

Appendix D

Results Field Test IJssel dike

Tests executed between: March & April 2019.

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Introduction

This appendix presents the test results of the direct pull tests executed with the grass sod pulling device. The test results are the basis of the study into the Strength of Grass Covers on Dikes. The tests presented in this appendix were executed on the IJssel dike at the location with the following coordinates: 52°28'58.1"N 6°05'01.2"E . The grass cover coverage at this location was of good quality and the subsoil is characterised as clay with a high sand content.

The objective of the field tests was to gain insights into the mechanical behaviour of the grass cover. The influence of the following processes were tested:

1. Tensile behaviour of cohesive sediments.
2. Tensile behaviour of grass roots.
3. Fatigue of the grass cover.

To test the influence of these processes, the following three different load regimes were designed: stepwise increased constant load, stepwise increased cyclic load and maximum force load. For each load regime, the analysis method was based on different metrics as summarized below:

1. Stepwise increased constant load.
 - Measurement of load and displacement.
 - Resulting elasticity.
 - Stress - Strain relation.
 - E modulus based on the final displacement induced by a constant load.
 - Time to reach 80% of the final displacement induced by a constant load.
2. Stepwise increased cyclic load.
 - Measurement of load and displacement.
 - Resulting elasticity per cycle.
 - Displacement per cycle.
 - Resulting total and partial elasticity per cycle.
 - Growth rate of the plastic and elastic deformation.
 - Growth rate of the elasticity.
3. Maximum force load.
 - Measurement of load and displacement.
 - Stress - Strain relation.

For each test, the dimensions and pictures of the tested grass cover sample are presented together with the metrics associated with the tested load regime.

Submerged Condition 2 Constant

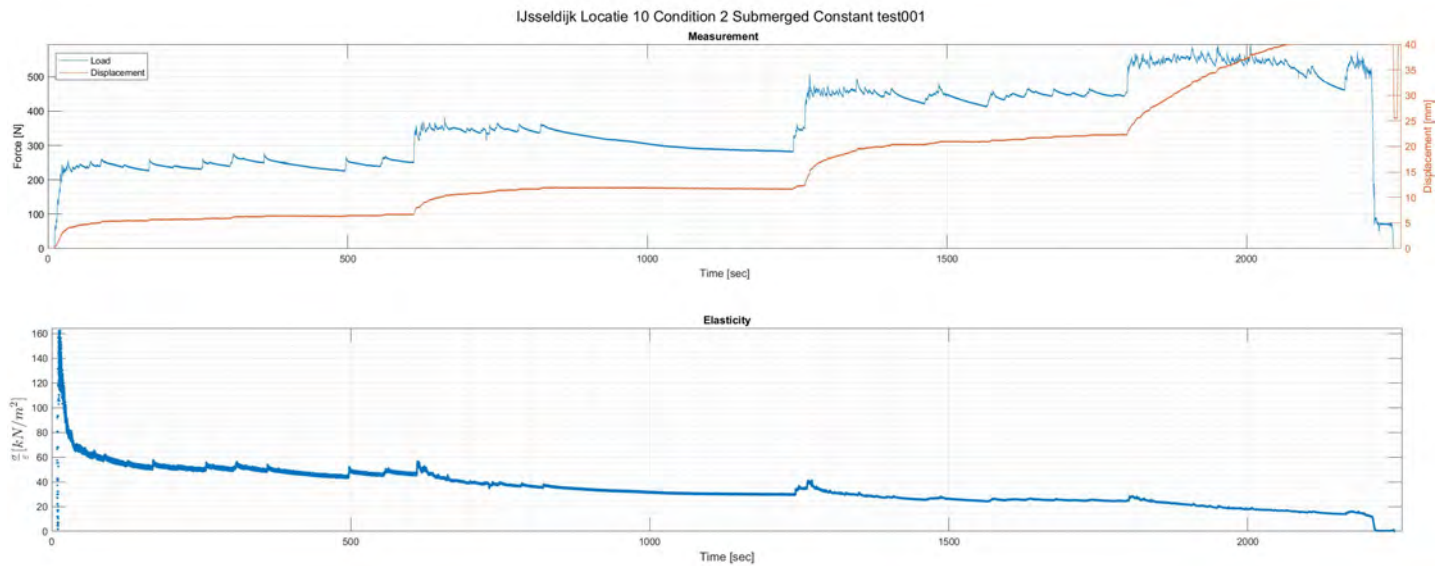
	Time to reach 80% of displacement [sec]	E [kN/m^2]	Weight Sod [kg]	Width Sod [cm]	Mean Height Sod [cm]	Mean Root Length [cm]
test002	121	18.92	7.1	35.0	8.6	7.1
test001	78	46.03	5.0	32.0	6.3	2.2
mean	99	32.47	6.0	33.5	7.4	4.7
median	99	32.47	6.0	33.5	7.4	4.7
75 th percentile	121	46.03	7.1	35.0	8.6	7.1
25 th percentile	78	18.92	5.0	32.0	6.3	2.2

test001

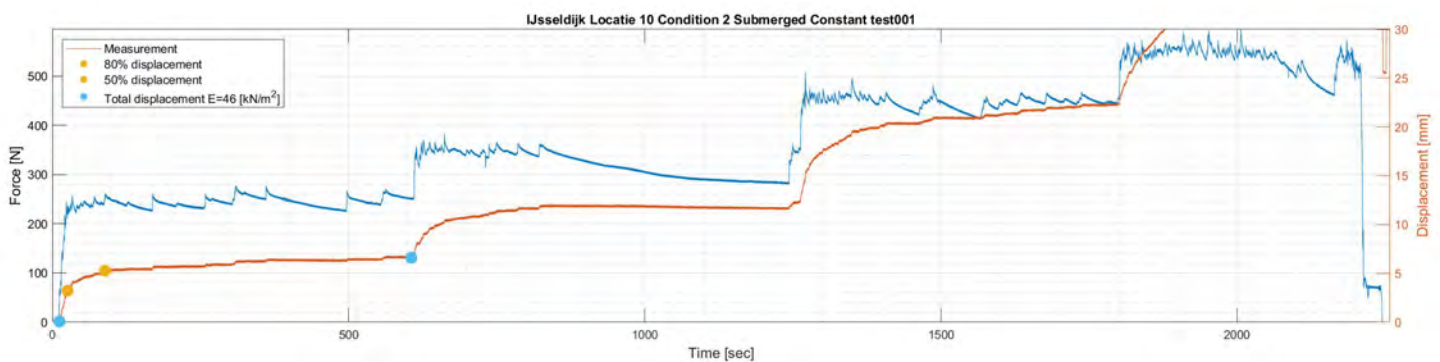
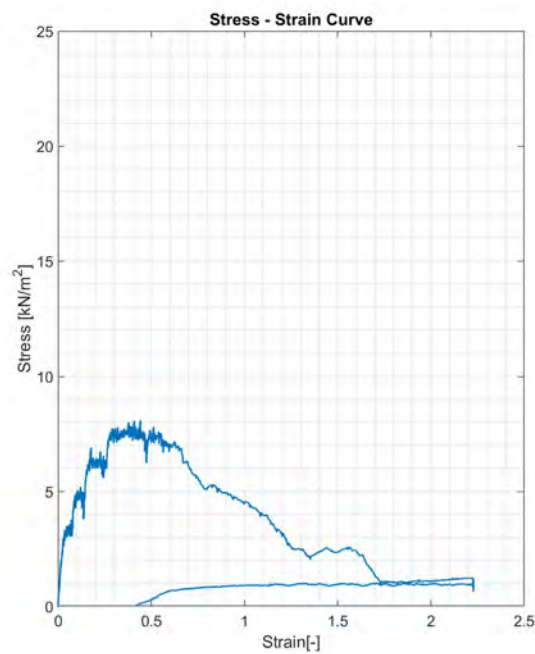
	value 1	value 2	value 3	mean
Date	5-4-2019			
E	46.03 [kN/m ²]			
Time to reach 80% of displacement	78 [sec]			
Width Sod	35 [cm]			
Weight Sod	71 [N]			
Sod Height	11	9	5	8.6
Root Length	8	8	5	7.1
Comments				



Figure 2.1: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



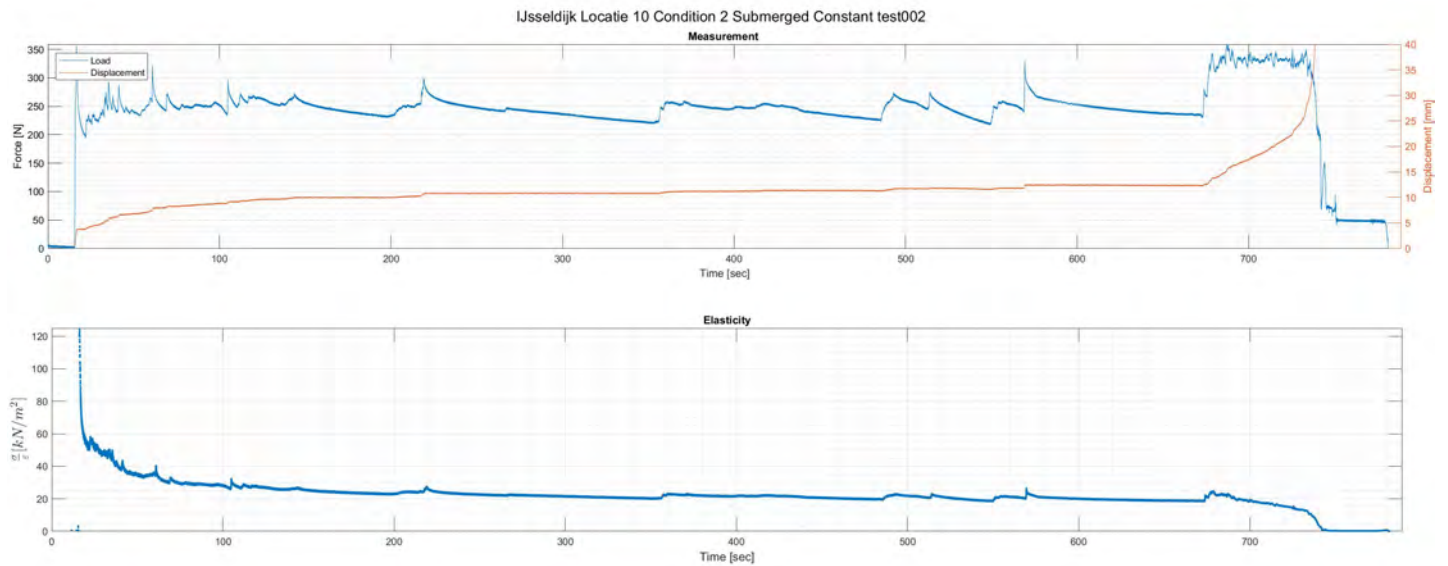
Displacement rate under step increased constant loading. The blue dots indicate the total or final displacement as result of the induced load during the first 600 seconds of loading. The yellow dot indicates 80% of the final displacement

test002

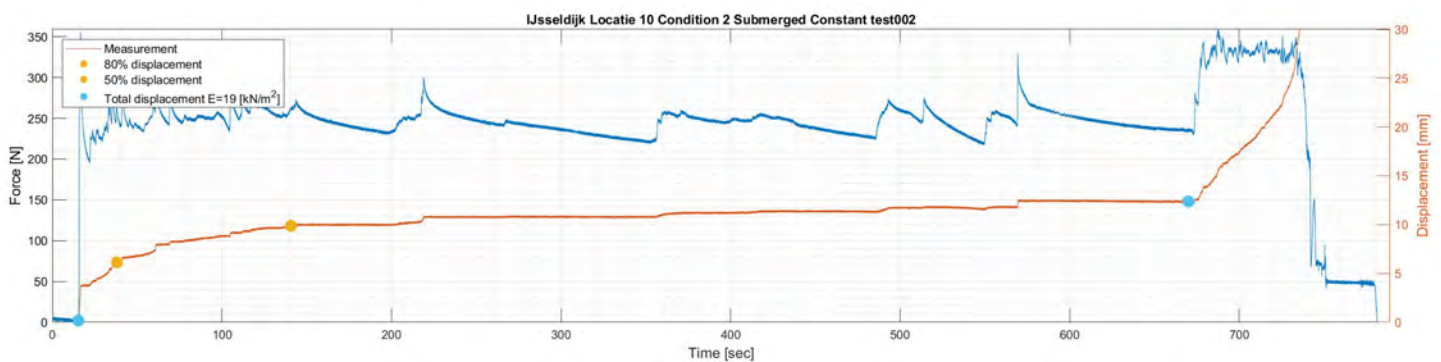
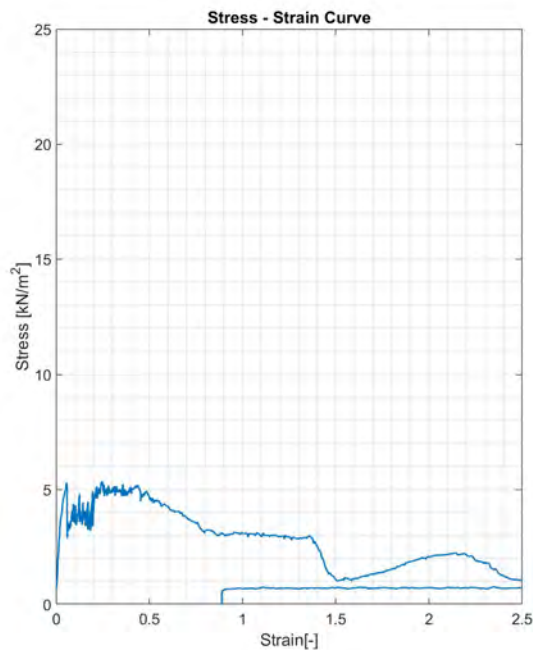
		value 1	value 2	value 3	mean
Date		5-4-2019			
E	$[kN/m^2]$	18.92			
Time to reach 80% of displacement	$[sec]$	121			
Width Sod	$[cm]$	32			
Weight Sod	$[N]$	50			
Sod Height	$[cm]$	8	5	4	6.3
Root Length	$[cm]$	1	3	4	2.2
Comments					



Figure 2.2: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



Displacement rate under step increased constant loading. The blue dots indicate the total or final displacement as result of the induced load during the first 600 seconds of loading. The yellow dot indicates 80% of the final displacement

Submerged Condition 2 Cyclic

Load block	Growth rate $\frac{\Delta U}{n}$ [mm]											
	Plastic deformation						Maximum deformation					
	0-600	600-1200	1200-1800	0-600	600-1200	1200-1800	0-600	600-1200	1200-1800	0-600	600-1200	1200-1800
test001	1.34e-02	2.17e-01	NaN	1.58e-02	2.68e-01	NaN	1.88e+02	3.86e+02	NaN	3.60e+02	7.22e+02	NaN
test002	1.75e-03	-4.37e-02	NaN	4.00e-03	4.10e-02	NaN	1.59e+02	2.94e+02	NaN	3.00e+02	5.48e+02	NaN
test003	5.12e-03	6.48e-02	NaN	7.40e-03	1.24e-01	NaN	1.61e+02	3.31e+02	NaN	3.19e+02	6.47e+02	NaN
test005	2.53e-02	2.84e-01	NaN	3.77e-02	5.68e-01	NaN	1.67e+02	2.51e+02	NaN	3.29e+02	4.89e+02	NaN
mean	1.14e-02	1.31e-01	NaN	1.62e-02	2.50e-01	NaN	1.69e+02	3.15e+02	NaN	3.27e+02	6.01e+02	NaN
median	9.26e-03	1.41e-01	NaN	1.16e-02	1.96e-01	NaN	1.64e+02	3.13e+02	NaN	3.24e+02	5.97e+02	NaN
75 th percentile	1.93e-02	2.51e-01	NaN	2.67e-02	4.18e-01	NaN	1.77e+02	3.58e+02	NaN	3.45e+02	6.84e+02	NaN
25 th percentile	3.44e-03	1.06e-02	NaN	5.70e-03	8.23e-02	NaN	1.60e+02	2.73e+02	NaN	3.09e+02	5.18e+02	NaN

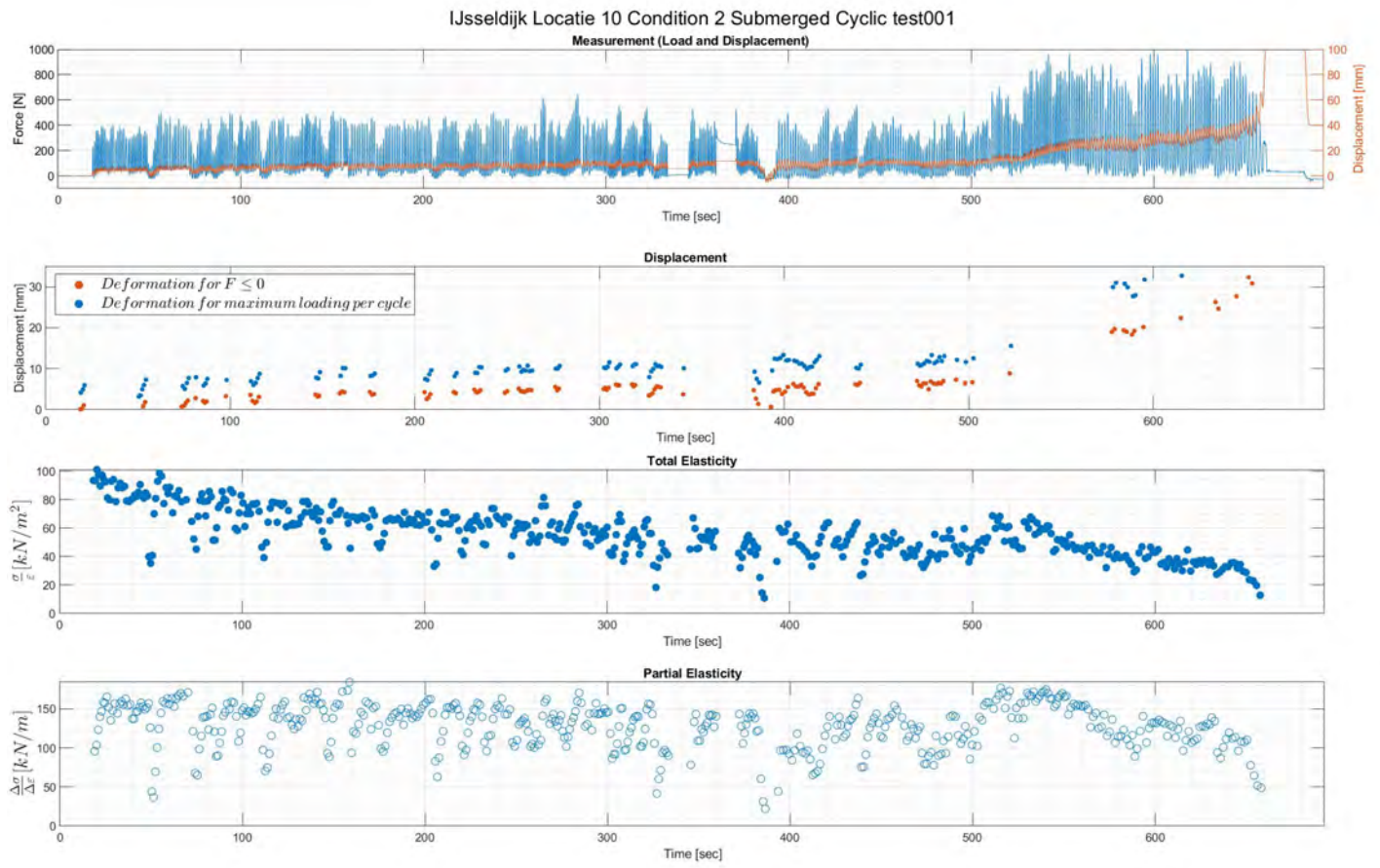
	Weight Sod [kg]	Width Sod [cm]	Mean Height Sod [cm]	Mean Root Length [cm]
test001	2.9	25.0	8.8	6.8
test002	5.8	30.0	6.8	5.6
test003	7.4	34.0	8.4	8.2
test005	5.2	38.0	8.4	7.6
Mean	5.3	31.8	8.1	7.1
Median	5.5	32	8.4	7.2
75 th percentile	6.6	36	8.6	7.9
25 th percentile	4	36	7.6	6.2

test001

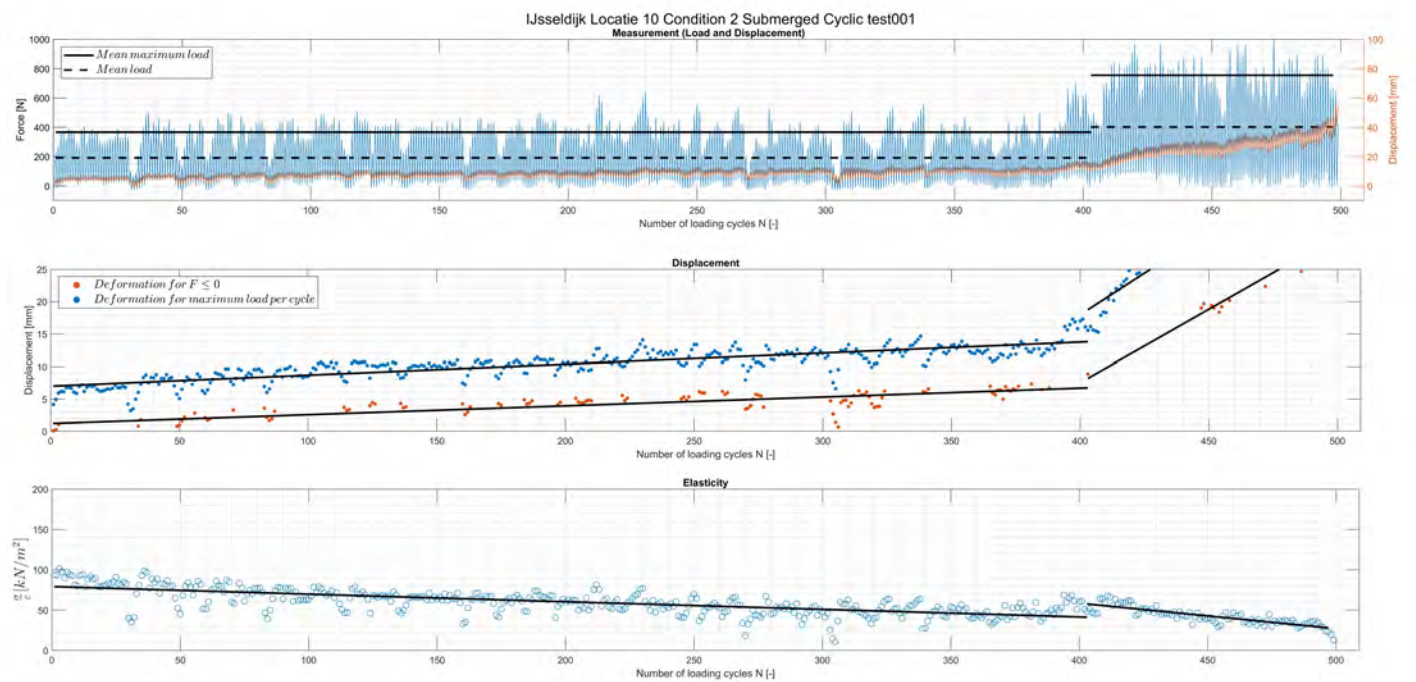
		value 1	value 2	value 3	mean
Date		5-4-2019			
Mean load	[N]	1.88e+02	3.86e+02		2.87e+02
Mean maximum load	[N]	3.60e+02	7.22e+02		5.41e+02
Growth rate Plastic deformation	$\frac{\Delta U}{n}$ [mm]	1.34e-02	2.17e-01		
Growth rate Maximum deformation	$\frac{\Delta U}{n}$ [mm]	1.58e-02	2.68e-01		
Width Sod	[cm]	25			
Weight Sod	[N]	29			
Sod Height	[cm]	10	8	8	8.8
Root Length	[cm]	5	8	8	6.8
Comments					



