spans in Norway?

Halsafjorden crossing concept (Kristian Berntsen, SVV)
Thank you for your attention