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The Effect on the Hull Global Analysis by the Topside Module Idealization Method

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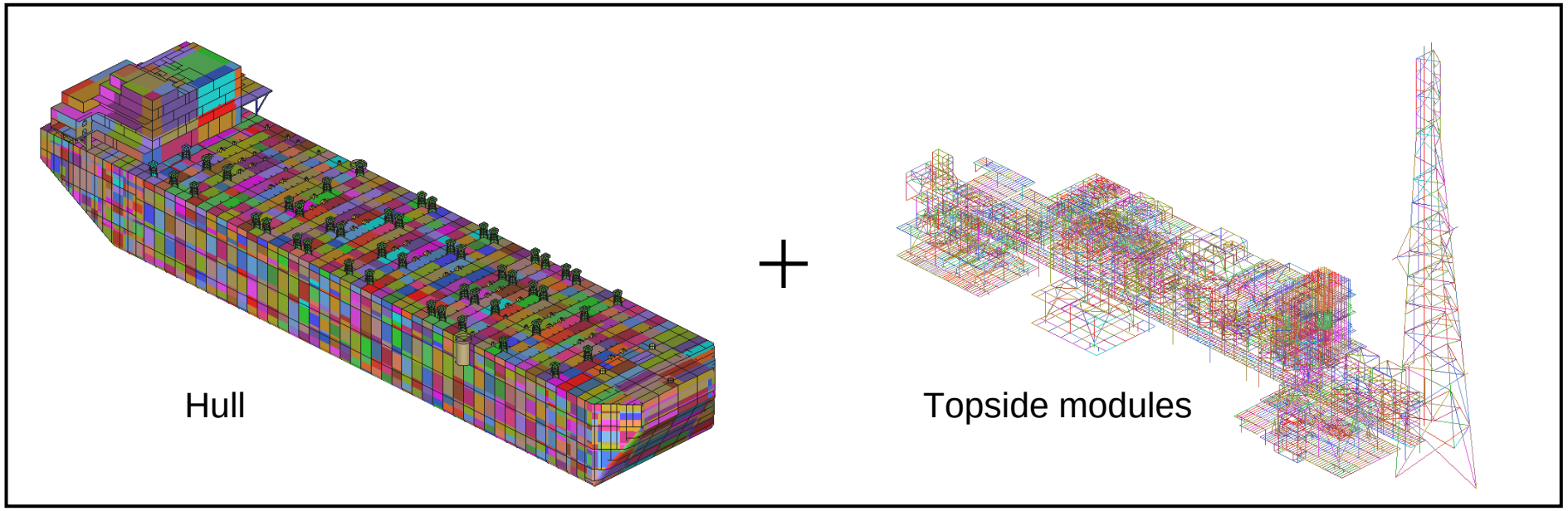
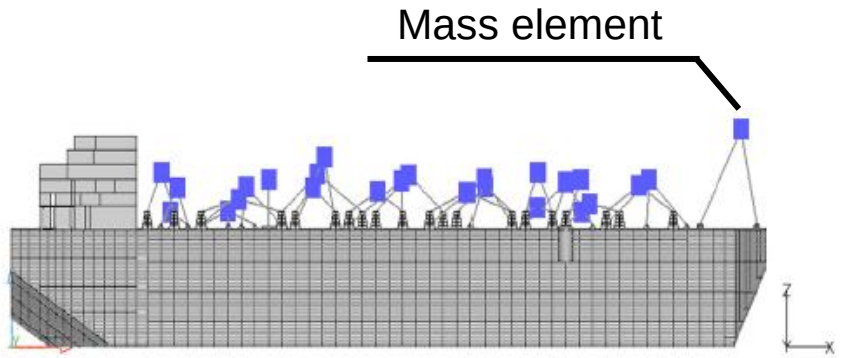
1. Introduction : Global Analysis



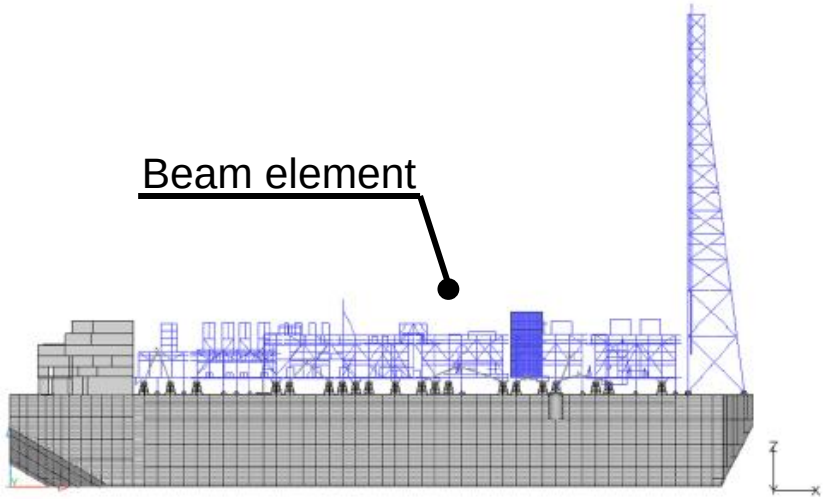
- FEA(**F**inite **E**lement **A**nalysis) using the FE model for whole ship
- Hull structure, topside modules and interface
- Assessment for overall hull girder stiffness and all primary hull members
- Difficulty & Time-consuming → Approximately 3.5 months to be required

1. Introduction : Mass Method



Component	Idealization	Description
Topside module	**Mass**	1. Mass is an element that has the same weight as the topside weight. 2. Mass should be modelled at the COG (**C**enter **O**f **G**ravity) of each topside structure.
Interface	**RBE2** (**R**igid **B**ody **E**lement)	1. RBE2 is an element that is used for connecting two elements as a rigid.
Hull	Shell & Beam	1. Shell elements for plate / Beam elements for stiffener

