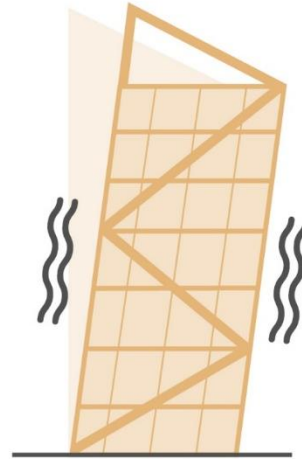


DynaTTB

Dynamic Response of Tall Timber
Buildings under Service Load



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March 2019 – October 2022

NTNU

Moelven

SWECO

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EXETER

smithandwallwork
engineers

EIFFAGE

CSTB
le futur en construction

GALFO

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RISE

Linnæus University

Univerza v Ljubljani



arbonis

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Mjöstornet, March 2019

Taller and taller buildings



1996
5 storeys
Stud and rail
Välludden,
Växjö



2009
8 storeys
CLT
Portvakten,
Växjö



2012
10 storeys
CLT
Forte,
Melbourne



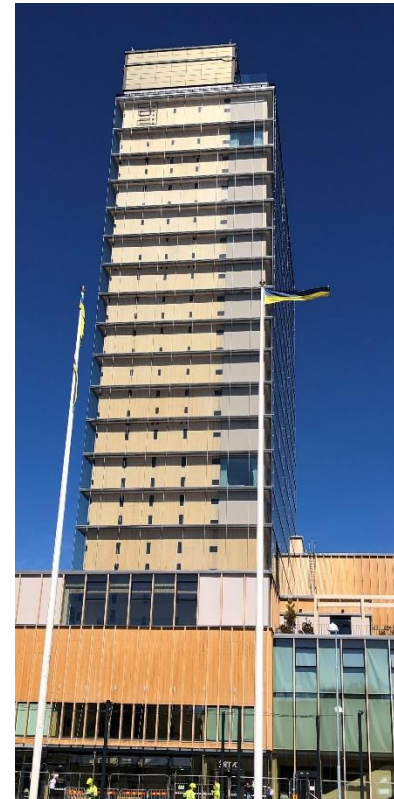
2015
14 storeys
Glulam trusses
TREET,
Bergen



2019
18 storeys
Glulam trusses
Mjöstornet,
Brummundal

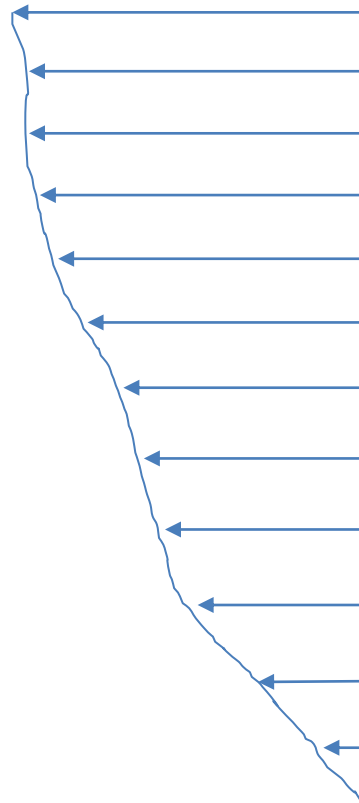
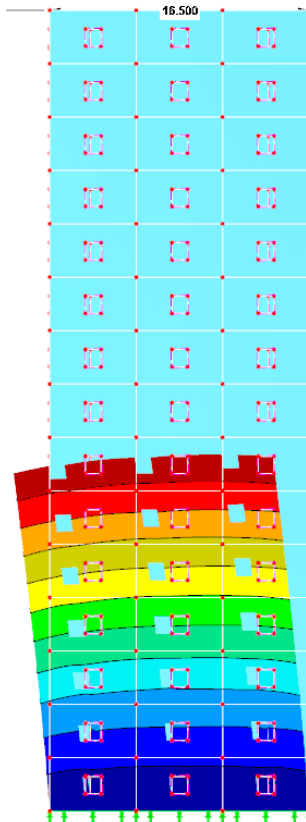


