DNV·GL

SOFTWARE

Fixed offshore analysis in Bladed

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DNV GL

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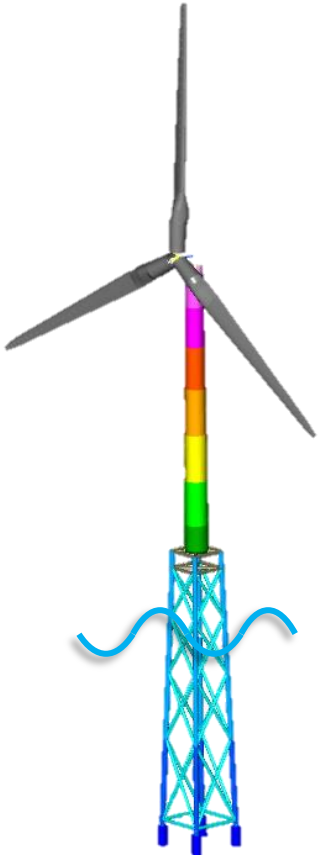
Contents

- Sequential analysis
- Integrated analysis
  - verification with SACS
- Superelement approach
  - for Bladed 4.8



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Sequential Analysis

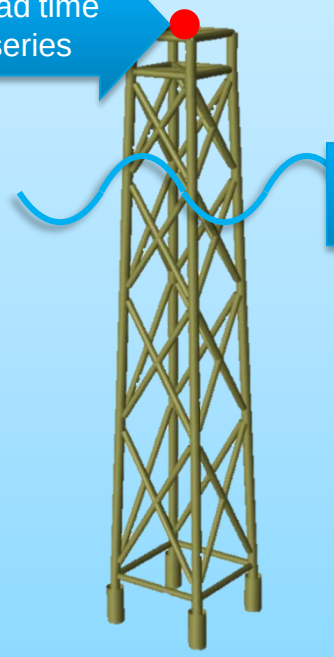
Offshore Code
Jacket design
(SACS, SESAM..)

Model

Bladed
Wind and wave loads
Coupled analysis

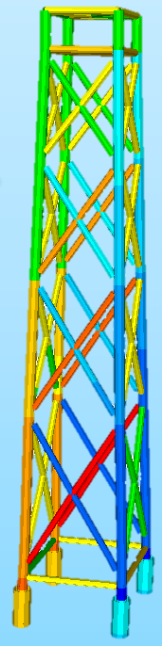
Load time series

Offshore Code
Wave loads
Structural analysis



Results

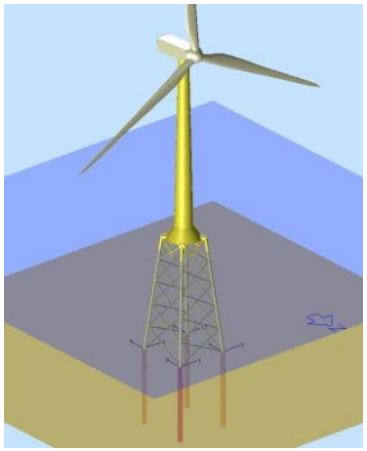
Offshore Code
FLS and ULS
analysis



Interfacing Bladed with offshore codes

- Export Bladed -> Offshore code (Load histories and model)
  - Bladed can export to SACS and ASAS format
  - SESAM can read Bladed data

- Export Offshore code -> Bladed (model only)
  - SACS (and soon SESAM) can output a model in Bladed format

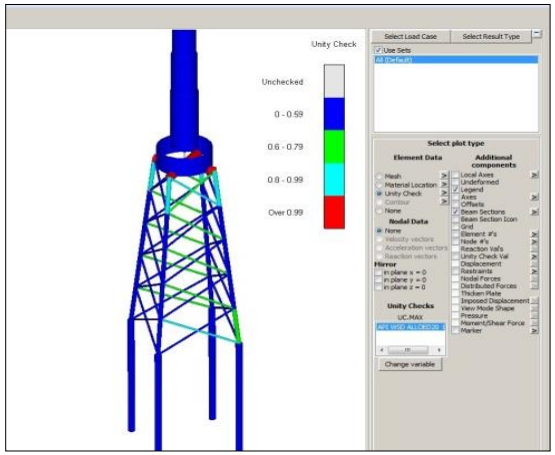


SACS, SESAM, ASAS

Export from Bladed

SACS, (soon SESAM)

Export from Offshore Code



Integrated load simulation

Fatigue life & code checks

Sequential Analysis

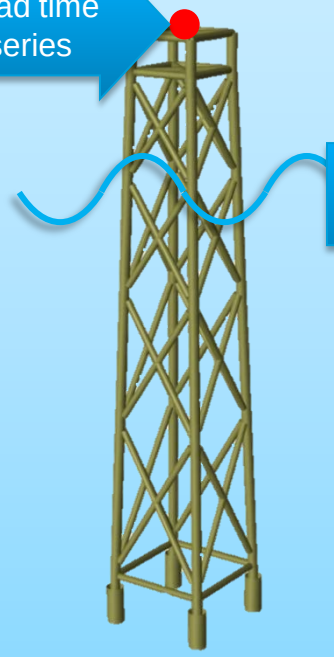
Offshore Code
Jacket design
(SACS, SESAM..)