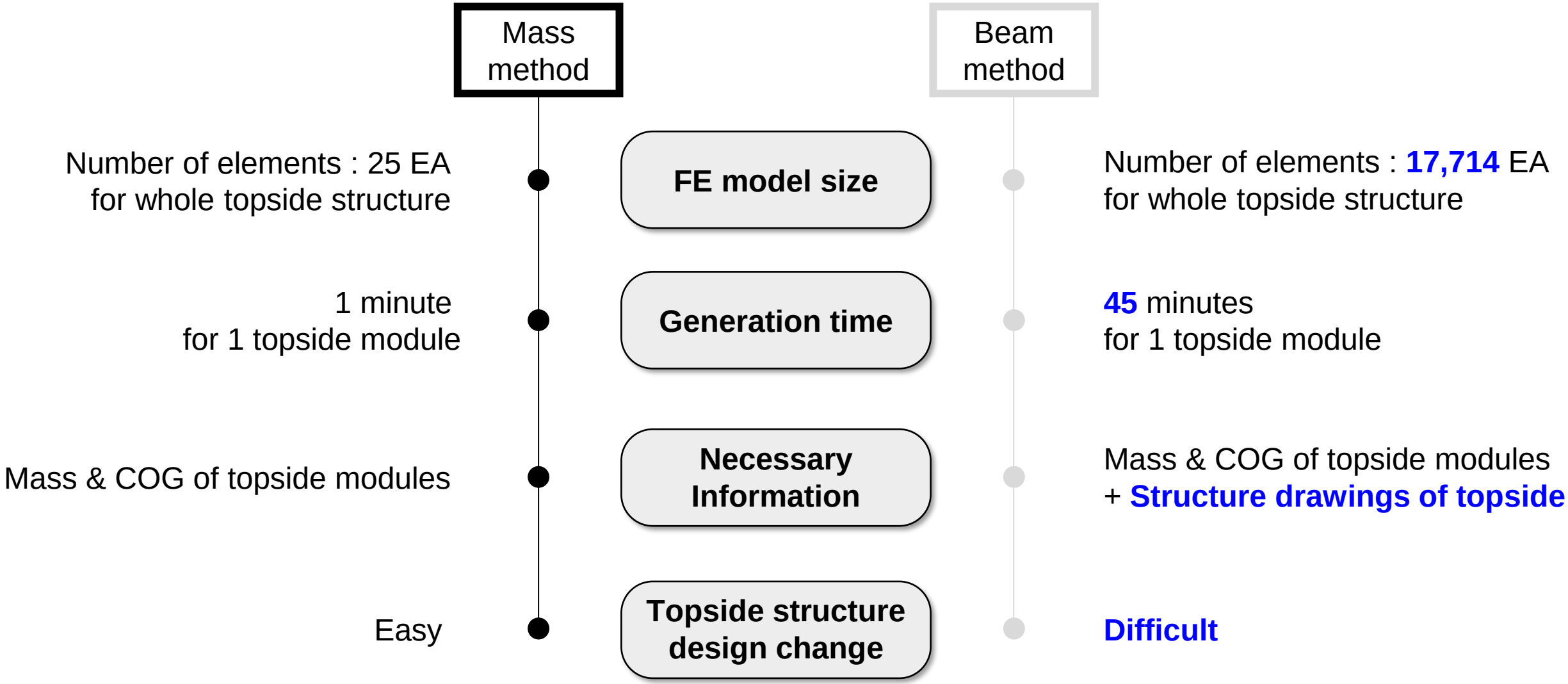
1. Introduction : Beam Method



Component	Idealization	Description
Topside module	**Beam**	1. Beam is an element that has the material and property. 2. Beam should be modelled the same as the topside structure drawings.
Interface		
Hull	Shell & Beam	1. Shell elements for plate / Beam elements for stiffener

Why this method is recently required,
- The maturity of topside structure FE model would be improved.
- The effect of inertia force distribution and deflection for topside modules would be verified.

2. Researches : Objective



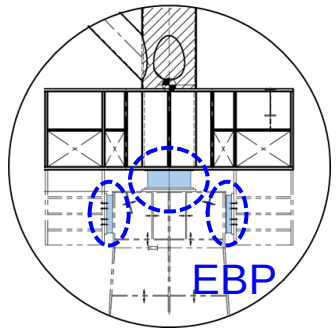
2. Researches : Methodology

➢ Comparison

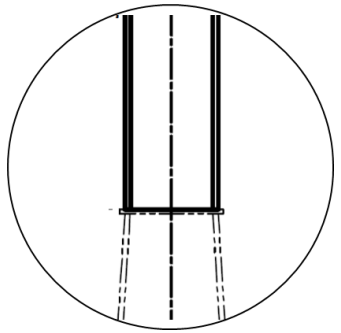
- Global analyzes for mass method and beam method are conducted.
- Except for the topside module idealization method, all other conditions are the same.
- The results of the two(2) global analyses are compared.

➢ Topside modules are classified according to the interface type.