2020
18 storeys
Hybrid
Hyperion,
Bordeaux



2021
19 storeys
CLT
Sara Culture centre,
Skellefteå

For Tall buildings (+12-14 storeys) the top acceleration will decide the structural design

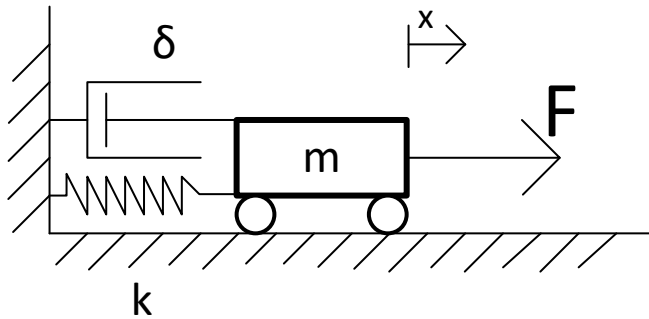


Uncomfortable

Motion sickness
(0.1-0.5 Hz)

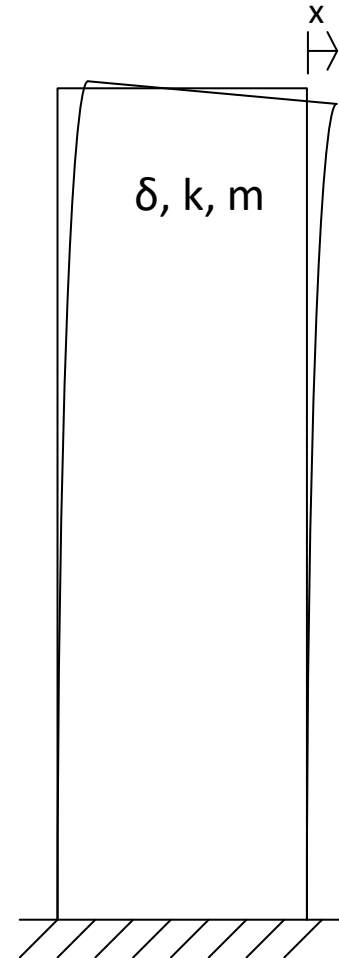
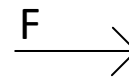
Fear

Governing factors - dynamics



Movement due to load

- Mass
- Stiffness
- Damping



Comfort
Serviceability limit state
Low load levels

Mass – relatively well know

Stiffness – designed but
when built still?