Model

Bladed…
Wind and wave loads
Coupled analysis

Load time series

Offshore Code
Wave loads
Structural analysis



Results

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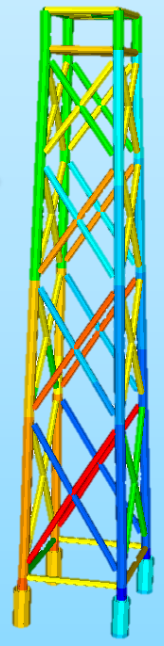
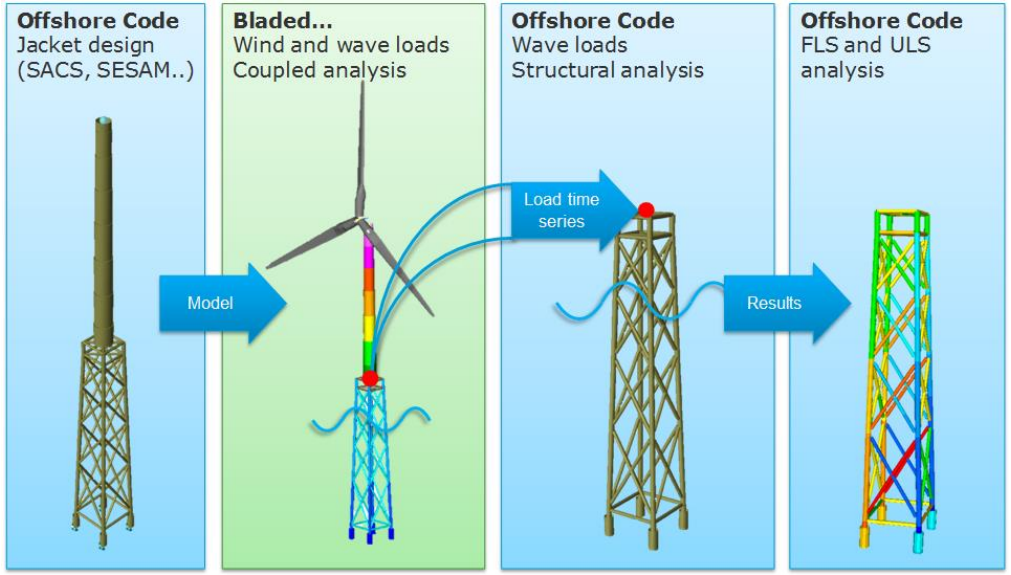


Sequential Analysis



- ↑ Familiar to offshore designer
- ↑ Full aero-elastic model for coupled dynamics

Integrated analysis

- ↓ Wave loads calculation and structural analysis is duplicated
- ↓ Hard for FD and WTG designer to optimise the jacket

Superelement

- ↓ Limit on structural complexity of jacket
- ↓ Foundation designer must share design with WTG designer

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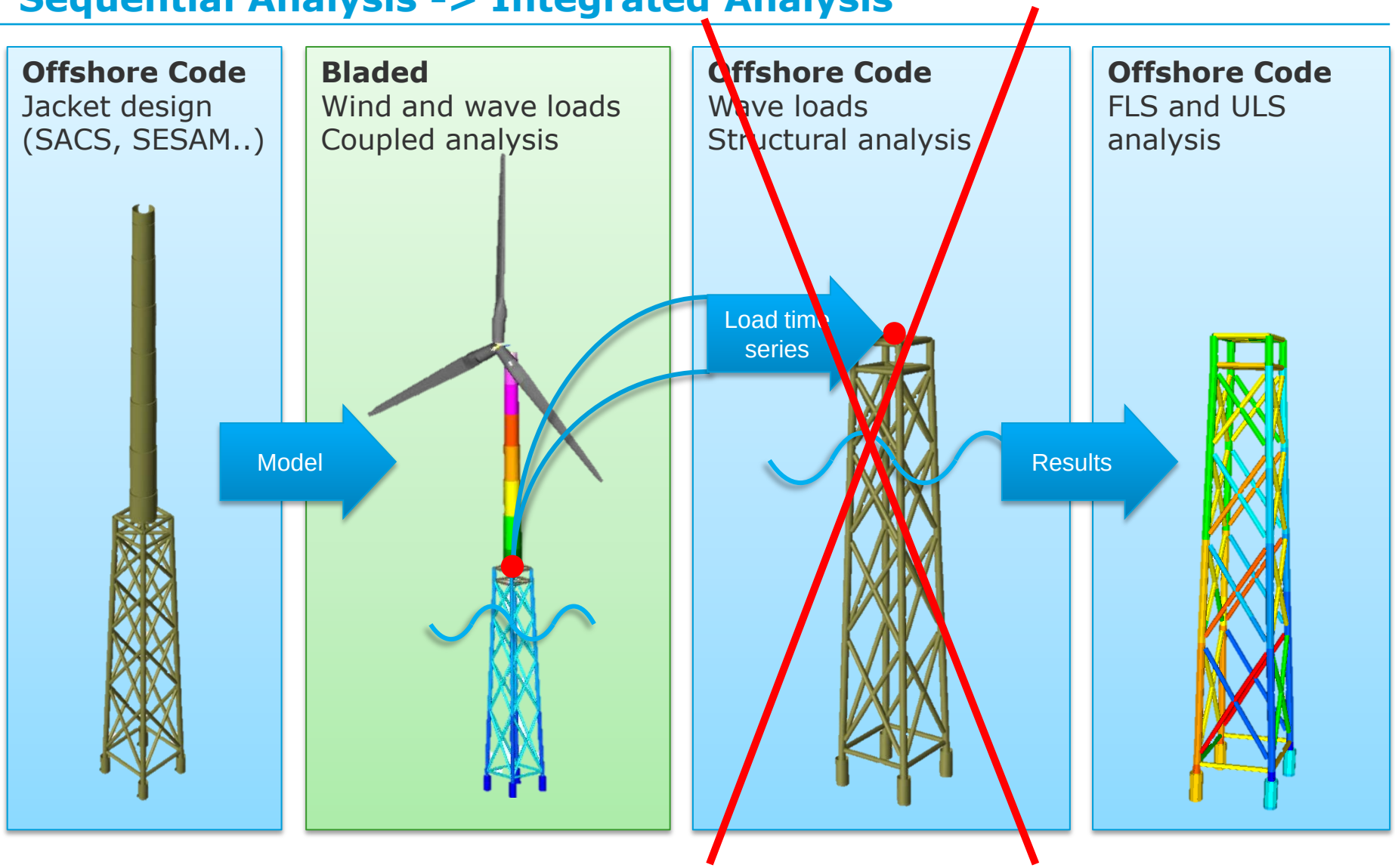
Sequential Analysis -> Integrated Analysis



