Nets with bending restistance AquaSim

TR-FOU-2222-5

Revision 1

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Nets with bending resistance AquaSim

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Summary:

This document presents the possibility to analyze nets including the bending stiffness of the nets in AquaSim.

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Content

1 Introduction

For normal nets in AquaSim, the bending stiffness of the net elements are not included to the analysis. There is however the possibility to include the bending stiffness.

2 Theoretical formulation

Structural response of the elements is found by including the bending resistance of the nets. Each twine can then be modeled as a beam. Data can be put is manually or the AquaSim default data can be applied. The AquaSim default data are

For structural response the elements are built up exactly as flag shaped membrane elements. For this element type bending sti

3 Validation

3.1 Validation case 1 one element

The basic idea for this validation is to compare the net with bending stiffness to net without bending stiffness for cases where the results should be equal or very similar.

Figure 1 the net being 10 meters in the y- direction and stretching from the surface to 10 meter below at 10 meter in the x- direction.

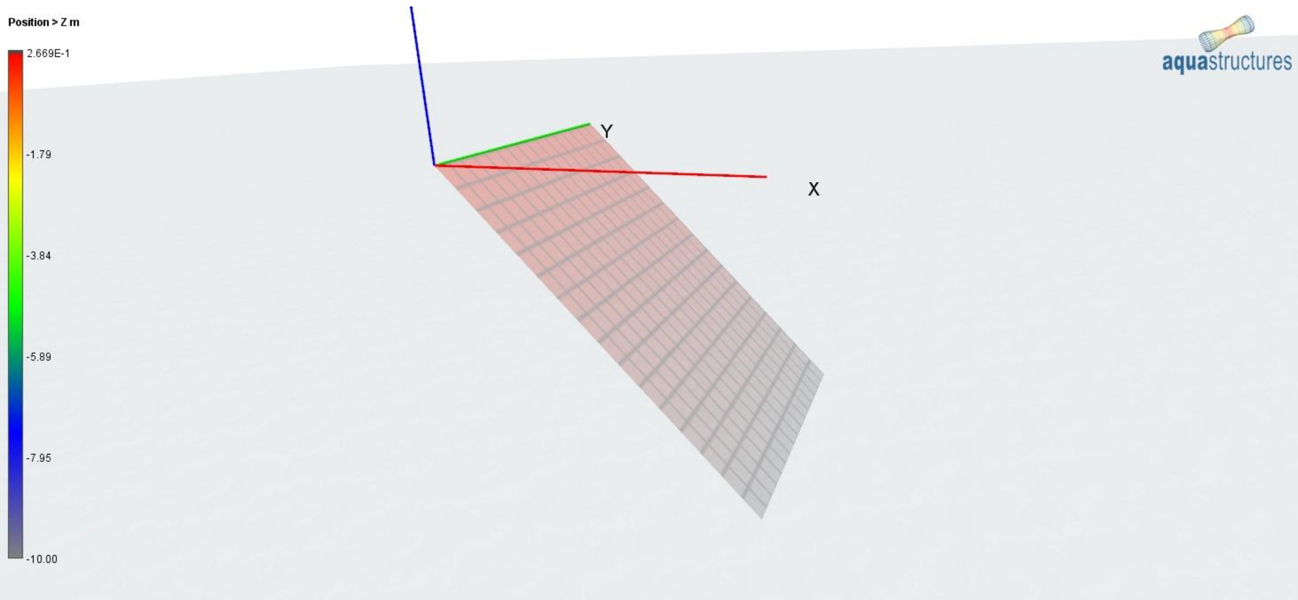

Figure 1 Analysis case with one net element for comparison of new element with bending to old element withoud bending stiffness

3.1.1 Springs at all 4 corners

The first validation case for this one element validation case is applying springs to all corners, the applying a uniform current velocity as load. The results shown in Table 1 shows how results match as they should for this case.

Table 1 Comparison of forces

No bending	**Fx**	**Fy**	**Fz**
Spring 1	7173	5534	2673
Spring 2	7173	5529	2673
Spring 3	7177	5534	2669
Spring 4	7177	5529	2669
With bending			
Spring 1	7173	5534	2673
Spring 2	7173	5529	2673
Spring 3	7177	5534	2669
Spring 4	7177	5529	2669
Delta			
Spring 1	0	0	0
Spring 2	0	0	0
Spring 3	0	0	0
Spring 4	0	0	0

3.1.2 Free hanging net exposed to current and waves

In this case the net is fixed in the two nodes in the water line in the translatory degrees of freedom. Then current and waves are applied.

Figure 2 shows a comparison of the two net elements. As there should be, there is good correspondence.