Damping – unknown,
lacking data

Example buildings



Tromsø, 10 stories, CLT elements



Yoker, 7 storeys, CLT



Trinity College building, 4 stories, CLT elements



Treed-IT, 12 storeys,



Hyperion, 18 storeys, hybrid + CLT



Eken, 6 storeys, Glulam



Karantanika, 4 storeys, CLT



Mjøstårnet, 18 storeys, Glulam

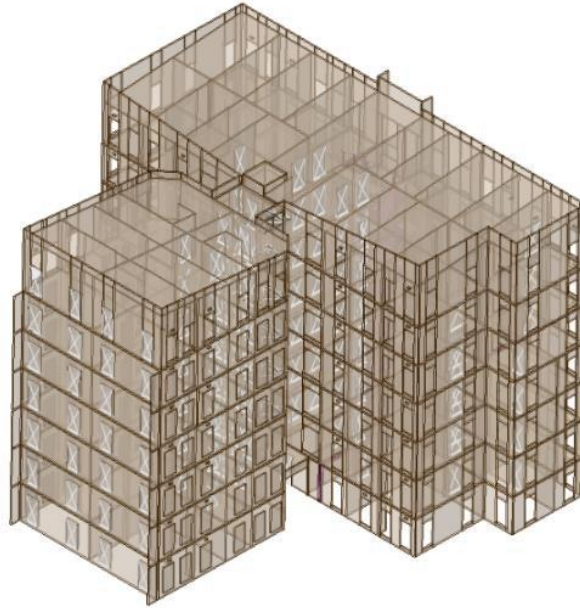


InnoRenew, 4 stories, CLT elements

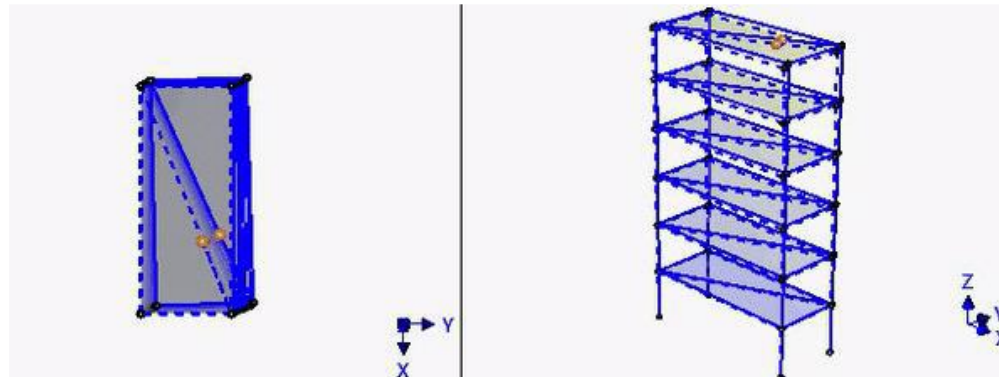


MEASUREMENTS

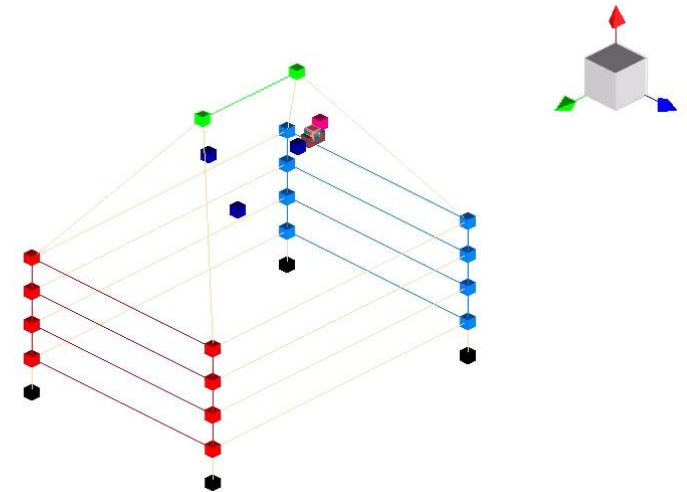
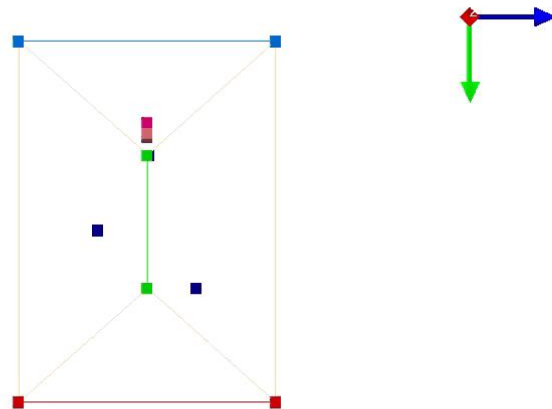
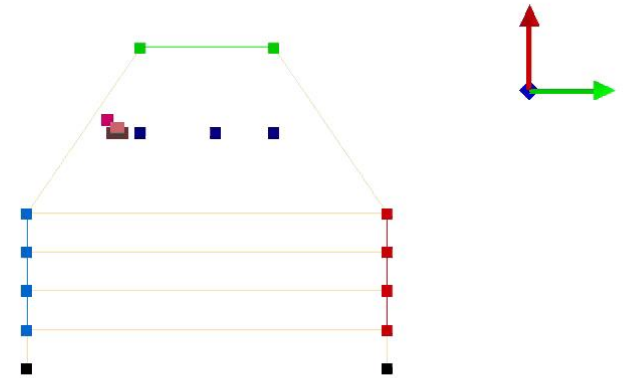
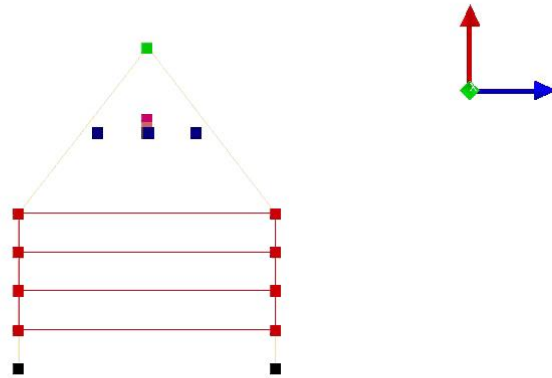
Yoker