Integrated Analysis

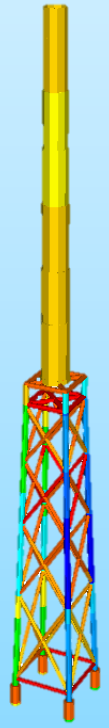
Offshore Code
Jacket design

Model

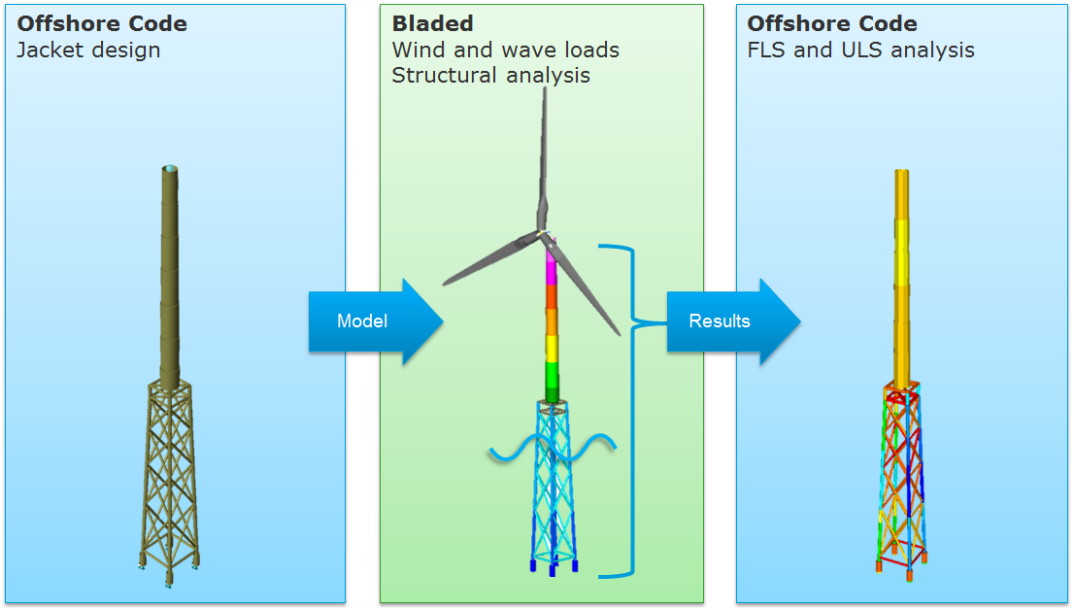
Bladed
Wind and wave loads
Coupled structural analysis

Results

Offshore Code
FLS and ULS analysis



Integrated Analysis

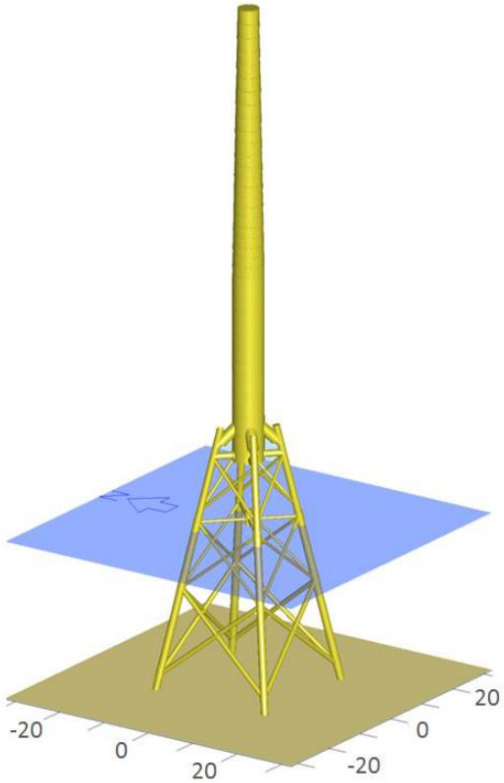


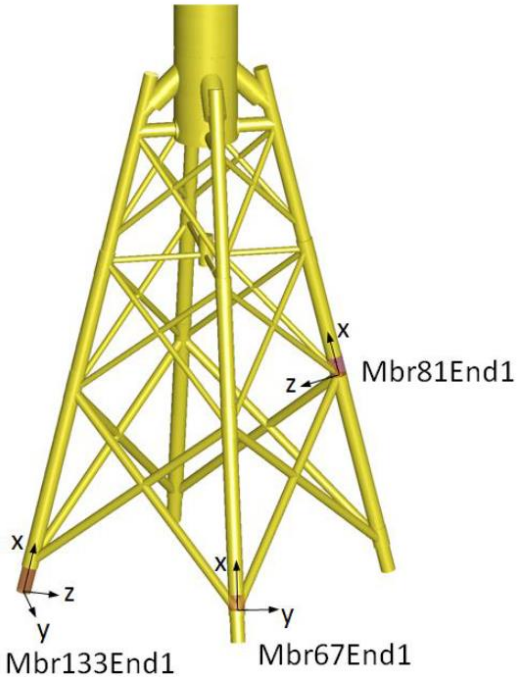
- ↑ Wave and load calculation only done once
- ↑ Easy for FD and WTG designer to optimise design → Project FORCE *
- ↓ Limit on structural complexity of jacket
- ↓ Foundation designer must share design with WTG designer

* https://www.dnvgl.com/energy/feature-articles/project-force.html

Integrated analysis: Bladed and SACS comparison

- **Aims:**
  - Show that wave loading and internal load calculation is equivalent in Bladed and SACS
  - Improve confidence to move to "integrated" approach