Topside module	Interface type
Sliding type	The topside modules and hull structures are connected via **EBP**(**E**lastomeric **B**earing **P**ad).
Welding type	The topside modules and hull structures are directly connected by **welding.**



[Sliding type]

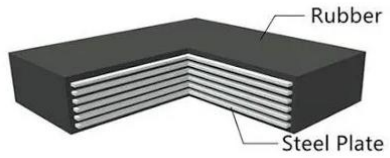

[Welding type]

➢ Study cases

Study 1	Definition of how to idealize EBP
Study 2	Comparison of mass method and beam method for sliding type
Study 3	Comparison of mass method and beam method for welding type

2. Researches : Study 1

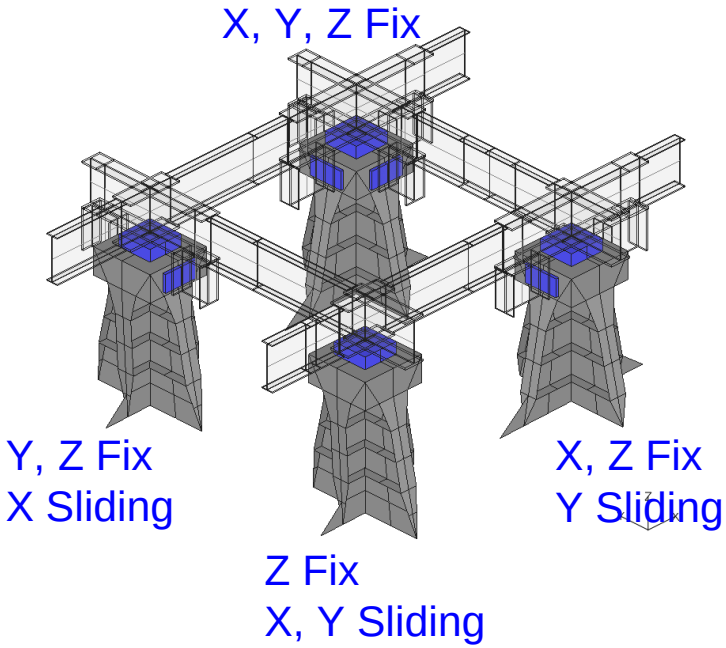
- Definition of how to idealize EBP



- EBP
  - It is a steel plate laminated rubber.
  - It is used to accommodate axial, shear and rotational movement so it keeps structures safe from impact, damage and deformation.

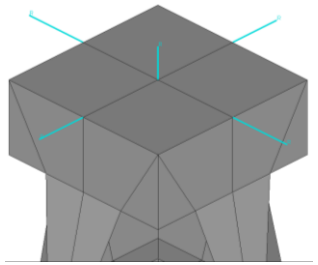
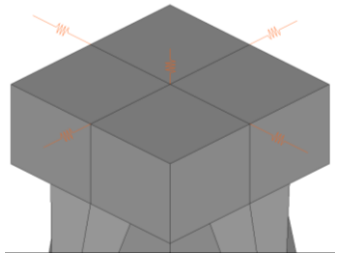
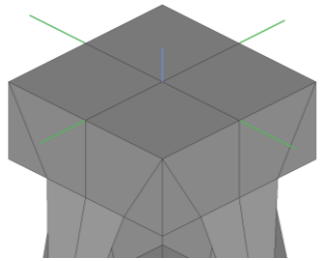
- Features of EBP

Features	Study item
1) Rubber	How to idealize the rubber properties
2) Friction	How to consider the friction force caused by sliding
3) Contact	How to consider the face contact



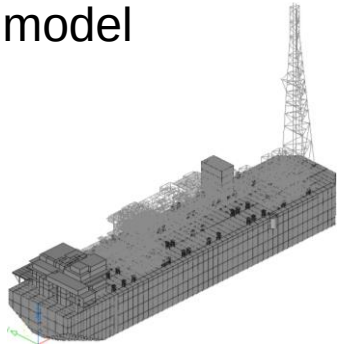
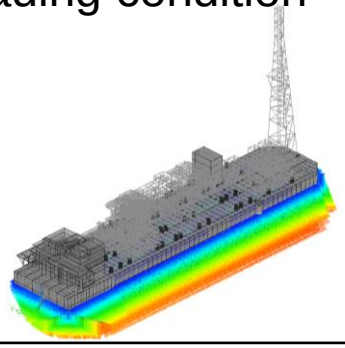
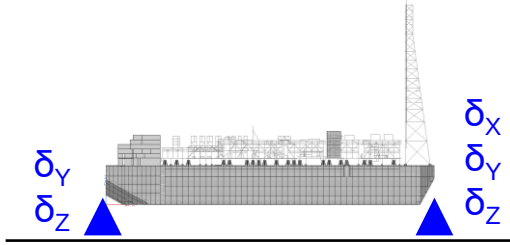
⇒ In order to accurately distribute the inertia force by the topside modules to the hull, EBP idealization study is conducted.

2. Researches : Study 1 – Cases

Case		Case 1 : RBE2	Case 2 : Spring	Case 3 : Rod
Description		An element used to connect two(2) elements as rigid body 	An element that has a stiffness and is used where a spring connection is required 	An element that has axial stiffness and is used to idealize beam structures with width and height 
Reason for selection		RBE2 is useful to simply connect the two(2) elements without any additional information.	In order to consider the stiffness of rubber	In order to consider the stiffness and dimension of rubber
Features	1) Rubber	-	It can be considered by inputting stiffness.	
	2) Friction	Ignored (Friction reduces the reaction loads because it acts in the opposite direction to the behavior of the topside structure.)		
	3) Contact	Ignored (The scope of this research is linear analysis.)		
Information for using this element		No additional information is required. → **Simple to use**	EBP stiffness is needed.	EBP stiffness and dimension are needed.