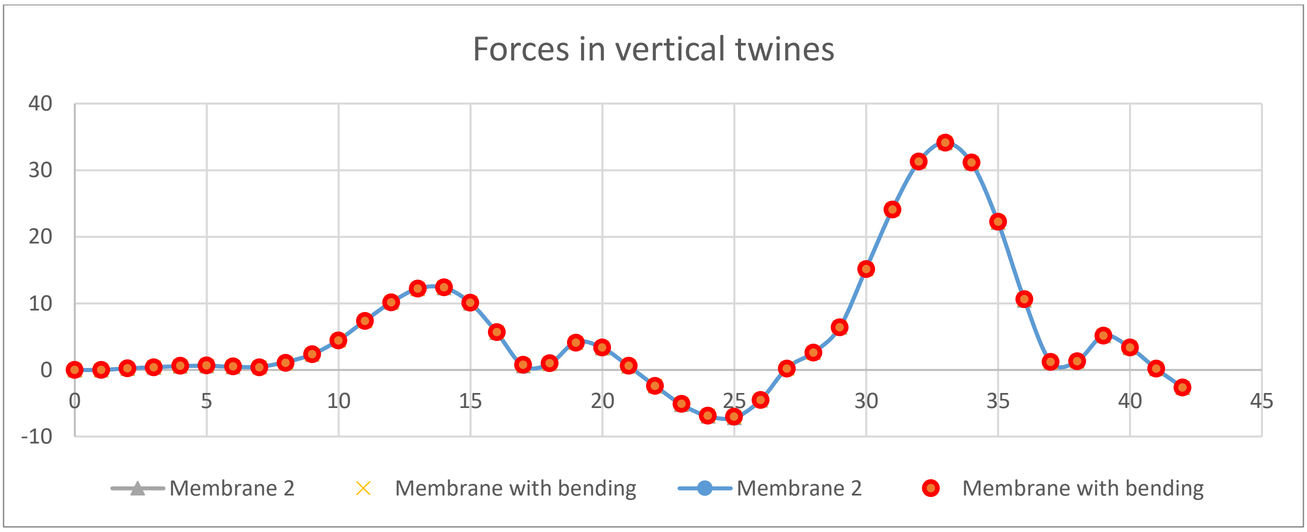

Figure 2 Blue line is membrane without bending stiffness and the red dots is the membrane with bending stiffness.

3.1.3 Comparison of bending stiffness,10 element model.

Figure 3 shows banding moment about the local z- axis for the beam model. Figure 4 shows bending moment in the vertical twines for the net with bending stiffness in the twines model. As seen from comparing Figure 3 and Figure 4, results compare well.