Figure 3.1: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



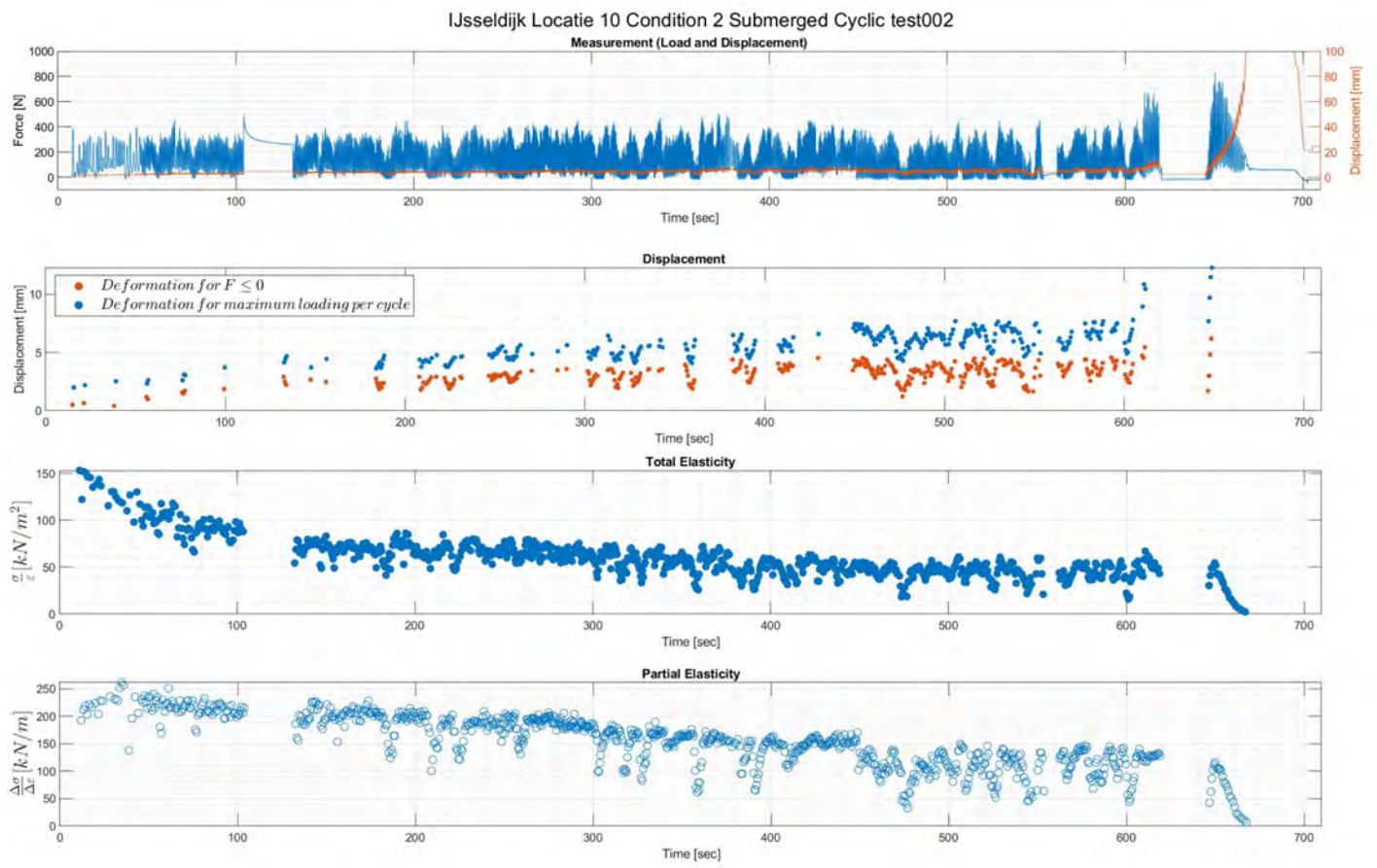
Development of displacement and elasticity are shown as function of number of cycles.

test002

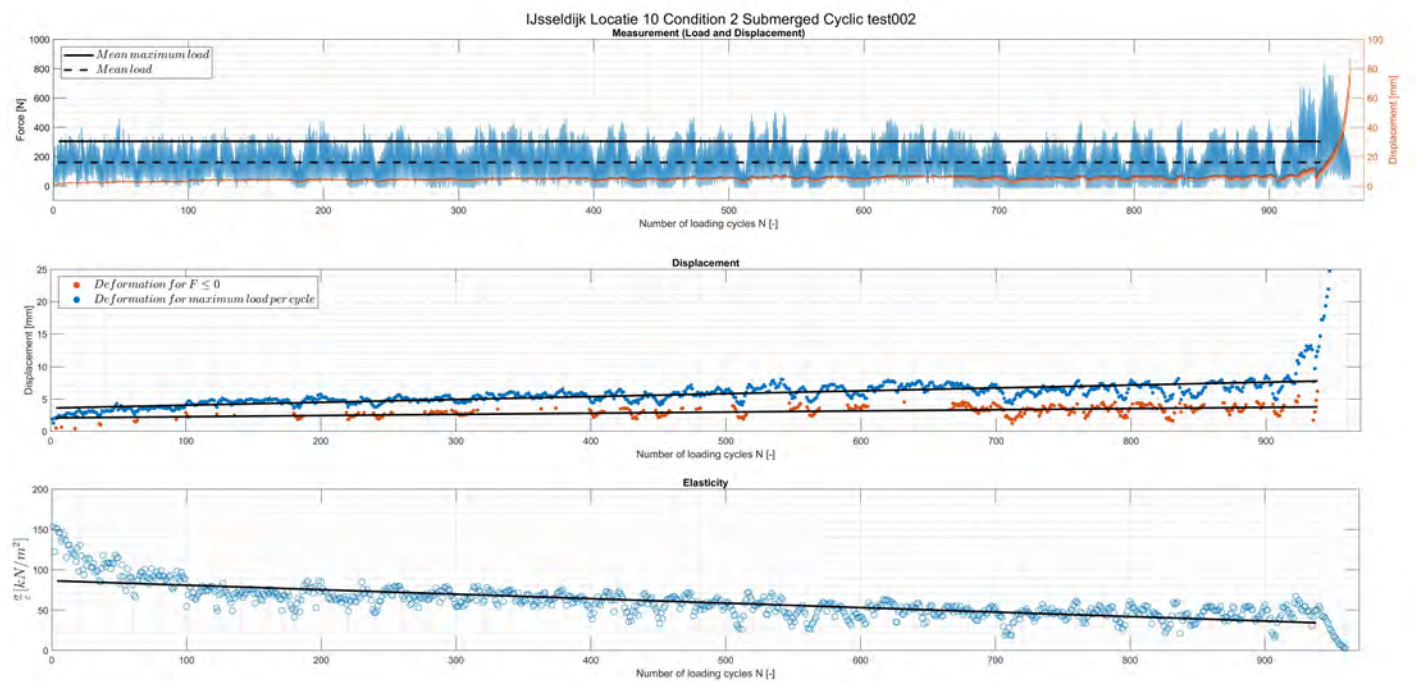
		value 1	value 2	value 3	mean
Date		8-4-2019			
Mean load	[N]	1.59e+02	2.94e+02		2.26e+02
Mean maximum load	[N]	3.00e+02	5.48e+02		4.24e+02
Growth rate Plastic deformation	$\frac{\Delta U}{n}$ [mm]	1.75e-03	-4.37e-02		
Growth rate Maximum deformation	$\frac{\Delta U}{n}$ [mm]	4.00e-03	4.10e-02		
Width Sod	[cm]	30			
Weight Sod	[N]	58			
Sod Height	[cm]	8	6	6	6.8
Root Length	[cm]	5	6	6	5.6
Comments					



Figure 3.2: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



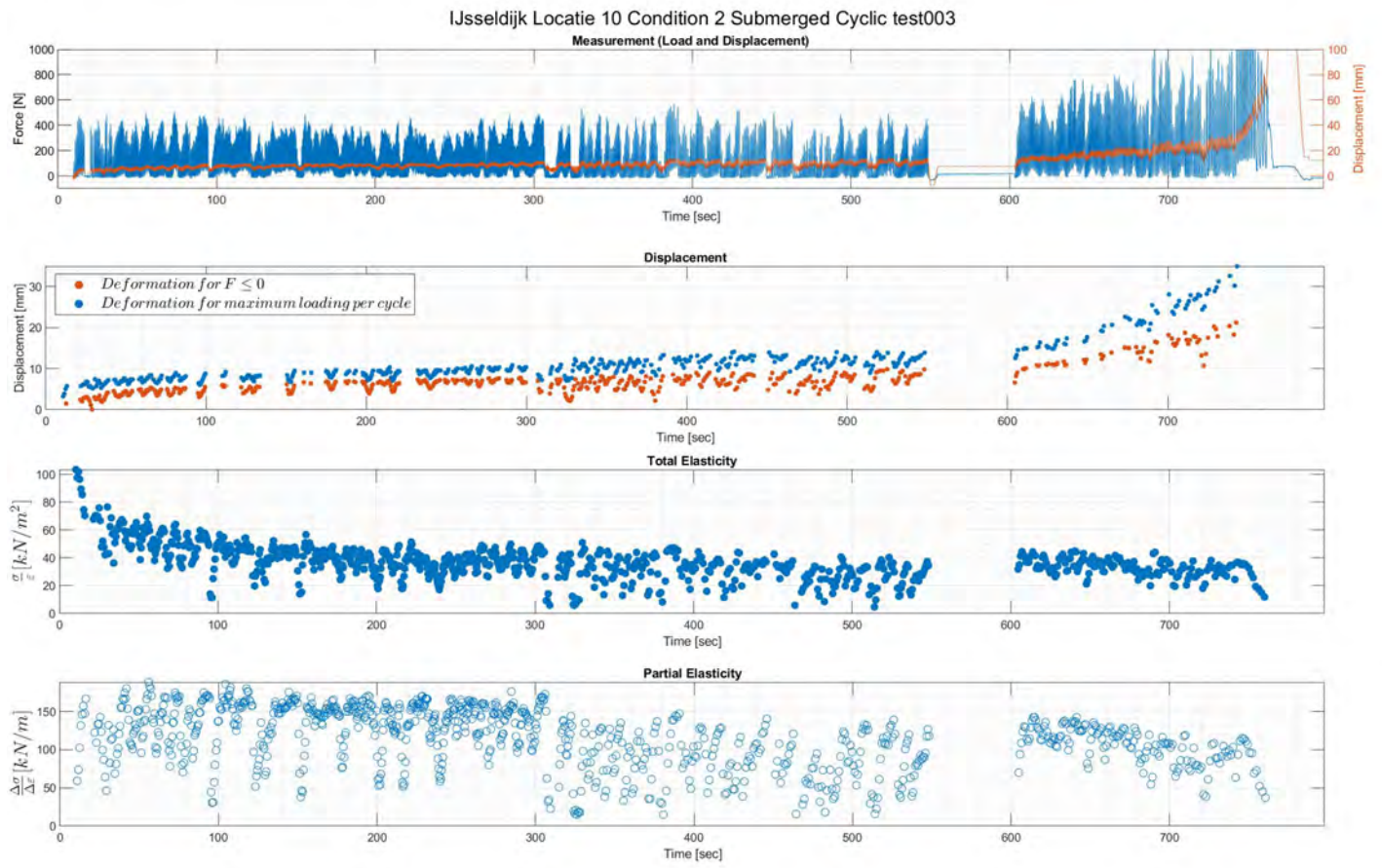
Development of displacement and elasticity are shown as function of number of cycles.

test003

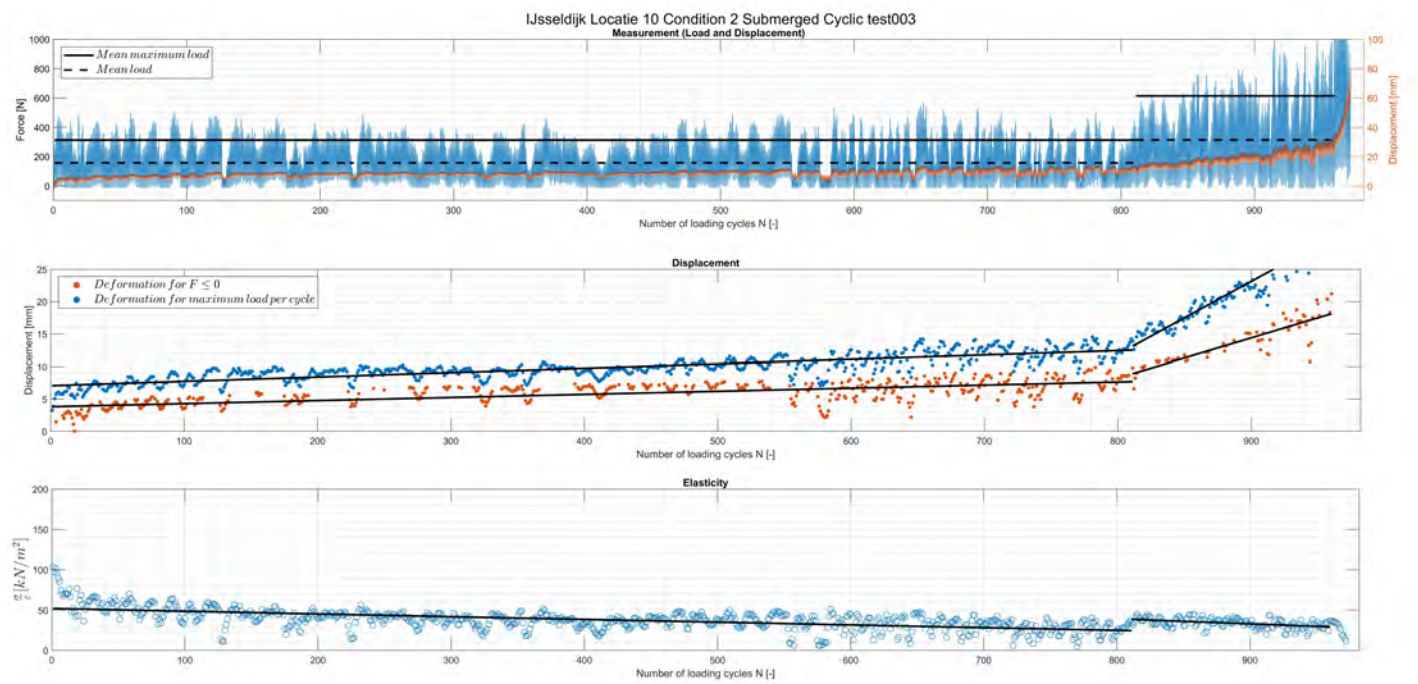
		value 1	value 2	value 3	mean
Date		8-4-2019			
Mean load	[N]	1.61e+02	3.31e+02		2.46e+02
Mean maximum load	[N]	3.19e+02	6.47e+02		4.83e+02
Growth rate Plastic deformation	$\frac{\Delta U}{n}$ [mm]	5.12e-03	6.48e-02		
Growth rate Maximum deformation	$\frac{\Delta U}{n}$ [mm]	7.40e-03	1.24e-01		
Width Sod	[cm]	34			
Weight Sod	[N]	74			
Sod Height	[cm]	10	8	8	8.4
Root Length	[cm]	9	8	8	8.2
Comments					



Figure 3.3: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



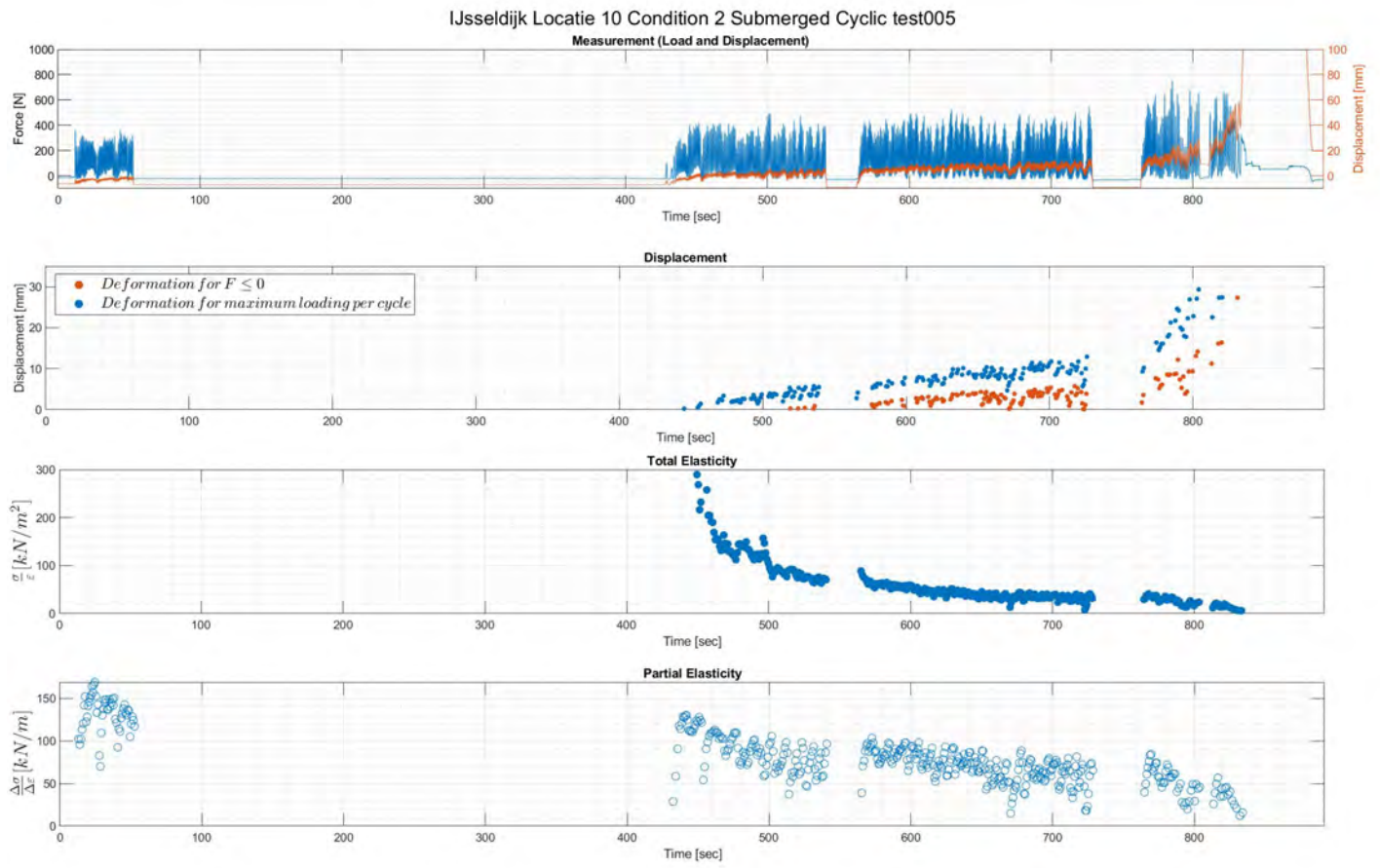
Development of displacement and elasticity are shown as function of number of cycles.

test005

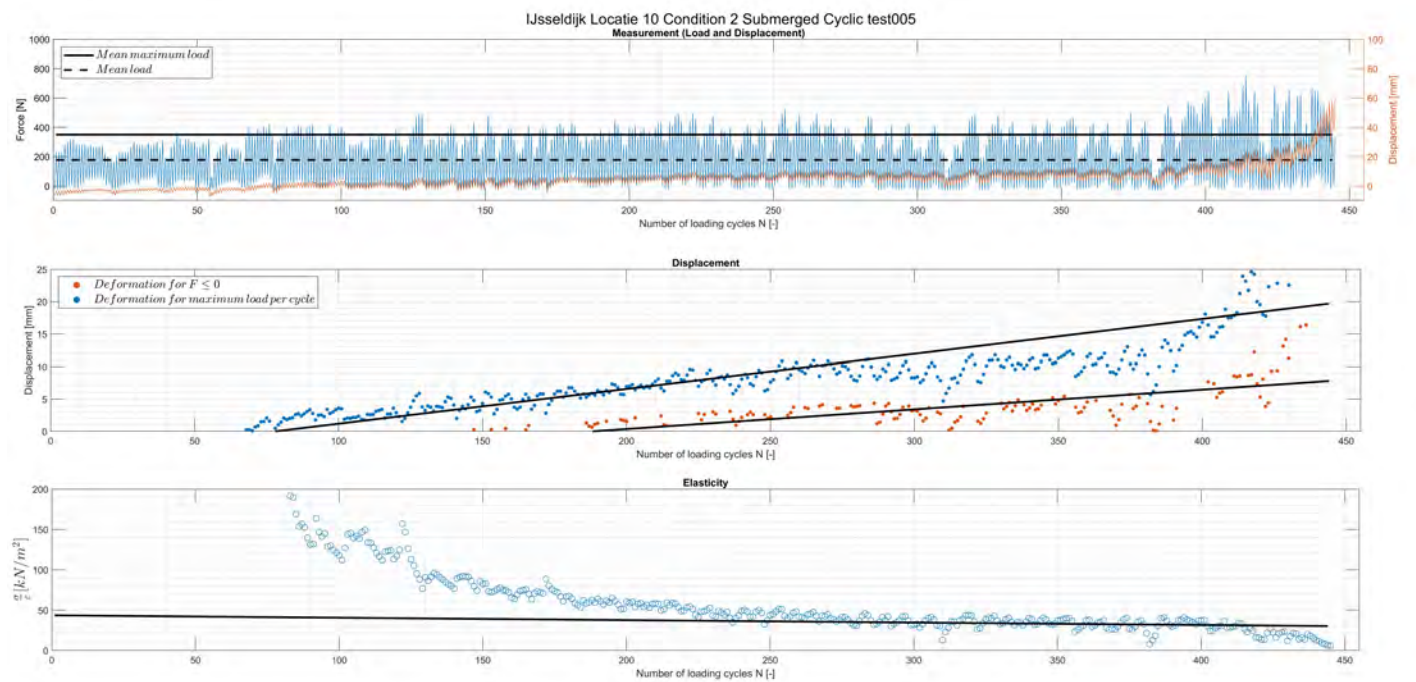
		value 1	value 2	value 3	mean
Date		8-4-2019			
Mean load	[N]	1.67e+02	2.51e+02		2.09e+02
Mean maximum load	[N]	3.29e+02	4.89e+02		4.09e+02
Growth rate Plastic deformation	$\frac{\Delta U}{n}$ [mm]	2.53e-02	2.84e-01		
Growth rate Maximum deformation	$\frac{\Delta U}{n}$ [mm]	3.77e-02	5.68e-01		
Width Sod	[cm]	38			
Weight Sod	[N]	52			
Sod Height	[cm]	10	9	7	8.4
Root Length	[cm]	10	7	7	7.6
Comments					



Figure 3.4: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



Development of displacement and elasticity are shown as function of number of cycles.

