Offshore design implications of non-linear wave models

Gerry Ryan, Tianning Tang, Ross McAdam and Tom Adcock

Sea-Swallows

Engineering and Physical Sciences Research Council

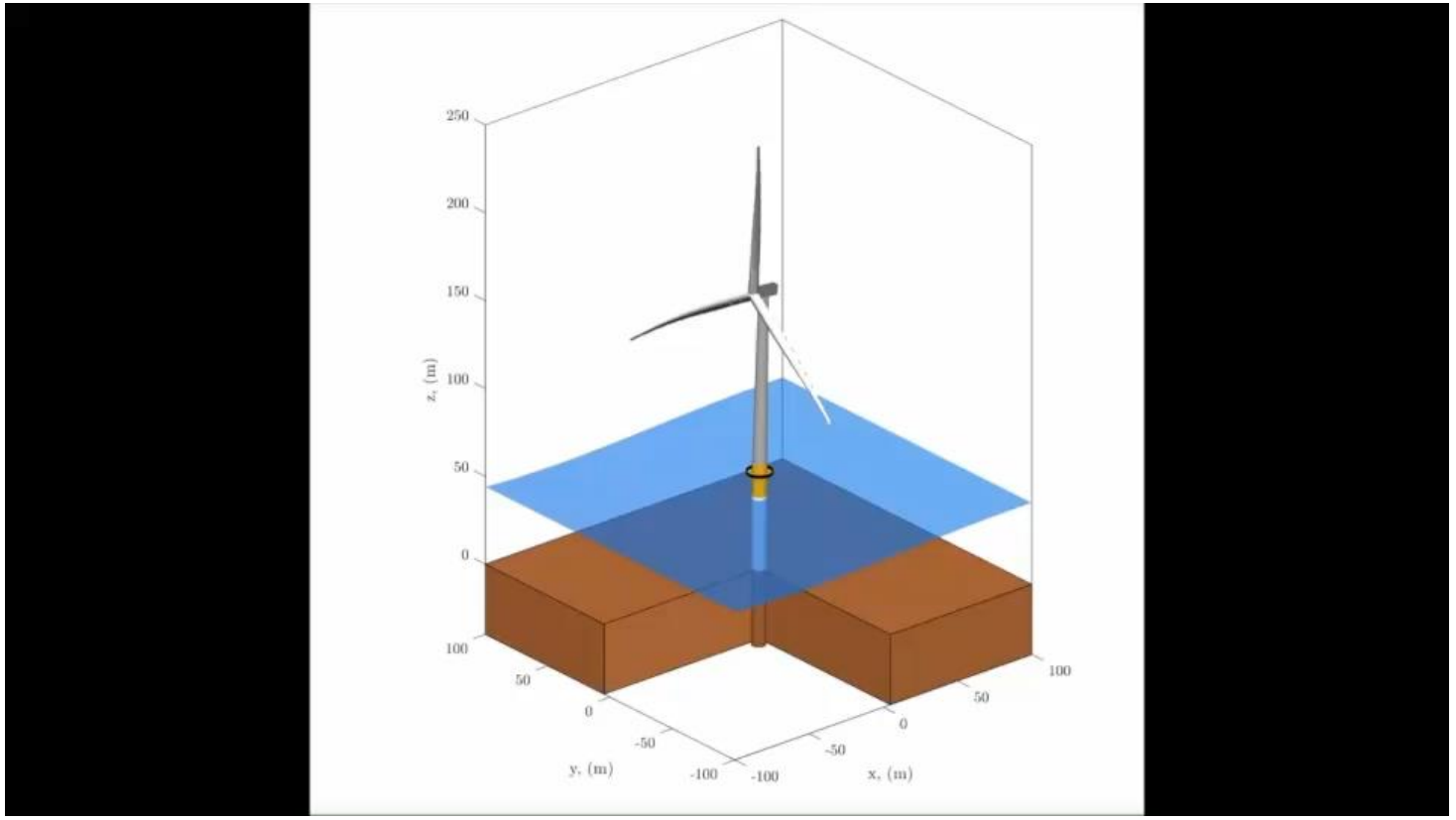
UNIVERSITY OF BATH

UNIVERSITY OF OXFORD

University of Strathclyde Glasgow

Numerical model

- In house aero-hydro-elastic code OxDyn
- Mainly made up of 1D elements
- Iwan model for the Foundation to capture damping accurately