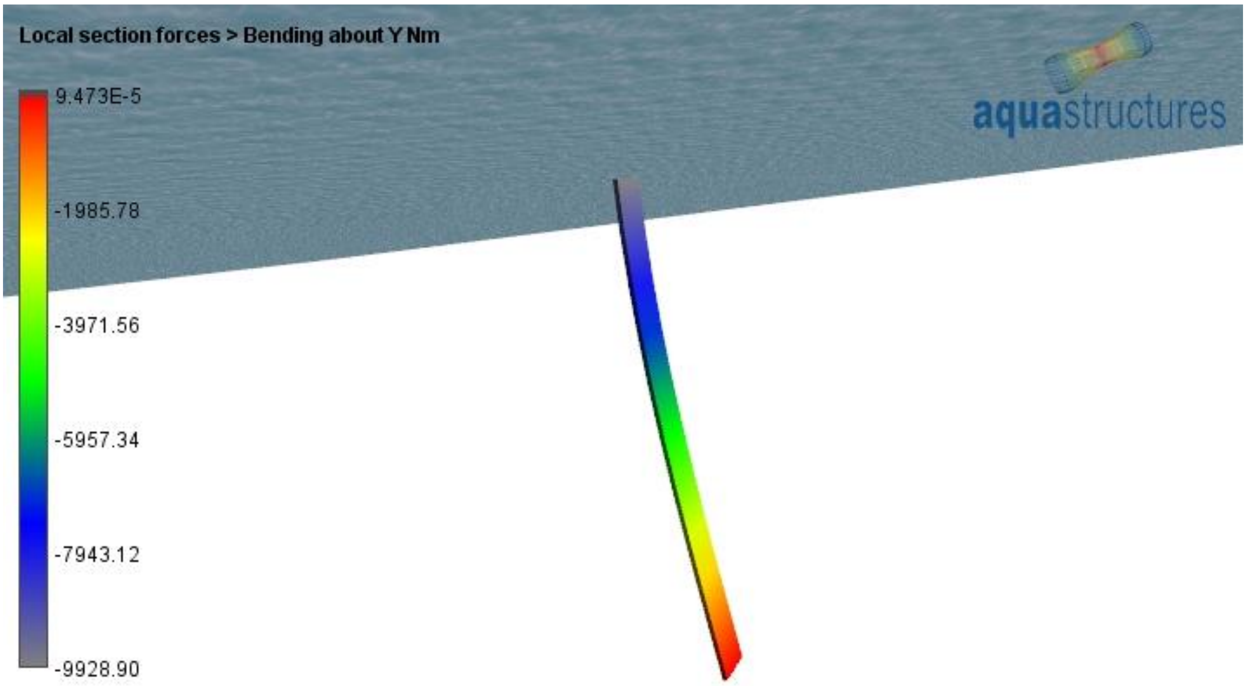

Figure 3 beam model, bending moment about local y-axis

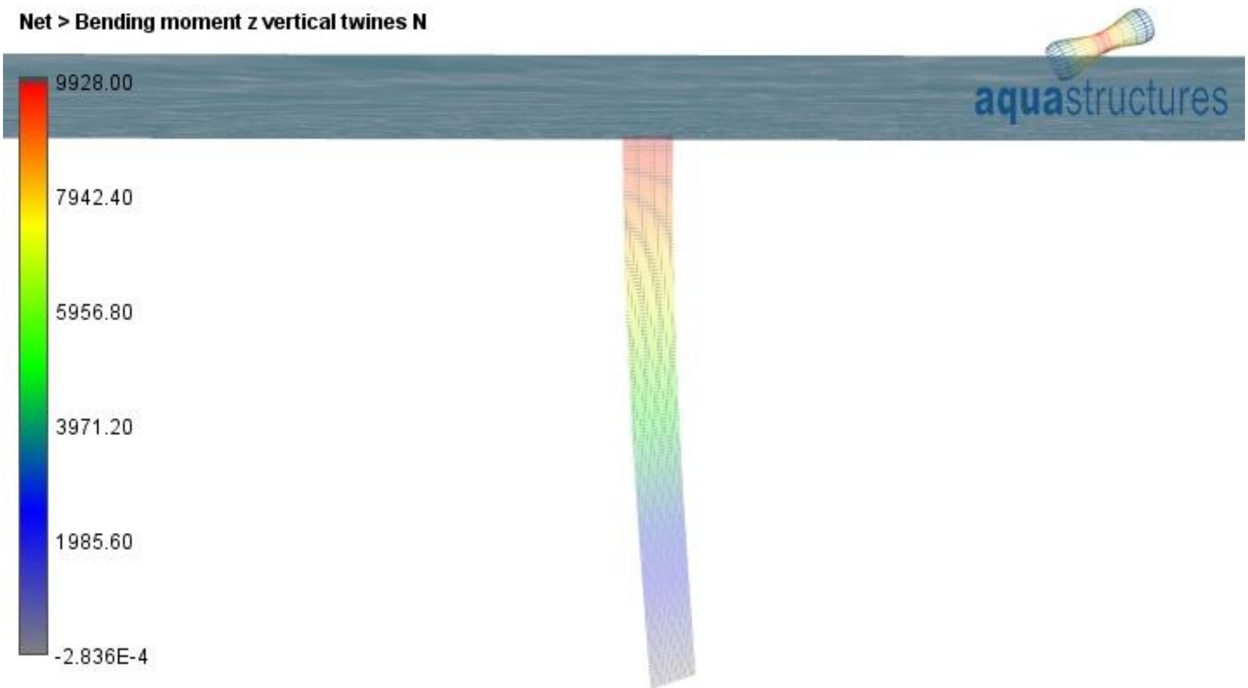

Figure 4 Net model, bending moment about local z-axis

Figure 5 shows displacement in the x-direction for the beam model and Figure 6 corresponding for the net model. As seen from comparing Figure 5 and Figure 6, results compare well.