2. Researches : Study 1 - Analysis Condition

❖ Program : S-DLA (**S**HI **D**ynamic **L**oading **A**pproach for global analysis)

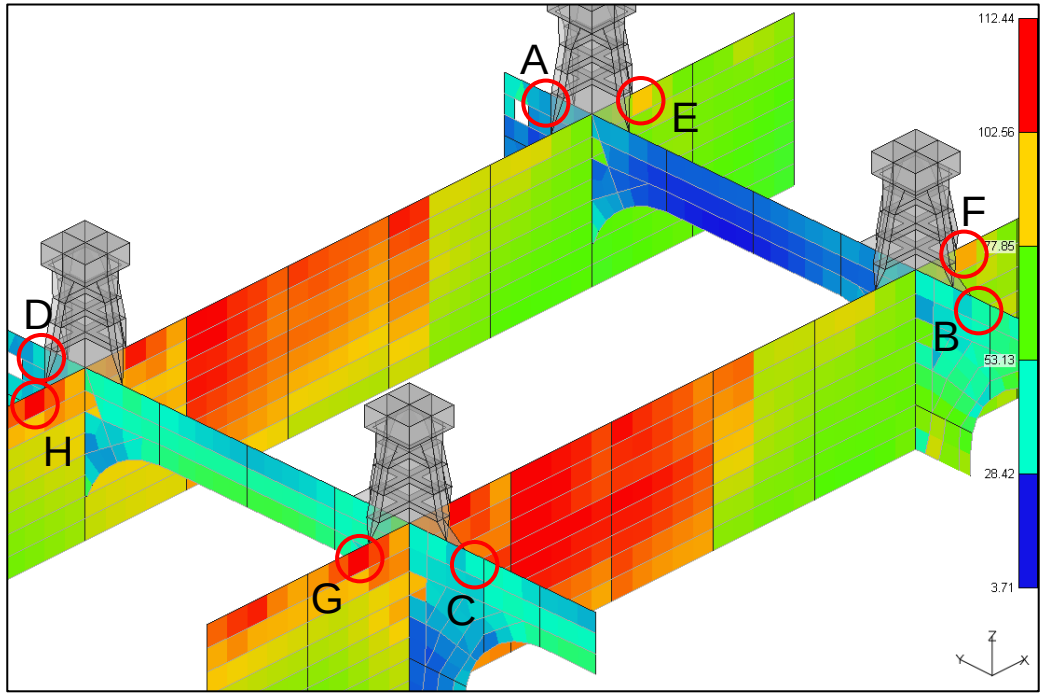
FE model 	• Type : FPSO • Size : VLCC class of about 300m • Mesh size : 1 longitudinal stiffener spacing (800~900 mm) • Topside modules : beam model • Interface : **RBE2 / Spring / Rod**
Loading condition 	• Condition : Full load condition • Loads : Gravity / External sea pressure / Internal tank pressure / Topside weight • DLP (Dominant Load Parameter) : Vertical bending moment(Hog, Sag) / Vertical shear force(Max, Min) / Horizontal bending moment(Pos, Neg)
Boundary condition 	• Simple support : To minimize the boundary effect

2. Researches : Study 1 – Results

➢ Von-mises stress

(MPa)	Case 1 (RBE2)	Case 2 (Spring)	Case 3 (Rod)	(Max – Min) / Criteria[1)]
A	18.39	18.41	18.42	0.01%
B	32.20	32.12	32.14	0.03%
C	28.27	28.28	28.27	0.00%
D	24.82	24.79	24.79	0.01%
E	78.66	78.63	78.68	0.02%
F	82.32	82.34	82.35	0.01%
G	111.49	111.52	111.51	0.01%
H	108.04	108.07	108.13	0.03%

Note 1) Criteria : LR allowable stress (319.5 MPa)

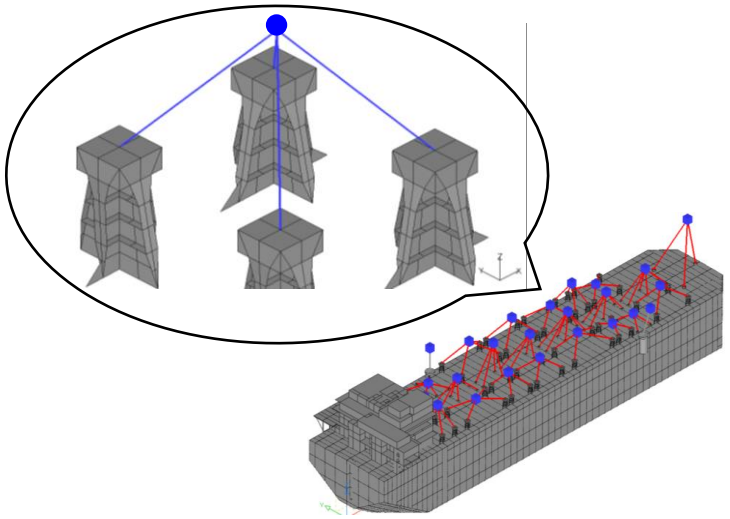
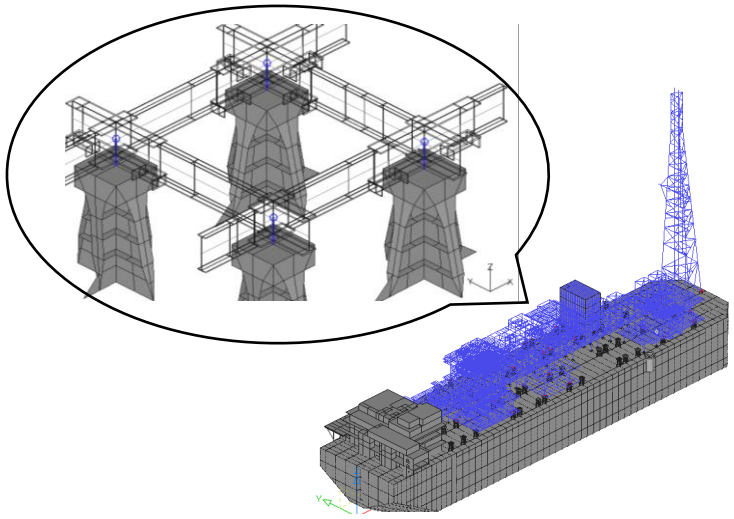


- 8 points are selected in midship & the areas under the module supports.
- The study results show that stresses are almost same in all cases.
- What the important thing in EBP idealization is not the type of elements but **the force distribution to hull**.