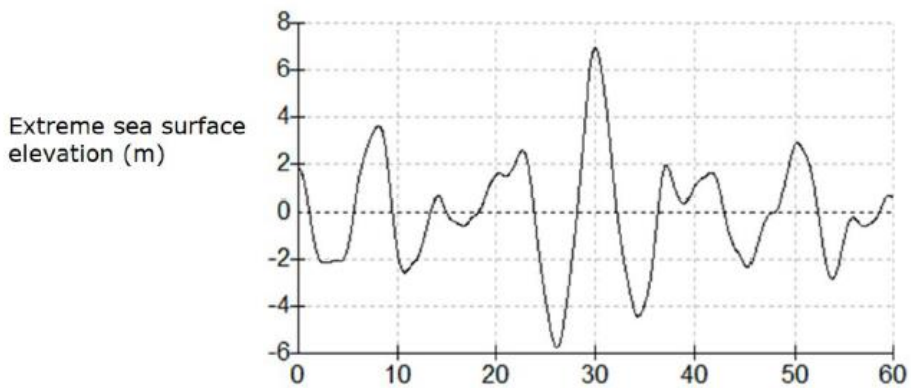


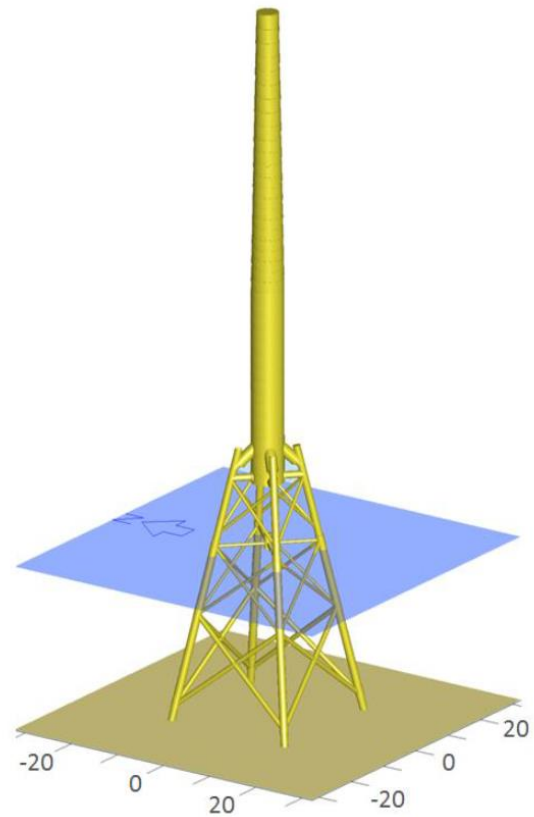
Bladed and SACS comparison

- **Method:** Apply fatigue and extreme waves to dynamic structural model

Extreme conditions:

- H_s = 6.83 m
- Constrained wave = 12.7 m

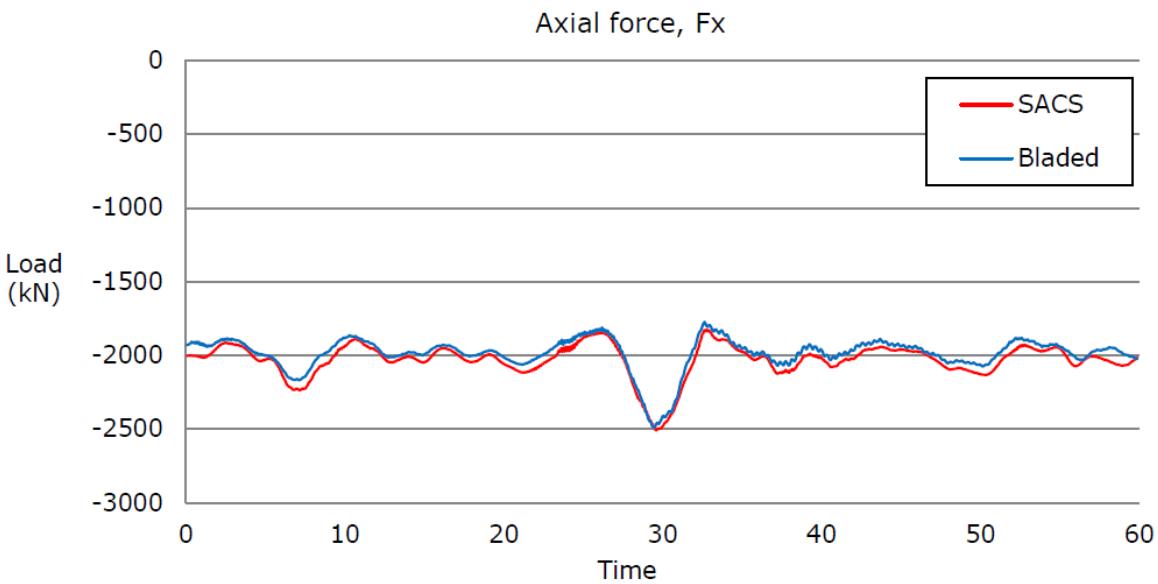


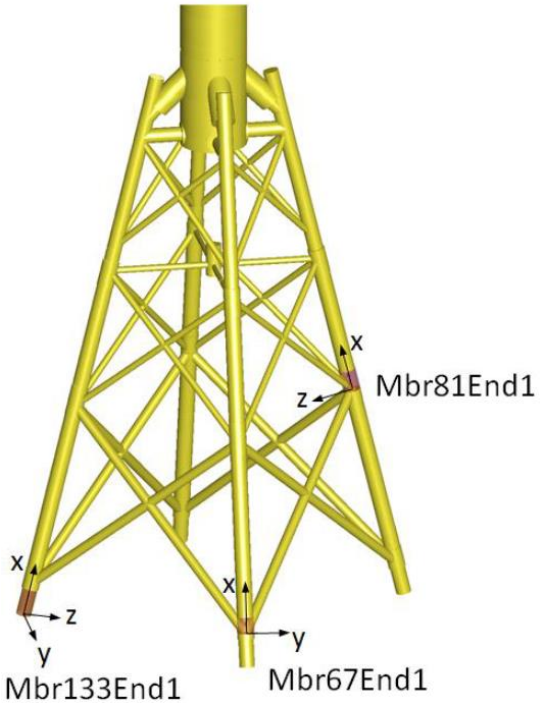


Bladed and SACS comparison

- **Results:** Compare member loads in Bladed and SACS

Extreme loading: Member 67

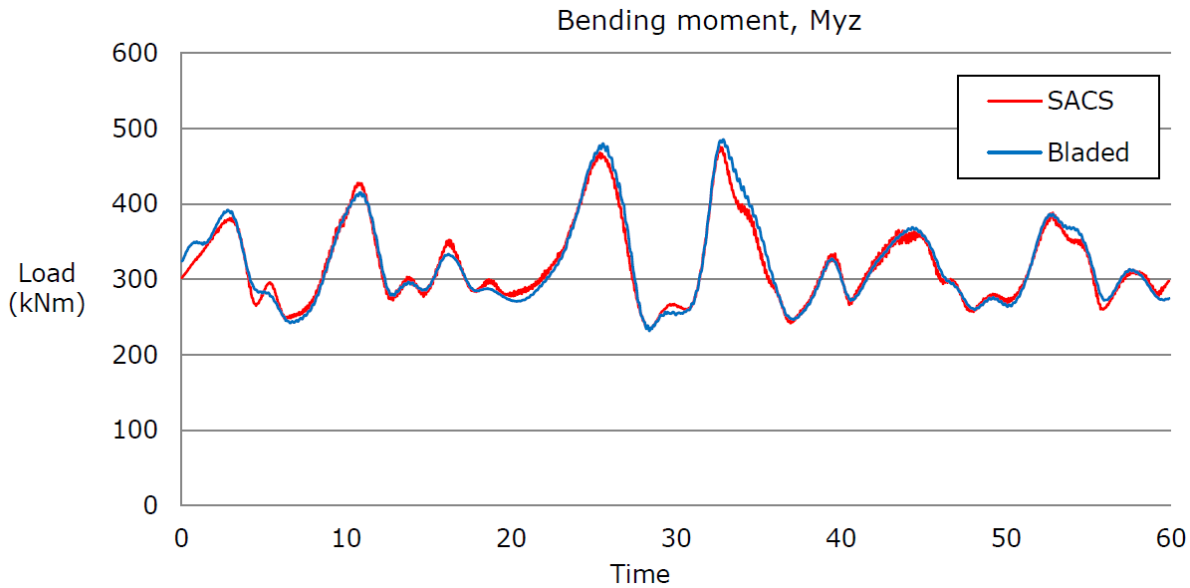


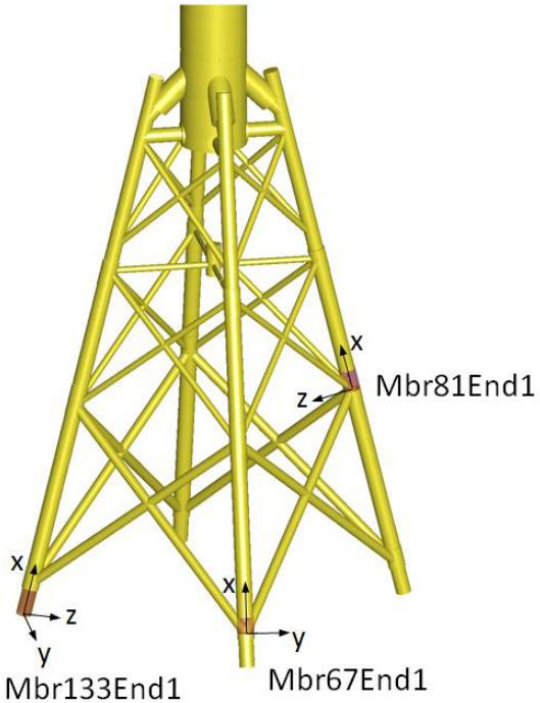


Bladed and SACS comparison

- **Results:** Compare member loads in Bladed and SACS

Extreme loading: Member 81



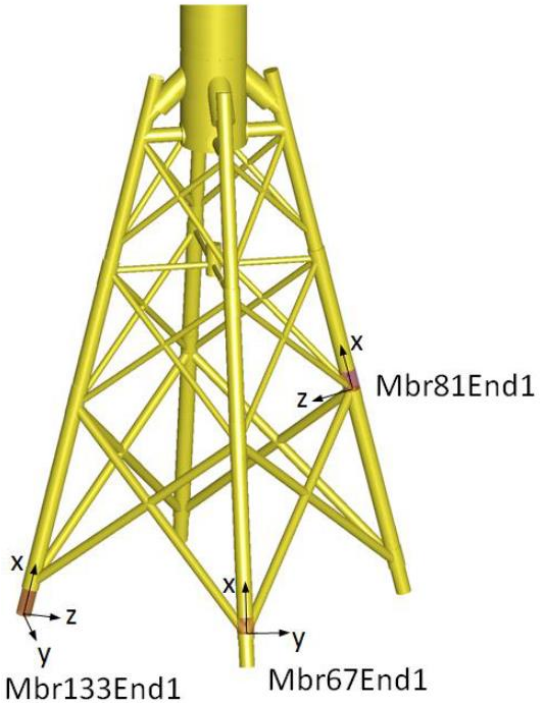


Bladed and SACS comparison

- **Results:** Compare member loads in Bladed and SACS

Extreme loading: summary

		% diff
Member 67	Axial force (kN)	0.8
	Shear force (kN)	2.8
	Bending moment (kNm)	7.4
Member 81	Axial force (kN)	1.4
	Shear force (kN)	-3.6
	Bending moment (kNm)	-2.1
Member 133	Axial force (kN)	3.7
	Shear force (kN)	-7.0
	Bending moment (kNm)	-7.8