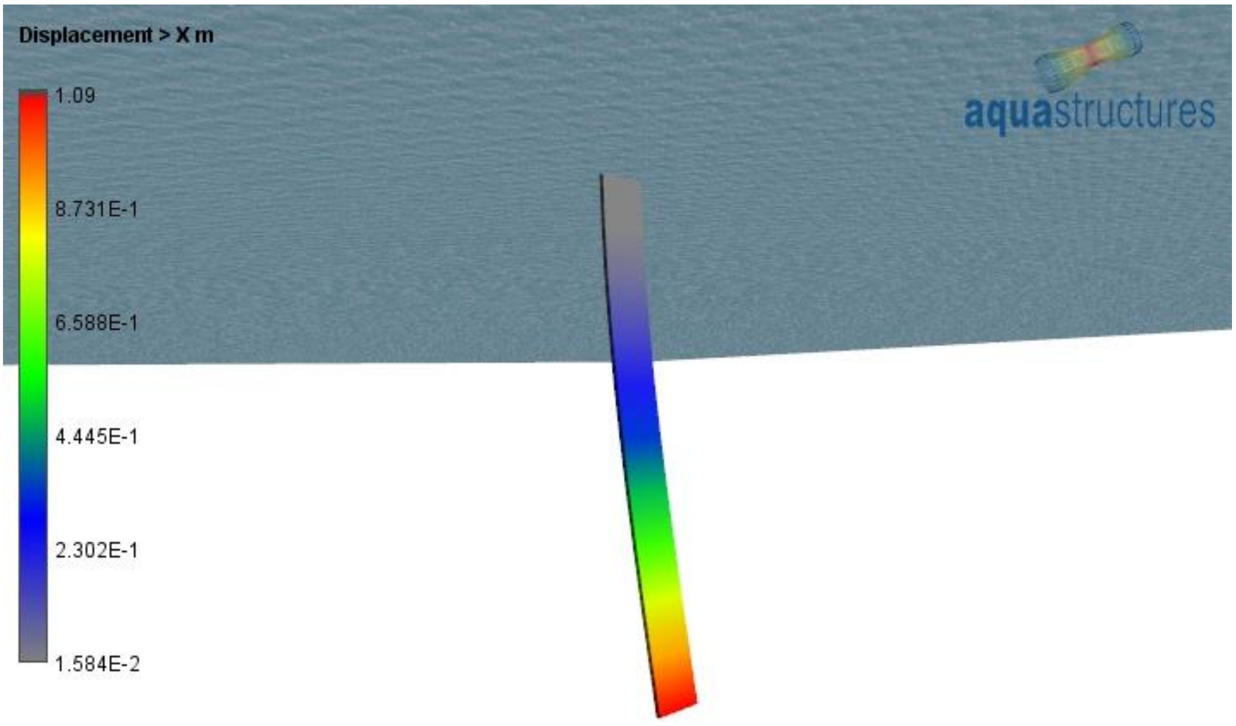

Figure 5 Displacement in the x-direction for the beam model

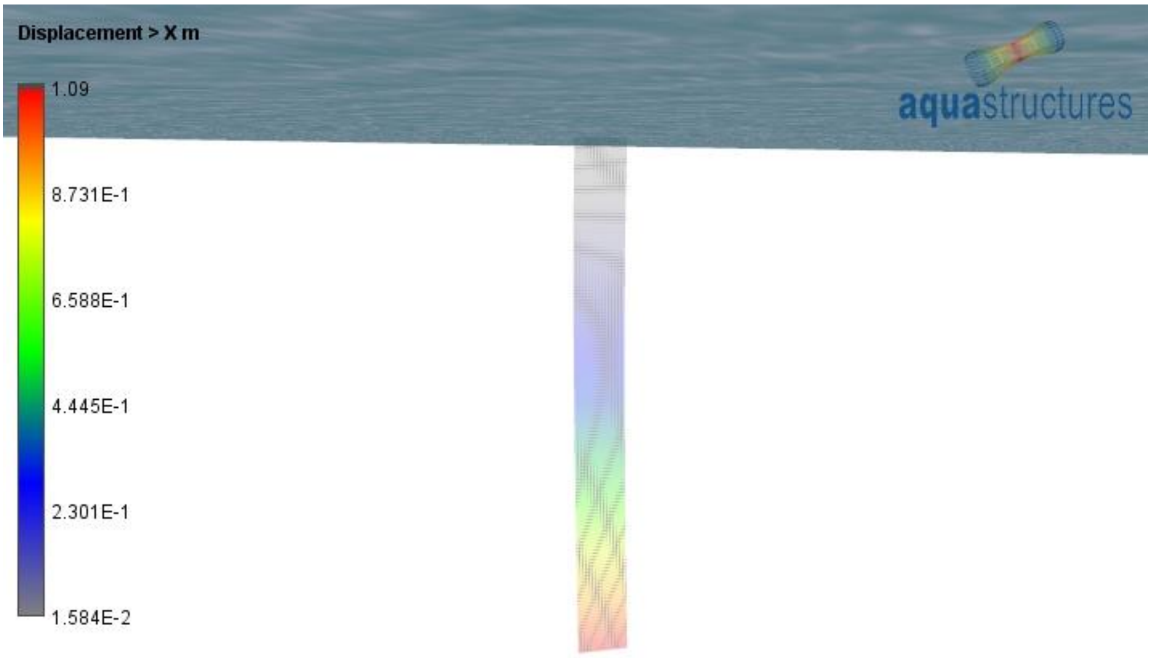

Figure 6 Displacement in the x-direction for the net model (net with bending stiffness)