⇒ RBE2 which is familiar, fast and simple element should be applied to EBP idealization.

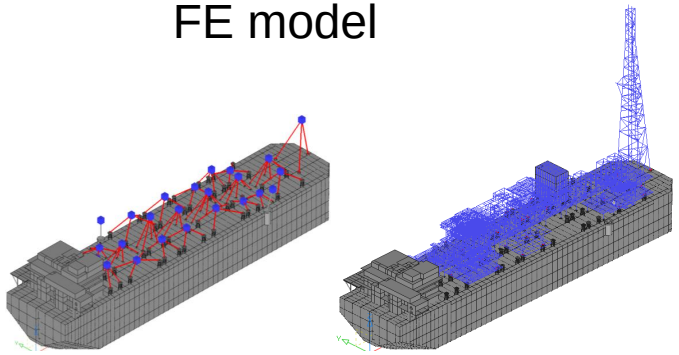
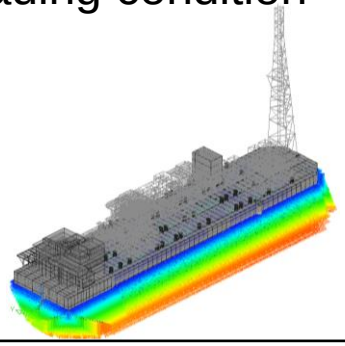
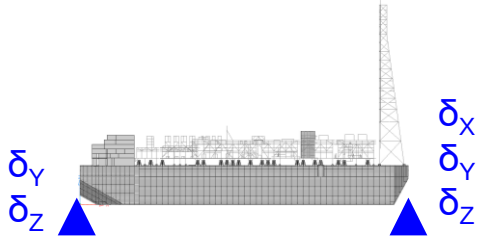
2. Researches : Study 2

- Comparison of mass method and beam method for sliding type
- Cases for study 2
  - It is decided to use RBE2 for EBP idealization in study 1.
  - Based on this, two(2) cases are selected.

Case	**Case 1 : Mass**	**Case 2 : Beam**
Description	All topside modules are idealized as **mass** element.	All topside modules are idealized as beam element.
FE model		

2. Researches : Study 2 – Analysis Condition

❖ Program : S-DLA (**S**HI **D**ynamic **L**oading **A**pproach for global analysis)

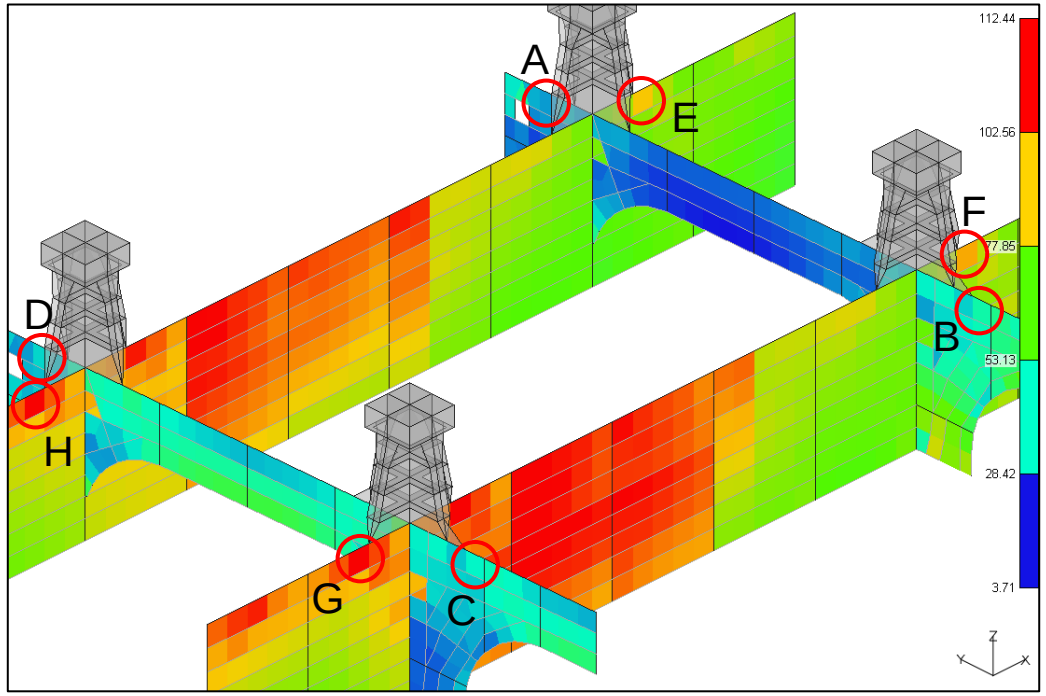
FE model 	• Type : FPSO • Size : VLCC class of about 300m • Mesh size : 1 longitudinal stiffener spacing (800~900 mm) • Topside modules : **Beam and mass model** • Interface : RBE2
Loading condition 	• Condition : Full load condition • Loads : Gravity / External sea pressure / Internal tank pressure / Topside weight • DLP (Dominant Load Parameter) : Vertical bending moment(Hog, Sag) / Vertical shear force(Max, Min) / Horizontal bending moment(Pos, Neg)
Boundary condition 	• Simple support : To minimize the boundary effect

2. Researches : Study 2 – Results

- Von-mises stress

(MPa)	Case 1 (Mass)	Case 2 (Beam)	(Max – Min) / Criteria[1)]
A	16	18	0.8%
B	32	32	0.2%
C	27	28	0.3%
D	23	25	0.7%
E	80	79	-0.4%
F	81	82	0.6%
G	111	112	0.3%
H	109	108	-0.1%