Sea-Swallows

Engineering and Physical Sciences Research Council

UNIVERSITY OF BATH

UNIVERSITY OF OXFORD

University of Strathclyde Glasgow

Turbine

- DTU 10 MW turbine
- Metocean parameters based roughly on North Sea

Parameters	Values
Rated power	10 MW
Rated wind speed	11.4 m/s
Cut-in, cut-out speed	4 m/s, 26 m/s
Controller	Variable-speed pitch control
Rotor speed	6 rpm–9.6 rpm
Rotor diameter	178.3 m
Hub height	119 m above mean sea level
Water depth	45 m
Embedded pile length	40 m
Monopile diameter	8.0 m
Monopile thickness	89 mm
Rayleigh damping ratio (critical)	0.6% (no tuned mass damper)

Sea-Swallows

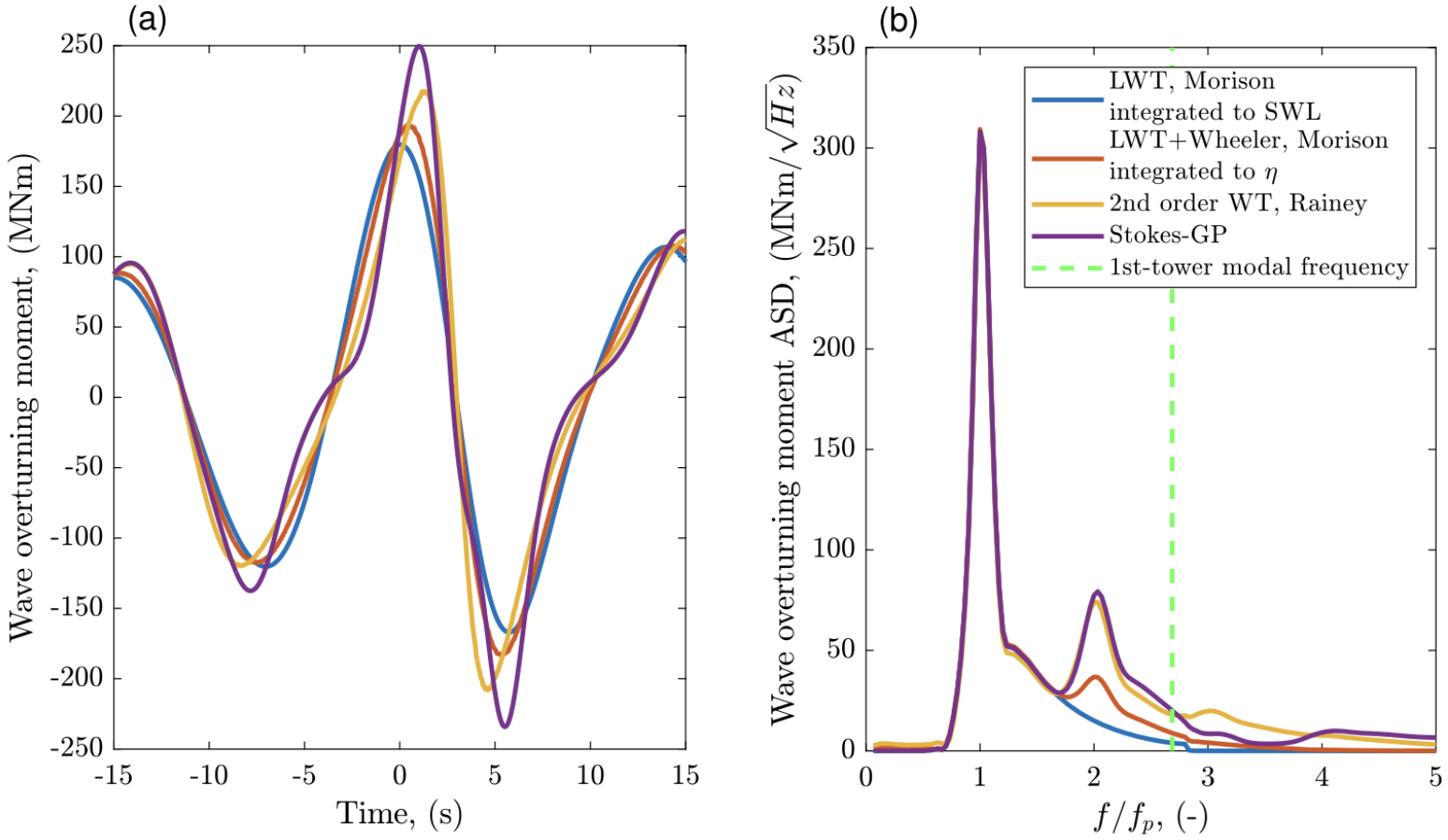
Engineering and Physical Sciences Research Council