3.1.4 Comparison of results for a typical fish farm cage

In this section forces are compared for accounting for bending stiffness or not

Consider the case seen in Figure 7

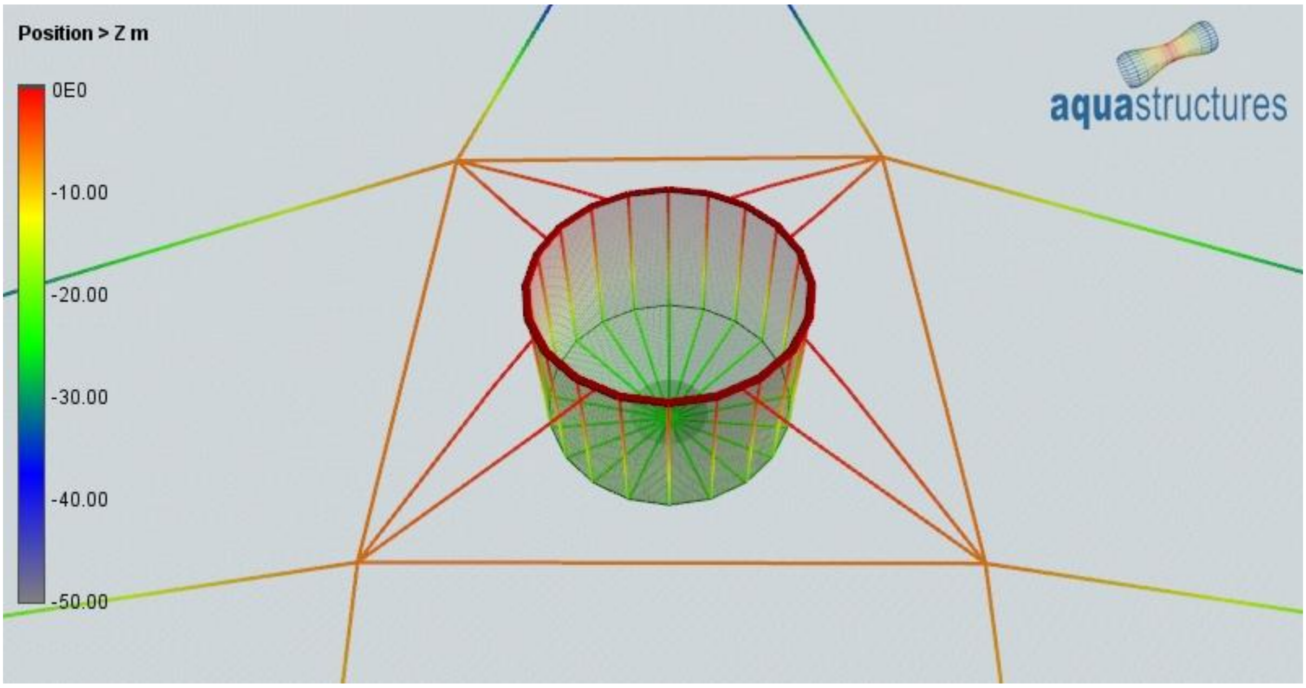

Figure 7 Analysis case for comparison

For the case in Figure 7, forces are compared at the position seen in Figure 8.

