Comparative analysis of design codes for portable offshore units

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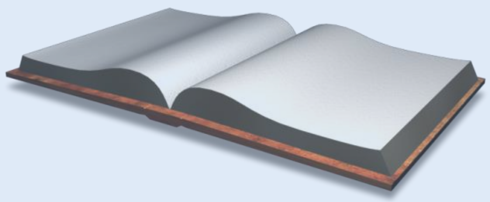
A comparative analysis between four design codes has been carried out for a portable offshore unit in this master thesis.

The purpose of this comparison is to sort the codes in order to the conservative-non conservative results.

Methodology

Design codes



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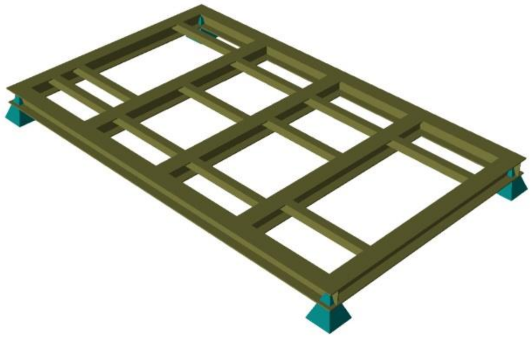
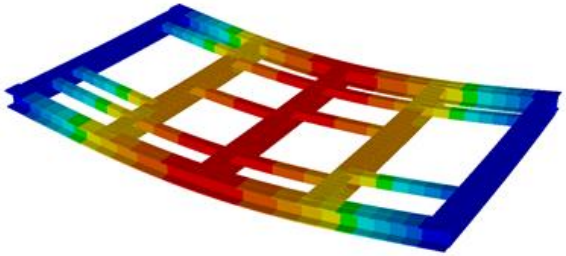
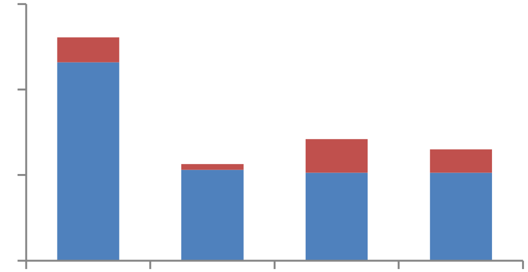


Portable offshore unit

DNV software

Results





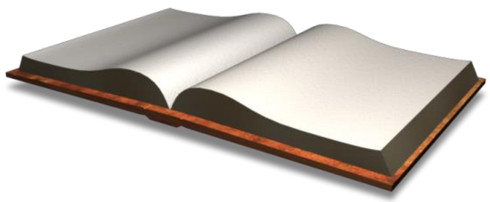
Conclusions

Methodology

energy API	American Petroleum Institute *(API)*	API RP 2A-WSD API RP 2A-WSD
EUROCODES BUILDING THE FUTURE	European Standards *(Eurocodes or EN)*	EN 1991-1-1,3,4 EN 1993-1-1,8
ISO	International Standards *(ISO)*	ISO 19902 ISO 19906
standard.no	Norwegian Standards *(Norsok, NS or N)*	N-001 N-003 N-004

Methodology

Design codes



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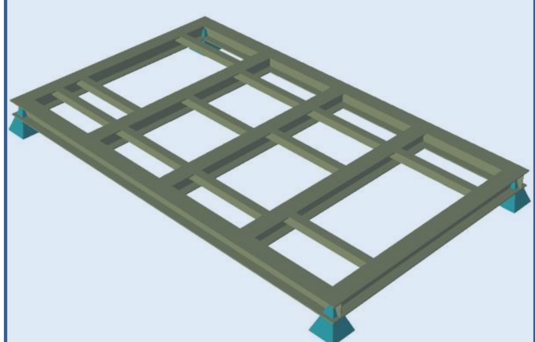
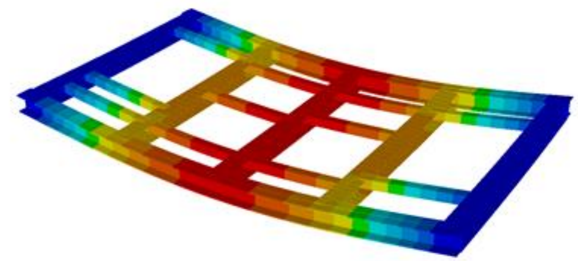
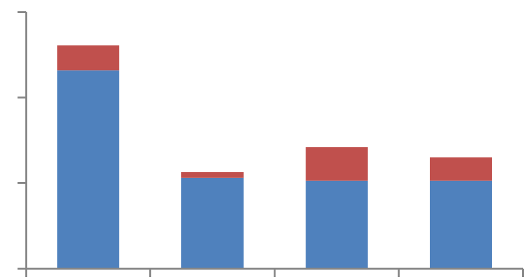