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Eken



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Treed-It

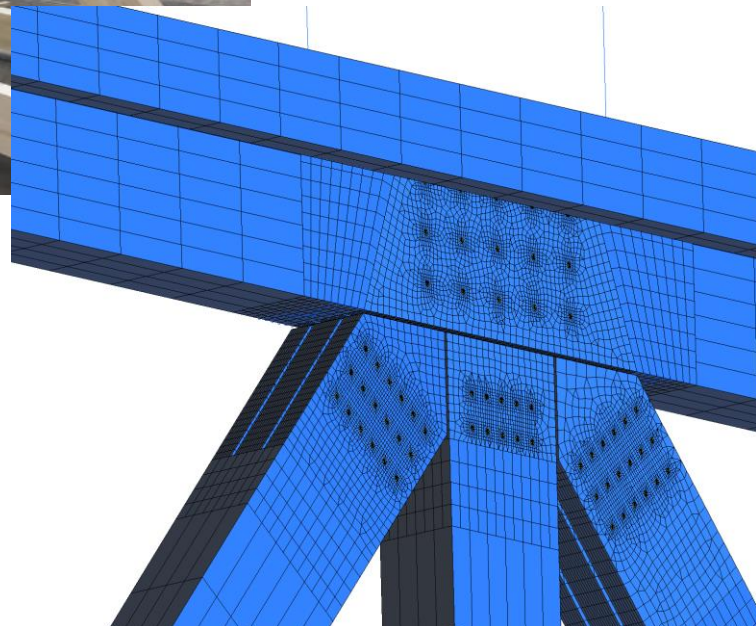
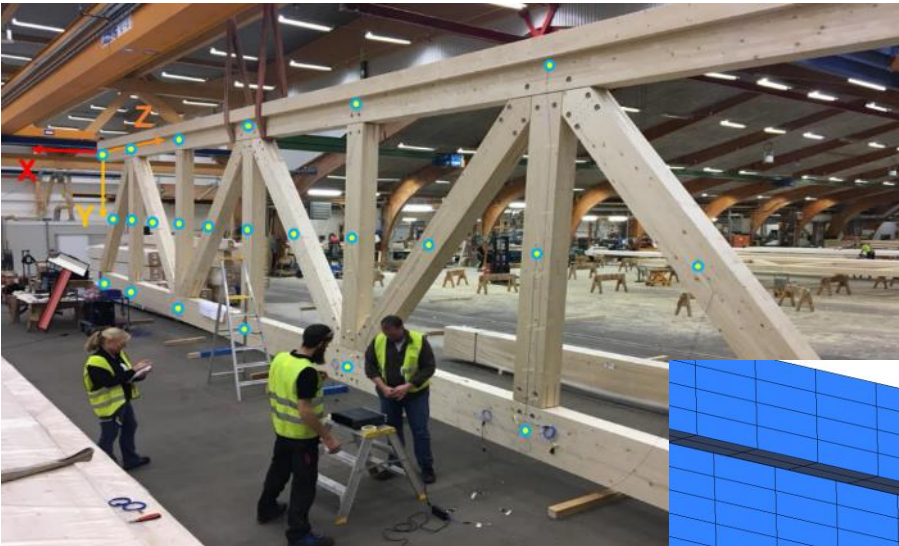