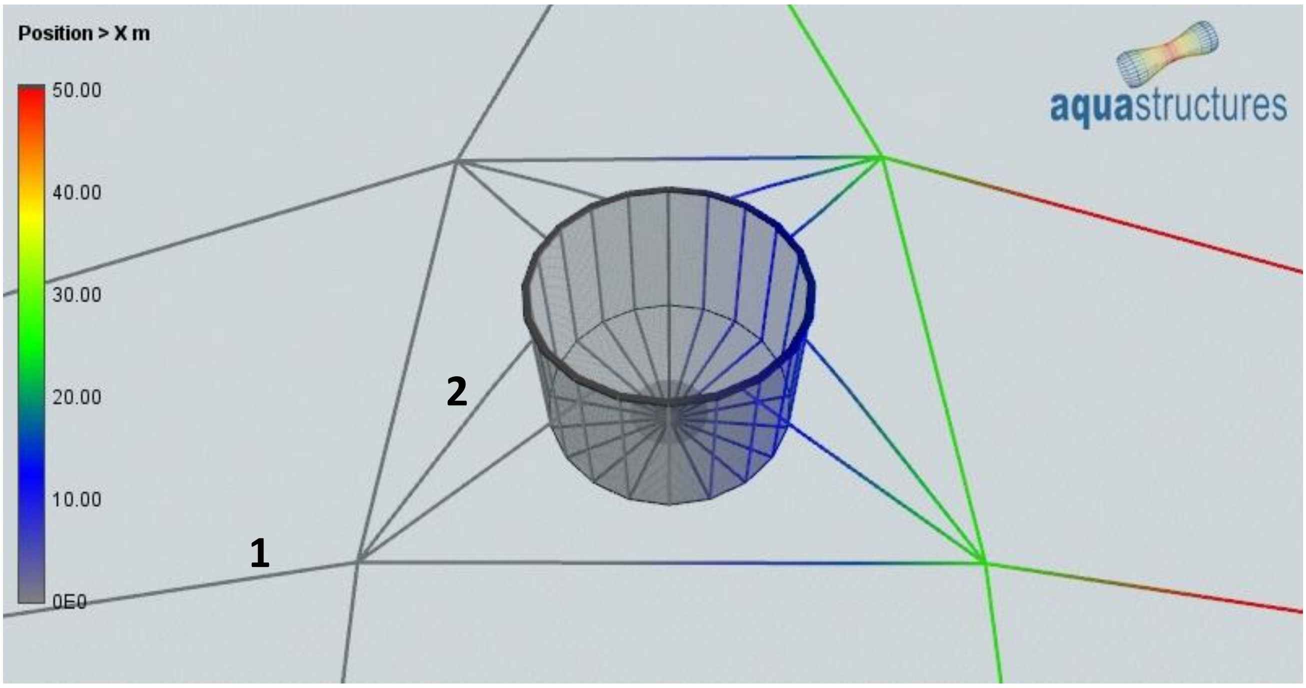

Figure 8 Locations where forces are compared

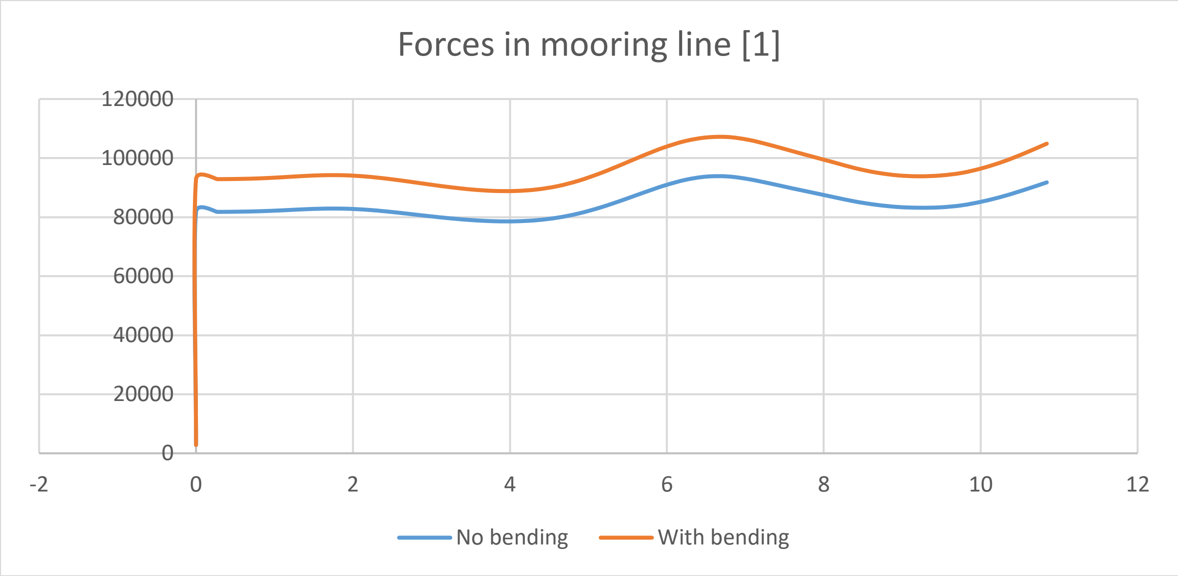

Figure 9

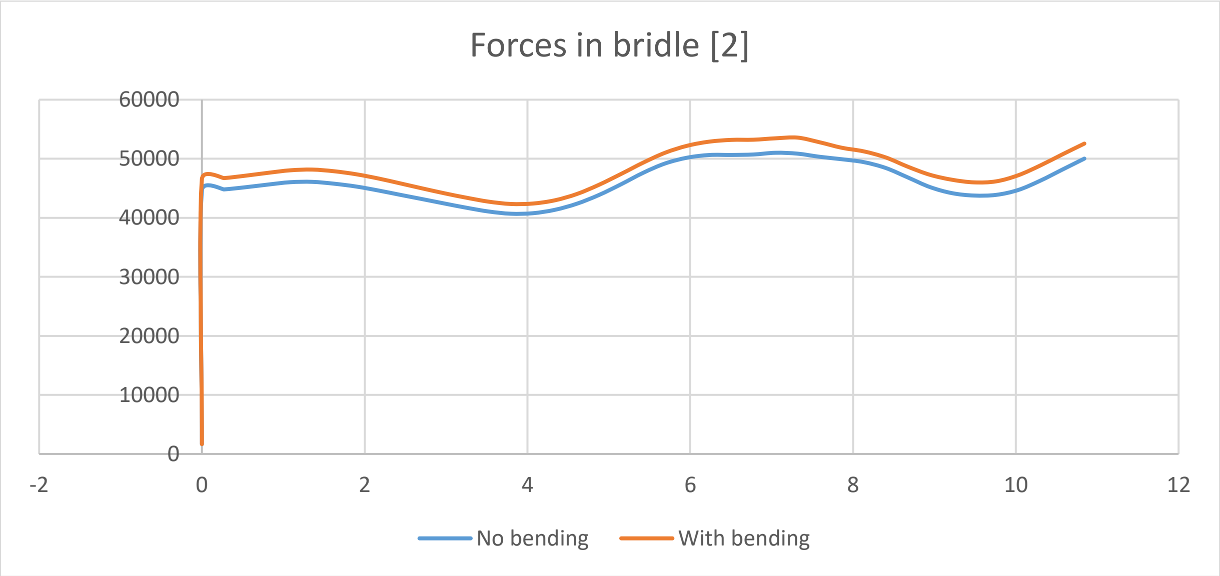

Figure 10

As seen by comparing Figure 9 and Figure 10 forces are higher when resistance to bending moment is accounted for. This is logical as resistance to bending moment means that the structure is stiffer so that

4 AquaSim implementaton

The physics of this element is handled as stated in Table 2.

Table 2 Handling of properties when bending moment

Property	How it is handled
Weight and bouyancy	Values are lumped to elements at 4 nodes in the same way as the net element without bending resistance.
Current	Current forces are lumped to 4 nodes in the same way as the net element without bending resistance.
Wave forces	Wave forces are lumped to 4 nodes in the same way as the net element without bending resistance.
Stiffness	Analogy can be given to beams in a pattern of the twines similar to the classic net element being seen as truss in a pattern similar to twines
Mass	Mass is lumped to 4 nodes in the same way as the net element without bending resistance.

The element has the number 11 as component number (type) as shown (highlighted in blue) in Figure 11.

```
3        version
4       !Number of nodes        :New Model
1       !Beams/trusses and membranes
1       0       0       0       0       0       0       0       0       0         #Waves, #Irregular wave indicator, #Dum
1       0       0       0       0       0       0       0       0       0         #Nr of Currents, #Dummy 9-17
1       0       0       0       0       0       0       0       0       0         #Materials + some geom, #Linebreaks, #D
0       0       0       0       0       0       0       0       0       0         #Conservative node loads, #Rollers,  #W
0       0       0       0       0       0       0       0       0       0         #Springs, #Local Nodes, #Predescribed d
0       0       0       0       0       0       0       0       0       0         #DragtypeLoads, #WindLoads, #ImpulseLoa
0       0       0       0       0       0       0       0       0       0         #Different hydrodynamic loads, #POI, #R
1 1.0E9 7.853981633974482E-7 5.0E-5 5.0E-5 0.01 0.01 0.0 1025.0 1.5 0.0 0.0 13 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 1 0.0 0.0
1       10.0    0.0     -10.0   1       1       1       1       1       1
2       10.0    10.0    -10.0   1       1       1       1       1       1
3       0.0     0.0     0.0     0 0 0 1 1       1       1       1       1
4       0.0     10.0    0.0     0 0 0 1 1       1       1       1       1
1       11      1       1       2       4       3
0       0       0       0       0       0       0       0       0       0       0       0       0       0       0
2.0     5.0     0.0     1.0     0.0     0.0     0.0     0.0     0.0      ## Seastate/Current/Wind parameters
-1.0    0       1       0.5     4.0     0.01    3       0       -100.0  1.0     0.0      ## Depth/Randnum/DynParameters G
2       3000    40      20      1       0       0       ## InitIncrement, MaxIterations, NumStepsWaveTotal, NumStepsWave
1       -1.0    -1.0    1.0     1.0
0       0       0       0       0.0     0       0       0       0       1       0       0       0       0       0
```