UNIVERSITY OF BATH

UNIVERSITY OF OXFORD

University of Strathclyde Glasgow

Wave groups



Sea-Swallows

Engineering and Physical Sciences Research Council

University of Bath

University of Oxford

University of Strathclyde Glasgow

Design calcs

DLC –	Mode –	U_{hub} (m/s)	I –	H_s (m)	T_p (s)	T_p/T_n –	$H_s k_p/2$ –	KC –
1.4	Operating	11.3	–	1.8	7.3	1.7	0.07	0.6
1.6	Operating	11.3	0.14	5.6	10.6	2.4	0.11	1.9
6.1	Parked	22.0	0.11	2.6	5.7	1.0	0.17	1.0
6.1	Parked	39.4	0.11	8.4	11.3	2.0	0.15	3.3
6.1	Parked	33.6	0.11	6.2	17.0	3.0	0.06	2.4
6.1	Parked	24.7	0.11	3.3	22.6	4.0	0.02	1.3
6.1	Parked	45.8	0.11	11.4	14.9	2.6	0.13	4.5

Sea-Swallows

Engineering and Physical Sciences Research Council

University of Bath

University of Oxford

University of Strathclyde Glasgow

Design calcs

DLC –	Mode –	U_{hub} (m/s)	I –	H_s (m)	T_p (s)	T_p/T_n –	$H_s k_p/2$ –	KC –
1.4	Operating	11.3	–	1.8	7.3	1.7	0.07	0.6
1.6	Operating	11.3	0.14	5.6	10.6	2.4	0.11	1.9
6.1	Parked	22.0	0.11	2.6	5.7	1.0	0.17	1.0
6.1	Parked	39.4	0.11	8.4	11.3	2.0	0.15	3.3
6.1	Parked	33.6	0.11	6.2	17.0	3.0	0.06	2.4
6.1	Parked	24.7	0.11	3.3	22.6	4.0	0.02	1.3
6.1	Parked	45.8	0.11	11.4	14.9	2.6	0.13	4.5