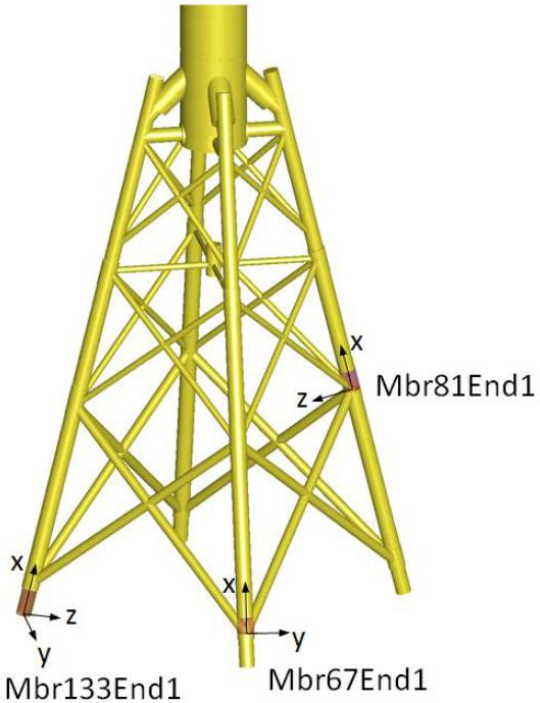


Bladed and SACS comparison

- **Results:** Compare member loads in Bladed and SACS

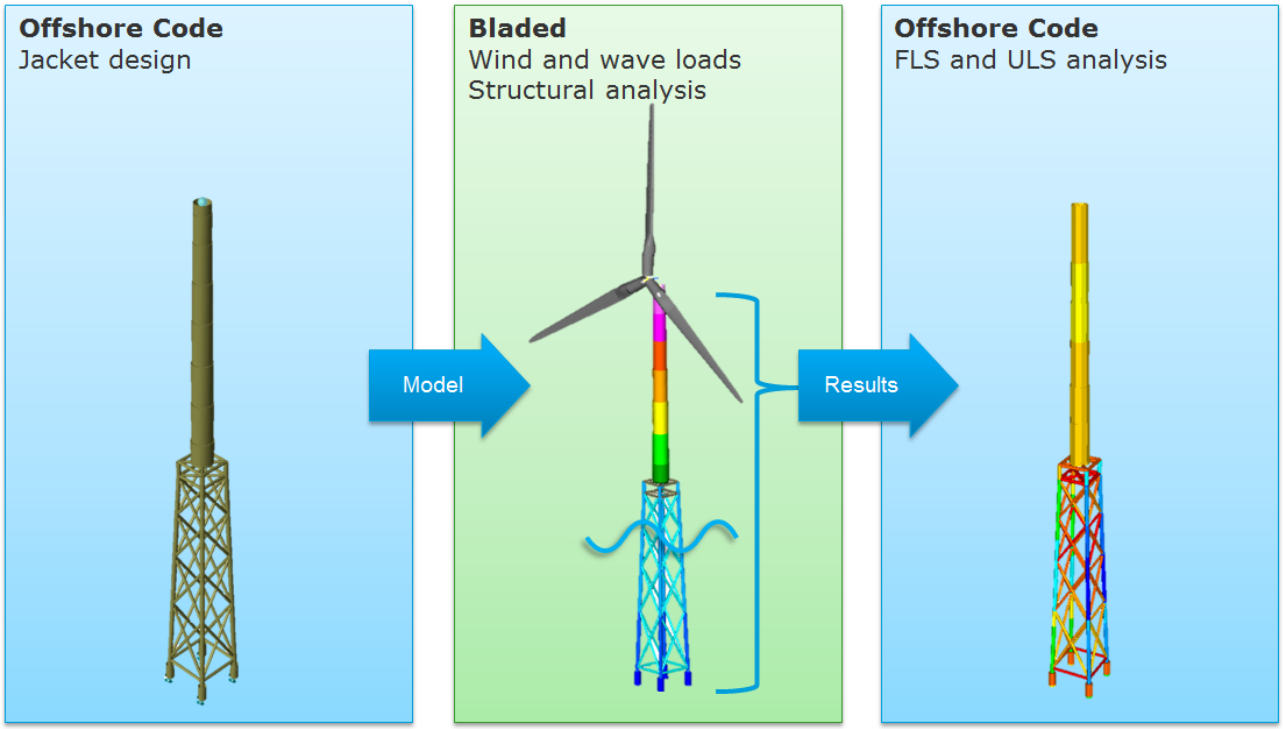
Fatigue loading: summary

		% diff
Member 67	Axial Force (kN)	2.9
	Shear Force (kN)	-7.8
	Bending Moment (kNm)	-1.0
Member 81	Axial Force (kN)	-4.4
	Shear Force (kN)	-1.8
	Bending Moment (kNm)	0.9
Member 133	Axial Force (kN)	8.0
	Shear Force (kN)	-1.4
	Bending Moment (kNm)	-1.8



Bladed and SACS comparison

- **Conclusion:**
  - Wave loads and internal load calculation very similar in Bladed and SACS
  - Internal loads can be calculated in Bladed, allowing more “integrated” design



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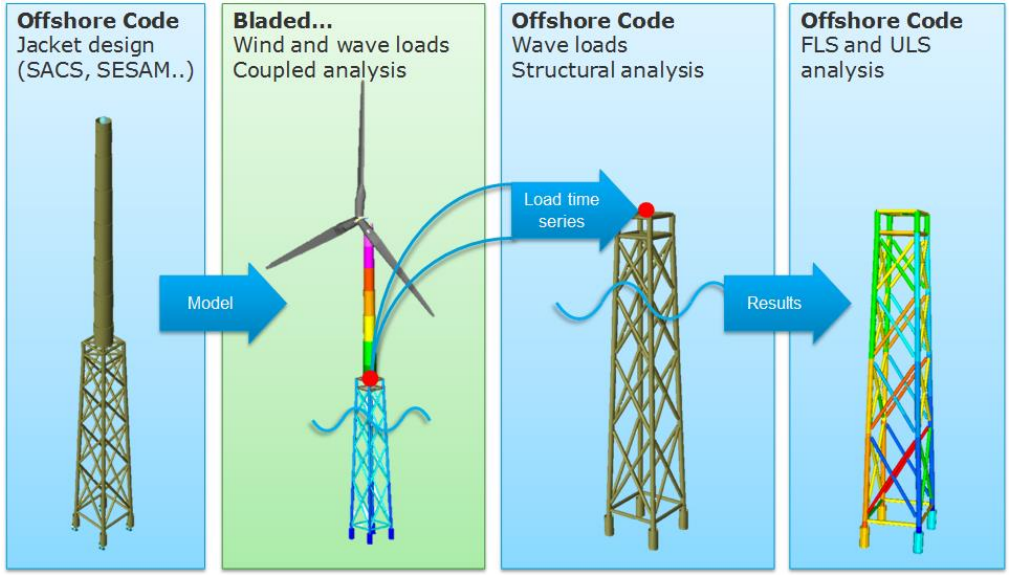
Reminder: Sequential Analysis



