Footbridge vibrations due to pedestrian load.

Danish guidelines and examples

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Overview

- New tendencies for footbridges
- Dynamic load from pedestrians
- Footbridge in resonance
- Danish guidelines* on footbridge comfort
- Examples of footbridges in Denmark

* Danish Road Directorate, nov. 2002:
Road and footbridges, Rules for loads and calculations

New tendencies for footbridges

International tendency for new footbridges :

- longer span
- new lightweight and stronger materials
- innovative structures

Results often in

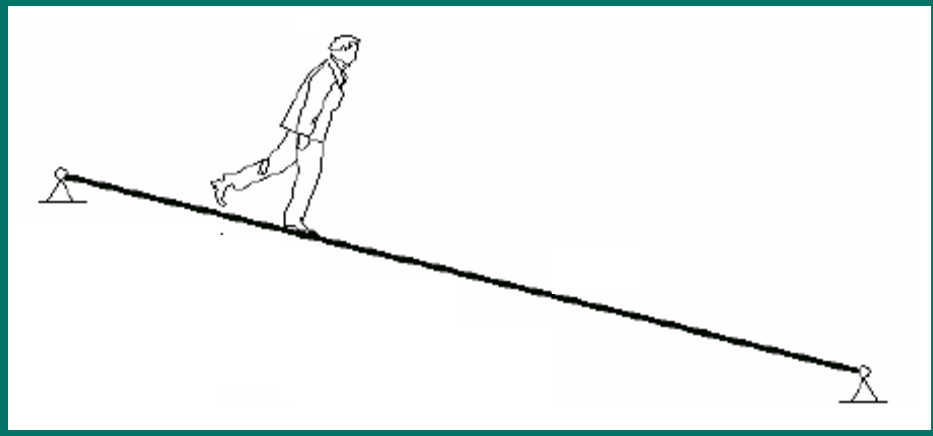
- lightweight footbridges with
- low damping and
- low natural frequencies

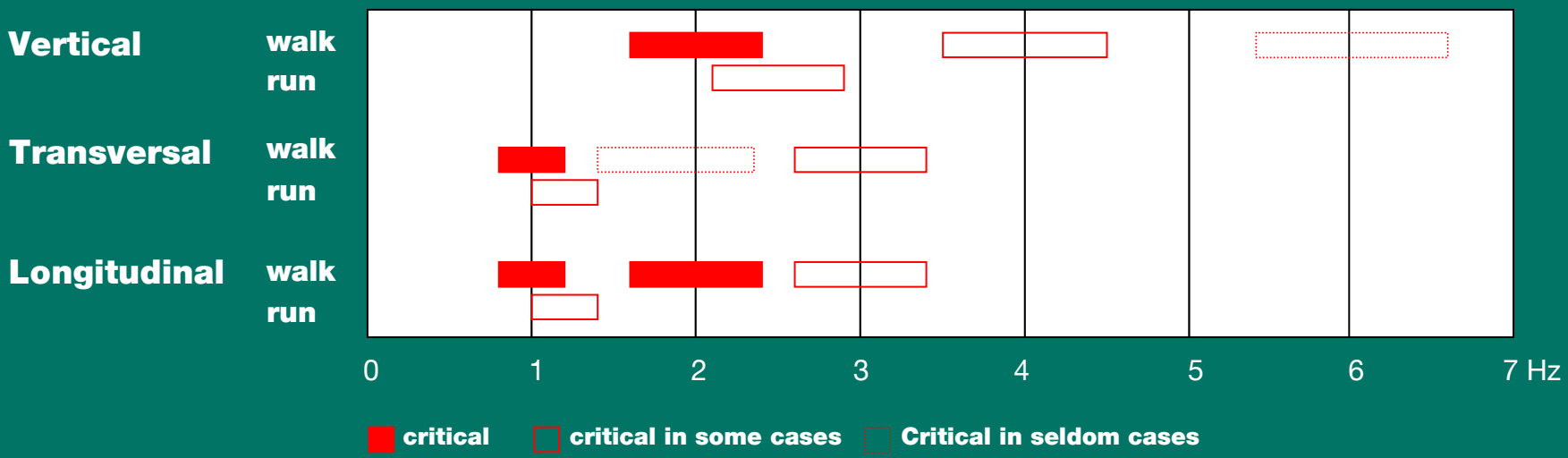
This often leads to larger vibrations

Dynamic load from pedestrians

	Step frequency
Slow walk	~ 1.7 Hz
Normal walk	~ 2.0 Hz
Fast walk	~ 2.3 Hz
Slow run (Jogging)	~ 2.5 Hz
Fast run (Sprint)	> 3.2 Hz