Sea-Swallows

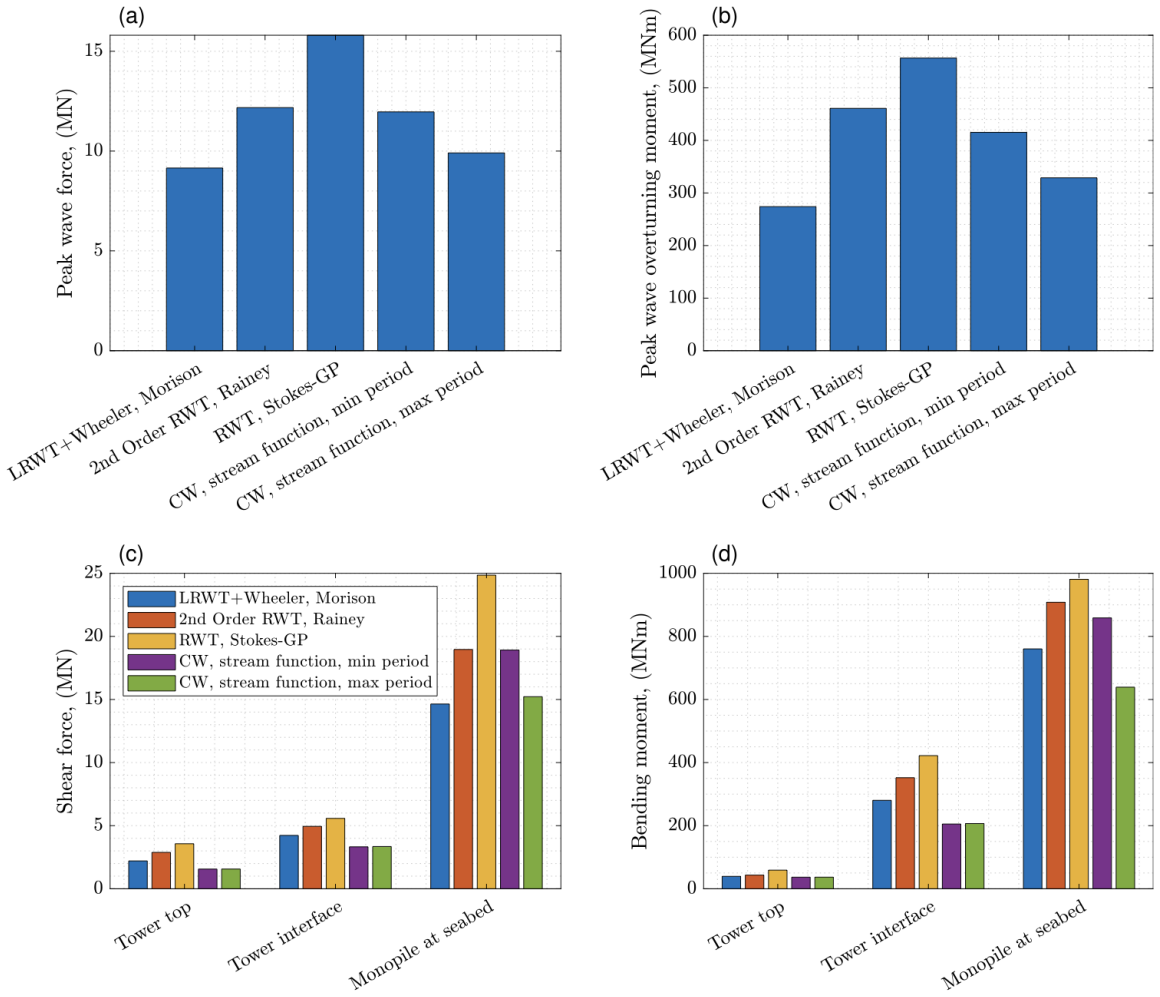
Engineering and Physical Sciences Research Council