Submerged Condition 2 Max

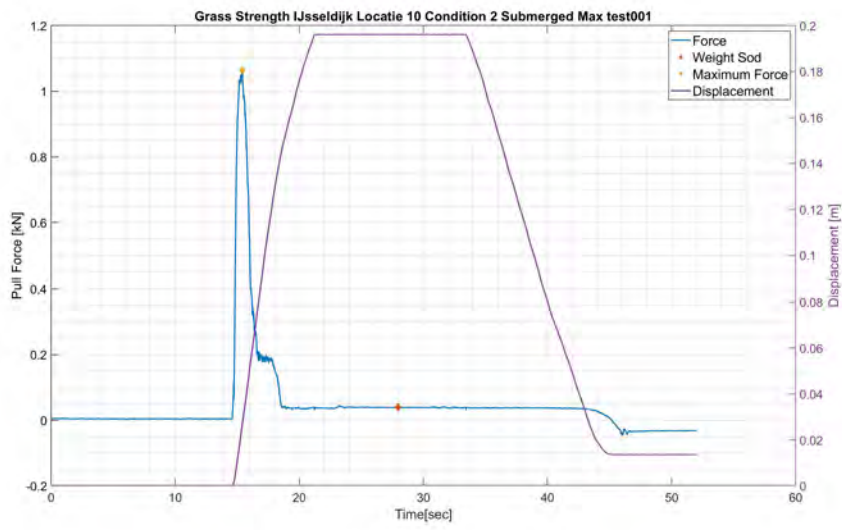
	F max [N]	Weight Sod [kg]	Width Sod [cm]	Mean Height Sod [cm]	Mean Root Length [cm]
test001	1046	3.8	34	5.6	10.0
test002	1189	3.8	27	7.7	8.8
Mean	1118	3.8	30.5	6.6	9.4
Median	1118	3.8	31	7	9
75 th percentile	1189	3.8	34	8	10
25 th percentile	1046	3.8	34	6	9

test001

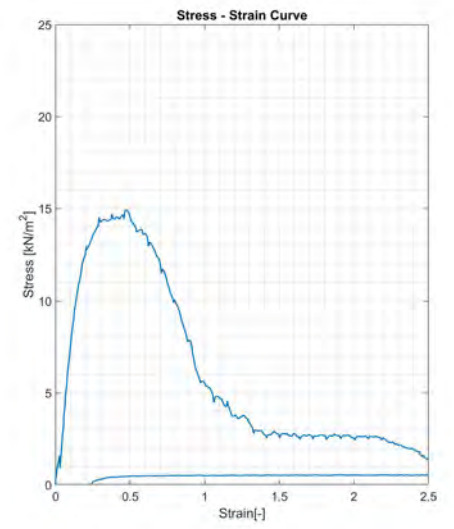
	value 1	value 2	value 3	mean
Date	5-4-2019			
Maximum load [N]	1047			
Width Sod [cm]	34			
Weight Sod [N]	38			
Sod Height [cm]	7	5	0	5.6
Root Length [cm]	10	10	0	10
Comments				



Figure 4.1: Pictures of tested grass sod.



Measurement of load and displacement



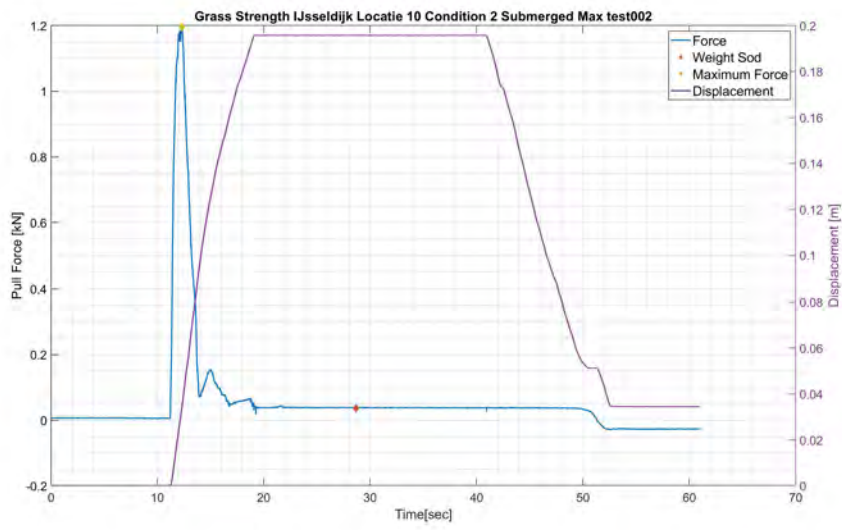
Stress - Strain relation.

test002

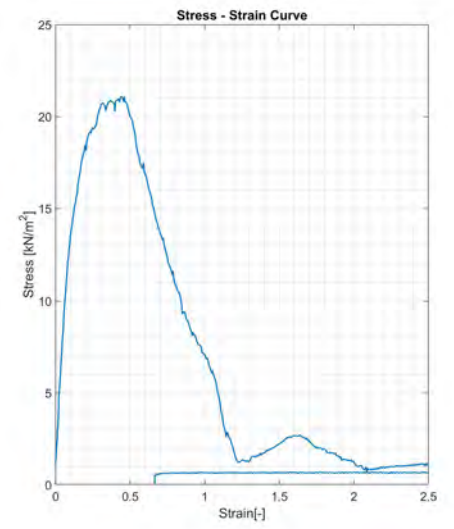
	value 1	value 2	value 3	mean
Date	5-4-2019			
Maximum load [N]	1189			
Width Sod [cm]	27			
Weight Sod [N]	38			
Sod Height [cm]	9	5	10	7.7
Root Length [cm]	6	10	10	8.8
Comments				



Figure 4.2: Pictures of tested grass sod.



Measurement of load and displacement



Stress - Strain relation.

Submerged Condition 2 Constant

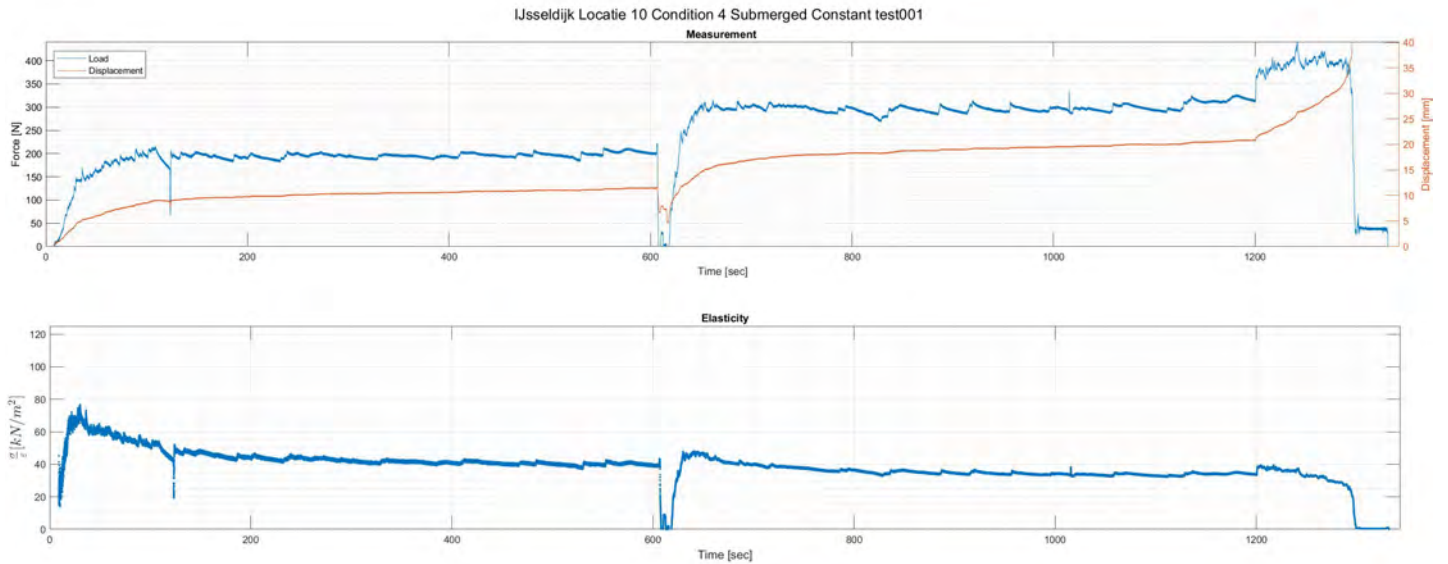
	Time to reach 80% of displacement [<i>sec</i>]	E [kN/m^2]	Weight Sod [<i>kg</i>]	Width Sod [<i>cm</i>]	Mean Height Sod [<i>cm</i>]	Mean Root Length [<i>cm</i>]
test004	52	42.78	3.8	21.0	9.4	3.8
test003	133	37.35	6.8	21.0	8.9	3.9
test002	31	36.59	3.0	21.0	8.0	5.8
test001	92	39.09	4.1	21.0	8.8	4.8
mean	77	38.95	4.4	21.0	8.8	4.6
median	72	38.22	4.0	21.0	8.8	4.4
75 th percentile	112	40.93	5.4	21.0	9.1	5.3
25 th percentile	42	36.97	3.4	21.0	8.4	3.8

test001

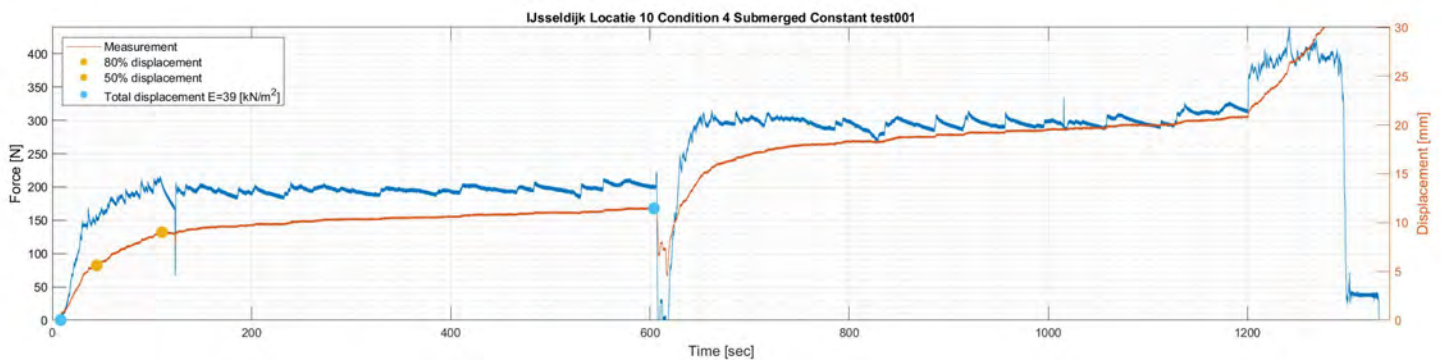
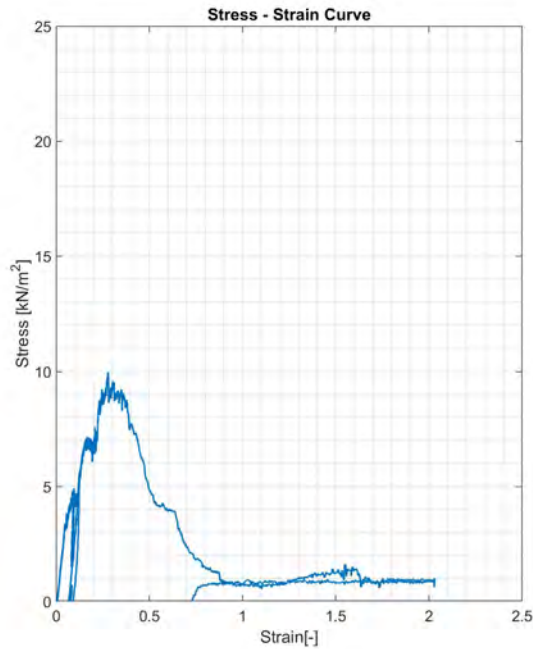
	value 1	value 2	value 3	mean
Date	25-4-2019			
E	39.09			
Time to reach 80% of displacement	92			
Width Sod	21			
Weight Sod	38			
Sod Height	13	10	4	9.4
Root Length	3	4	4	3.8
Comments				



Figure 5.1: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



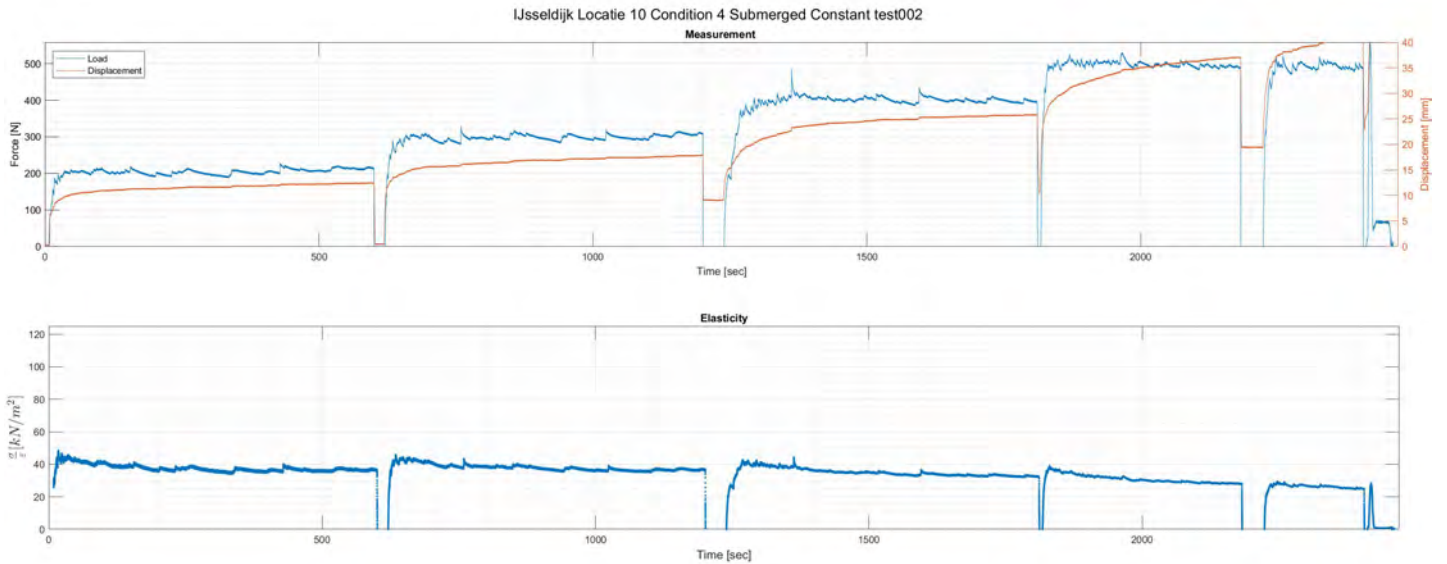
Displacement rate under step increased strain constant loading. The blue dots indicate the total or final displacement as result of the induced load during the first 600 seconds of loading. The yellow dot indicates 80% of the final displacement

test002

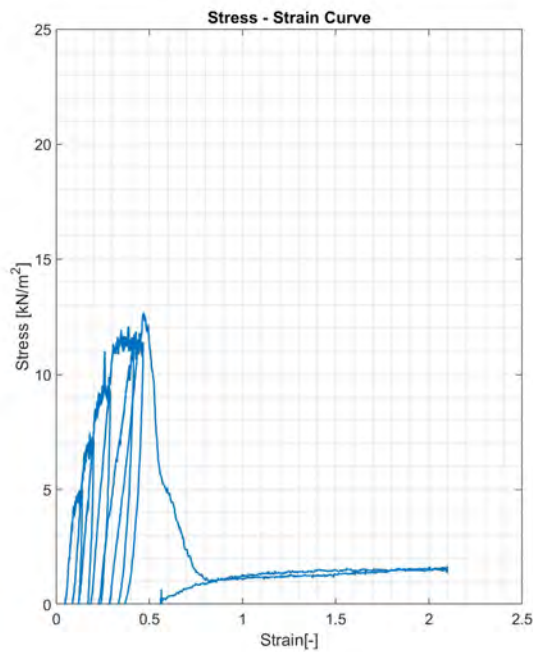
	value 1	value 2	value 3	mean
Date	25-4-2019			
E	36.59			
Time to reach 80% of displacement	31			
Width Sod	21			
Weight Sod	68			
Sod Height	13	9	6	8.9
Root Length	3	3	6	3.9
Comments				



Figure 5.2: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



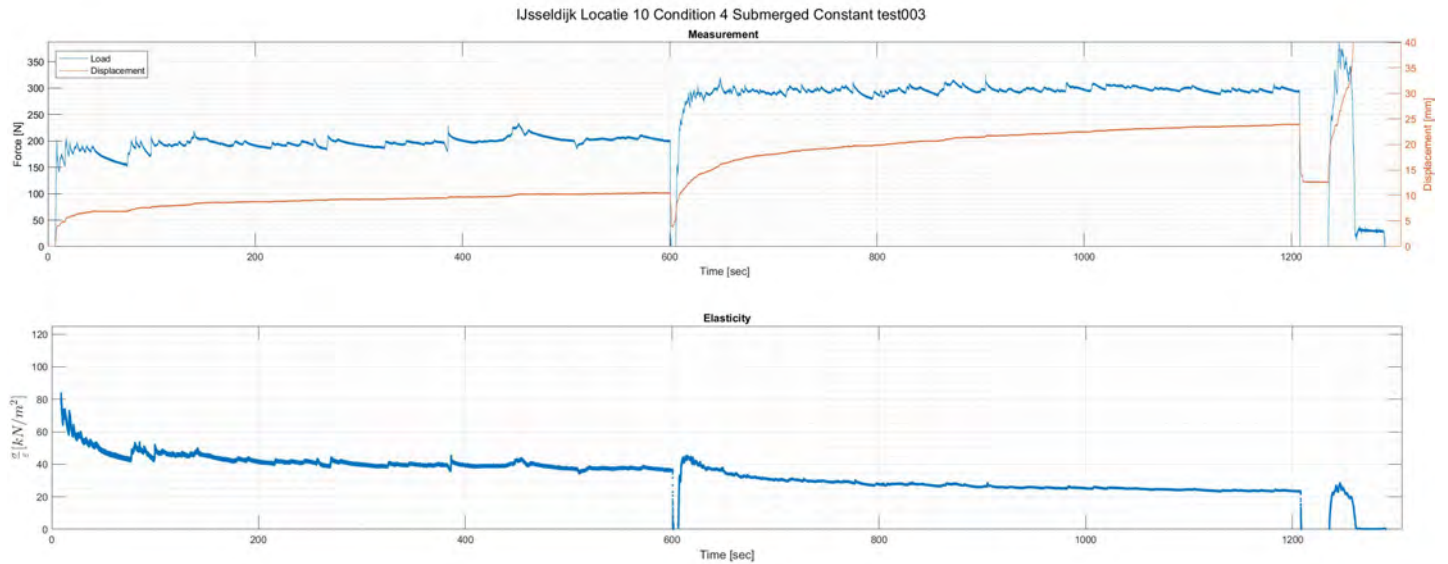
Displacement rate under step increased constant loading. The blue dots indicate the total or final displacement as result of the induced load during the first 600 seconds of loading. The yellow dot indicates 80% of the final displacement

test003

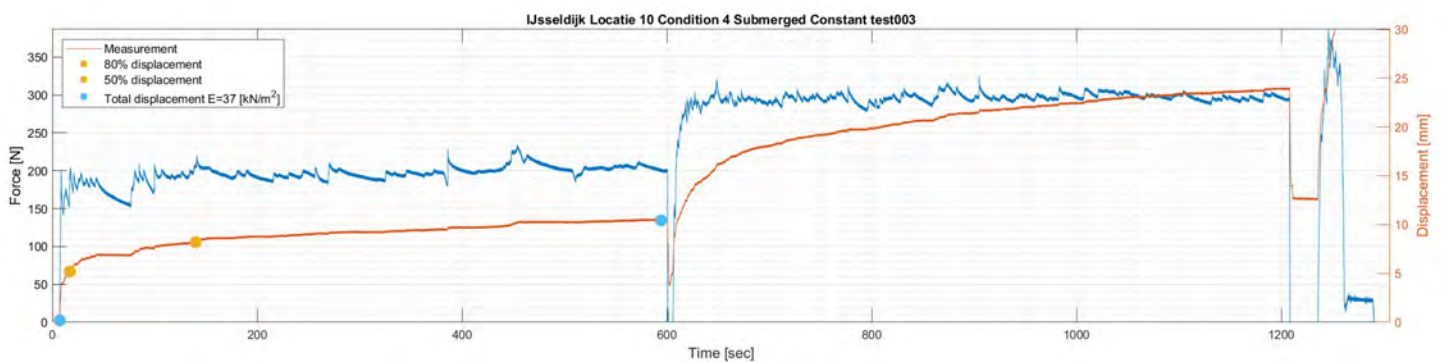
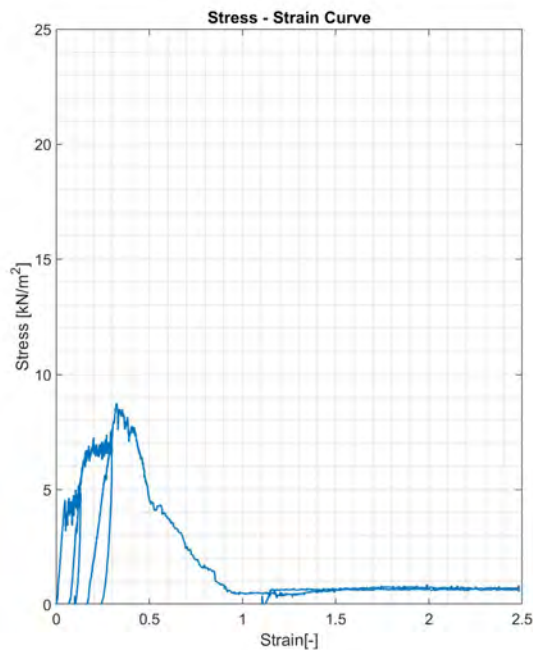
	value 1	value 2	value 3	mean
Date	25-4-2019			
E	37.35 $[kN/m^2]$			
Time to reach 80% of displacement	133 $[sec]$			
Width Sod	21 $[cm]$			
Weight Sod	30 $[N]$			
Sod Height	9	7	7	8
Root Length	5	6	7	5.8
Comments				



Figure 5.3: Pictures of tested grass sod.