Footbridge resonance from pedestrians





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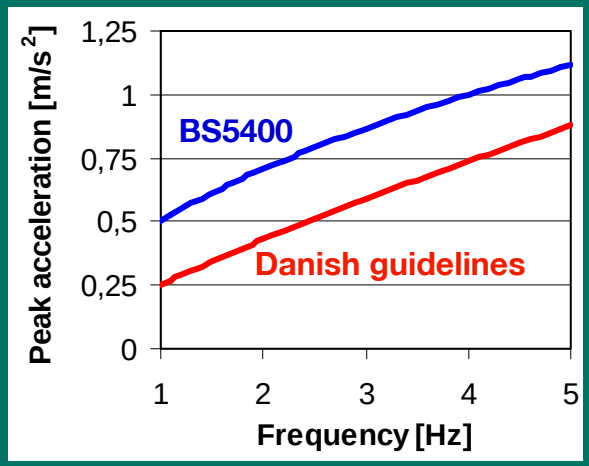
Danish guidelines: Comfort accept criteria



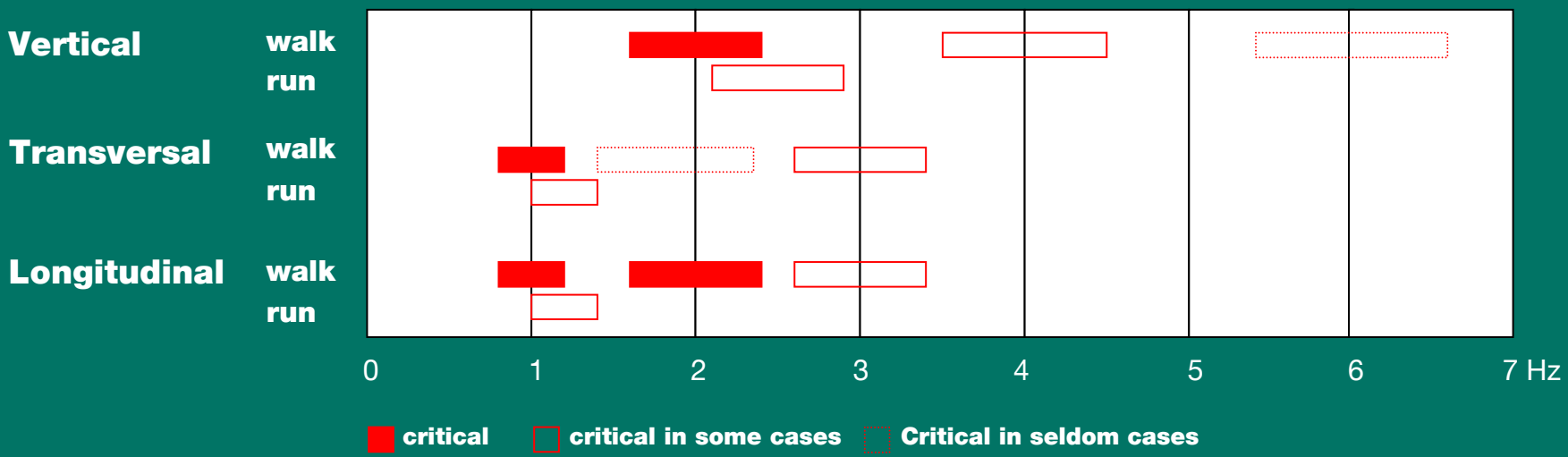
$f_0 < 5$ Hz

$f_0 > 5$ Hz

Comfort criteria:

$\ddot{U}_{peak} < 0{,}25\ f_0^{0{,}78}$ m/s²

Comfort fulfilled



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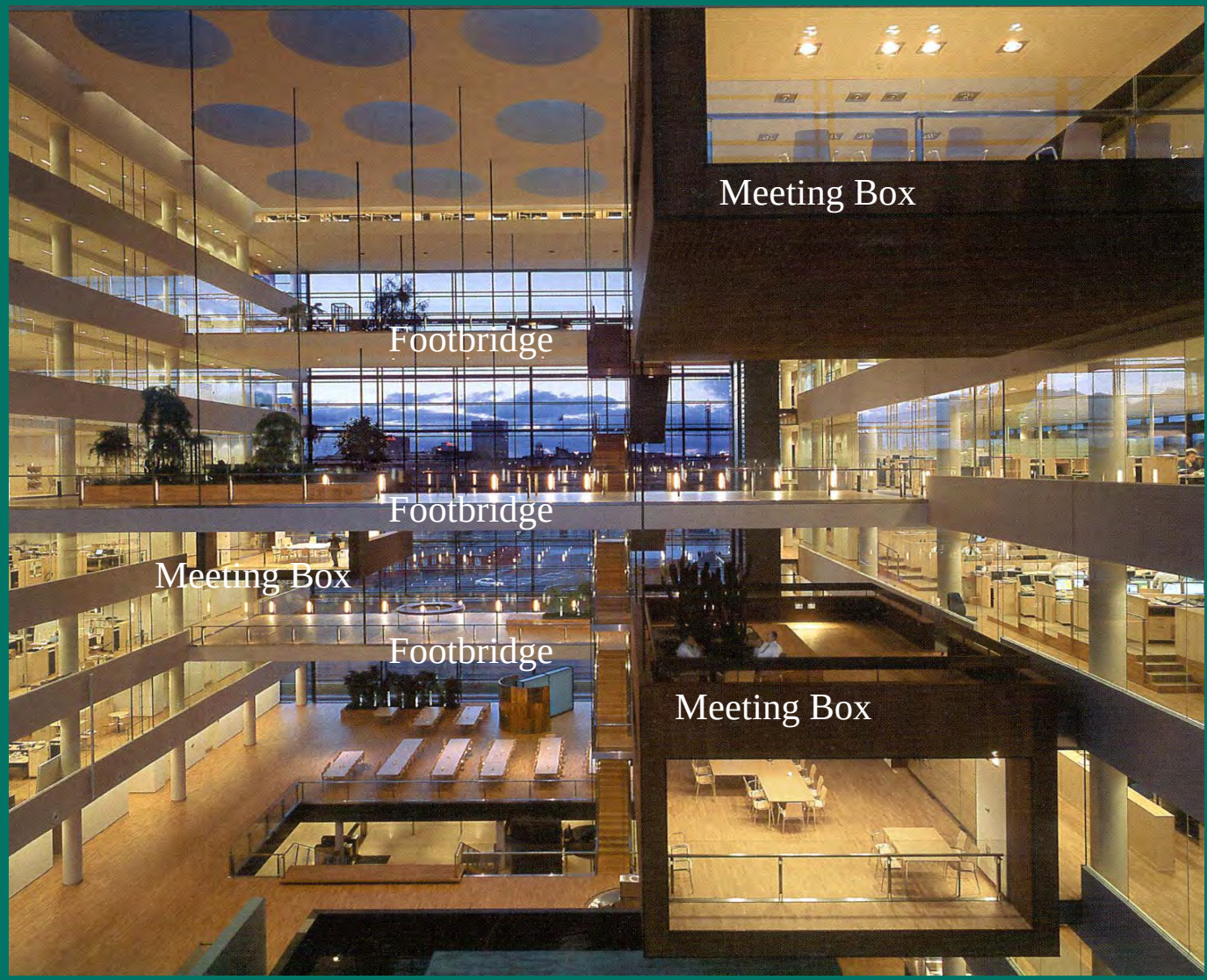
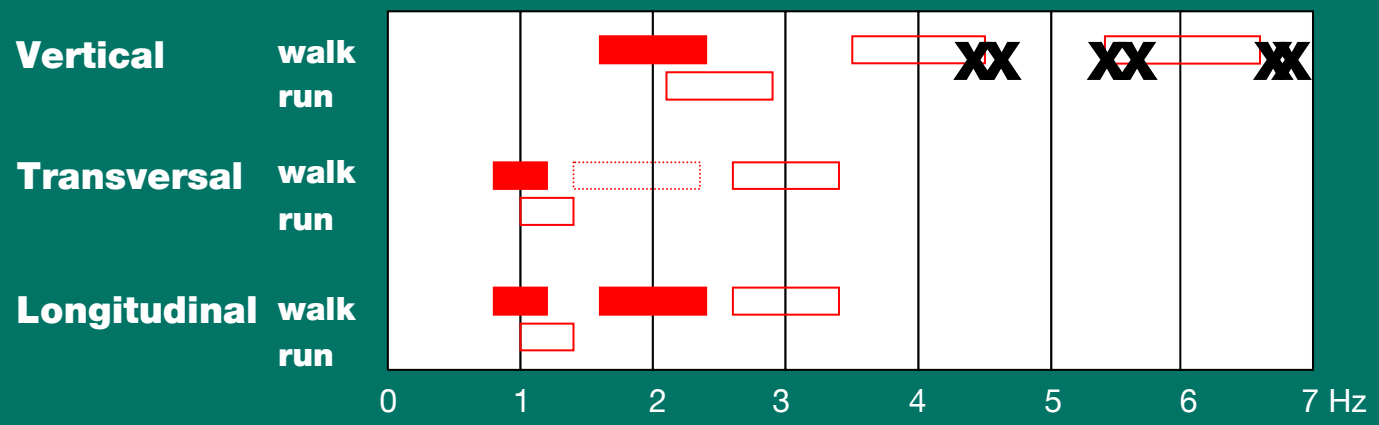
Exampel: Nykredit Atrium