UNIVERSITY OF BATH

UNIVERSITY OF OXFORD

University of Strathclyde Glasgow

Internal and external forces



Sea-Swallows

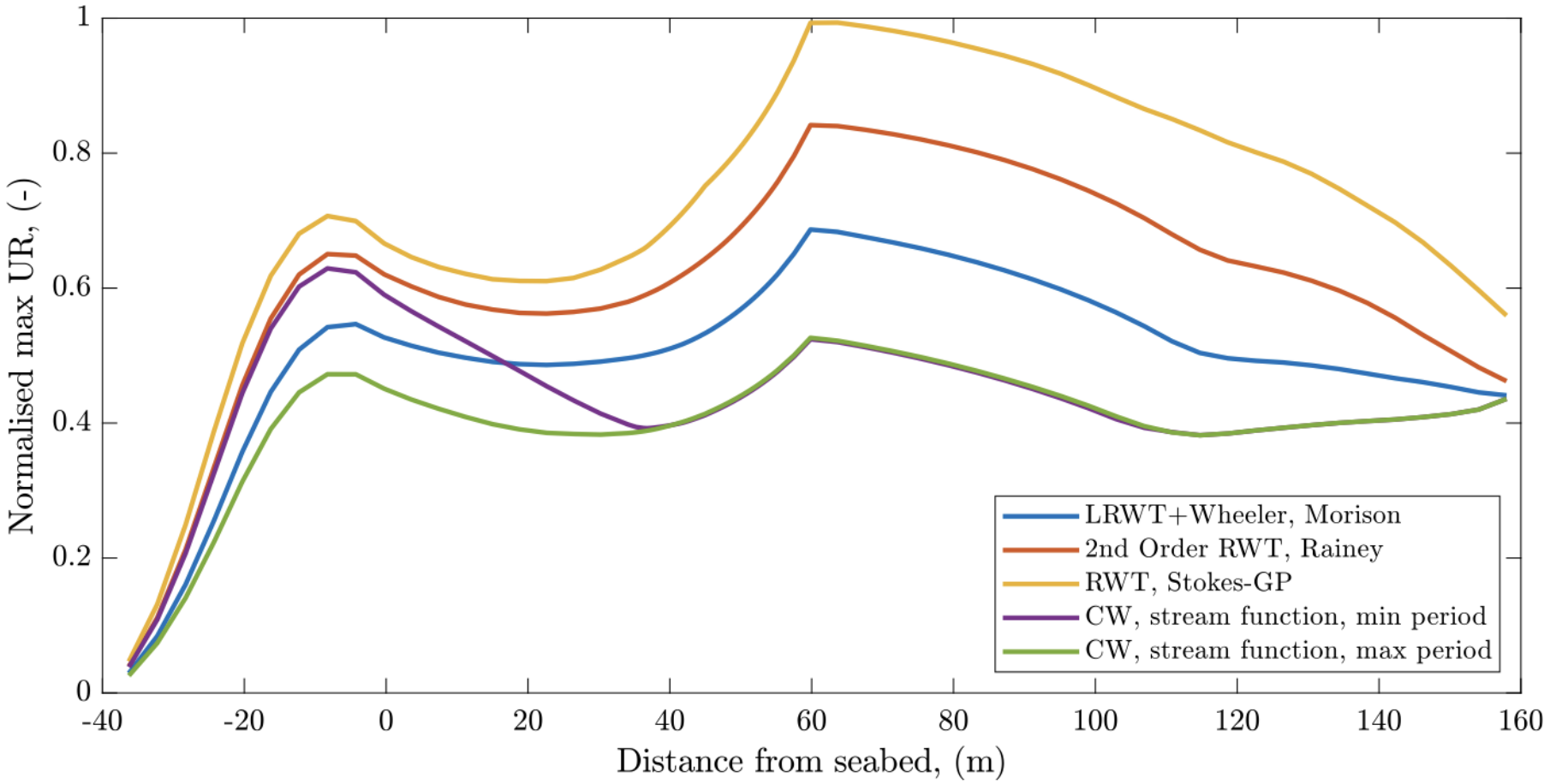
Engineering and Physical Sciences Research Council

UNIVERSITY OF BATH

UNIVERSITY OF OXFORD

University of Strathclyde Glasgow

Steel utilisation



Sea-Swallows

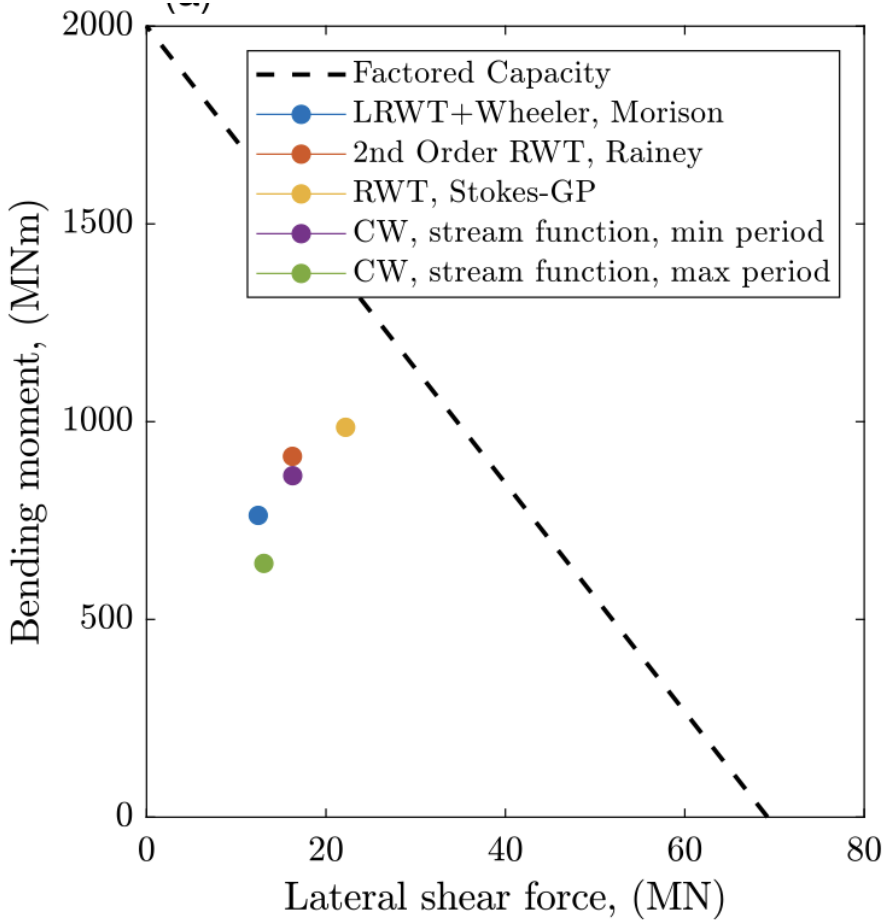
Engineering and Physical Sciences Research Council