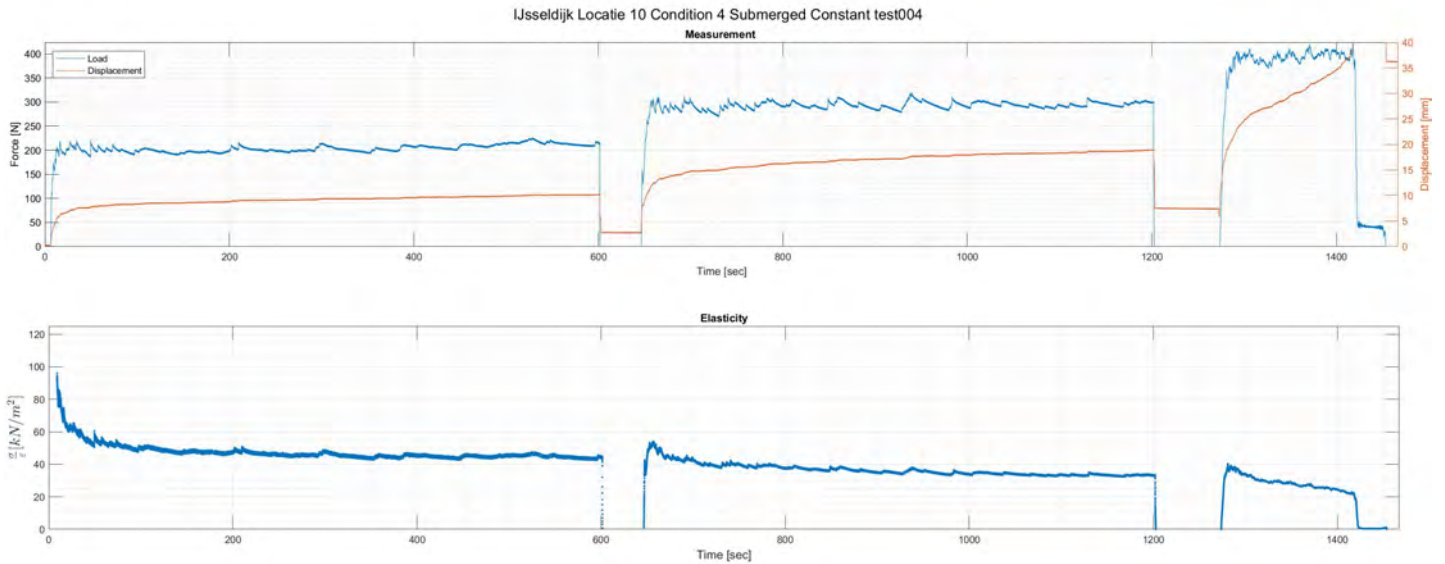
Measurement of load and displacement and resulting elasticity.



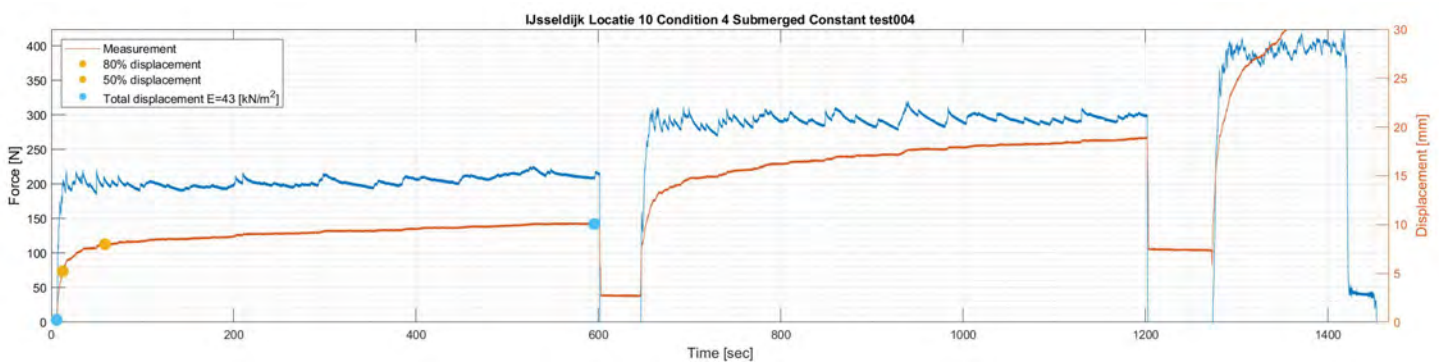
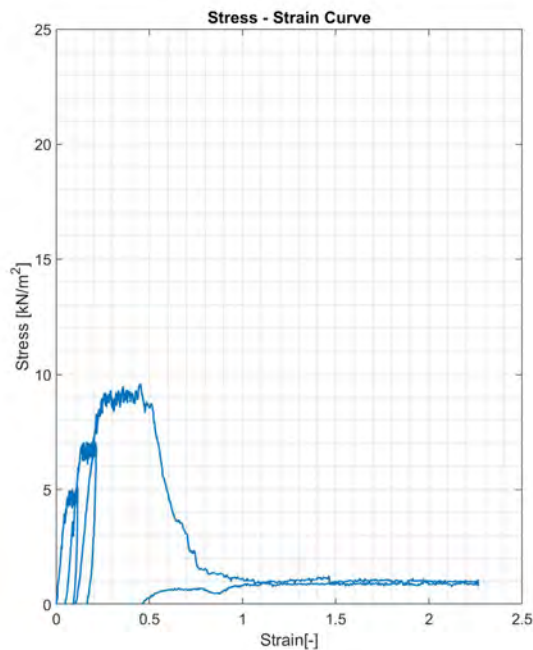
Displacement rate under step increased strain constant loading. The blue dots indicate the total or final displacement as result of the induced load during the first 600 seconds of loading. The yellow dot indicates 80% of the final displacement

test004

	value 1	value 2	value 3	mean
Date	25-4-2019			
E	42.78			
Time to reach 80% of displacement	52			
Width Sod	21			
Weight Sod	41			
Sod Height	10	7	0	8.8
Root Length	4	6	0	4.8
Comments	COM			



Measurement of load and displacement and resulting elasticity.



Displacement rate under step increased strain constant loading. The blue dots indicate the total or final displacement as result of the induced load during the first 600 seconds of loading. The yellow dot indicates 80% of the final displacement

Submerged Condition 4 Cyclic

Load block	Growth rate $\frac{\Delta U}{n}$ [mm]											
	Plastic deformation						Maximum deformation					
	0-600	600-1200	1200-1800	0-600	600-1200	1200-1800	0-600	600-1200	1200-1800	0-600	600-1200	1200-1800
test001	5.22e-03	1.09e-01	NaN	6.22e-03	1.61e-01	NaN	8.92e+01	1.77e+02	NaN	1.81e+02	3.47e+02	NaN
test002	1.24e-02	NaN	NaN	1.84e-02	NaN	NaN	8.32e+01	NaN	NaN	1.65e+02	NaN	NaN
test003	1.87e-02	3.11e+00	NaN	2.73e-02	4.61e+00	NaN	8.09e+01	1.56e+02	NaN	1.66e+02	2.94e+02	NaN
test004	1.28e-03	1.68e-01	NaN	2.15e-03	2.28e-01	NaN	5.71e+01	1.77e+02	NaN	1.27e+02	3.48e+02	NaN
mean	9.38e-03	1.13e+00	NaN	1.35e-02	1.67e+00	NaN	7.76e+01	1.70e+02	NaN	1.60e+02	3.30e+02	NaN
median	8.79e-03	1.68e-01	NaN	1.23e-02	2.28e-01	NaN	8.21e+01	1.77e+02	NaN	1.66e+02	3.47e+02	NaN
75 th percentile	1.55e-02	2.38e+00	NaN	2.29e-02	3.52e+00	NaN	8.62e+01	1.77e+02	NaN	1.74e+02	3.48e+02	NaN
25 th percentile	3.25e-03	1.24e-01	NaN	4.18e-03	1.78e-01	NaN	6.90e+01	1.61e+02	NaN	1.46e+02	3.07e+02	NaN

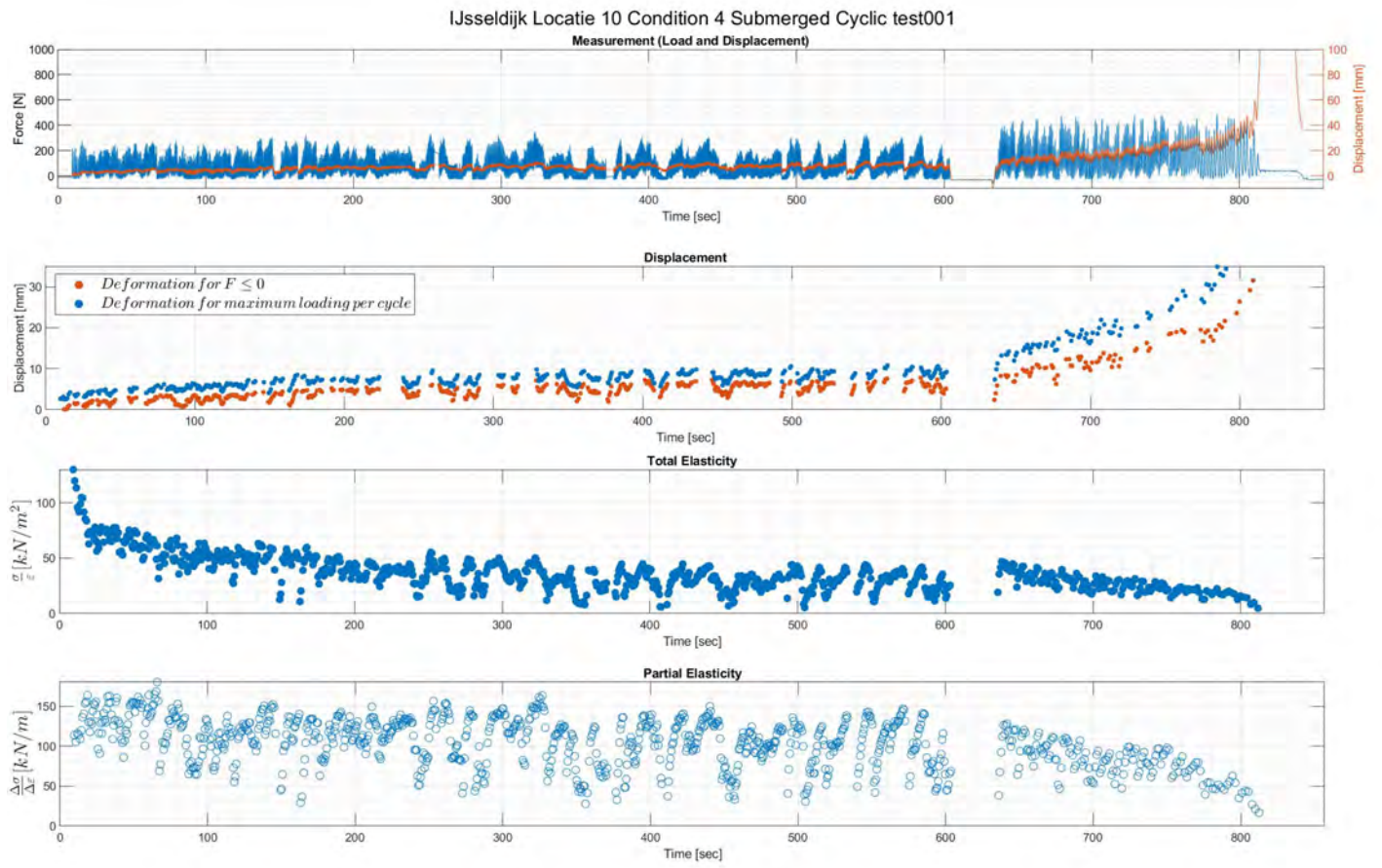
	Weight Sod [kg]	Width Sod [cm]	Mean Height Sod [cm]	Mean Root Length [cm]
test001	3.6	21.0	7.1	7.2
test002	2.5	21.0	7.4	7.0
test003	2.7	21.0	7.7	7.1
test004	3.3	21.0	6.6	5.4
Mean	3	21	7.2	6.7
Median	3	21	7.3	7.1
75 th percentile	3.4	21	7.6	7.1
25 th percentile	2.6	21	6.9	6.2

test001

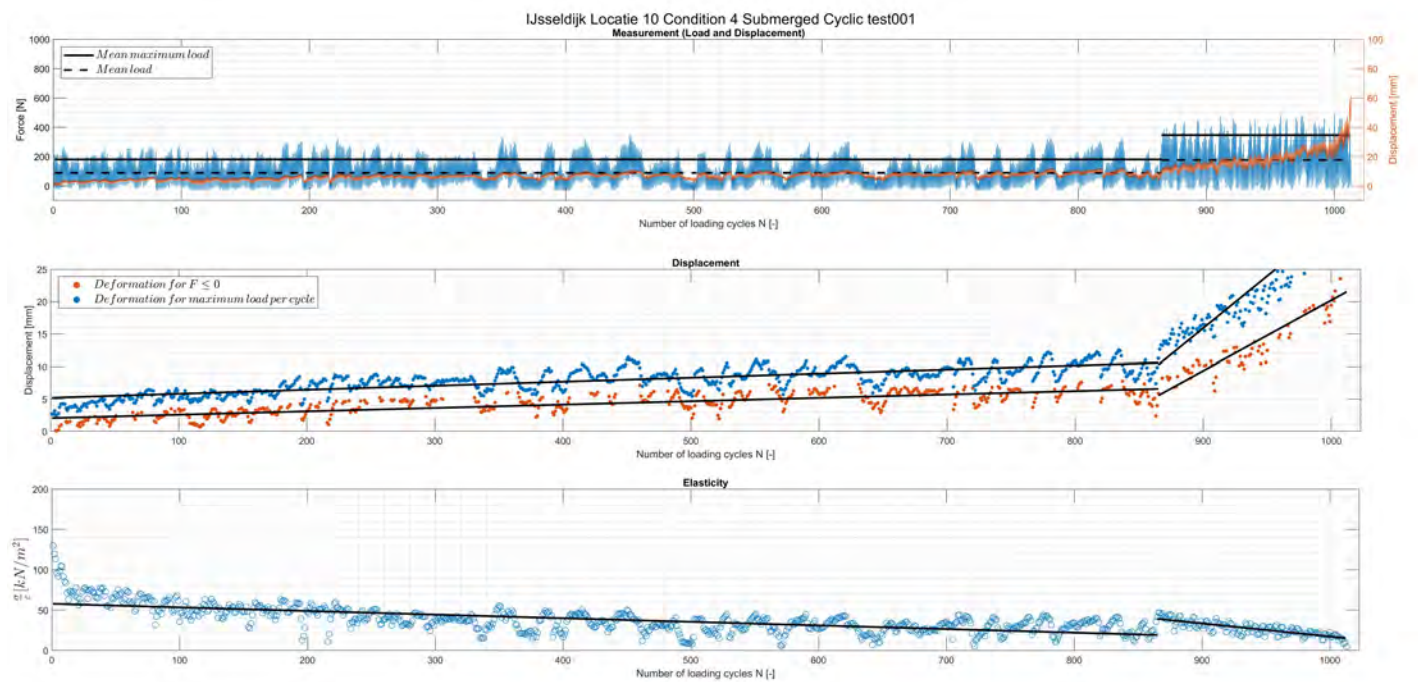
		value 1	value 2	value 3	mean
Date		8-4-2019			
Mean load	[N]	8.92e+01	1.77e+02		1.33e+02
Mean maximum load	[N]	1.81e+02	3.47e+02		2.64e+02
Growth rate Plastic deformation	$\frac{\Delta U}{n}$ [mm]	5.22e-03	1.09e-01		
Growth rate Maximum deformation	$\frac{\Delta U}{n}$ [mm]	6.22e-03	1.61e-01		
Width Sod	[cm]	21			
Weight Sod	[N]	36			
Sod Height	[cm]	9	7	8	7.1
Root Length	[cm]	8	8	8	7.2
Comments					



Figure 6.1: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



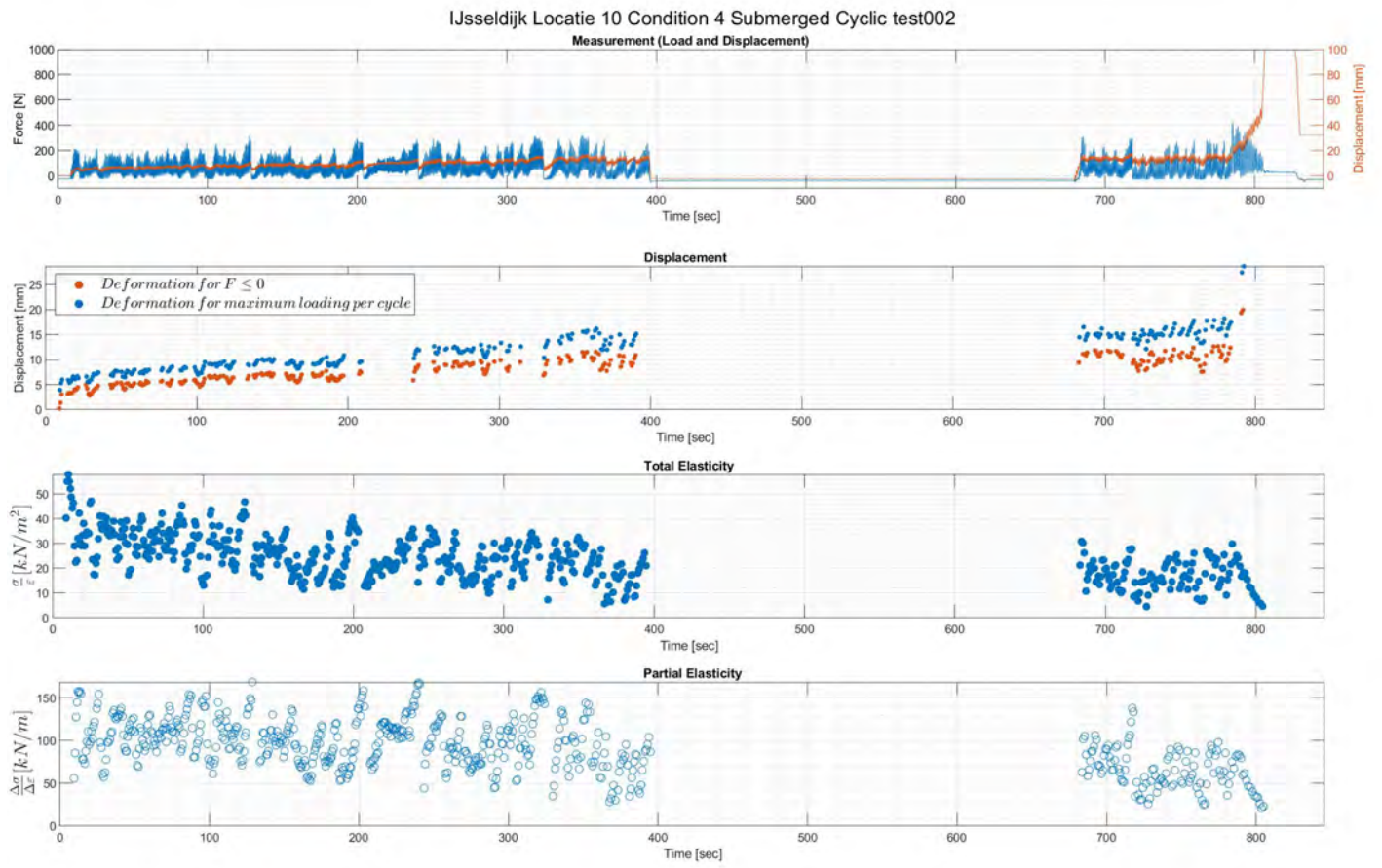
Development of displacement and elasticity are shown as function of number of cycles.