Example: Nykredit Atrium



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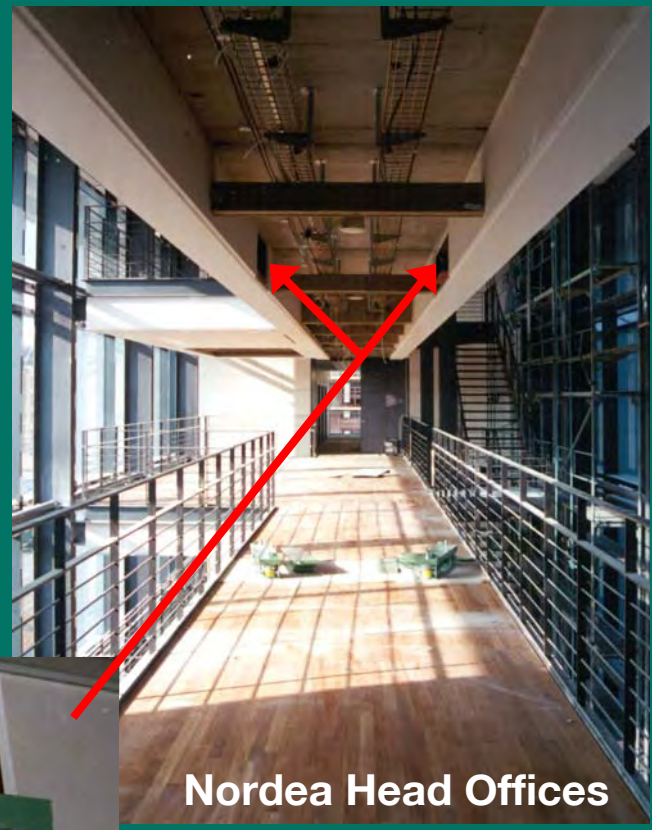
Dampning

	ζ (rel. to critical)
Steel	0.4 %
Composite steel-concrete	0.6 %
Reinforced concrete	0.8 %
Wood	1.5 %

(recommended by the Danish guidelines)