Portable offshore unit

DNV software

Results





Conclusions

Methodology

According to DNV Standard 2.7-3:

- PO Units are intended for offshore transportation and installation/lifting
- Designed to carry equipment over its main frame to be lifted from deck to deck
- Not intended to carry general cargo
- Maximum mass between 25 - 100 t

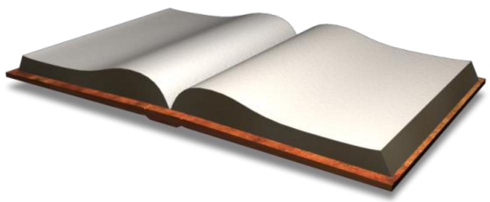
⇓

Difference with containers

(DNV Standard 2.7-1)

Methodology

Design codes



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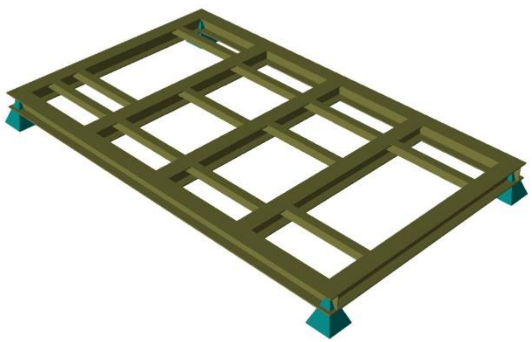
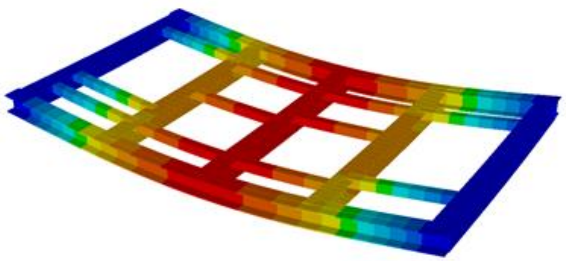
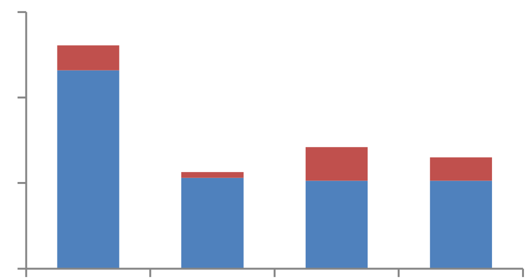


Portable offshore unit

DNV software

Results





Conclusions

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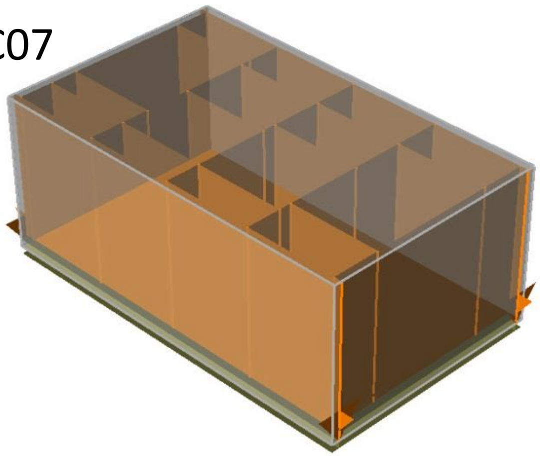
Combined load cases

	Combined load cases								
	00	01_N	02_NE	03_E	04_SE	05_S	06_SW	07_W	08_NW
Load cases									
LC00_Grav	x	ULS 00							
LC01_Struc	x								
LC02_Equip	x								
LC03_Pip	x								
LC04_Inst	x								
LC05_Elec	x								
LC06_Var	x								
LC07_Live	x								
LC08_Wind_N		x							
LC09_Wind_NE			x						
LC10_Wind_E				x					
LC11_Wind_SE					x				
LC12_Wind_S						x			
LC13_Wind_SW							x		
LC14_Wind_W								x	
LC15_Wind_NW									x
LC16_Ice	x								