test002

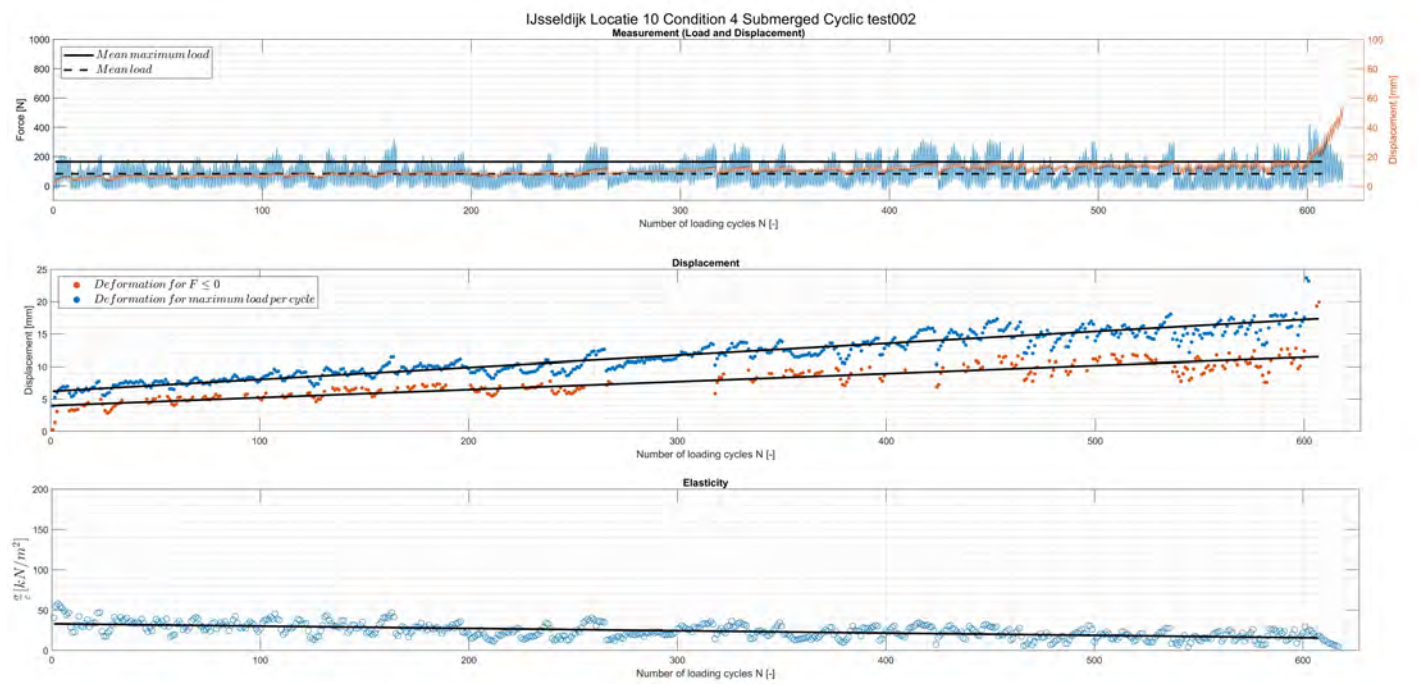
		value 1	value 2	value 3	mean
Date		8-4-2019			
Mean load	[N]	8.32e+01			8.32e+01
Mean maximum load	[N]	1.65e+02			1.65e+02
Growth rate Plastic deformation	$\frac{\Delta U}{n}$ [mm]	1.24e-02			
Growth rate Maximum deformation	$\frac{\Delta U}{n}$ [mm]	1.84e-02			
Width Sod	[cm]	21			
Weight Sod	[N]	26			
Sod Height	[cm]	8	6	0	7.4
Root Length	[cm]	7	7	0	7
Comments					



Figure 6.2: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



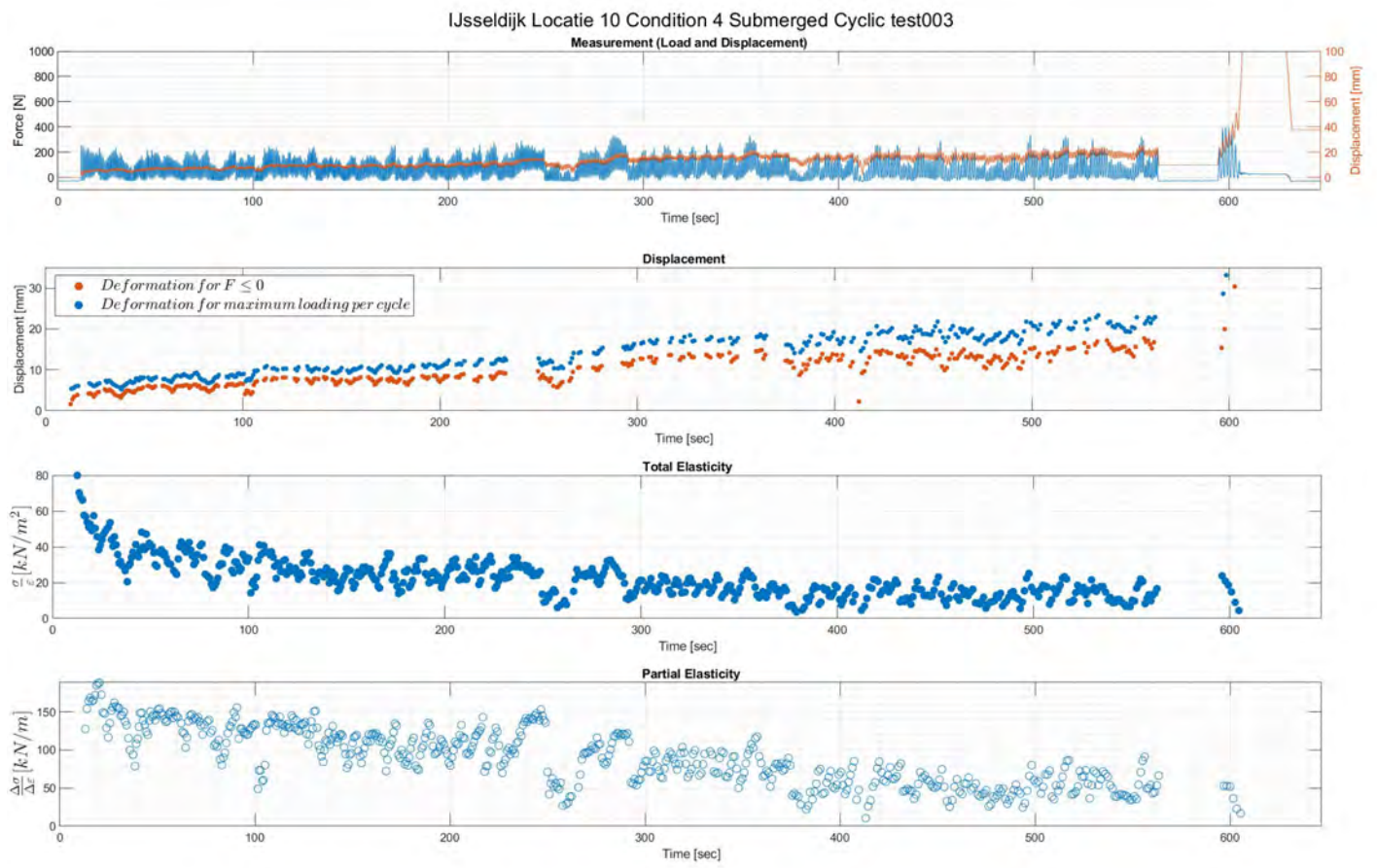
Development of displacement and elasticity are shown as function of number of cycles.

test003

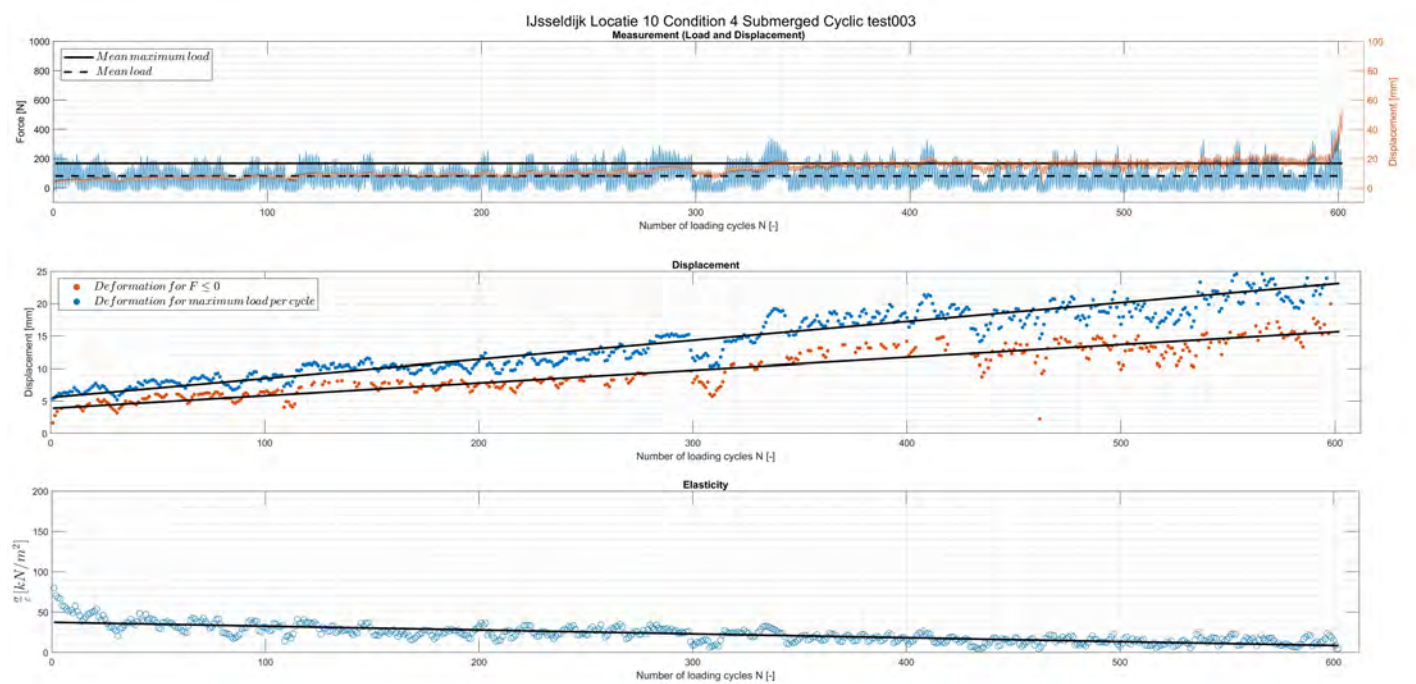
		value 1	value 2	value 3	mean
Date		8-4-2019			
Mean load	[N]	8.09e+01	1.56e+02		1.18e+02
Mean maximum load	[N]	1.66e+02	2.94e+02		2.30e+02
Growth rate Plastic deformation	$\frac{\Delta U}{n}$ [mm]	1.87e-02	3.11e+00		
Growth rate Maximum deformation	$\frac{\Delta U}{n}$ [mm]	2.73e-02	4.61e+00		
Width Sod	[cm]	21			
Weight Sod	[N]	27			
Sod Height	[cm]	8	7	8	7.7
Root Length	[cm]	5	7	8	7.1
Comments					



Figure 6.3: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



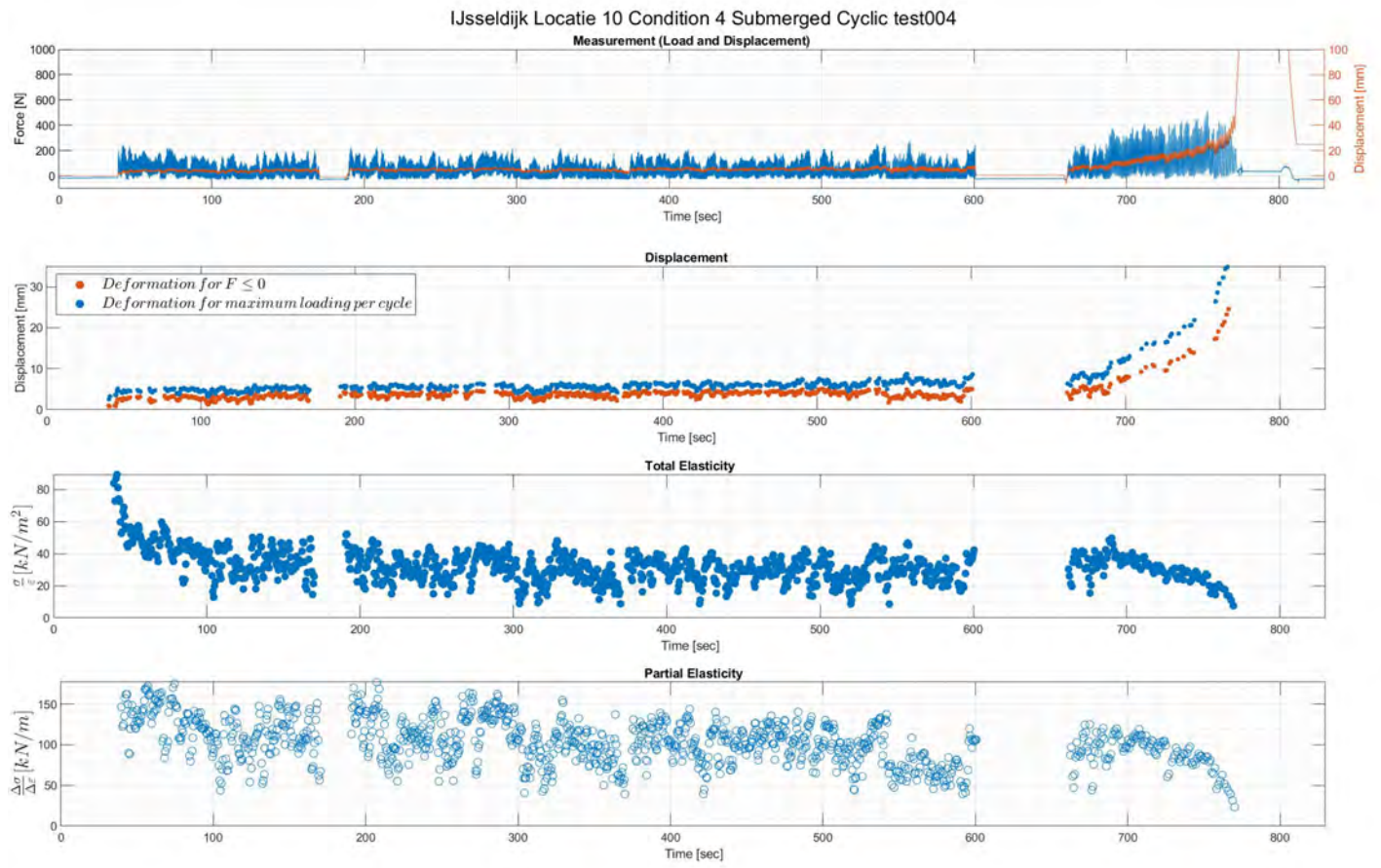
Development of displacement and elasticity are shown as function of number of cycles.

test004

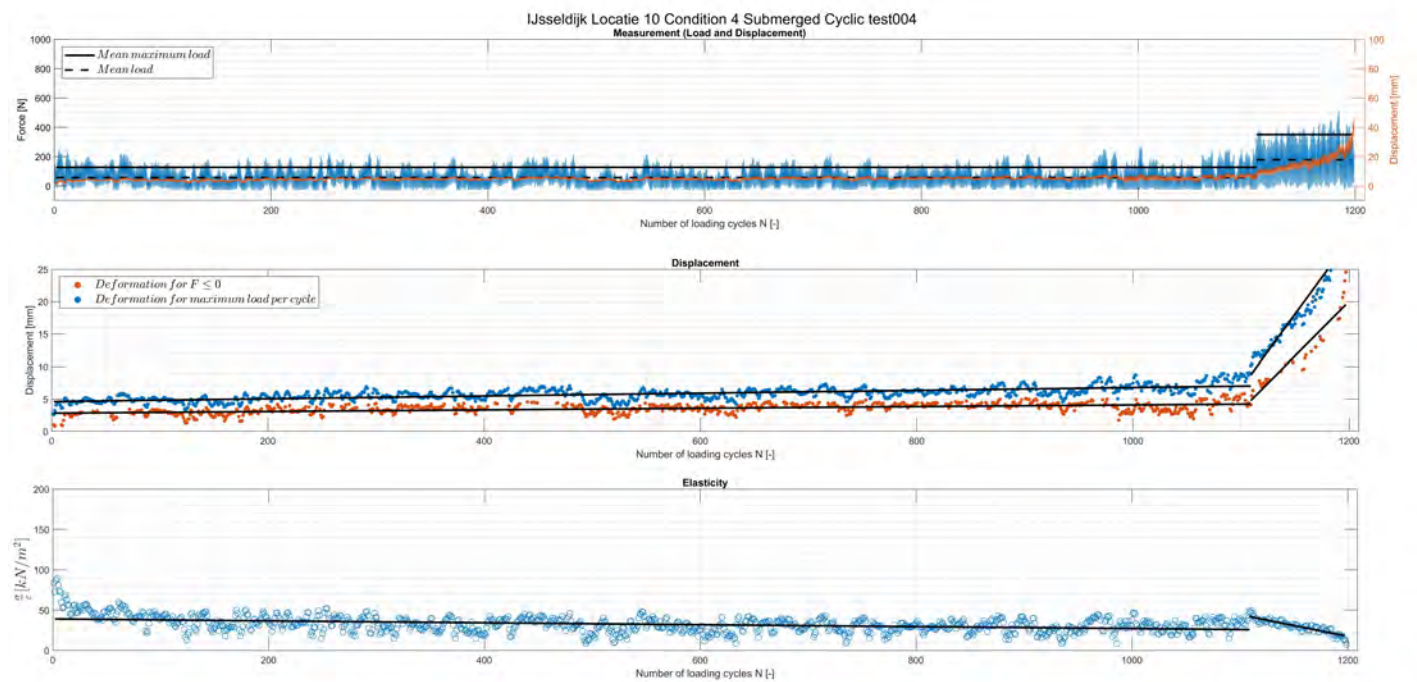
		value 1	value 2	value 3	mean
Date		25-4-2019			
Mean load	[N]	5.71e+01	1.77e+02		1.17e+02
Mean maximum load	[N]	1.27e+02	3.48e+02		2.37e+02
Growth rate Plastic deformation	$\frac{\Delta U}{n}$ [mm]	1.28e-03	1.68e-01		
Growth rate Maximum deformation	$\frac{\Delta U}{n}$ [mm]	2.15e-03	2.28e-01		
Width Sod	[cm]	21			
Weight Sod	[N]	33			
Sod Height	[cm]	9	6	5	6.6
Root Length	[cm]	5	6	5	5.4
Comments		controleer meting			



Figure 6.4: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



Development of displacement and elasticity are shown as function of number of cycles.

Submerged Condition 4 Max

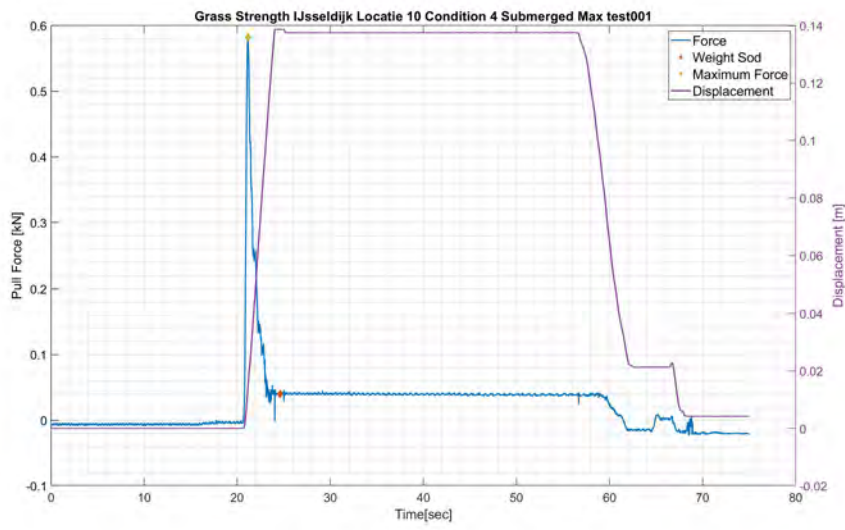
	F max [N]	Weight Sod [kg]	Width Sod [cm]	Mean Height Sod [cm]	Mean Root Length [cm]
test001	578	4.0	21	6.5	7.3
test002	1006	3.7	21	7.0	4.7
test003	860	4.7	21	7.5	6.0
test004	631	2.2	21	5.6	6.4
test005	697	4.0	21	7.6	8.0
Mean	755	3.7	21	6.8	6.5
Median	697	4.0	21	7	6
75 th percentile	897	4.2	21	8	7
25 th percentile	617	3.3	21	6	6

test001

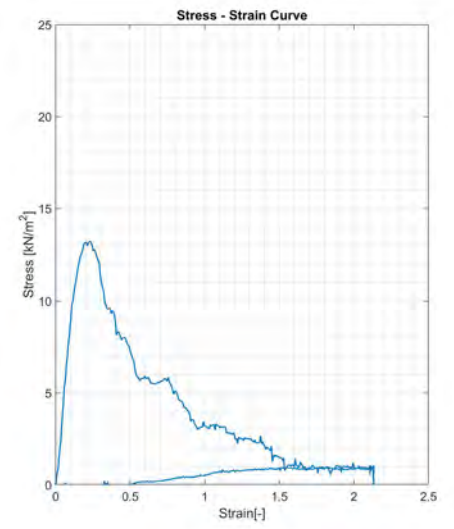
	value 1	value 2	value 3	mean
Date	25-4-2019			
Maximum load [N]	577			
Width Sod [cm]	21			
Weight Sod [N]	40			
Sod Height [cm]	8	5	8	6.5
Root Length [cm]	1	8	8	7.3
Comments				



Figure 7.1: Pictures of tested grass sod.