- Added internal damping (up to ca. 2%)
- Tuned Mass Dampers (up to ca. 10%)
- Viscous and friction dampers (above 10%)

Examples of Tuned Mass Dampers



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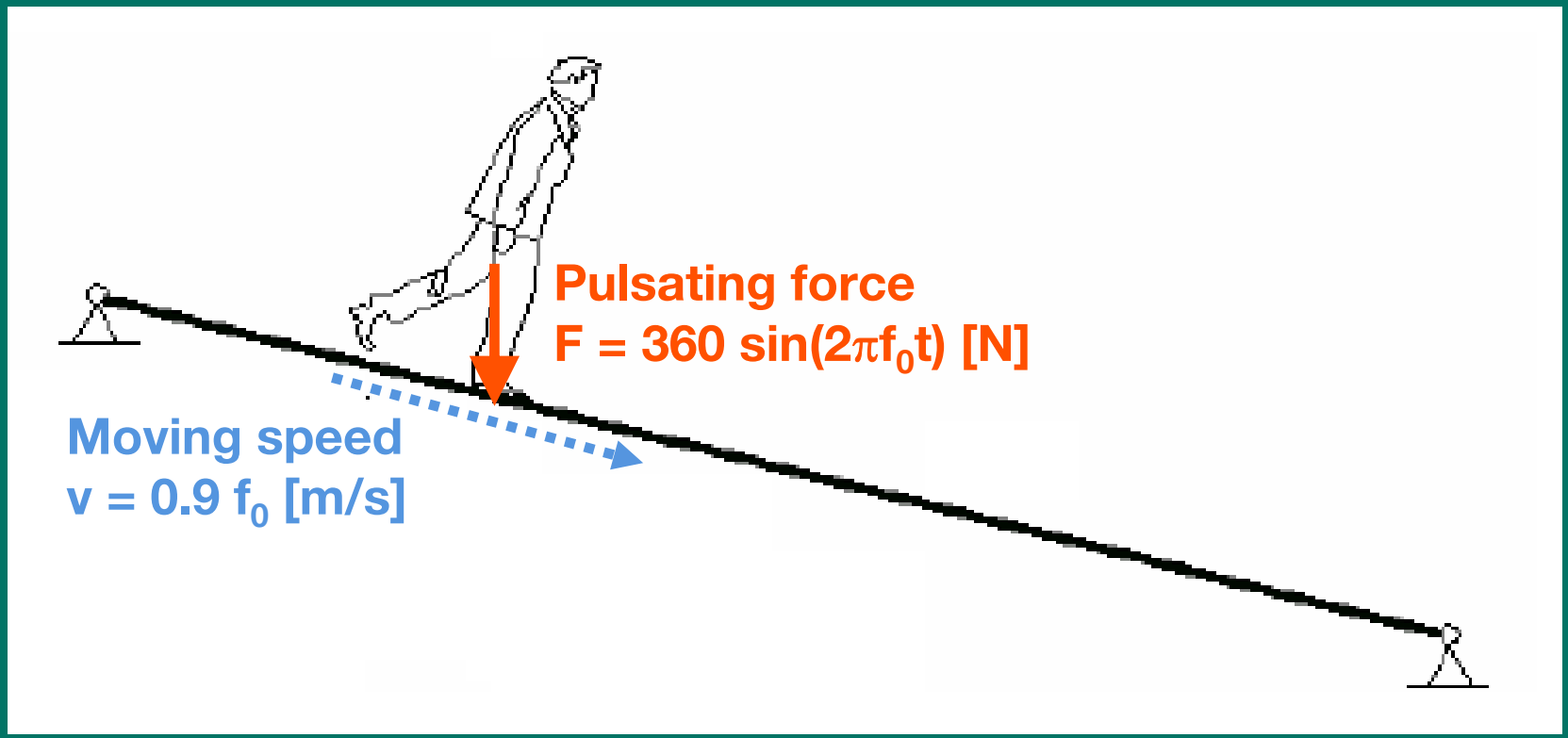
Danish guidelines: Recommended design load

Maximal vertical vibration is calculated for load case:



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Example: New Langelinie footbridge