Note 1) Criteria : LR allowable stress (319.5 MPa)

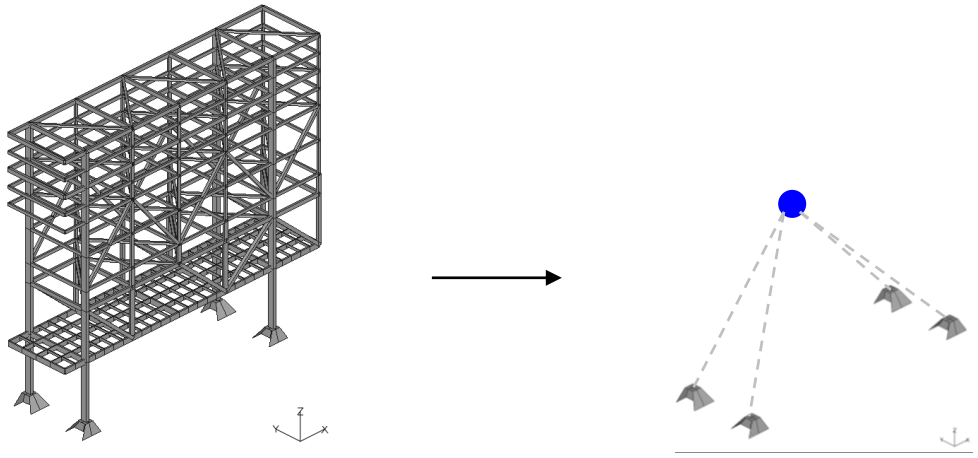


- 8 points are selected in midship & the areas under the module supports.
- The study results show that stresses are almost same in two(2) cases.
- What the important thing for topside module idealization is not the type of elements but the **weight and COG**.

⇒ Mass which is familiar, fast and simple element should be applied to topside module idealization.

2. Researches : Study 3

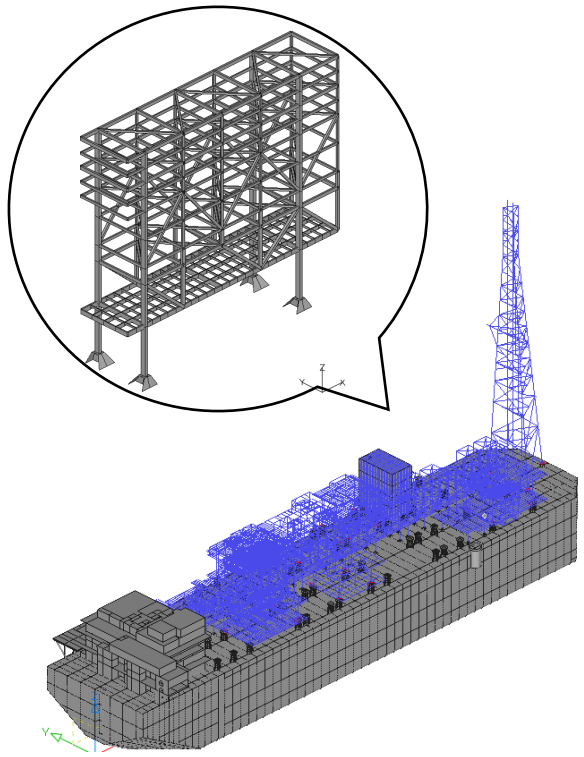
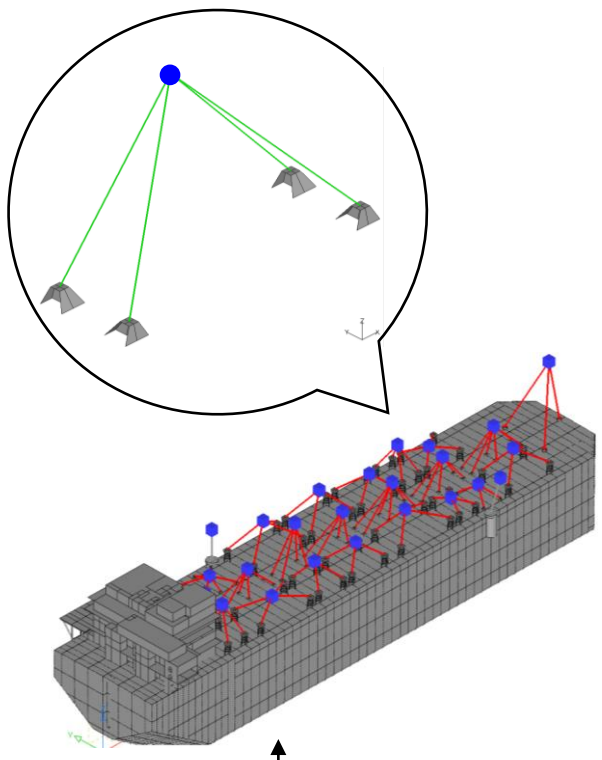
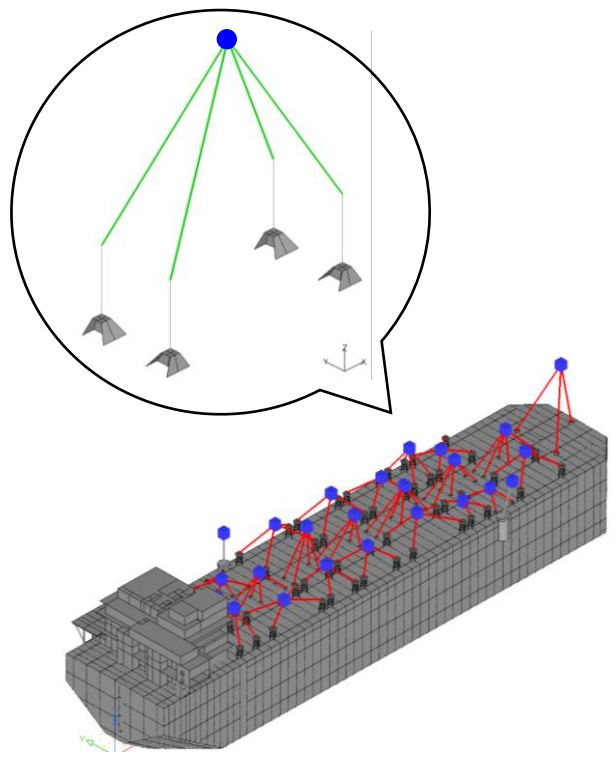
- Comparison of mass method and beam method for welding type
- Interface for welding type
  - The topside modules and hull structures are directly connected by welding.
  - If beam element for topside module is replaced mass, topside and hull structures are disconnected.