Measurement of load and displacement



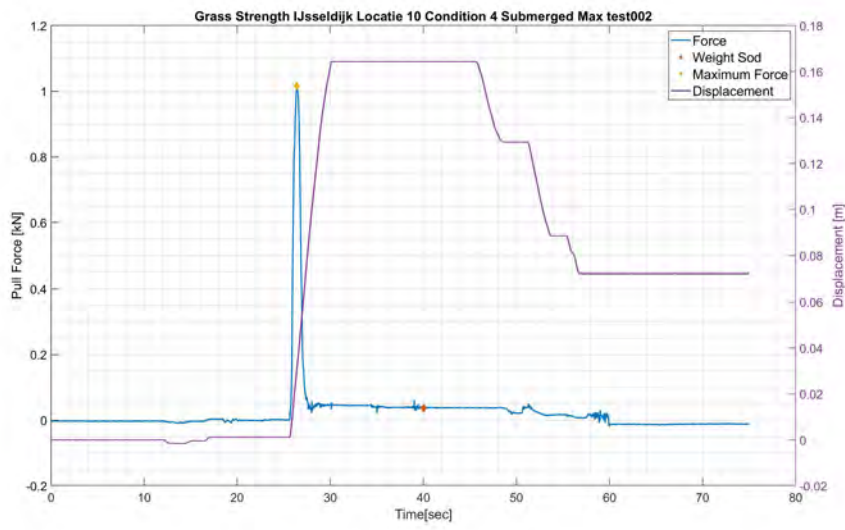
Stress - Strain relation.

test002

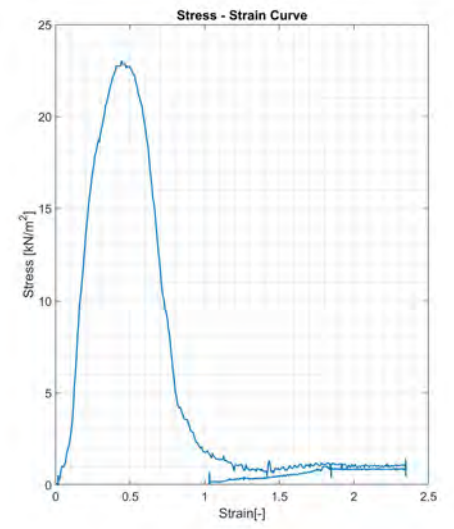
	value 1	value 2	value 3	mean
Date	25-4-2019			
Maximum load [N]	1007			
Width Sod [cm]	21			
Weight Sod [N]	37			
Sod Height [cm]	9	7	5	7
Root Length [cm]	4	5	5	4.7
Comments				



Figure 7.2: Pictures of tested grass sod.



Measurement of load and displacement



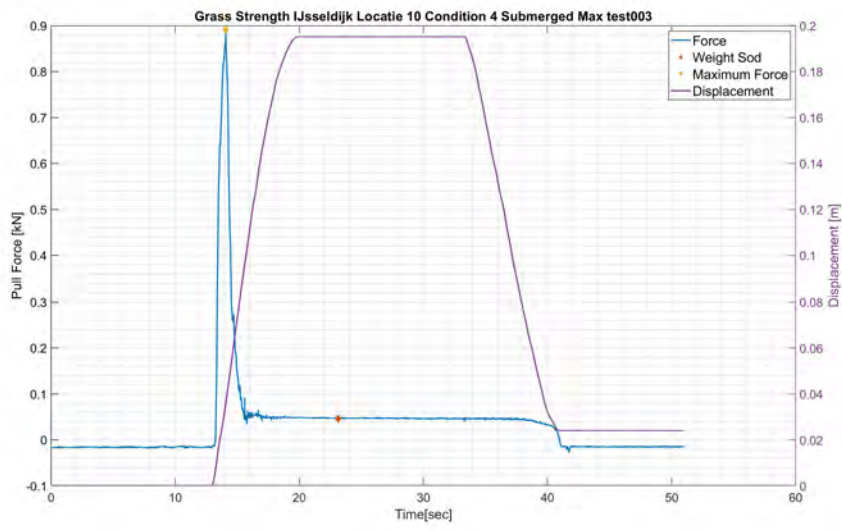
Stress - Strain relation.

test003

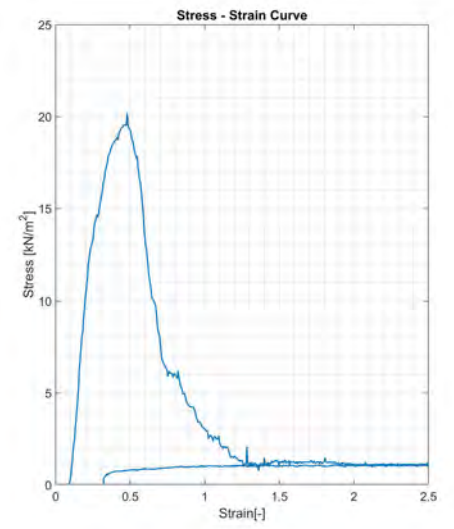
	value 1	value 2	value 3	mean
Date	25-4-2019			
Maximum load [N]	862			
Width Sod [cm]	21			
Weight Sod [N]	47			
Sod Height [cm]	8	7	0	7.5
Root Length [cm]	6	6	0	6
Comments				



Figure 7.3: Pictures of tested grass sod.



Measurement of load and displacement



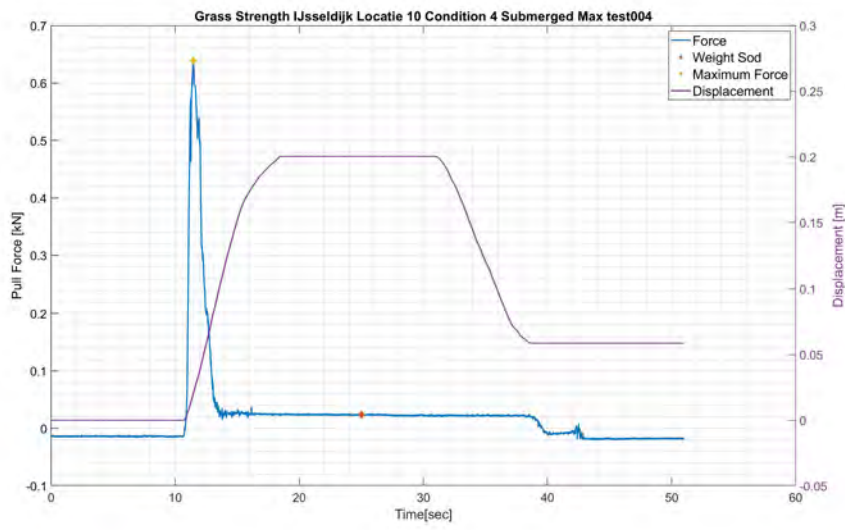
Stress - Strain relation.

test004

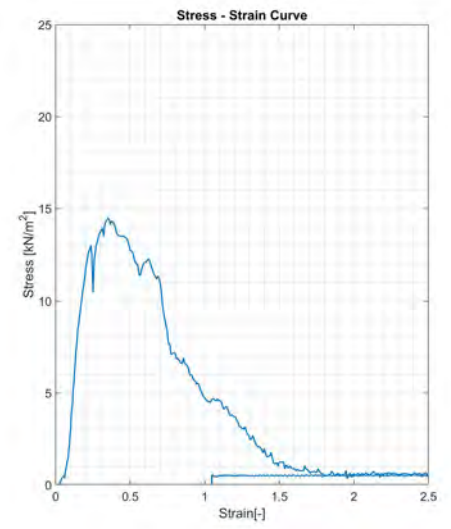
	value 1	value 2	value 3	mean
Date	25-4-2019			
Maximum load [N]	630			
Width Sod [cm]	21			
Weight Sod [N]	22			
Sod Height [cm]	7	5	0	5.6
Root Length [cm]	5	7	0	6.4
Comments				



Figure 7.4: Pictures of tested grass sod.



Measurement of load and displacement



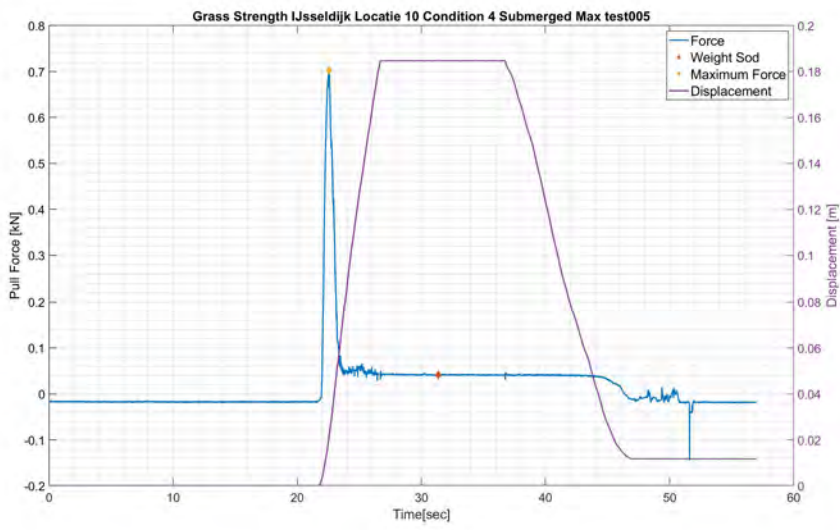
Stress - Strain relation.

test005

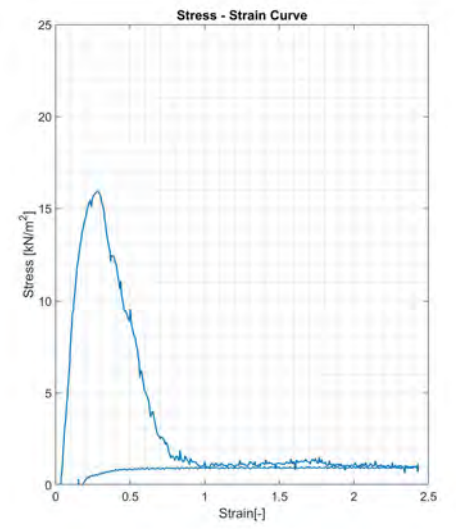
	value 1	value 2	value 3	mean
Date	25-4-2019			
Maximum load [N]	697			
Width Sod [cm]	21			
Weight Sod [N]	40			
Sod Height [cm]	9	7	8	7.6
Root Length [cm]	8	8	8	8
Comments				



Figure 7.5: Pictures of tested grass sod.



Measurement of load and displacement



Stress - Strain relation.

Submerged Condition 2 Constant

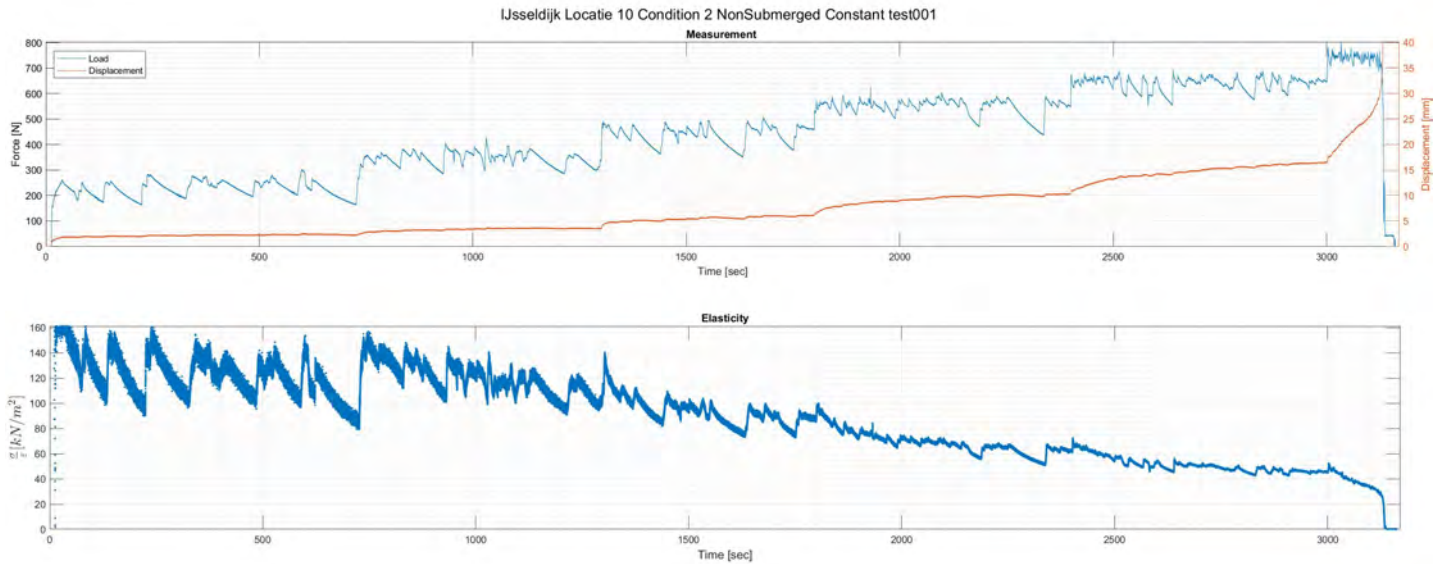
	Time to reach 80% of displacement [<i>sec</i>]	E [<i>kN/m²</i>]	Weight Sod [<i>kg</i>]	Width Sod [<i>cm</i>]	Mean Height Sod [<i>cm</i>]	Mean Root Length [<i>cm</i>]
test001	21	105.38	4.2	29.0	6.7	1.8
mean	21	105.38	4.2	29.0	6.7	1.8
median	21	105.38	4.2	29.0	6.7	1.8
75 th percentile	21	105.38	4.2	29.0	6.7	1.8
25 th percentile	21	105.38	4.2	29.0	6.7	1.8

test001

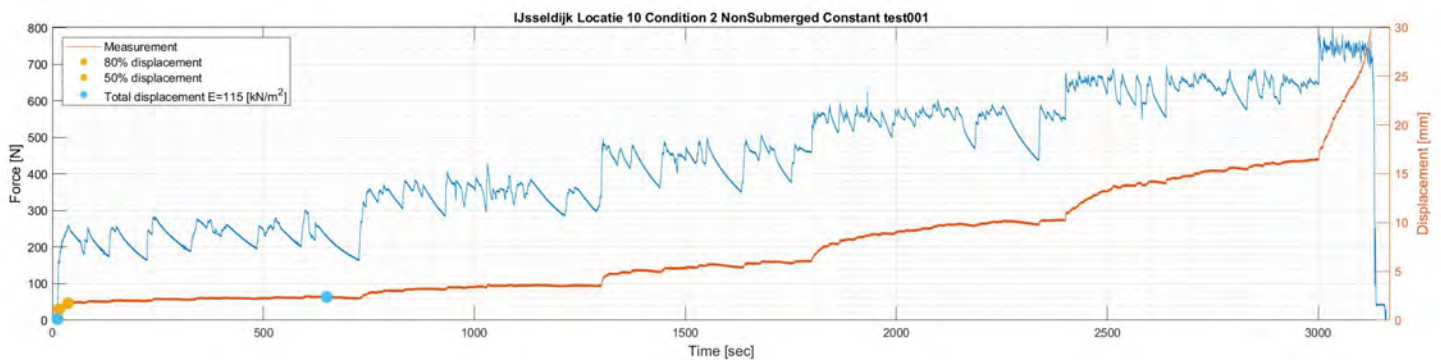
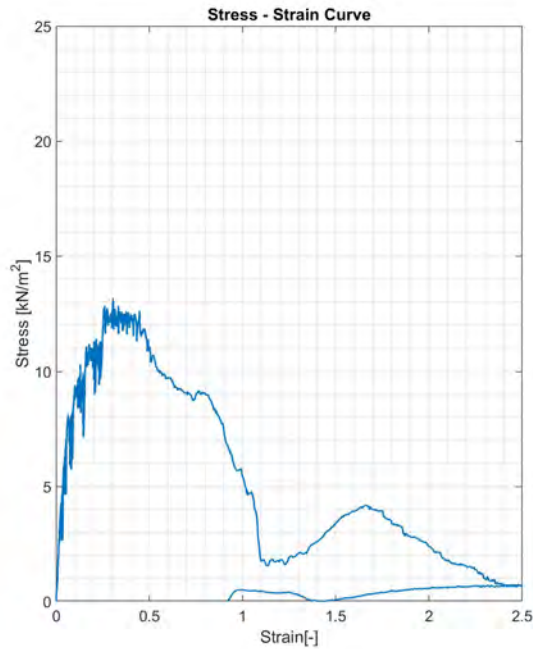
		value 1	value 2	value 3	mean
Date		8-4-2019			
E	$[kN/m^2]$	105.38			
Time to reach 80% of displacement	$[sec]$	21			
Width Sod	$[cm]$	29			
Weight Sod	$[N]$	42			
Sod Height	$[cm]$	11	6	2	6.7
Root Length	$[cm]$	3	1	2	1.8
Comments					



Figure 8.1: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



Displacement rate under step increased constant loading. The blue dots indicate the total or final displacement as result of the induced load during the first 600 seconds of loading. The yellow dot indicates 80% of the final displacement

NonSubmerged Condition 2 Max

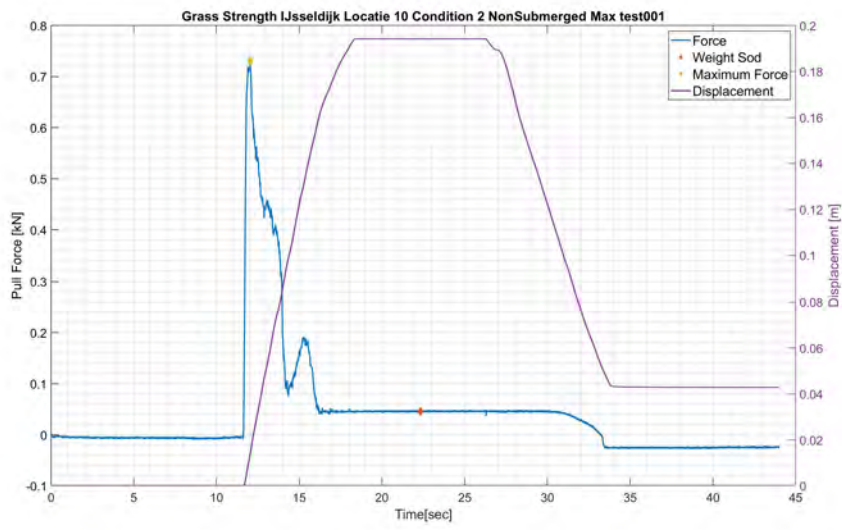
	F max [N]	Weight Sod [kg]	Width Sod [cm]	Mean Height Sod [cm]	Mean Root Length [cm]
test001	716	4.6	33	4.9	1.1
test002	847	6.2	24	9.0	3.2
test003	893	5.1	27	10.5	3.4
test004	1095	6.0	27	9.6	3.6
test005	897	7.3	32	10.4	1.6
test006	1305	6.9	24	12.6	2.3
test007	865	NaN	25	9.2	2.0
test008	791	5.2	31	9.0	2.0
test009	1163	4.5	27	7.9	4.0
test010	762	4.2	28	8.3	2.7
test011	1255	6.5	32	10.5	2.1
test012	857	5.8	29	9.3	1.9
test013	735	4.4	35	7.6	2.4
test014	1001	7.5	31	7.0	1.0
test015	1184	6.9	30	8.4	2.2
test016	1132	7.7	31	9.5	2.5
test017	1172	5.8	36	10.2	1.9
test018	919	3.9	30	9.2	3.4
test019	841	4.7	29	9.0	2.0
test020	941	5.0	27	10.1	2.0
test021	868	4.4	28	9.5	1.0
Mean	964	5.6	29.3	9.1	2.3
Median	897	5.5	29	9	2
75 th percentile	1140	6.7	31	10	3
25 th percentile	846	4.6	31	8	2

test001

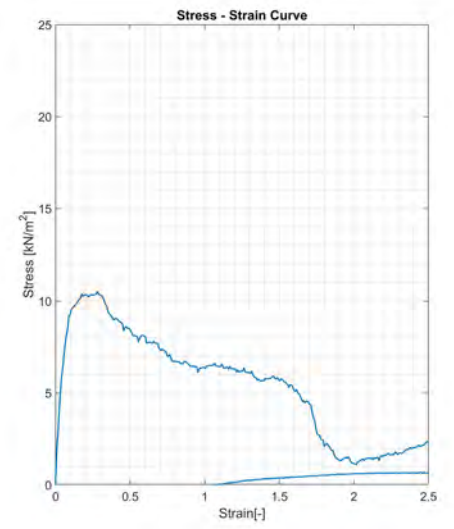
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	718			
Width Sod [cm]	33			
Weight Sod [N]	46			
Sod Height [cm]	10	7	1	4.9
Root Length [cm]	2	1	1	1.1
Comments				



Figure 9.1: Pictures of tested grass sod.



Measurement of load and displacement



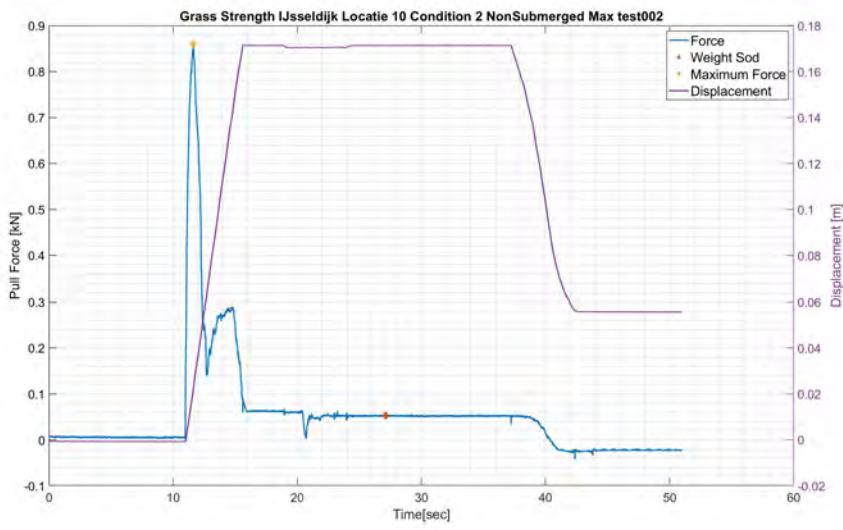
Stress - Strain relation.

test002

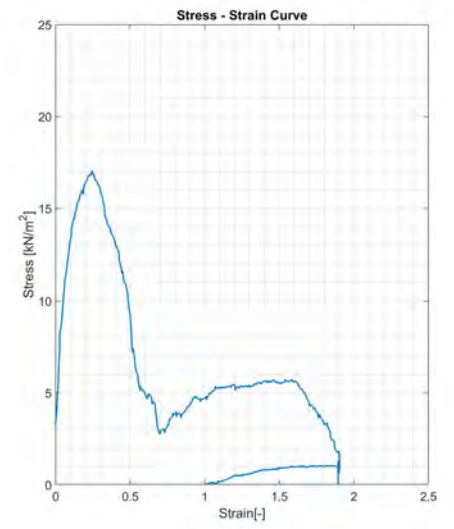
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	849			
Width Sod [cm]	24			
Weight Sod [N]	62			
Sod Height [cm]	10	9	6	9
Root Length [cm]	2	4	6	3.2
Comments				



Figure 9.2: Pictures of tested grass sod.