	Mode 1 – bending X [Hz]	Mode 2 – bending Y [Hz]	Mode 3 – torsion [Hz]
1st experiment	1.37	1.54	1.69
2nd experiment	1.39	1.49	1.62



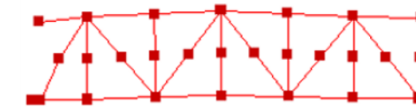
MODELLING

Details and assemblies



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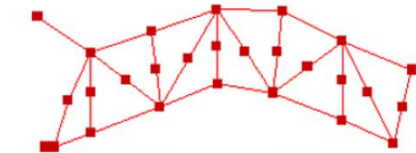
Experimental results



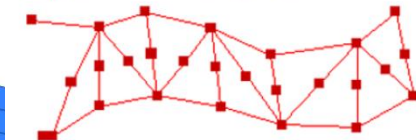
Exp. 1: 8.97 Hz and $\zeta_1 = 1.7 \%$



Exp. 2: 25.25 Hz and $\zeta_2 = 0.9 \%$



Exp. 3: 42.65 Hz and $\zeta_3 = 1.0 \%$

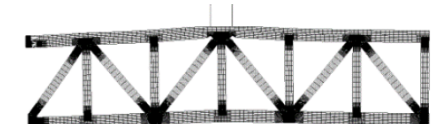


Exp. 4: 61.57 Hz and $\zeta_4 = 0.6 \%$

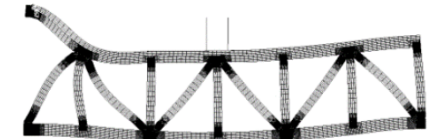


Exp. 5: 92.78 Hz and $\zeta_5 = 0.7 \%$

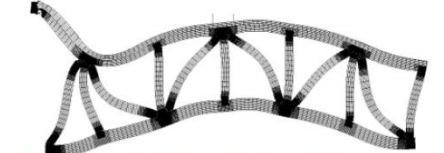
Numerical results



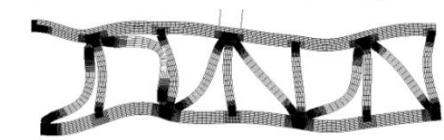
Num. 1: 8.97 Hz (0%) and $MAC_{1,1} = 0.99$



Num. 2: 39.8 Hz (+57%) and $MAC_{2,2} = 0.92$



Num. 3: 49.1 Hz (+15%) and $MAC_{3,3} = 0.87$

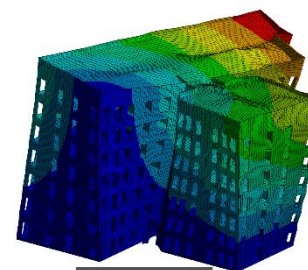
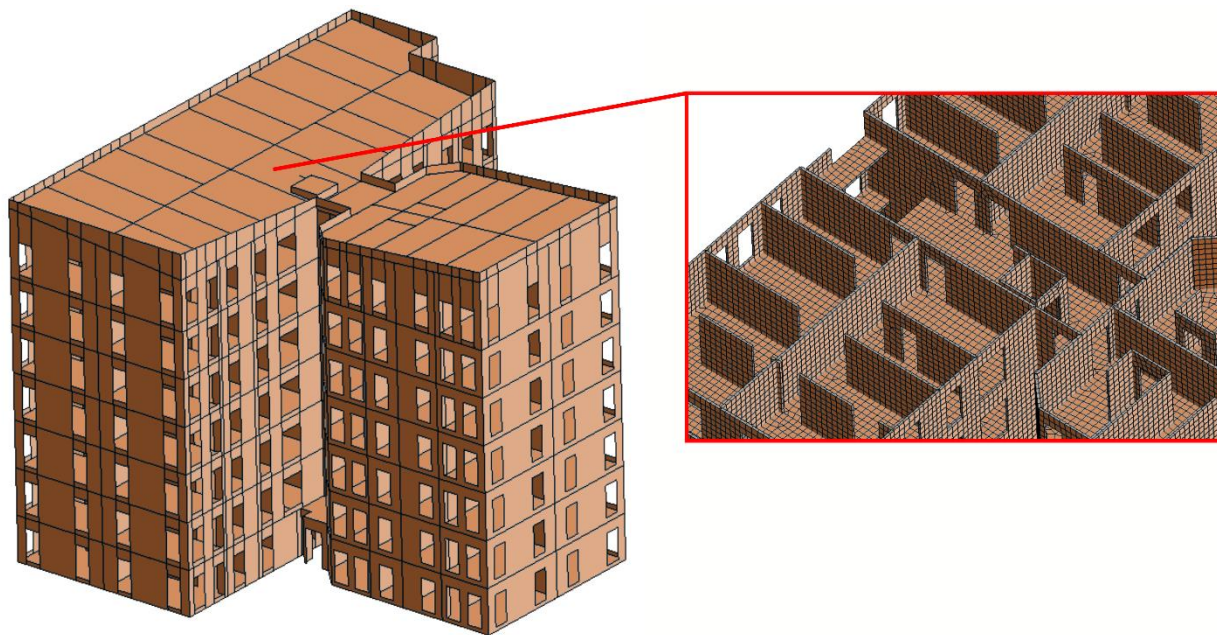