Beam method　　Mass method

⇒ A comparison study is conducted along with the interface idealization study.

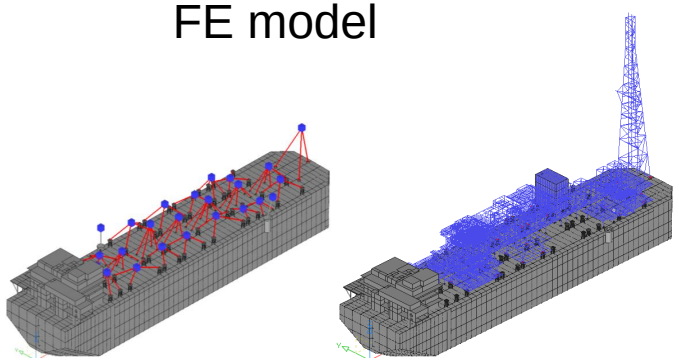
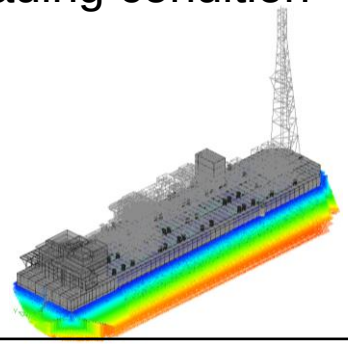
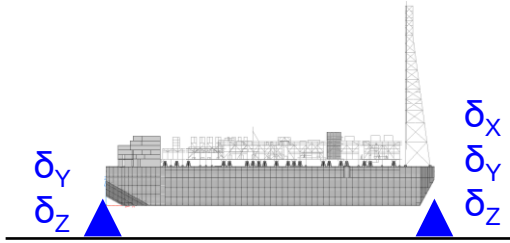
2. Researches : Study 3 – Cases

Case	Case 1 : Beam	Case 2 : Mass	Case 3 : Hybrid
Topside module	Beam	Mass	Mass
Interface		RBE2	**Beam + RBE2**
FE model			

The same method as sliding type is applied.
(Connect the top plate of interface supports and mass element)

2. Researches : Study 3 – Analysis Condition

❖ Program : S-DLA (**S**HI **D**ynamic **L**oading **A**pproach for global analysis)

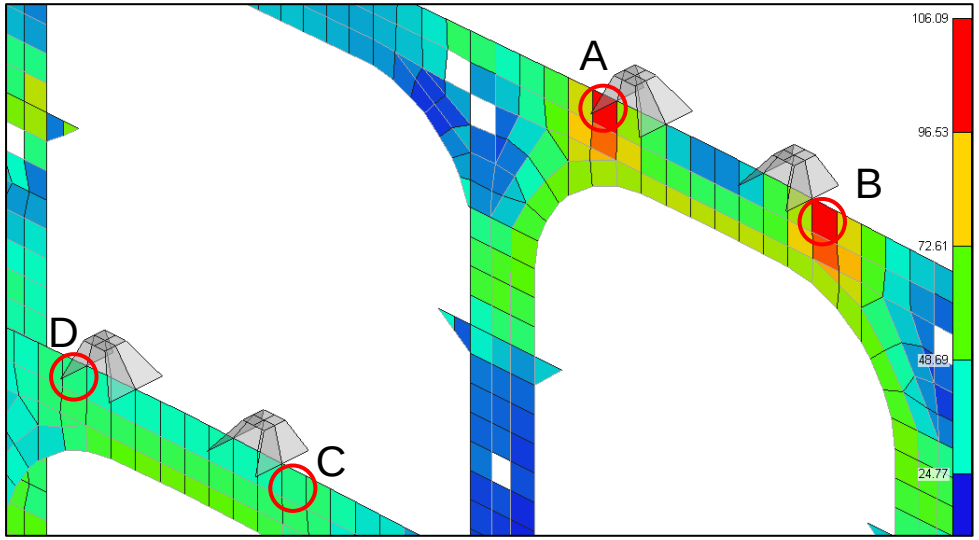
FE model 	• Type : FPSO • Size : VLCC class of about 300m • Mesh size : 1 longitudinal stiffener spacing (800~900 mm) • Topside modules : **Beam and mass model** • Interface : **Beam, RBE2 and hybrid (Beam+RBE2)**
Loading condition 	• Condition : Full load condition • Loads : Gravity / External sea pressure / Internal tank pressure / Topside weight • DLP (Dominant Load Parameter) : Vertical bending moment(Hog, Sag) / Vertical shear force(Max, Min) / Horizontal bending moment(Pos, Neg)
Boundary condition 	• Simple support : To minimize the boundary effect