Combined load cases

ULS00:
LC00 to LC07



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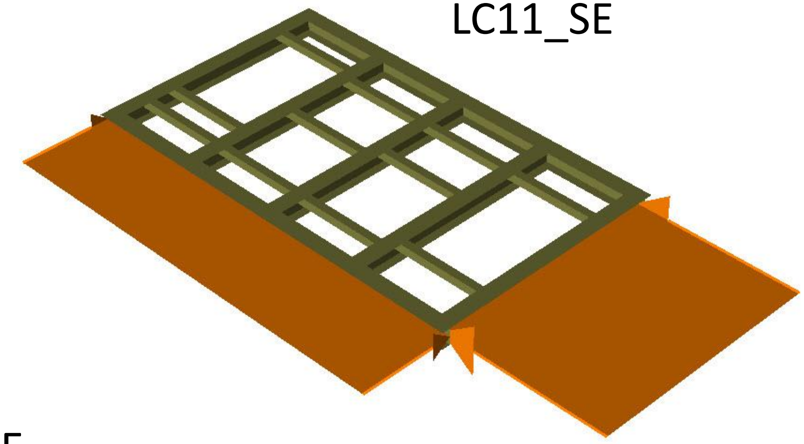
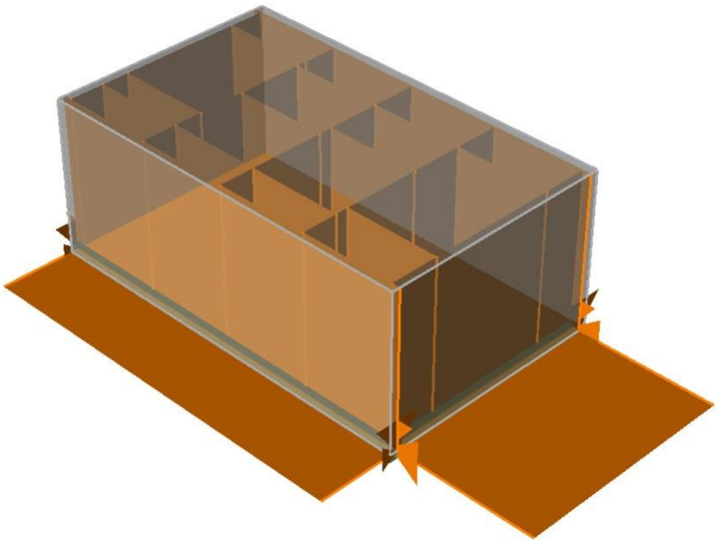
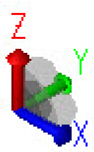
LC11_SE