Num. 6: 68.5 Hz (+11%) and $MAC_{4,6} = 0.79$

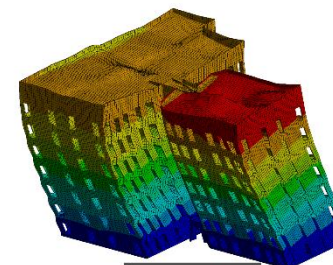


Num. 16: 102.7 Hz (+11%) and $MAC_{5,16} = 0.88$

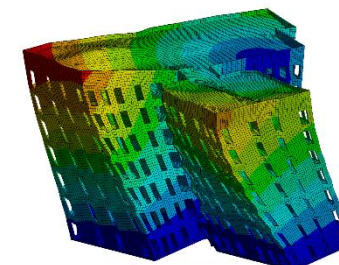
Full-scale models



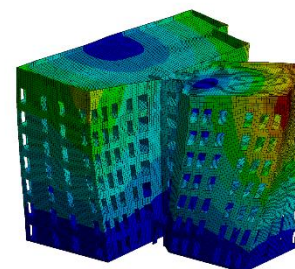
2,81 Hz



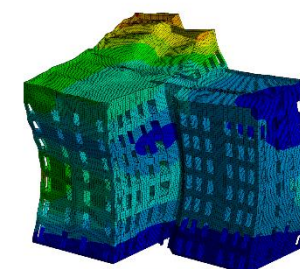
2,85 Hz