2. Researches : Study 3 – Results

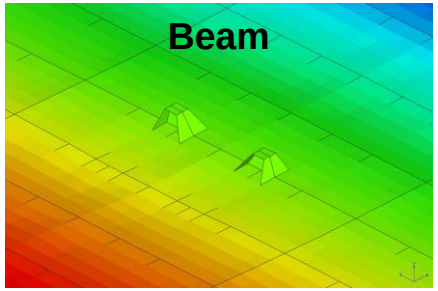
➢ Von-mises stress

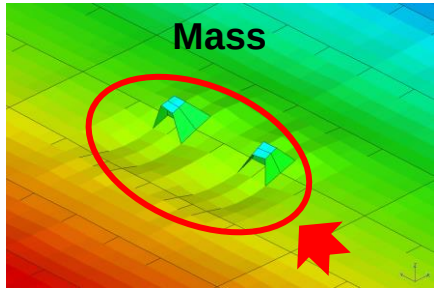
(MPa)	Case 1 (Beam)	Case 2 (Mass)	Case 3 (Hybrid)	(Max – Min) / Criteria[1)]
A	102	106	103	1.3%
B	104	102	101	0.7%
C	33	39	34	1.7%
D	34	34	31	0.8%

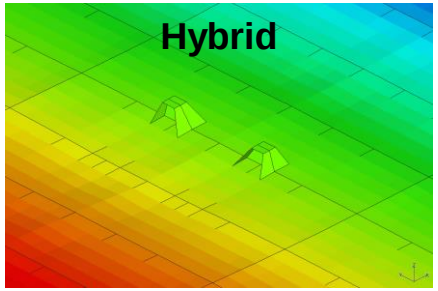
Note 1) Criteria : LR allowable stress (319.5 MPa)



- 4 points are selected in midship & the areas under the module supports.
- The study results show that stresses are almost same in all cases.
- What the important thing for topside module idealization is not the type of elements but **the weight and COG**.







Additionally, abnormal deformation in hull deck is observed in the Case 2 (Mass method) because global deformation is restricted by topside module.

⇒ Hybrid which is accurate and simple element should be applied to topside module idealization of welding type.

3. Conclusion

- The interface idealization method of sliding type is defined in study 1.
- For the sliding type, the difference between the mass method and the beam method is compared in study 2.
- The interface idealization method and the difference between the mass method and the beam method of welding type are analyzed in study 3.

- The results of all studies are summarized in the below table.

	Sliding type	Welding type
Topside module	Mass	Mass
Interface	RBE2	Hybrid (Beam+RBE2)

- In conclusion, the familiar, fast and simple mass method should be applied to global analysis.
- Eventually, these results should be technical basis for the requirement when conducting global analysis including topside modules.

Reference

- https://www.trelleborg.com/en/marine-and-infrastructure/products-solutions-and-services/infrastructure/bearings/elastomeric-bearings

- https://mocivilengineering.com/elastomeric-bearing-vs-pot-bearing/

- Guide for ‘Dynamic Loading Approach’ for Floating Production, Storage and Offloading Installation by ABS

Thank you for your attention this concludes the presentation

Questions?

Additional Study

- Type of mass element

  - There are two(2) types of mass elements used in FEA.
    - Lumped mass : A mass that has weight & MOI(Moment of Inertia) information.
    - Scalar mass : A mass that has only weight information.

(MPa)	Lumped mass		Scalar mass	(Max – Min) / Criteria
	Zero MOI	Actual MOI		
A	16	16	16	0.1%
B	32	34	31	0.9%
C	27	27	27	0.2%
D	23	23	23	0.1%
E	80	80	77	0.9%
F	81	81	78	1.2%
G	111	112	111	0.2%
H	109	108	109	0.1%

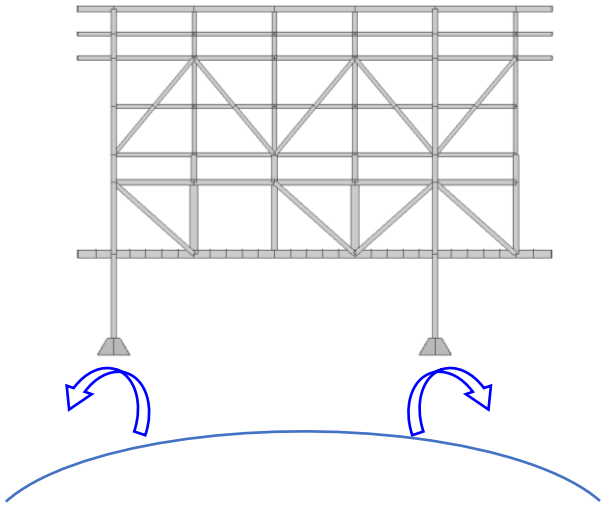
MOI of axial direction for each topside module is required.

⇒ **There is no difference in the results.** The type of mass is not important, but the important thing is **weight & COG** of topside structures.

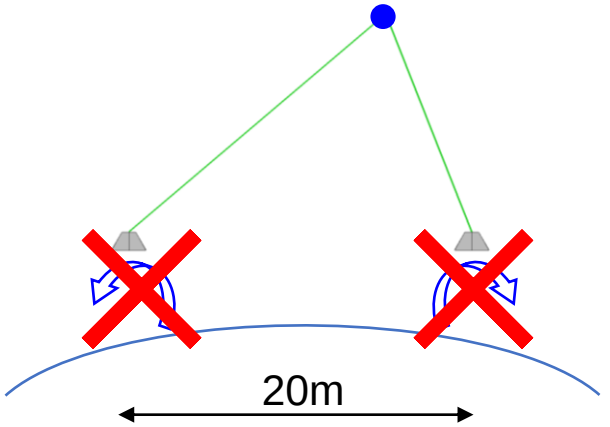
Reason of Abnormal Deformation

- Restriction of hull **global** deformation
  - The direct connection between the mass and the top plate of the interface support restricts the global deformation of the hull.
  - Therefore, Mass method does not provide accurate stress results.

Beam



Mass



Hybrid