Measurement of load and displacement



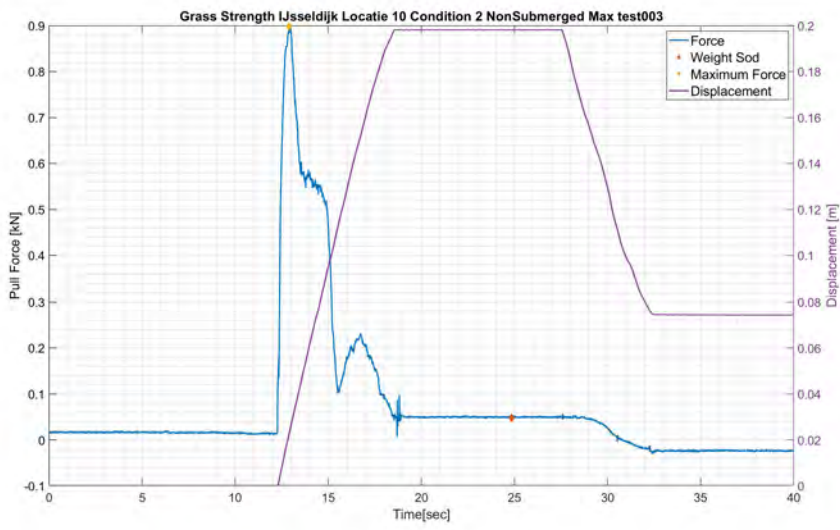
Stress - Strain relation.

test003

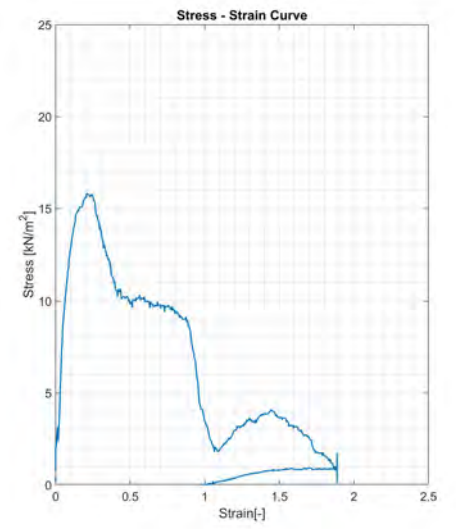
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	892			
Width Sod [cm]	27			
Weight Sod [N]	51			
Sod Height [cm]	13	10	8	10.5
Root Length [cm]	1	3	8	3.4
Comments				



Figure 9.3: Pictures of tested grass sod.



Measurement of load and displacement



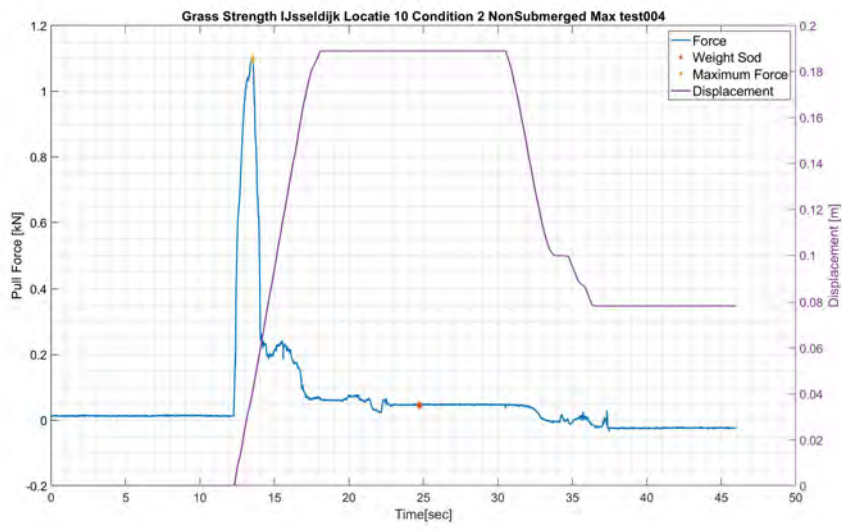
Stress - Strain relation.

test004

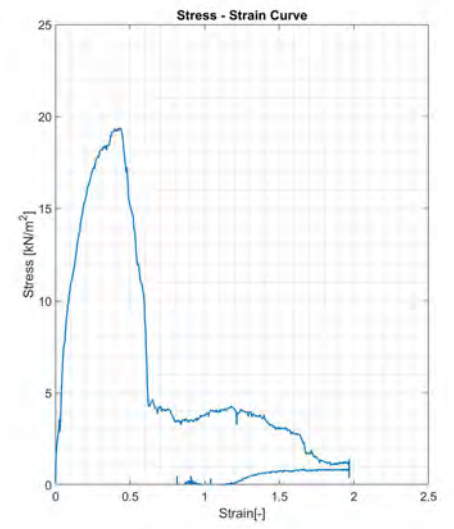
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	1094			
Width Sod [cm]	27			
Weight Sod [N]	60			
Sod Height [cm]	14	10	6	9.6
Root Length [cm]	2	2	6	3.6
Comments				



Figure 9.4: Pictures of tested grass sod.



Measurement of load and displacement



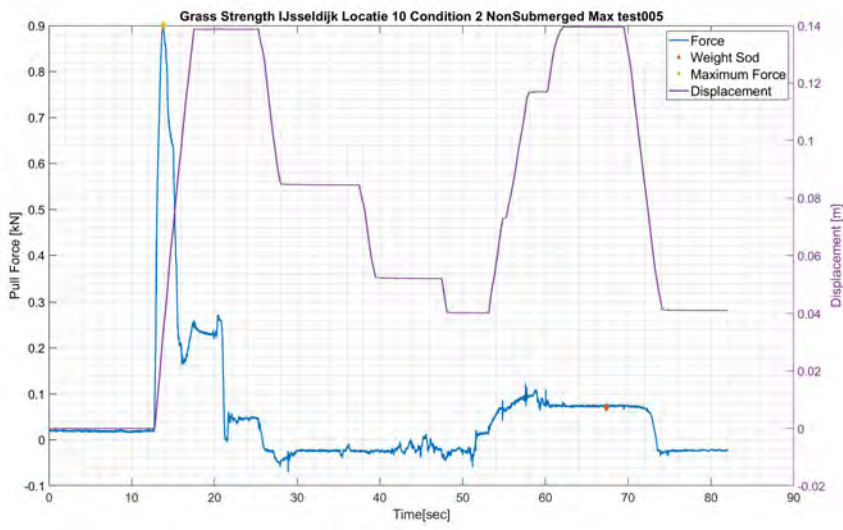
Stress - Strain relation.

test005

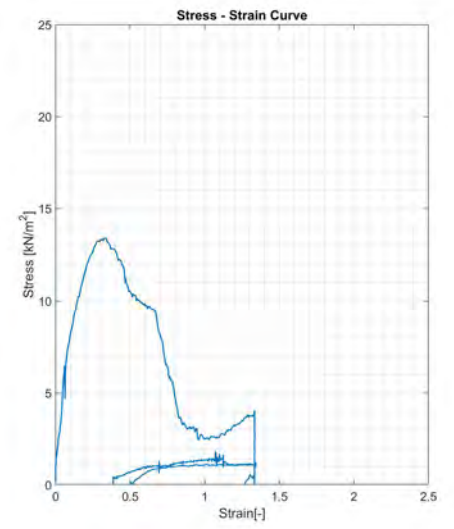
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	897			
Width Sod [cm]	32			
Weight Sod [N]	73			
Sod Height [cm]	15	13	3	10.4
Root Length [cm]	1	1	3	1.6
Comments				



Figure 9.5: Pictures of tested grass sod.



Measurement of load and displacement



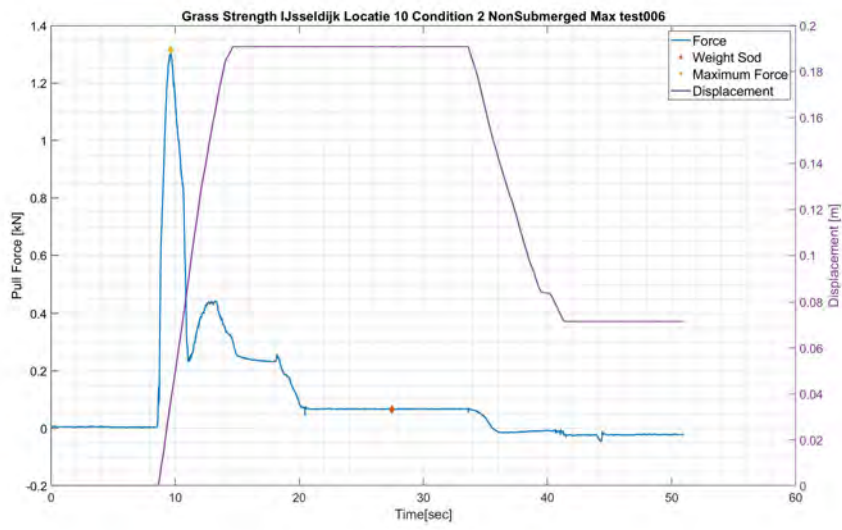
Stress - Strain relation.

test006

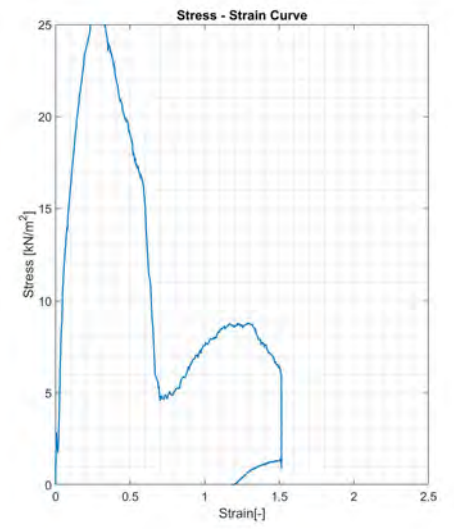
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	1305			
Width Sod [cm]	24			
Weight Sod [N]	69			
Sod Height [cm]	16	13	6	12.6
Root Length [cm]	1	2	6	2.3
Comments				



Figure 9.6: Pictures of tested grass sod.



Measurement of load and displacement



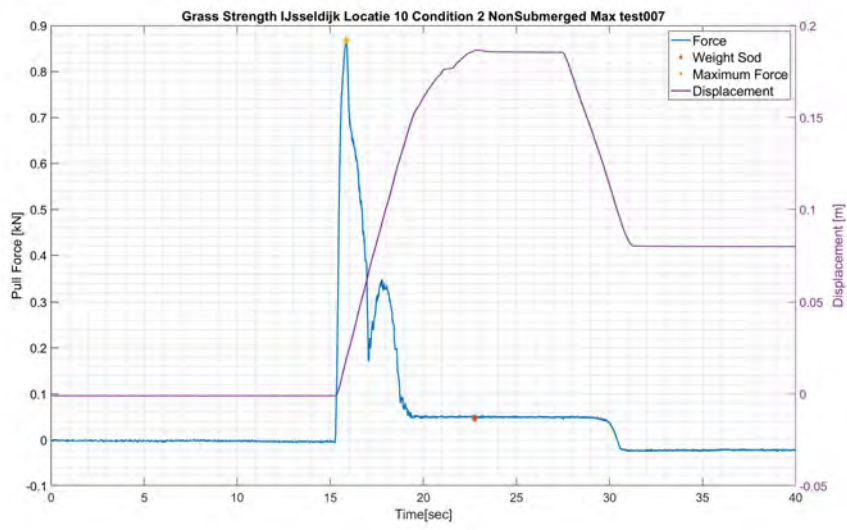
Stress - Strain relation.

test007

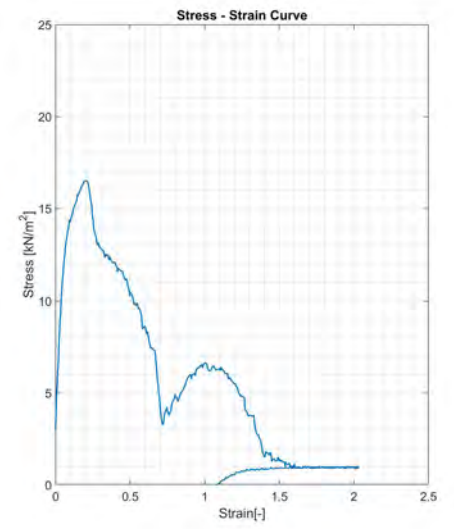
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	862			
Width Sod [cm]	25			
Weight Sod [N]	NaN			
Sod Height [cm]	10	6	0	9.2
Root Length [cm]	1	6	0	2
Comments				



Figure 9.7: Pictures of tested grass sod.



Measurement of load and displacement



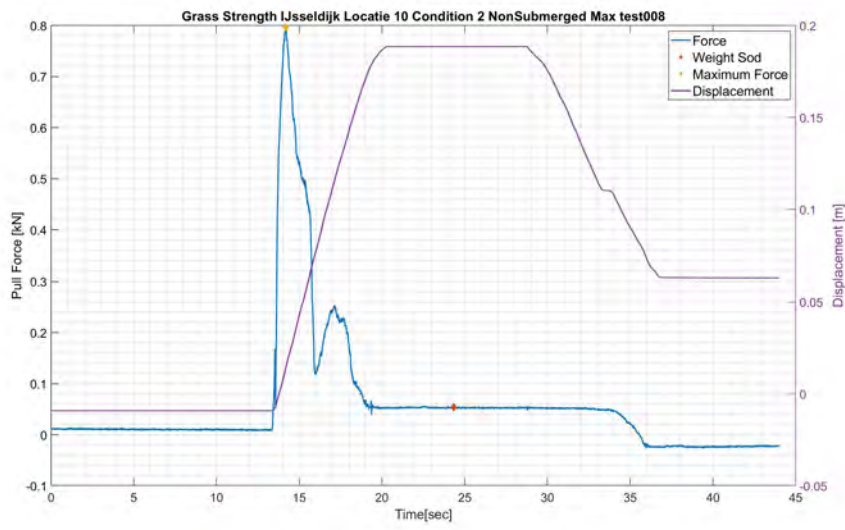
Stress - Strain relation.

test008

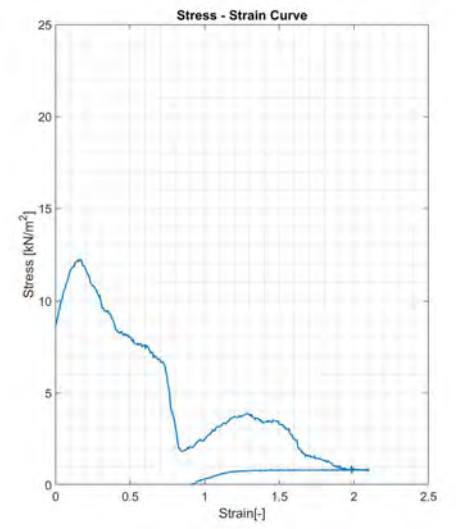
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	791			
Width Sod [cm]	31			
Weight Sod [N]	52			
Sod Height [cm]	10	8	0	9
Root Length [cm]	2	2	0	2
Comments				



Figure 9.8: Pictures of tested grass sod.



Measurement of load and displacement



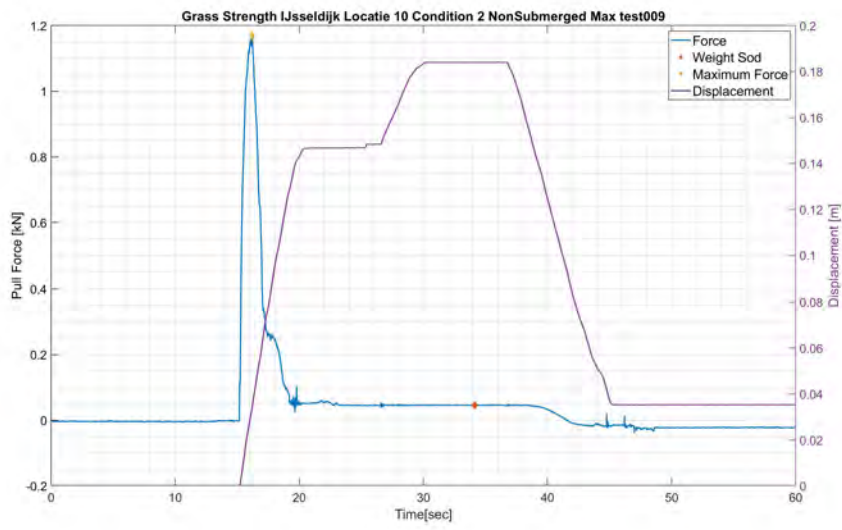
Stress - Strain relation.

test009

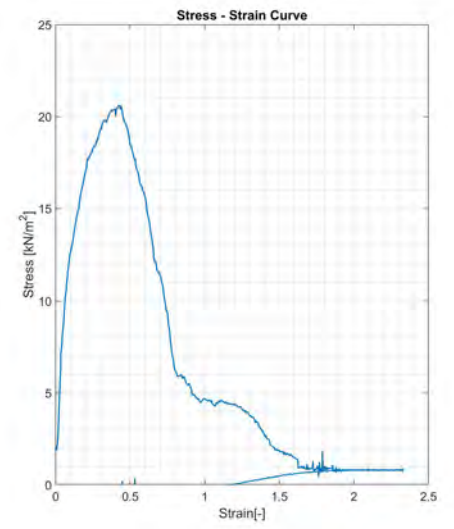
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	1161			
Width Sod [cm]	27			
Weight Sod [N]	45			
Sod Height [cm]	12	9	4	7.9
Root Length [cm]	5	3	4	4
Comments				



Figure 9.9: Pictures of tested grass sod.



Measurement of load and displacement



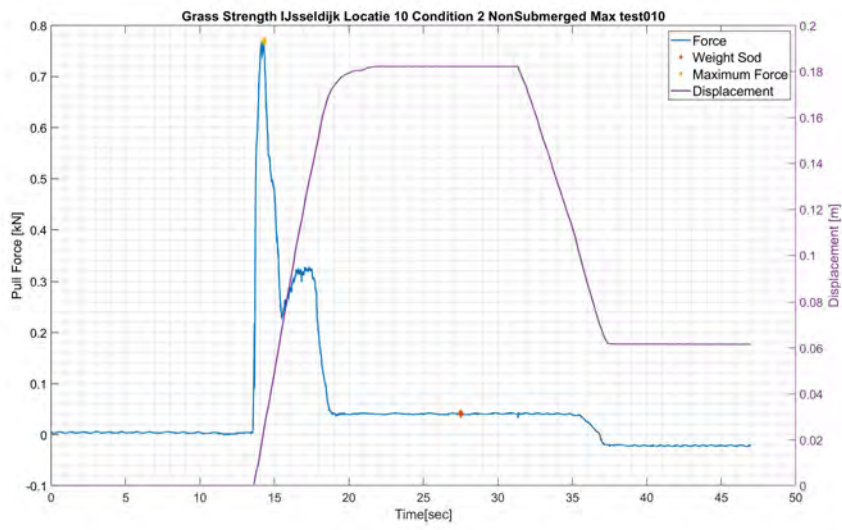
Stress - Strain relation.

test010

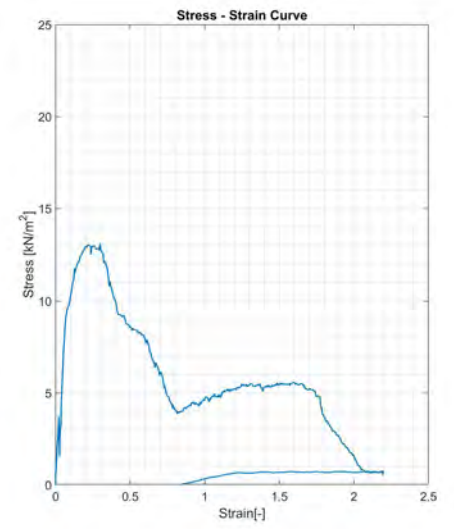
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	760			
Width Sod [cm]	28			
Weight Sod [N]	42			
Sod Height [cm]	9	8	0	8.3
Root Length [cm]	2	3	0	2.7
Comments				



Figure 9.10: Pictures of tested grass sod.



Measurement of load and displacement



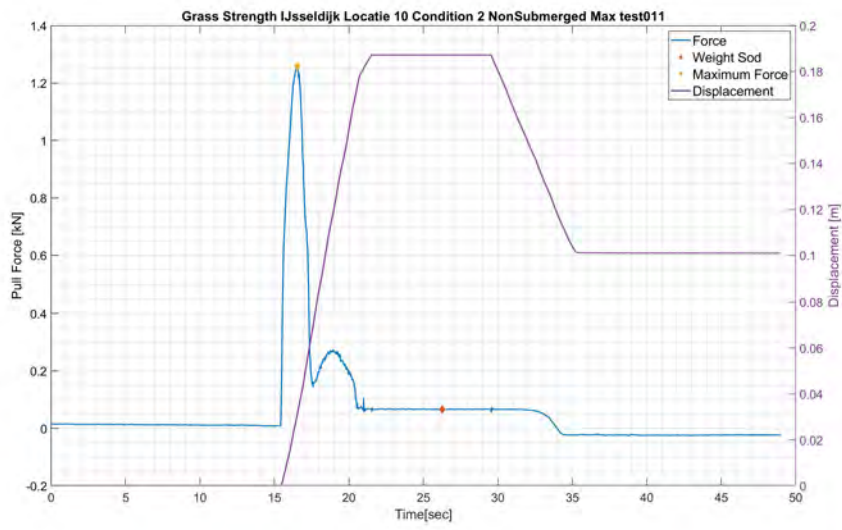
Stress - Strain relation.

test011

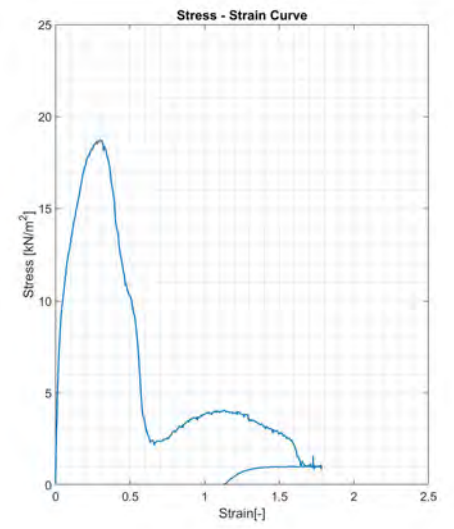
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	1254			
Width Sod [cm]	32			
Weight Sod [N]	65			
Sod Height [cm]	14	10	3	10.5
Root Length [cm]	2	2	3	2.1
Comments				



Figure 9.11: Pictures of tested grass sod.