Figure 11 Input file with one element

As seen from the top line of the file seen in Figure 11, the version in this case is 3. Using Aquasim solver version value less than 5 means only defaults values can be applied for the bending resistance values. These values are shown in

Define a local coordinate system where the local x- axis is from node 1 to node 2 and the local z-axis is from node 1 to 4 as shown in Figure 12.

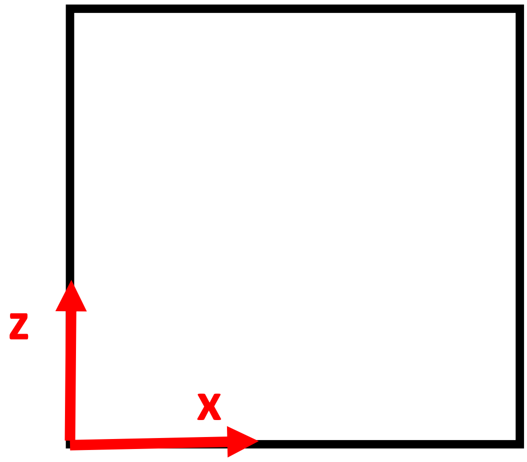

Figure 12 Local coordinate system

Table 3 shows default values for parameters for this type of elements.

Table 3 Default parameters element type 11

Input data	Abbreviation	Default
Elastic modulus horizontal twines	Ex	Emod
Elastic modulus vertical twines	Ez	Emod
Cross sectional area horizontal twines	Ax	Area
Cross sectional area vertical twines	Ay	Area
Shear modulus horizontal twines	Gx	Emod*0.4
Shear modulus vertical twines	Gy	Emod*0.4
Area moment of inertia horizontal twines*	Ix1	Area2*π/64
Area moment of inertia horizontal twines*	Iz1	Area2*π/64
Area moment of inertia vertical twines*	Ix2	Area2*π/64
Area moment of inertia vertical twines*	Iz2	Area2*π/64
Torsional resistance horizontal twines	It1	Area2*π/32
Torsional resistance vertical twines	It2	Area2*π/32

From Table 3 Emod is the elastic modulus in the type "2" membrane element and Area is the cross sectional area.

From inputfile version 5 or above all compponents have an input line that just beam and truss elements had in former versions. In version 5 and above the 2nd component line (used for drag data to truss and beams). In this input line, the parameters in Table 3 can be given as input in this line at the positions as shown in Table 4.

Table 4 Input data to membrane with bending stiffness, components type 11.

#	Input data	Abbreviation	Default
Old	Elastic modulus horizontal twines	Ex	Emod
2	Elastic modulus vertical twines	Ez	Emod
Old	Cross sectional area horizontal twines	Ax	Area
3	Cross sectional area vertical twines	Ay	Area
4	Shear modulus horizontal twines	Gx	Emod*0.4
5	Shear modulus vertical twines	Gy	Emod*0.4
6	Area moment of inertia horizontal twines*	Ix1	Area2*π/64
7	Area moment of inertia horizontal twines*	Iz1	Area2*π/64
8	Area moment of inertia vertical twines*	Ix2	Area2*π/64
9	Area moment of inertia vertical twines*	Iz2	Area2*π/64
10	Torsional resistance horizontal twines	It1	Area2*π/32
11	Torsional resistance vertical twines	It2	Area2*π/32

5 Appendix, example input files

5.1 One element case

3 version

4 !Number of nodes :New Model

1 !Beams/trusses and membranes

1 0 0 0 0 0 0 0 0 0 #Waves, #Irregular wave indicator, #Dummy 1-8

1 0 0 0 0 0 0 0 0 0 #Nr of Currents, #Dummy 9-17

1 0 0 0 0 0 0 0 0 0 #Materials + some geom, #Linebreaks, #Dummy 18-25

0 0 0 0 0 0 0 0 0 0 #Conservative node loads, #Rollers, #Winch out, #Max number of extra winch elements, #Winch in, #Dummy 26-30

0 0 0 0 0 0 0 0 0 0 #Springs, #Local Nodes, #Predescribed displacements, #Hinged springs, #Lineloads, #Valves, #Dummy 31-34

0 0 0 0 0 0 0 0 0 0 #DragtypeLoads, #WindLoads, #ImpulseLoads, #NonlinBend, #Dummy 35-40