ULS04_SE





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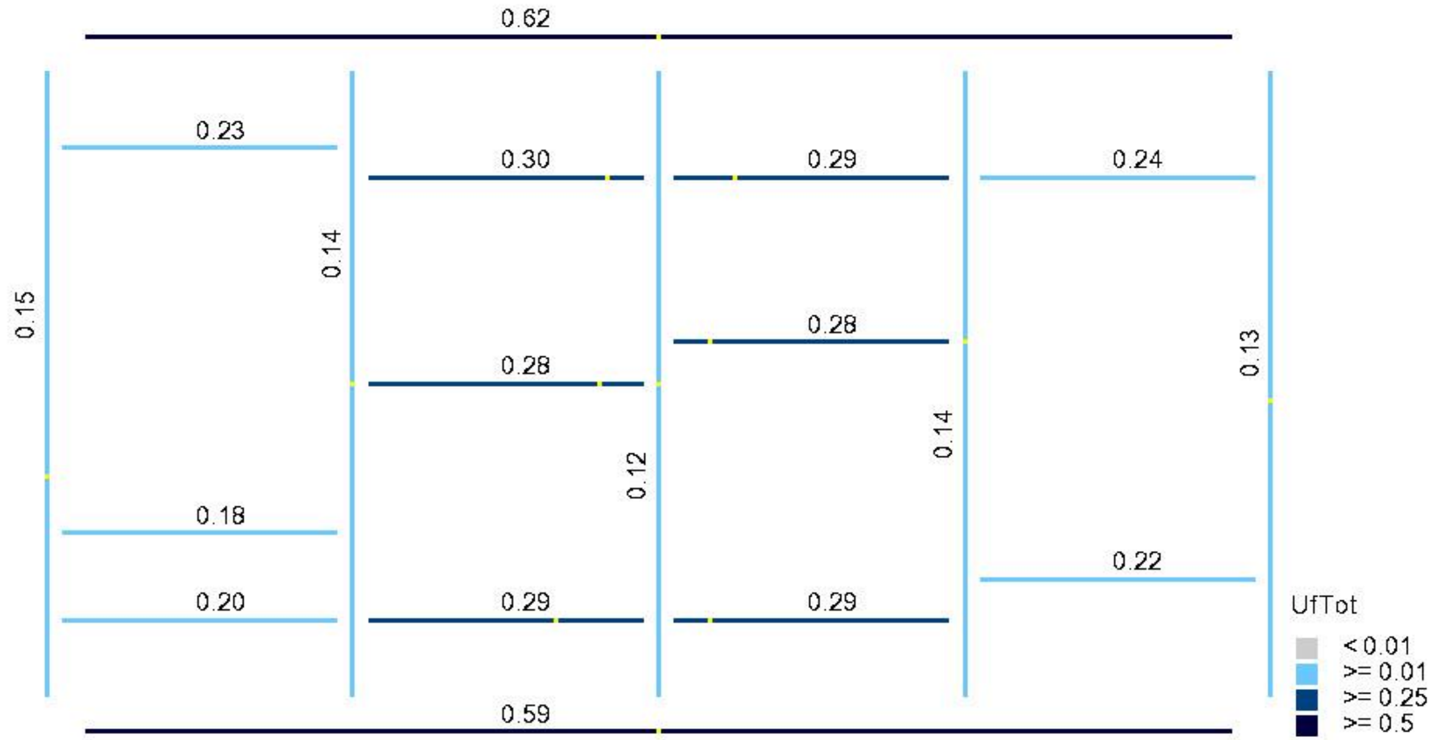
Capacity models

- Used to check the allowable stress levels on beams
- This check is performed through the use of the equations presented in the various code checking standards
- An *usage factor* is the result of these equations presented in codes:
  - If UF < 1.0, member is safe
  - If UF > 1.0, member is overloaded

Capacity models results



Analysis 1: API

	Member	LoadCase	Position	Usage factor	Formula
Primary structure	Long_1	ULS02_NE	0.50	0.62	uf3313
	Long_13	ULS06_SW	0.50	0.59	uf3313
	Transv_1	ULS06_SW	0.63	0.50	uf3313
	Transv_2	ULS01_N	0.50	0.14	uf3313
	Transv_3	ULS05_S	0.50	0.12	uf3313
	Transv_4	ULS05_S	0.44	0.14	uf3313
	Transv_5	ULS02_NE	0.48	0.13	uf3313
Secondary structure	Long_2	ULS06_SW	0.00	0.23	uf3313
	Long_3	ULS06_SW	0.83	0.30	uf3313
	Long_4	ULS04_SE	0.25	0.29	uf3313
	Long_5	ULS06_SW	0.00	0.23	uf3313
	Long_6	ULS08_NW	0.17	0.28	uf3313
	Long_7	ULS08_NW	0.81	0.28	uf3313
	Long_8	ULS08_NW	0.00	0.18	uf3313
	Long_9	ULS02_NE	0.00	0.22	uf3313
	Long_10	ULS08_NW	1.00	0.20	uf3313
	Long_11	ULS08_NW	0.67	0.29	uf3313
	Long_12	ULS02_NE	0.17	0.29	uf3313

However,

how can design codes be compared?

There are four main aspects related to the codes that determine UF:

1) Acting loads
2) Combined load cases factors
3) Security factors
4) Formulation for usage factors

1) Acting loads formulation

- Each code has his own formulas for load calculation.
- Obviously, no changes can be done in these formulas.

However, two “modifications” can be done to compare the codes:

A) Apply their own loads for each code.

B) Apply the same loads for the four codes, e.g., the maximum one.

2) Combined load cases factors (CLC factors)

- Each code has his own CLC factors.