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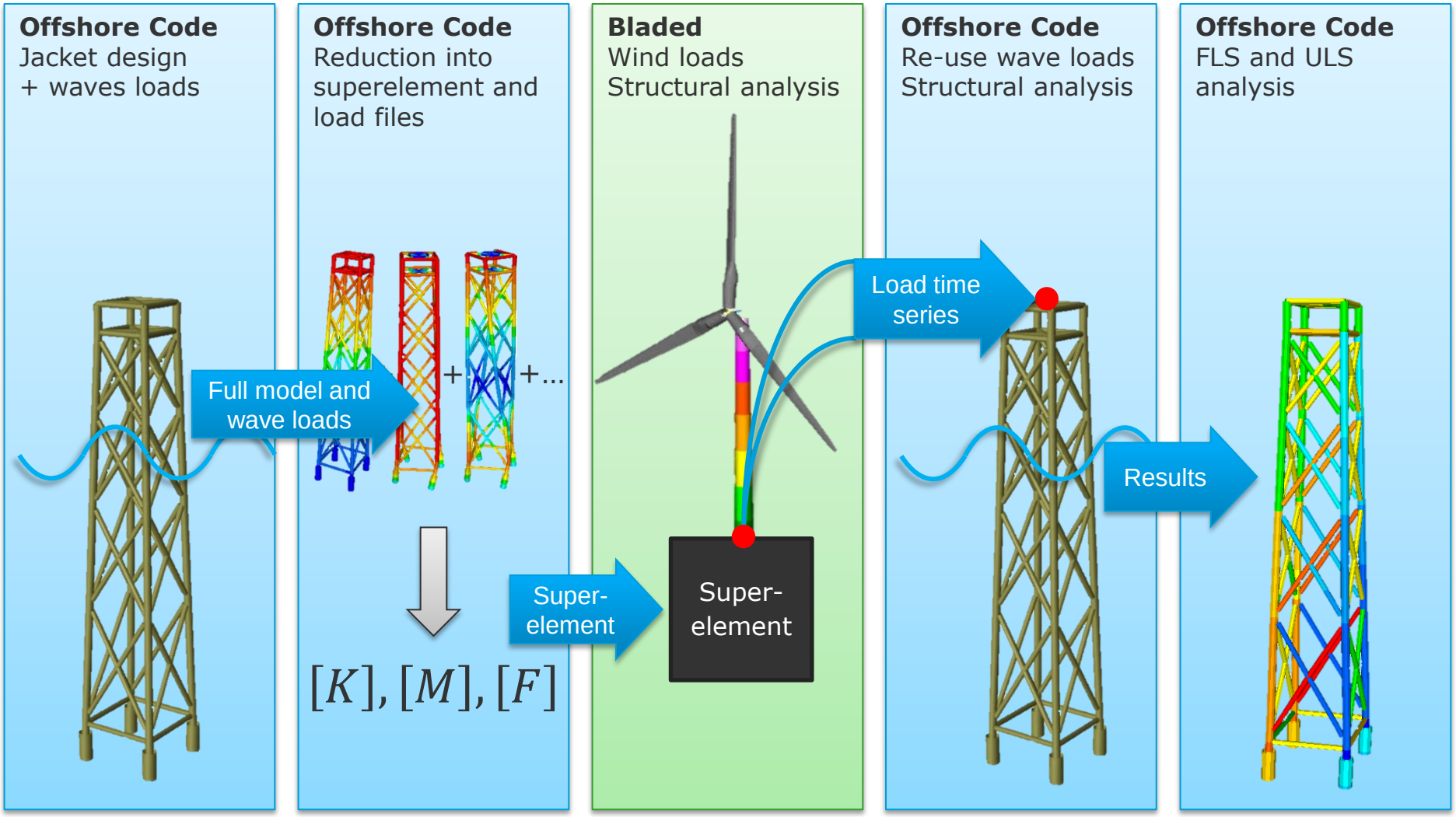
Integrated analysis

- ↓ Wave loads calculation and structural analysis is duplicated
- ↓ Hard for WTG and FD designers to optimise the jacket

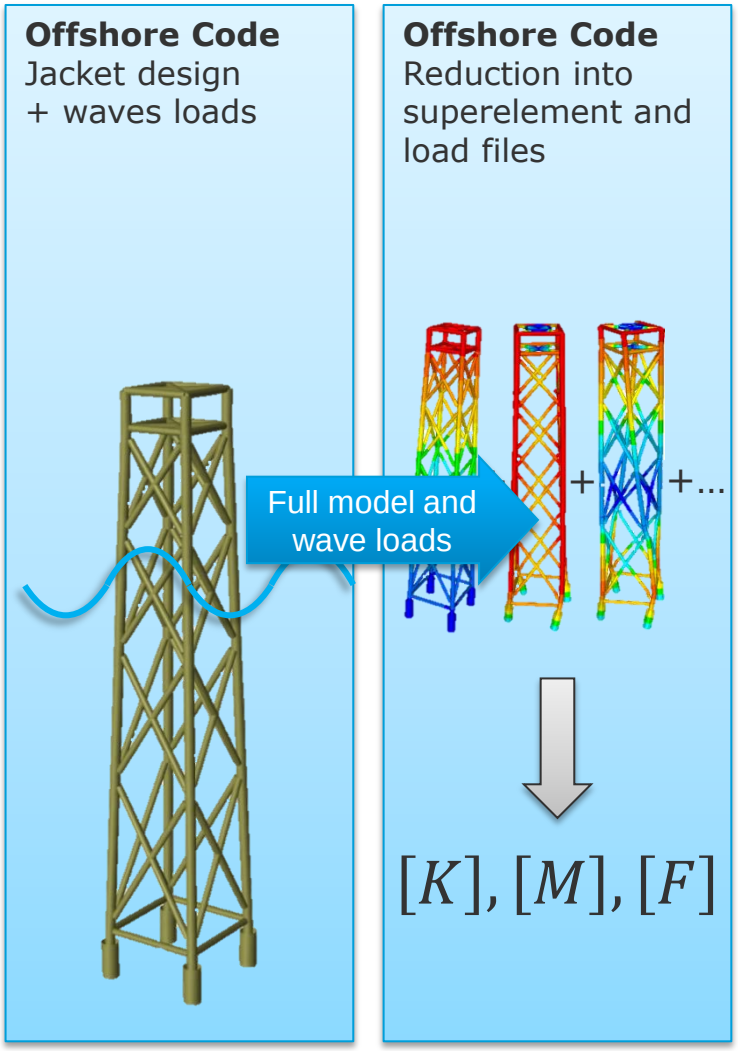
Superelement

- ↓ Limit on structural complexity of jacket
- ↓ Foundation designer must share design with WTG designer

Superelement Analysis (for Bladed 4.8)