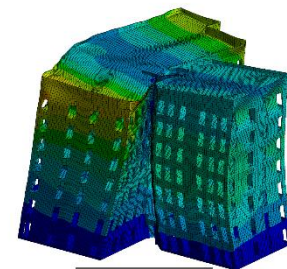
2,94 Hz



3,98 Hz



8,16 Hz



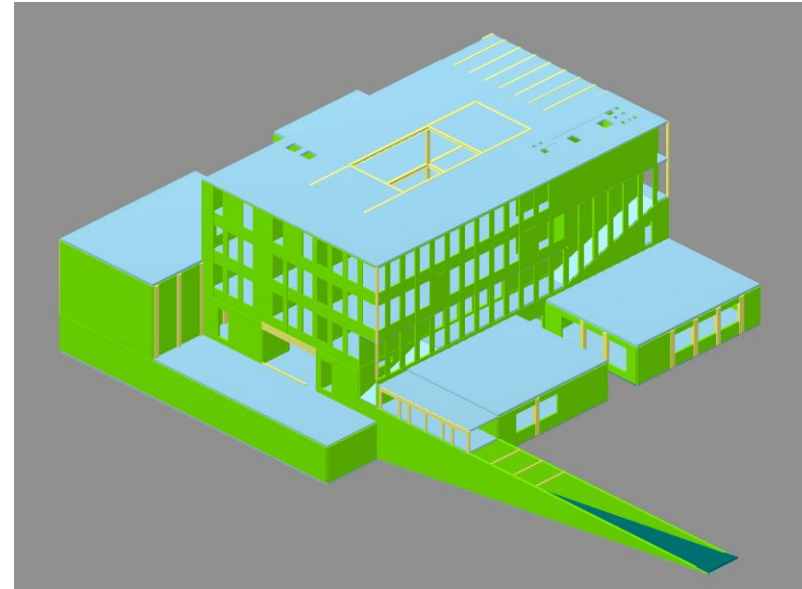
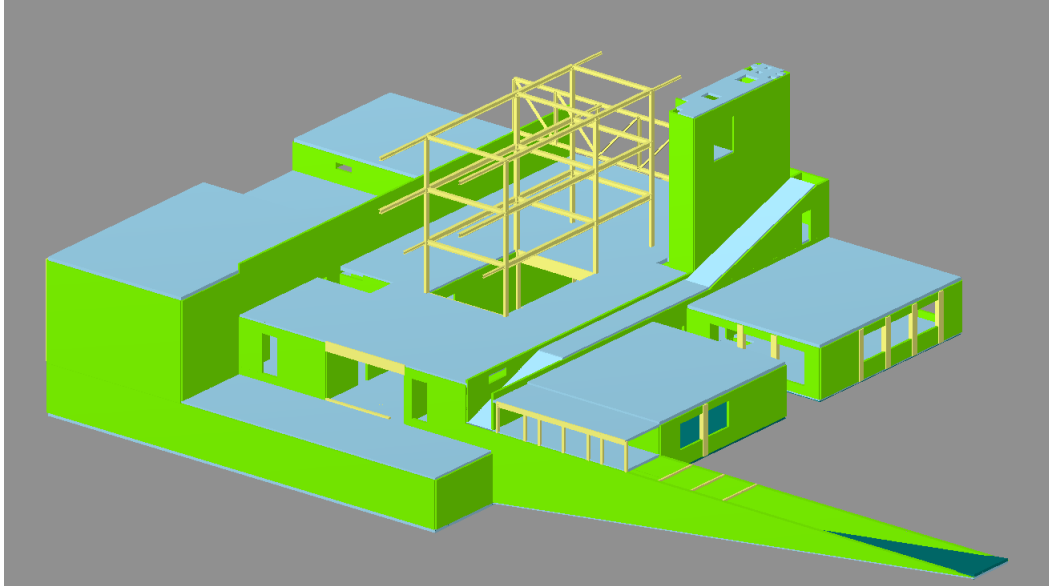
8,32 Hz

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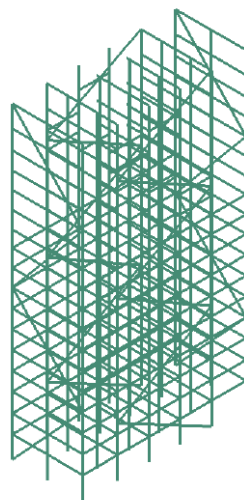
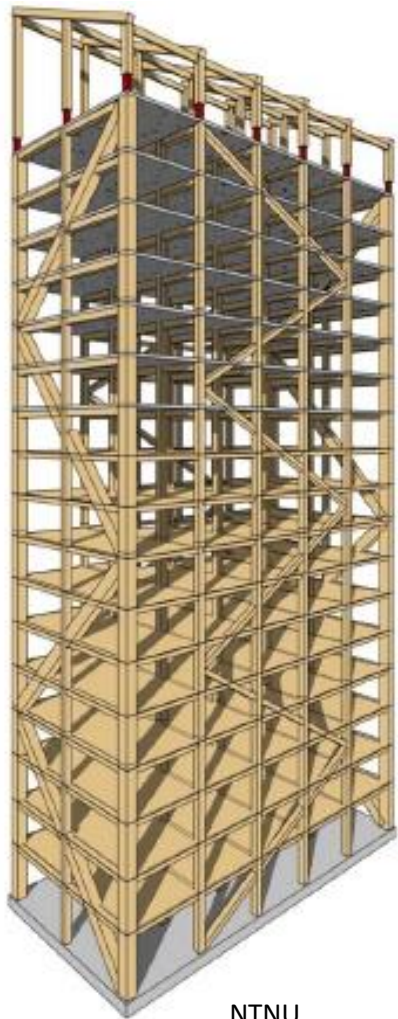
Full-scale models