	API							
Load case name	N	NE	E	SE	S	SW	W	NW
LC00_Grav *	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC01_Struc	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC02_Equip	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC03_Pip	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC04_Inst	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC05_Elec	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC06_Var	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC07_Live	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
LC08_Wind_N	1.35	-	-	-	-	-	-	-
LC09_Wind_NE	-	1.35	-	-	-	-	-	-
LC10_Wind_E	-	-	1.35	-	-	-	-	-
LC11_Wind_SE	-	-	-	1.35	-	-	-	-
LC12_Wind_S	-	-	-	-	1.35	-	-	-
LC13_Wind_SW	-	-	-	-	-	1.35	-	-
LC14_Wind_W	-	-	-	-	-	-	1.35	-
LC15_Wind_NW	-	-	-	-	-	-	-	1.35
LC16_Ice	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35

2) Combined load cases factors (CLC factors)

- Each code has his own CLC factors.

	Eurocode							
Load case name	N	NE	E	SE	S	SW	W	NW
LC00_Grav *	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
LC01_Struc	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
LC02_Equip	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
LC03_Pip	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
LC04_Inst	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
LC05_Elec	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
LC06_Var	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
LC07_Live	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
LC08_Wind_N	0.6	-	-	-	-	-	-	-
LC09_Wind_NE	-	0.6	-	-	-	-	-	-
LC10_Wind_E	-	-	0.6	-	-	-	-	-
LC11_Wind_SE	-	-	-	0.6	-	-	-	-
LC12_Wind_S	-	-	-	-	0.6	-	-	-
LC13_Wind_SW	-	-	-	-	-	0.6	-	-
LC14_Wind_W	-	-	-	-	-	-	0.6	-
LC15_Wind_NW	-	-	-	-	-	-	-	0.6
LC16_Ice	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

2) Combined load cases factors (CLC factors)

- Each code has his own CLC factors.

Load case name	ISO							
	N	NE	E	SE	S	SW	W	NW
LC00_Grav *	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC01_Struc	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC02_Equip	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC03_Pip	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC04_Inst	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC05_Elec	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC06_Var	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
LC07_Live	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
LC08_Wind_N	1.35	-	-	-	-	-	-	-
LC09_Wind_NE	-	1.35	-	-	-	-	-	-
LC10_Wind_E	-	-	1.35	-	-	-	-	-
LC11_Wind_SE	-	-	-	1.35	-	-	-	-
LC12_Wind_S	-	-	-	-	1.35	-	-	-
LC13_Wind_SW	-	-	-	-	-	1.35	-	-
LC14_Wind_W	-	-	-	-	-	-	1.35	-
LC15_Wind_NW	-	-	-	-	-	-	-	1.35
LC16_Ice	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

2) Combined load cases factors (CLC factors)

- Each code has his own CLC factors.

Load case name	Norsok							
	N	NE	E	SE	S	SW	W	NW
LC00_Grav *	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC01_Struc	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC02_Equip	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC03_Pip	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC04_Inst	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC05_Elec	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LC06_Var	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
LC07_Live	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
LC08_Wind_N	0.7	-	-	-	-	-	-	-
LC09_Wind_NE	-	0.7	-	-	-	-	-	-
LC10_Wind_E	-	-	0.7	-	-	-	-	-
LC11_Wind_SE	-	-	-	0.7	-	-	-	-
LC12_Wind_S	-	-	-	-	0.7	-	-	-
LC13_Wind_SW	-	-	-	-	-	0.7	-	-
LC14_Wind_W	-	-	-	-	-	-	0.7	-
LC15_Wind_NW	-	-	-	-	-	-	-	0.7
LC16_Ice	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

2) Combined load cases factors (CLC factors)

- Each code has his own CLC factors.

Two options can be performed to compare the codes:

A) Use their own CLC factors for each code

B) Use the same CLC factors for all of them, e.g., 1.0

3) Security factors

- Some codes has their own security factors.
- For all the codes, security factors have been taken as one.