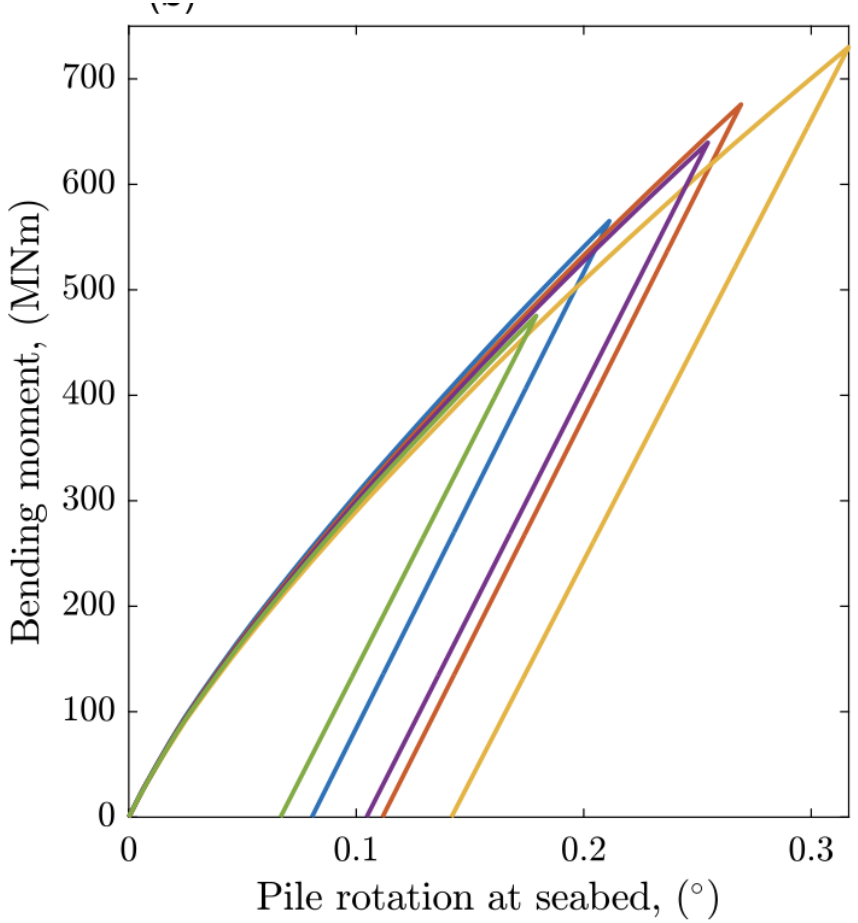
UNIVERSITY OF BATH

UNIVERSITY OF OXFORD

University of Strathclyde Glasgow

Geotechnical response





Caveats

- Results presented here are very sensitive to exact design and conditions chosen (e.g. water depth/natural frequency/damping ratio)
- Larger turbines (e.g. 15 MW) will have larger wind loads so wave loading is less important and so less of a difference in impact on design

Sea-Swallows

Engineering and Physical Sciences Research Council

University of Bath

University of Oxford

University of Strathclyde Glasgow

Conclusions

- The impact on design of using more sophisticated wave models is very complex!
- In some instances non-linear loading can produce significant differences
- Not clear whether analytical or experimental (Stokes-GP) gives more severe loads (case specific)