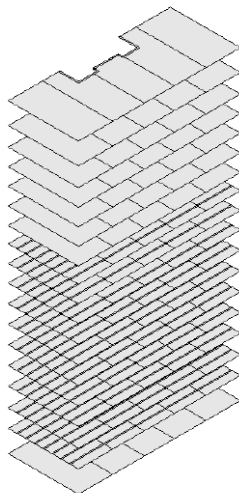
Vibration mode	FEM	In-Situ	Difference (period)
1	0,187 s (5,36 Hz)	0,208 s (4,81 Hz)	+11,2 %
2	0,132 s (7,57 Hz)	0,161 s (6,27 Hz)	+22,0 %
3	0,120 s (8,36 Hz)	0,141 s (7,08 Hz)	+17,5 %



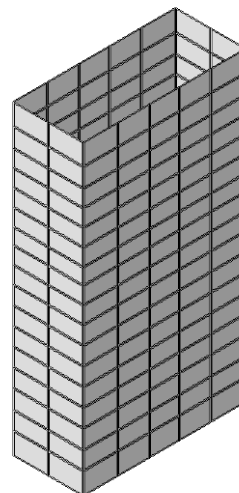
Full-scale models



(a) Frame Part



(b) Floor Part

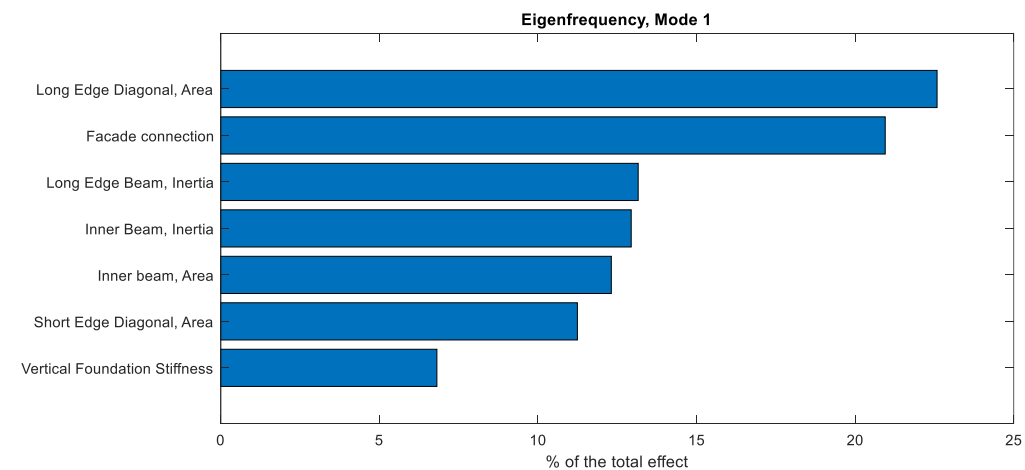


(c) Wall Part



(d) Shaft Part

Sensitivity study





IMPACT - RECOMMENDATIONS

Impact of the project



- Designers - Guidelines
 - Best practice for modelling
 - Data regarding damping
- Property owners and developer
 - Increased assurance regarding TTBs
- Researchers
 - Methods for evaluation of vibrations in TTBs
 - Eurocode development



Unexpected

- COVID – moving equipment and people from country to country for measurements
 - New equipment
- Codes give very varying results – varies 100% in acceleration
- Need to revisit the limitations for acceleration
 - University of Exeter invested in shaking tables
- Increased interest in human comfort – vibrations, accoustics...

Website: www.dynattb.com

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Sara Culture centre, June 2022

THANK YOU!