4) Formulation for usage factors

- Each code has his own formulas for UFs
- Obviously, no changes can be done

Aspects related to the codes that determine UF:

1) Acting loads formulation
2) Combined load cases factors
3) ~~Security factors~~
4) ~~Usage factors formulation~~

- Combinations can be just made with 1) and 2)
  1) Acting loads formulation
     - A) Own loads for each code
     - B) Same loads for all the codes
  2) CLC factors
     - A) Own CLC factors for each code
     - B) Same CLC factors for all the codes
- Four possible combinations: 1A-2A, 1A-2B, 1B-2A, 1B-2B
- Different scenarios were built for capacity models comparison

Capacity models comparison

Scenario	Analyses
Scenario 1	Analysis 1 to 4
Scenario 2	Analysis 5 to 8
Scenario 3	Analysis 9 to 12
Scenario 4	Analysis 13 to 16

Scenario 1 — Analysis 1 to 4

- Analysis 1: API
- Analysis 2: Eurocode
- Analysis 3: ISO
- Analysis 4: Norsok

Scenario 2 — Analysis 5 to 8

- Analysis 5: API
- Analysis 6: Eurocode
- Analysis 7: ISO
- Analysis 8: Norsok

Scenario 3 — Analysis 9 to 12

- Analysis 9: API
- Analysis 10: Eurocode
- Analysis 11: ISO
- Analysis 12: Norsok

Scenario 4 — Analysis 13 to 16

- Analysis 13: API
- Analysis 14: Eurocode
- Analysis 15: ISO
- Analysis 16: Norsok

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1) Acting loads formulation

- Differences in loads do not have almost any influence in the final results
- This was obvious even before running the analysis; the differences between own loads were reduced to wind loads.

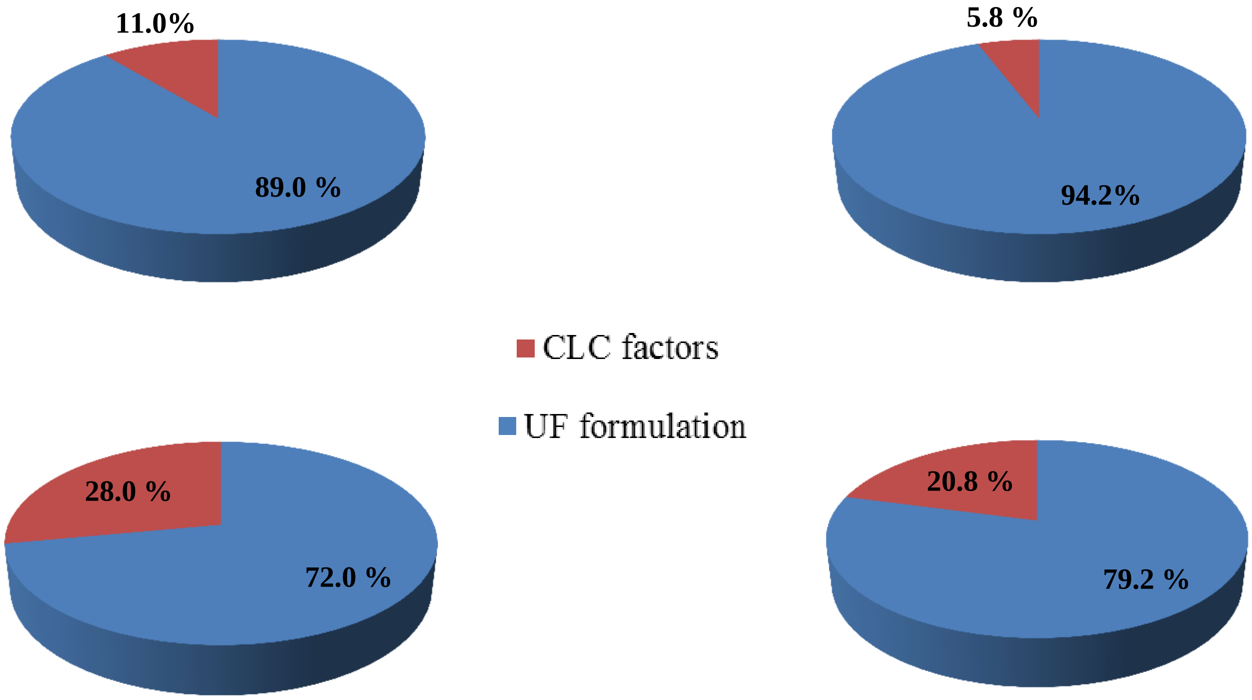
	API (kN)	Eurocode (kN)	ISO (kN)	Norsok (kN)
LC08_Wind_N	4.20	7.75	4.20	4.20
LC09_Wind_NE	5.00	8.25	5.00	5.00
LC10_Wind_E	3.00	4.10	3.00	3.00
LC11_Wind_SE	4.60	7.55	4.60	4.60
LC12_Wind_S	4.80	8.78	4.80	4.80
LC13_Wind_SW	5.50	9.09	5.50	5.50
LC14_Wind_W	3.50	4.77	3.50	3.50
LC15_Wind_NW	6.10	10.16	6.10	6.10