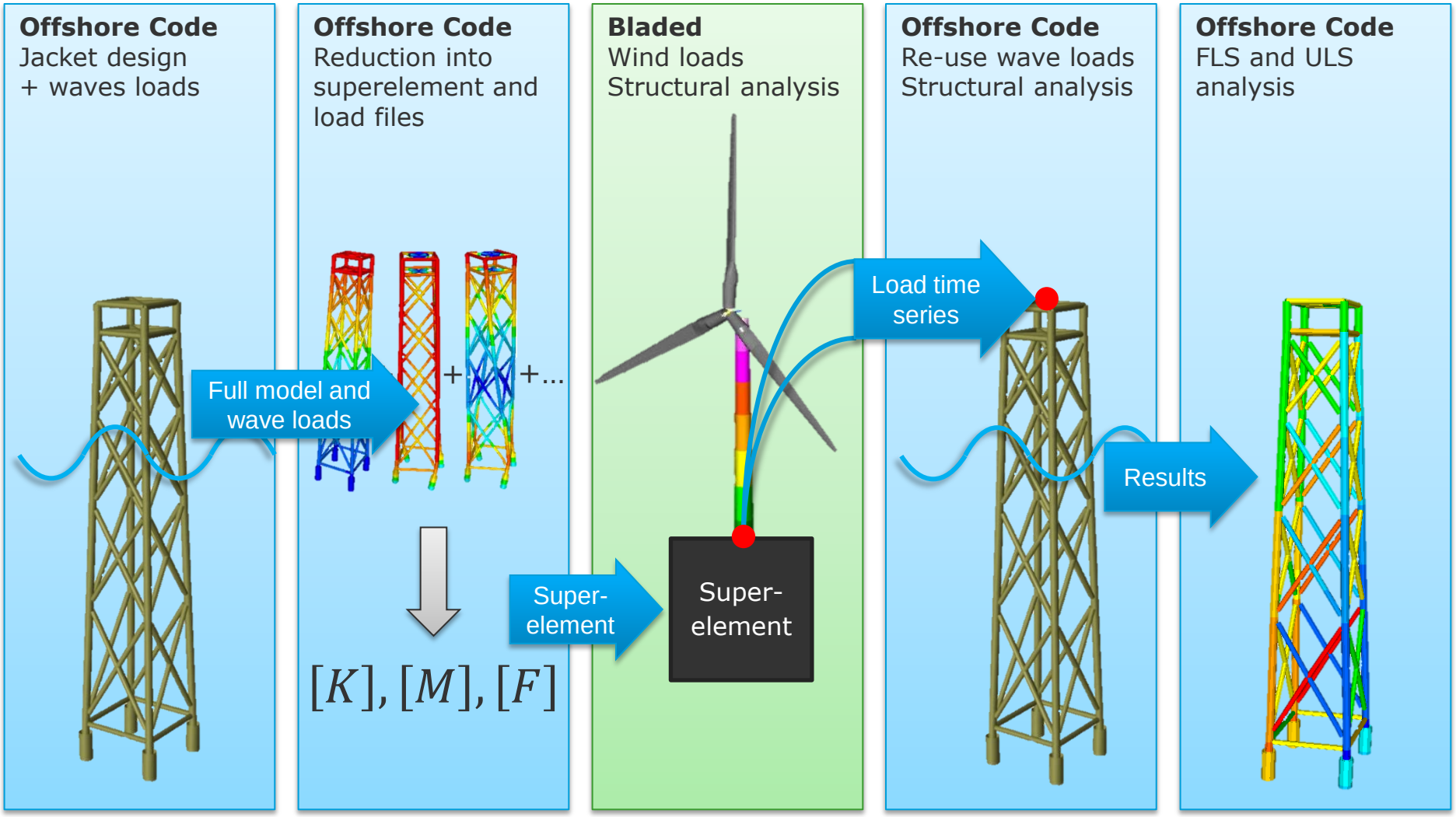


Creating a Superelement



- Superelement created using Craig-Bampton reduction
  - **Constraint modes**: applied displacements at jacket top
  - **Normal models**: Eigen modes with jacket top constrained
  - Modes give reduced [K], [M], [F] for use directly in Bladed

Superelement Analysis (for Bladed 4.8)



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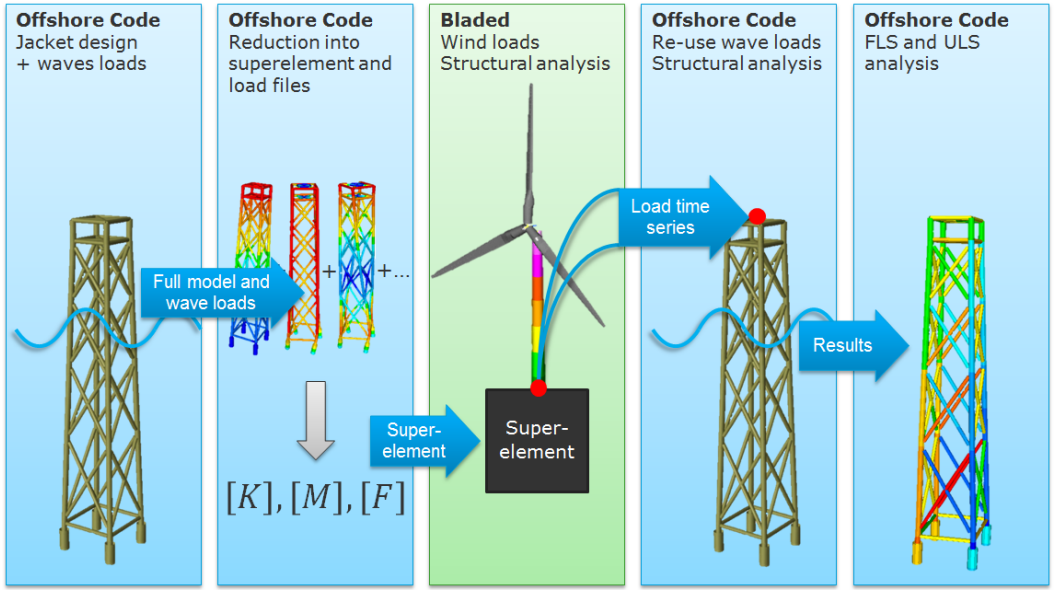

- ↑ FD does not need to share design with WTG designer
- ↑ Allows complex jacket features (e.g. shell elements)
- ↓ Wave loads calculated twice
- ↓ Difficult for FD and WTG designer to optimise design
- ↓ Not full hydro-elastic coupling (wave loads known at start)
- ↓ Superelement structure is linear (ok for jackets?)

Conclusion

Two methods for support structure design with Bladed

- "Integrated analysis" in Bladed
  - Allows for optimisation of turbine and support structure
  - Minimises repeated simulation (e.g. of wave loads)

- Superelement in Bladed (4.8…)
  - Allows complex support structure features (e.g. shells)
  - Reduces sensitive data exchange between jacket and turbine designers