0 0 0 0 0 0 0 0 0 0 #Different hydrodynamic loads, #POI, #RAODisplacement, #Lift, #RAOLoads, #Drift, #HorDiff, #Dummy 41-44

1 1.0E9 7.853981633974482E-7 5.0E-5 5.0E-5 0.01 0.01 0.0 1025.0 1.5 0.0 0.0 13 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 net

1 10.0 0.0 -10.0 1 1 1 1 1 1

2 10.0 10.0 -10.0 1 1 1 1 1 1

3 0.0 0.0 0.0 0 0 0 1 1 1 1 1 1

4 0.0 10.0 0.0 0 0 0 1 1 1 1 1 1

1 11 1 1 2 4 3

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 #Masstype, Extra

2.0 5.0 0.0 1.0 0.0 0.0 0.0 0.0 0.0 ## Seastate/Current/Wind parameters

-1.0 0 1 0.5 4.0 0.01 3 0 -100.0 1.0 0.0 ## Depth/Randnum/DynParameters G,B,TH

2 3000 40 20 1 0 0 ## InitIncrement, MaxIterations, NumStepsWaveTotal, NumStepsWave, Time compression

1 -1.0 -1.0 1.0 1.0

0 0 0 0 0.0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 #Slamming, Dynamic convergence, Threads, Extra

5.2 Ten element case

4 version

22 !Number of nodes :New Model

10 !Beams/trusses and membranes

1 0 0 0 0 0 0 0 0 0 #Waves, #Irregular wave indicator, #Dummy 1-8

1 0 0 0 0 0 0 0 0 0 #Nr of Currents, #Dummy 9-17

1 0 0 0 0 0 0 0 0 0 #Materials + some geom, #Linebreaks, #Dummy 18-25

2 0 0 0 0 0 0 0 0 0 #Conservative node loads, #Rollers, #Winch out, #Max number of extra winch elements, #Winch in, #Dummy 26-30

0 0 0 0 0 0 0 0 0 0 #Springs, #Local Nodes, #Predescribed displacements, #Hinged springs, #Lineloads, #Valves, #Dummy 31-34

0 0 0 0 0 0 0 0 0 0 #DragtypeLoads, #WindLoads, #ImpulseLoads, #NonlinBend, #Dummy 35-40

0 0 0 0 0 0 0 0 0 0 #Different hydrodynamic loads, #POI, #RAODisplacement, #Lift, #RAOLoads, #Drift, #HorDiff, #Dummy 41-44

1 1.0E11 0.007853981633974483 5.0E-5 5.0E-5 1.0 1.0 0.0 1025.0 1.0 0.0 0.0 13 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 net

1	0.0	0.0	-10.0	1	1	1	1	1	1
2	0.0	1.0	-10.0	1	1	1	1	1	1
3	0.0	0.0	-9.0	1	1	1	1	1	1
4	0.0	1.0	-9.0	1	1	1	1	1	1
5	0.0	0.0	-8.0	1	1	1	1	1	1
6	0.0	1.0	-8.0	1	1	1	1	1	1
7	0.0	0.0	-7.0	1	1	1	1	1	1
8	0.0	1.0	-7.0	1	1	1	1	1	1
9	0.0	0.0	-6.0	1	1	1	1	1	1
10	0.0	1.0	-6.0	1	1	1	1	1	1
11	0.0	0.0	-5.0	1	1	1	1	1	1
12	0.0	1.0	-5.0	1	1	1	1	1	1
13	0.0	0.0	-4.0	1	1	1	1	1	1
14	0.0	1.0	-4.0	1	1	1	1	1	1
15	0.0	0.0	-3.0	1	1	1	1	1	1
16	0.0	1.0	-3.0	1	1	1	1	1	1
17	0.0	0.0	-2.0	1	1	1	1	1	1
18	0.0	1.0	-2.0	1	1	1	1	1	1
19	0.0	0.0	-1.0	1	1	1	1	1	1
20	0.0	1.0	-1.0	1	1	1	1	1	1
21	0.0	0.0	0.0	0	0	0	0	0	0
22	0.0	1.0	0.0	0	0	0	0	0	0

1 11 1 1 2 4 3

2 11 1 3 4 6 5

3 11 1 5 6 8 7

4 11 1 7 8 10 9

5 11 1 9 10 12 11

6 11 1 11 12 14 13

7 11 1 13 14 16 15

8 11 1 15 16 18 17

9 11 1 17 18 20 19

10 11 1 19 20 22 21

1 1 500.0 0.0 0.0 0.0 0.0 0.0 0 0 0 0 #Pointload, #Dummy 32, #Dummy 33, #Dummy 34 #PointLoad 1

2 2 500.0 0.0 0.0 0.0 0.0 0.0 0 0 0 0 #Pointload, #Dummy 32, #Dummy 33, #Dummy 34 #PointLoad 1

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 #Masstype, Extra

1.0 5.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 ## Seastate/Current/Wind parameters

-1.0 0 1 0.5 4.0 1.0 3 0 -100.0 1.0 0.0 ## Depth/Randnum/DynParameters G,B,TH

5 3000 0 20 1 0 0 ## InitIncrement, MaxIterations, NumStepsWaveTotal, NumStepsWave, Time compression

1 -1.0 -1.0 1.0 1.0

0 0 0 0 0.0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 #Slamming, Dynamic convergence, Threads, Extra