2) Combined load cases factors

Scenario	Analysis	Load calculation (1)	CLC factors (2)
1	1-4	Own loads	Own CLC
2	5-8	Own loads	Equal CLC
3	9-12	Equal load	Own CLC
4	13-16	Equal load	Equal CLC

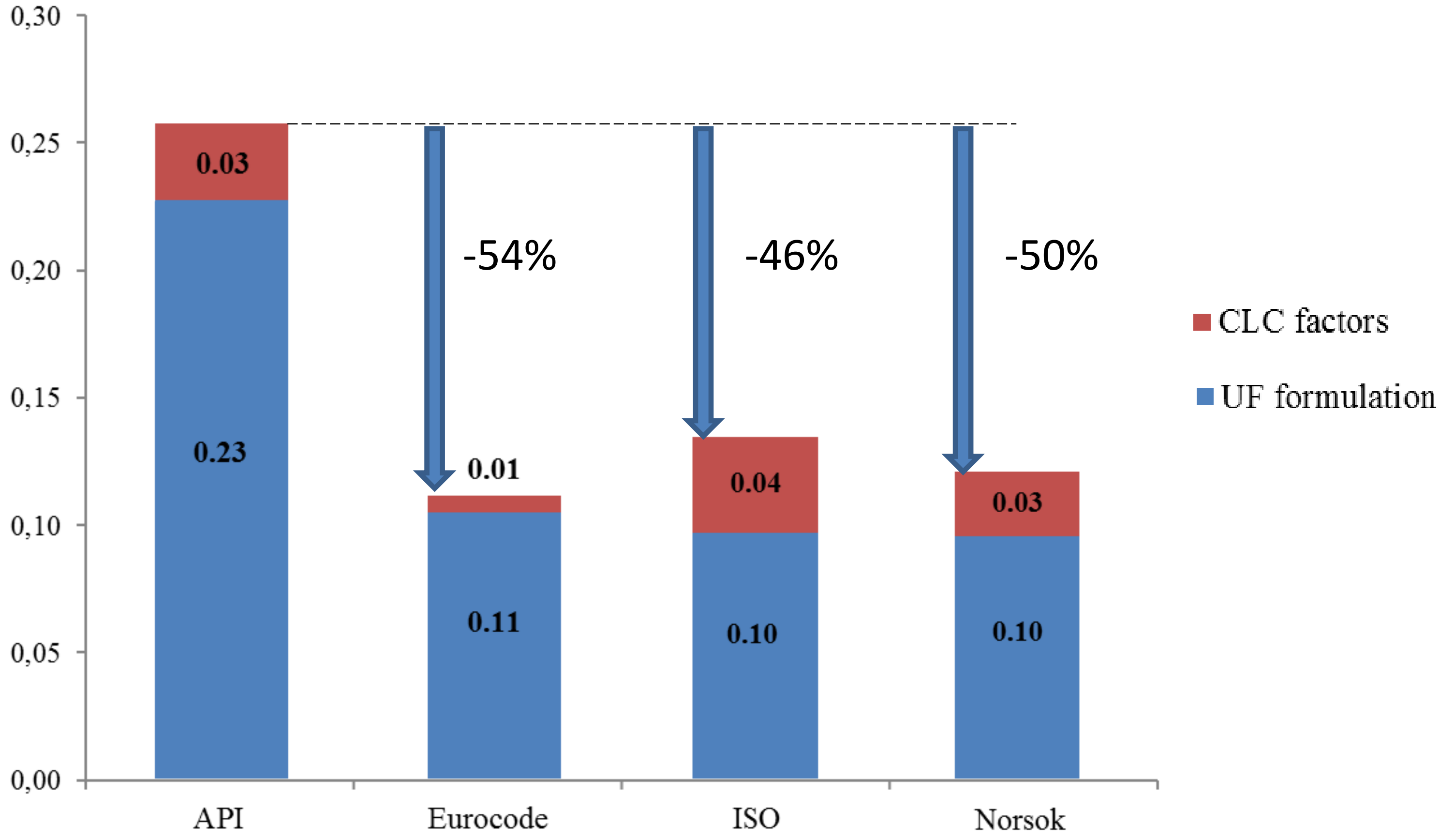
- Interesting comparison would be 1 vs 2 and 3 vs 4