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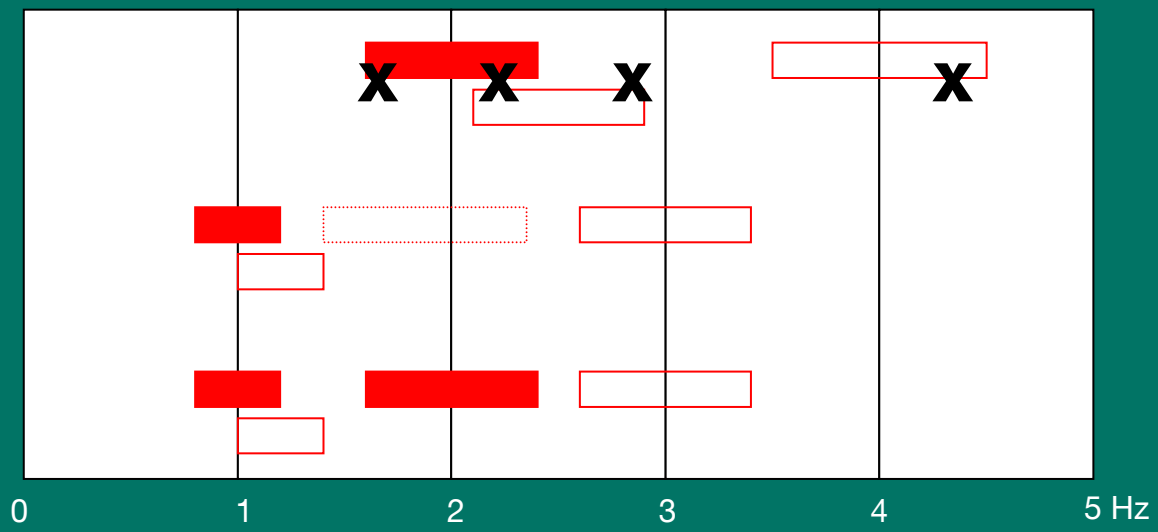

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TMD design procedure

Bridge design phase:

- Preliminary TMD-design
- Structural design incl. space and installation requirements for TMD

End of bridge construction:

- Vibration measurements
  - natural frequencies
  - structural damping
  - vibration level for critical loads
- Final TMD-design, production, testing and installation
- Tuning and design verification measurements

Example: Nokia footbridge

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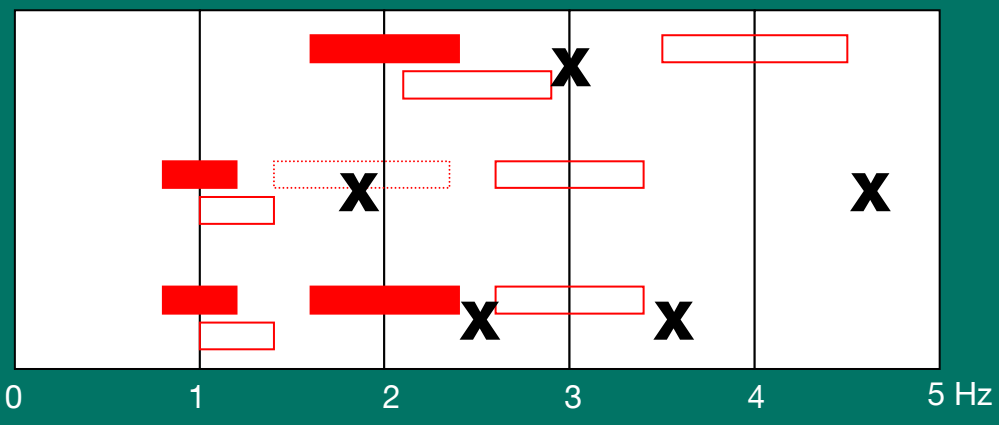

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Conclusion

International footbridges:

- Innovative design
- long-span
- lightweight

lead to published research and experience within

- pedestrian dynamic loading
- structural behavior
- vibration damping and control

~~So far: Vibration damping used as problem solver~~

Vibration damping should be:

A design tool for more daring footbridges!