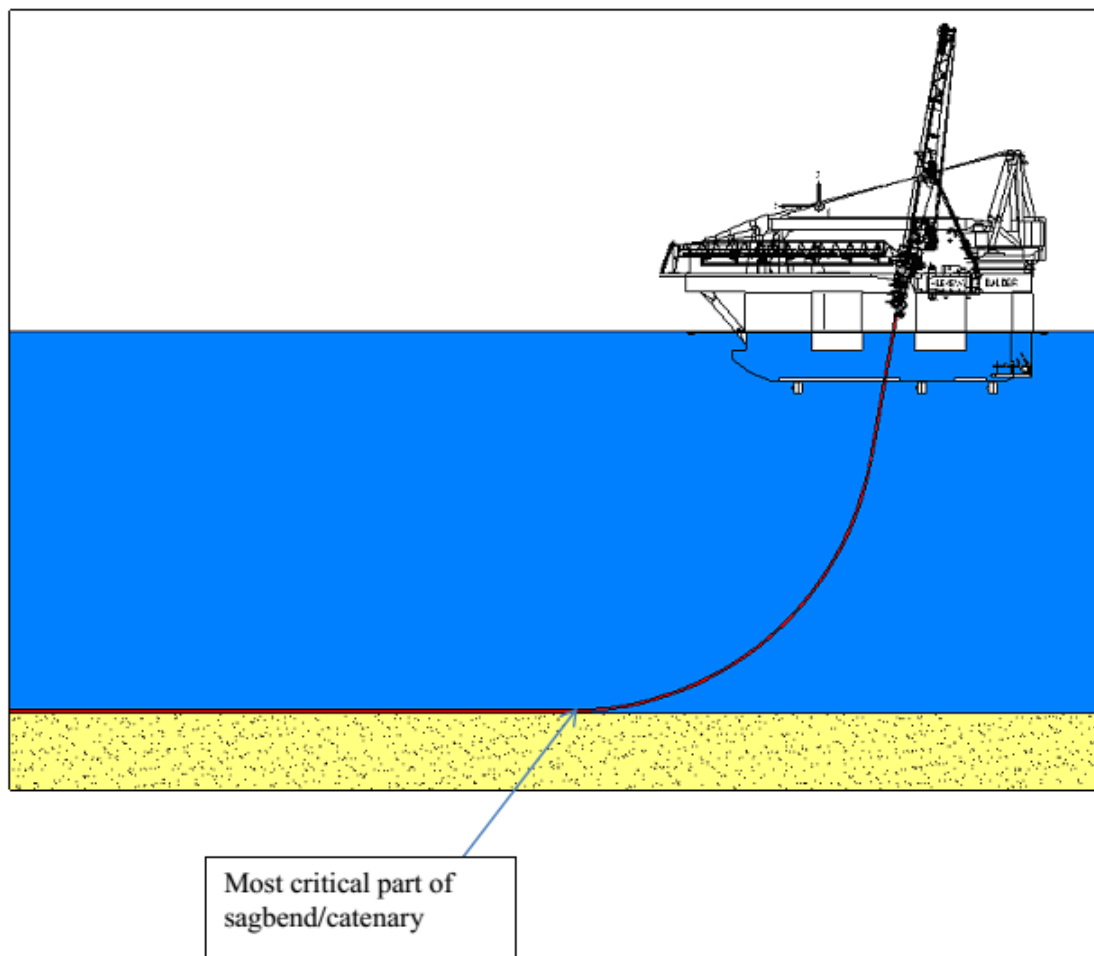


### The Pipeline Catenary:

For deepwater pipelay, the shape of the pipe catenary (the bend of the pipe towards the seabed) is determined by the tension on the pipe and not by the bending stiffness, due to the large length of the pipe.

This means that the pipe shape can be calculated using a standard analytical catenary formula (hence the name, alternative name is sagbend especially in S-Lay operations). In order to avoid buckling of the pipe at the bend at the seabed (the most critical part) a horizontal tension is needed that determines the whole shape of the catenary. A practical value for the allowable bend stress due to the pipe bend is  $0.65 \times \sigma_{\text{yield}}$ . A typical pipe quality is API X65 ( $\sigma_{\text{yield}} = 448\text{MPa}$ ).

This constant horizontal tension leads to an ever larger ramp angle (relative to horizontal) and larger pipe tension for greater water depths, as the vertical component (the submerged pipe weight) increases.



The assignment consists of three parts:

- 1.) Derive the analytical formula for the pipe tension and ramp angle, dependent on pipe properties and waterdepth by combining the standard catenary formula's (in Dutch kettinglijn formules) and the bending criterion. Note the stress due to the pipe tension can be neglected at the seabed.
- 2.) Write out the calculation for the following situation to check the formula's, please note that the dynamic top tension is 1.2 times the normal calculated tension to account for vessel motions:

Pipe OD (inch)	Pipe OD (mm)	Water Depth (m)	Wall Thickness	Dynamic Top Tension (in Tons)	Ramp Angle (degrees)	Lay Back (m)	Material	Horizontal Force (Tons)
18	457	2500	28,6	427	86,46	571	X65	26,7

- 3.) Put the formula in e.g. excel or matlab and complete the table below, to get an idea of typical pipe tensions and ramp angles:

Pipe OD (inch)	Pipe OD (mm)	Water Depth (m)	Wall Thickness	Dynamic Top Tension (in Tons)	Ramp Angle (degrees)	Lay Back (m)	Material	Horizontal Force (Tons)
18	457	2500	28,6	427	86,46	571	X65	26,7
		2000	27				X65	
		1000	27				X65	
		500	27				X65	
		250	27				X65	
		100	27				X65	
		50	27				X65	
16	406,4	2500	25,4				X65	
		1500	22,2				X65	
		500	22,2				X65	
		100	22,2				X65	
		50	22,2				X65	
12.75	323,9	3000	23,8				X65	
		2000	20,6				X65	
		1000	17,5				X65	
		500	15,9				X65	
		250	15,9				X65	
		100	15,9				X65	
		50	15,9				X65	
6.625	168,3	3000	14,3				X65	
		2000	12,7				X65	
		1000	11				X65	
		500	8,7				X65	
		250	8,7				X65	
		100	8,7				X65	
		50	8,7				X65	