2) Combined load cases factors

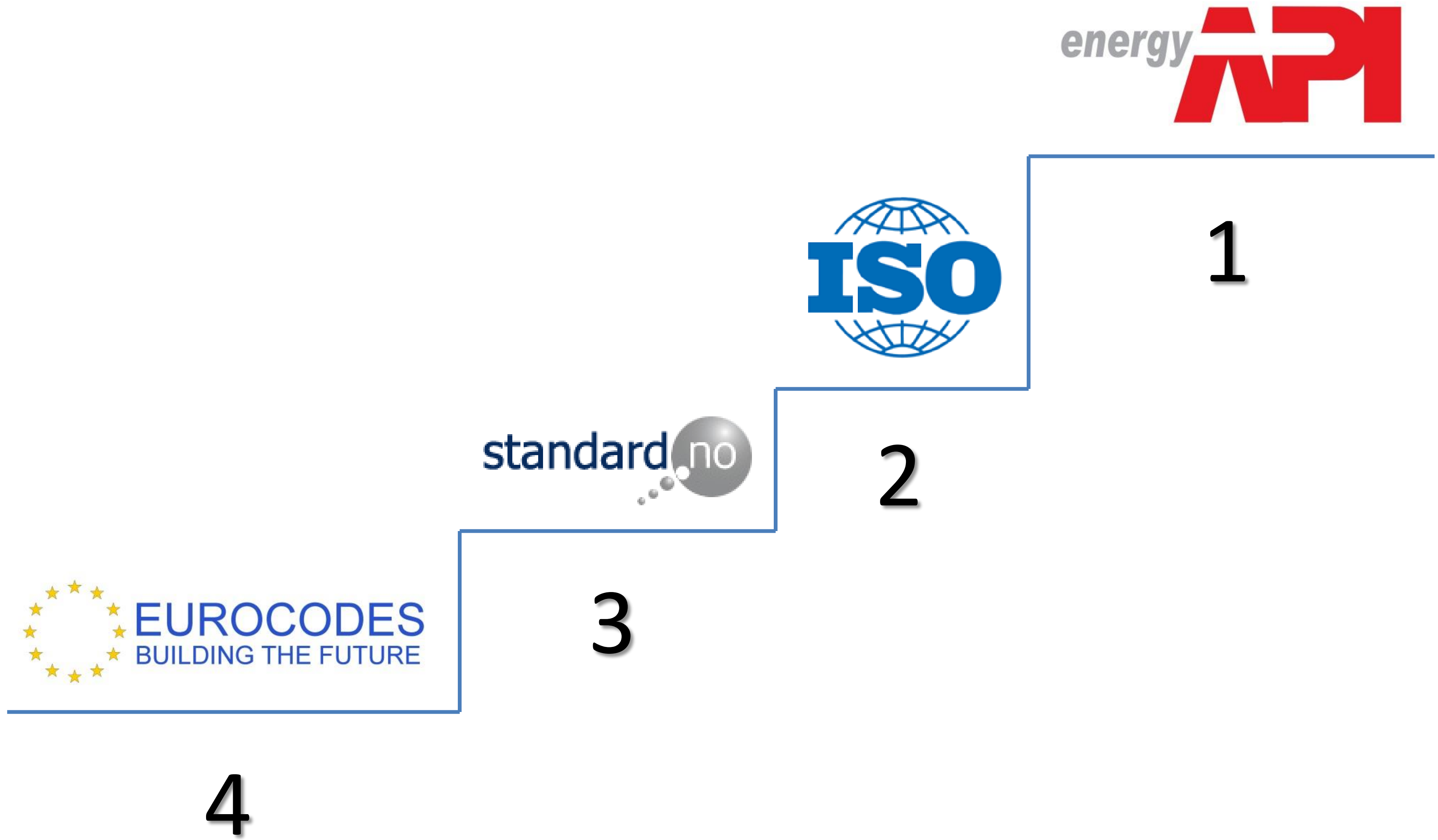


Capacity models conclusions

- API is largely the most conservative code.
- Scenario 3 vs 4, average value for all the beams



Capacity models conclusions



- Race for the most conservative code

Thank you for your attention

Dziękuję bardzo za uwagę

Muchas gracias por su atención