Measurement of load and displacement



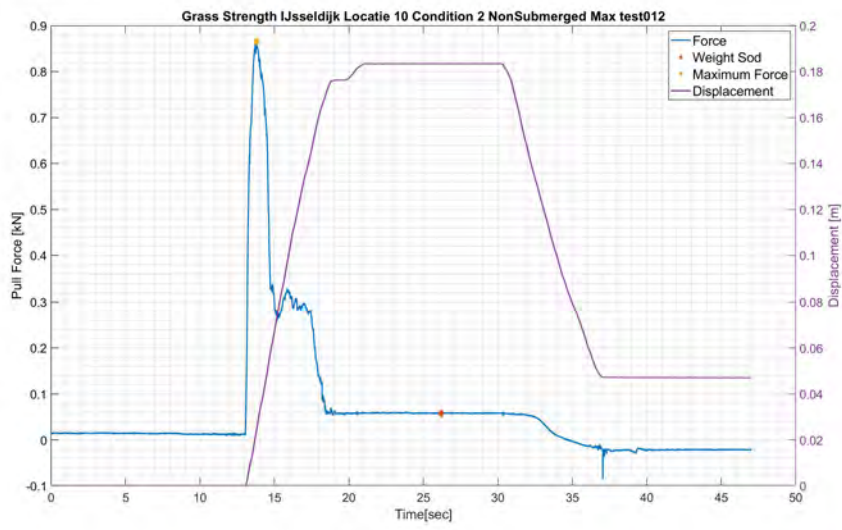
Stress - Strain relation.

test012

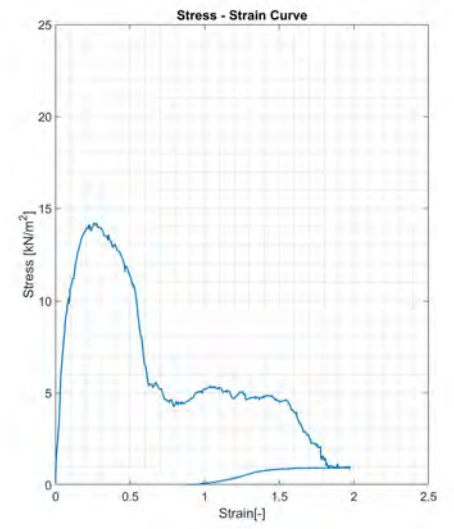
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	857			
Width Sod [cm]	29			
Weight Sod [N]	58			
Sod Height [cm]	12	8	5	9.3
Root Length [cm]	1	2	5	1.9
Comments				



Figure 9.12: Pictures of tested grass sod.



Measurement of load and displacement



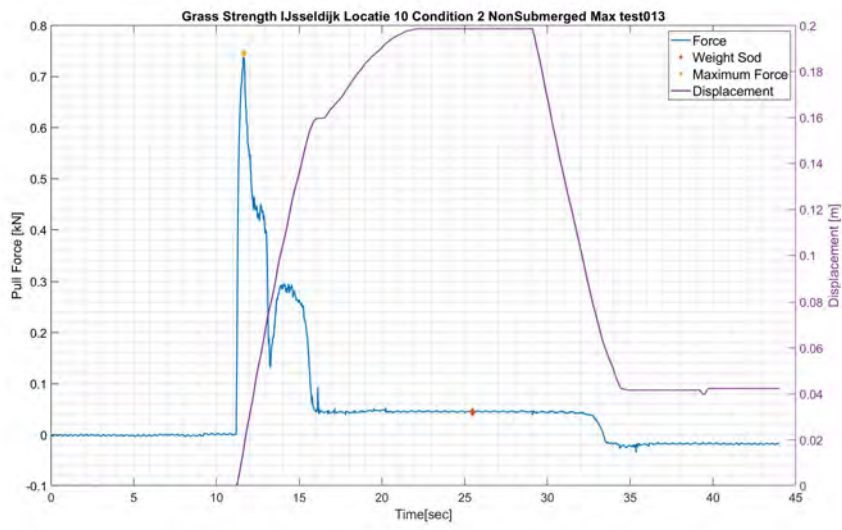
Stress - Strain relation.

test013

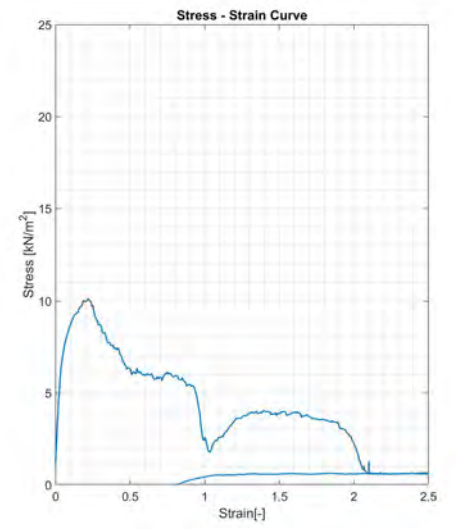
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	734			
Width Sod [cm]	35			
Weight Sod [N]	44			
Sod Height [cm]	8	6	0	7.6
Root Length [cm]	2	4	0	2.4
Comments				



Figure 9.13: Pictures of tested grass sod.



Measurement of load and displacement



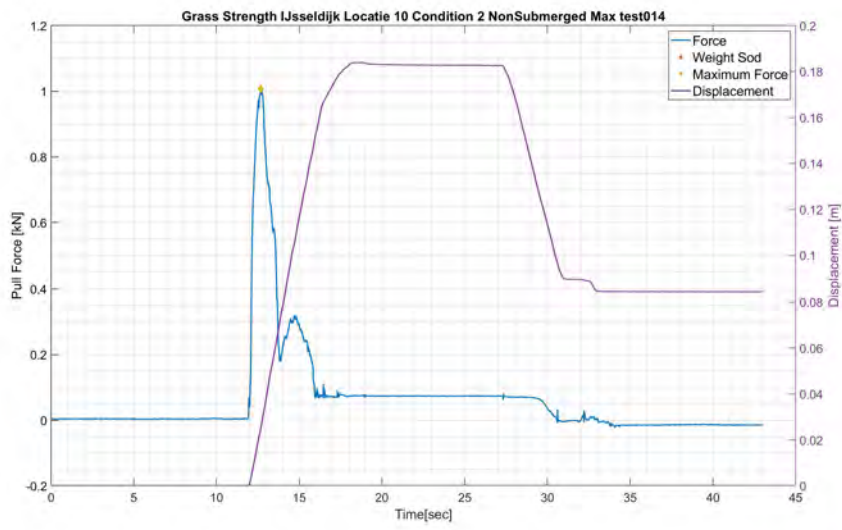
Stress - Strain relation.

test014

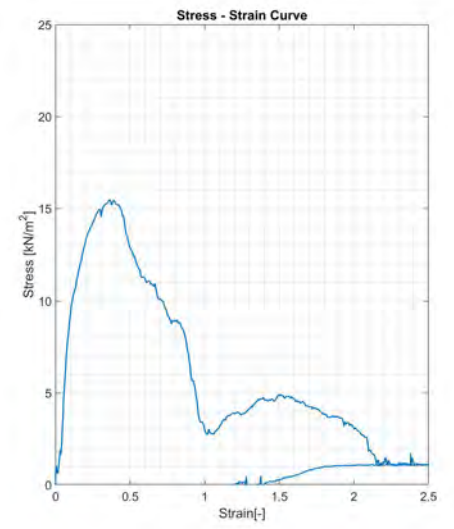
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	1001			
Width Sod [cm]	31			
Weight Sod [N]	75			
Sod Height [cm]	12	10	1	7
Root Length [cm]	1	1	1	1
Comments				



Figure 9.14: Pictures of tested grass sod.



Measurement of load and displacement



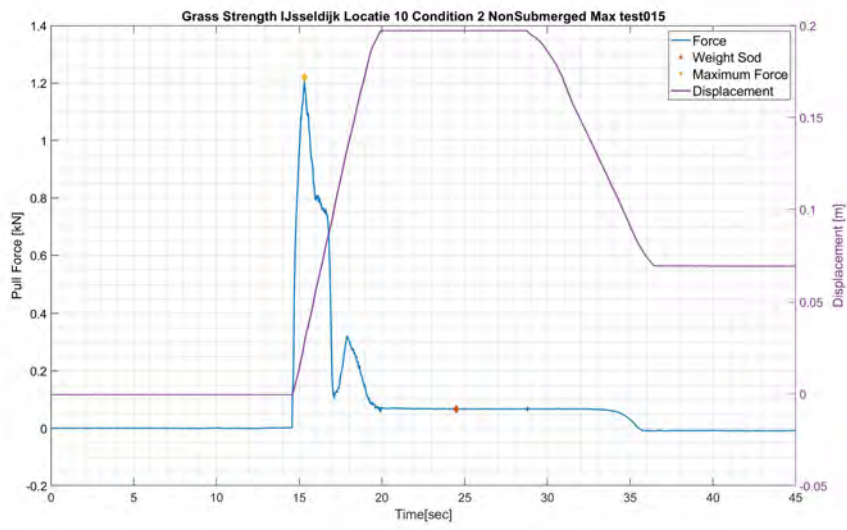
Stress - Strain relation.

test015

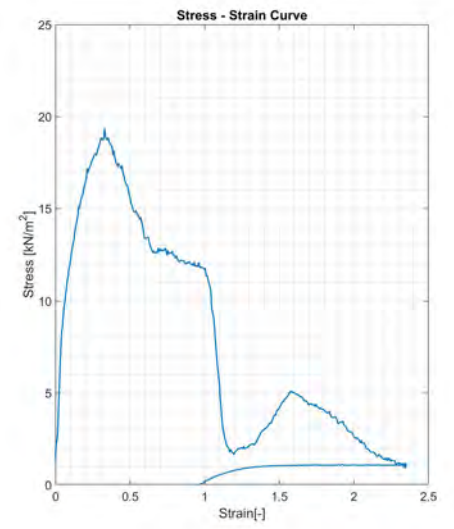
	value 1	value 2	value 3	mean
Date	2-4-2019			
Maximum load [N]	1187			
Width Sod [cm]	30			
Weight Sod [N]	69			
Sod Height [cm]	11	9	4	8.4
Root Length [cm]	1	2	4	2.2
Comments				



Figure 9.15: Pictures of tested grass sod.



Measurement of load and displacement



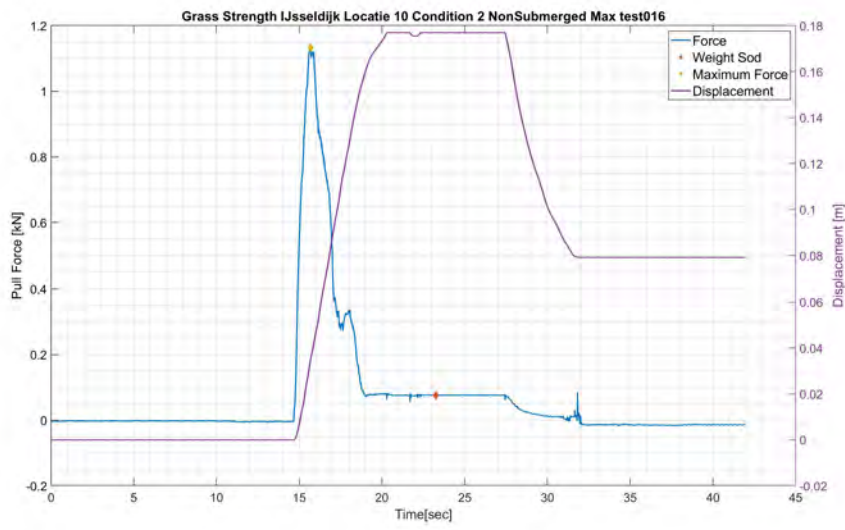
Stress - Strain relation.

test016

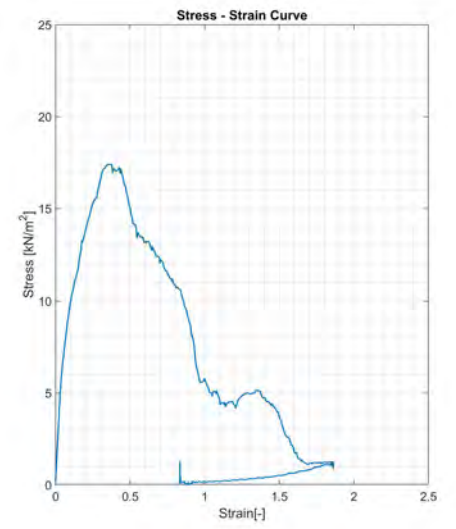
	value 1	value 2	value 3	mean
Date	4-4-2019			
Maximum load [N]	1131			
Width Sod [cm]	31			
Weight Sod [N]	77			
Sod Height [cm]	15	11	6	9.5
Root Length [cm]	1	4	6	2.5
Comments				



Figure 9.16: Pictures of tested grass sod.



Measurement of load and displacement



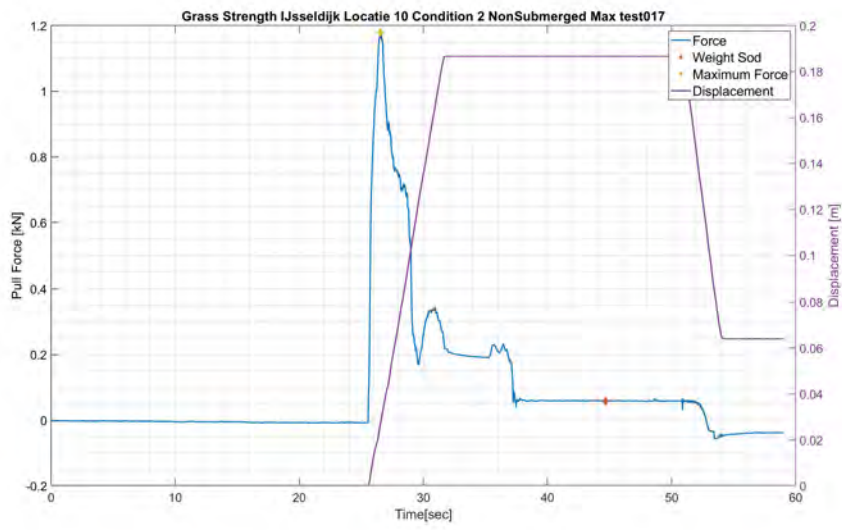
Stress - Strain relation.

test017

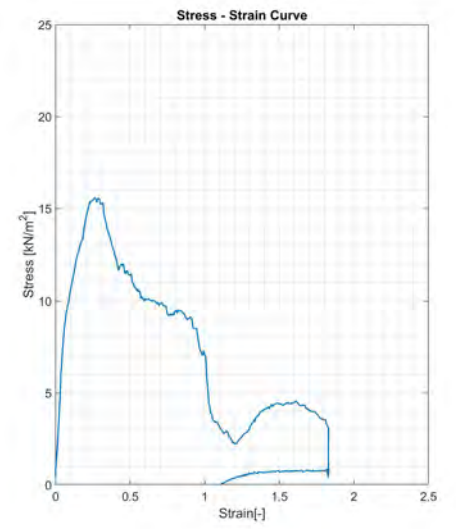
	value 1	value 2	value 3	mean
Date	4-4-2019			
Maximum load [N]	1172			
Width Sod [cm]	36			
Weight Sod [N]	58			
Sod Height [cm]	13	9	5	10.2
Root Length [cm]	1	2	5	1.9
Comments				



Figure 9.17: Pictures of tested grass sod.



Measurement of load and displacement



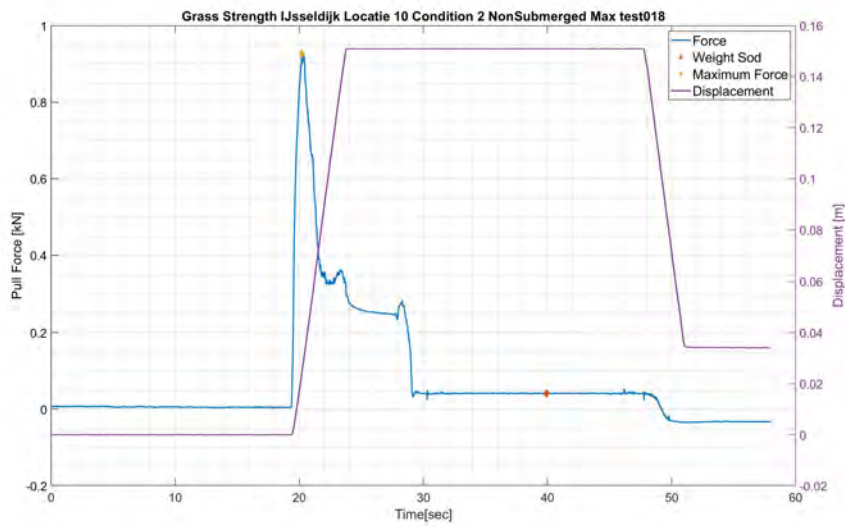
Stress - Strain relation.

test018

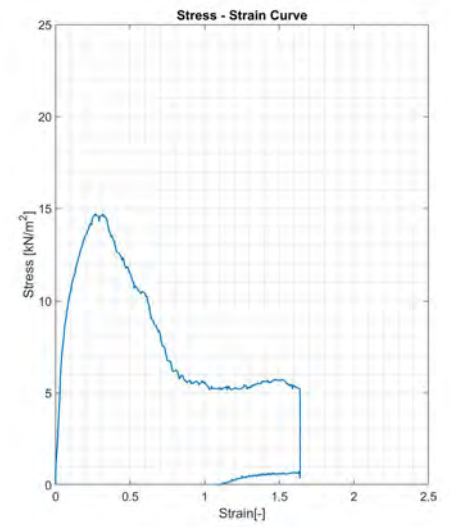
	value 1	value 2	value 3	mean
Date	4-4-2019			
Maximum load [N]	920			
Width Sod [cm]	30			
Weight Sod [N]	39			
Sod Height [cm]	11	10	5	9.2
Root Length [cm]	3	3	5	3.4
Comments				



Figure 9.18: Pictures of tested grass sod.



Measurement of load and displacement



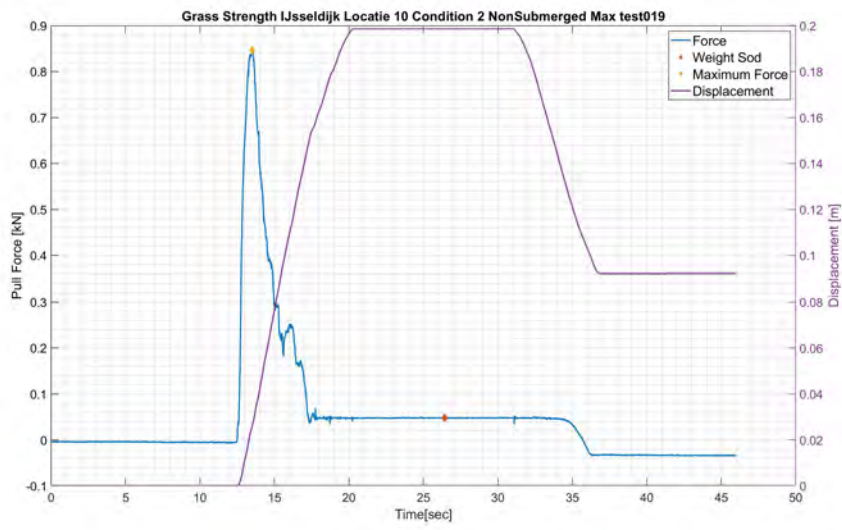
Stress - Strain relation.

test019

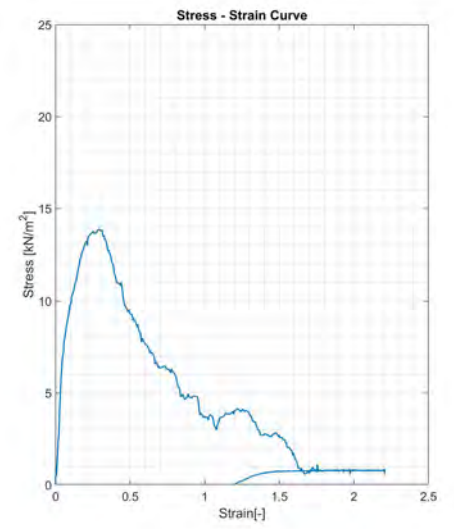
	value 1	value 2	value 3	mean
Date	4-4-2019			
Maximum load [N]	842			
Width Sod [cm]	29			
Weight Sod [N]	47			
Sod Height [cm]	13	9	5	9
Root Length [cm]	2	1	5	2
Comments	Paddenhol			



Figure 9.19: Pictures of tested grass sod.



Measurement of load and displacement



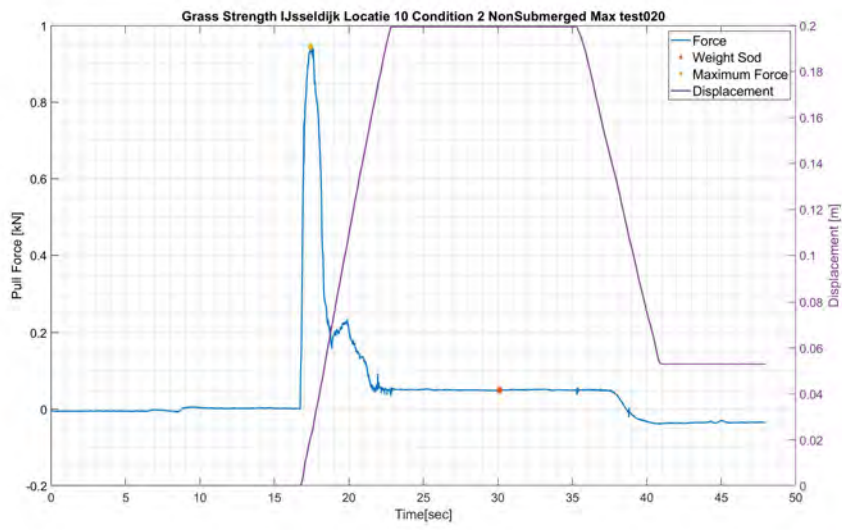
Stress - Strain relation.

test020

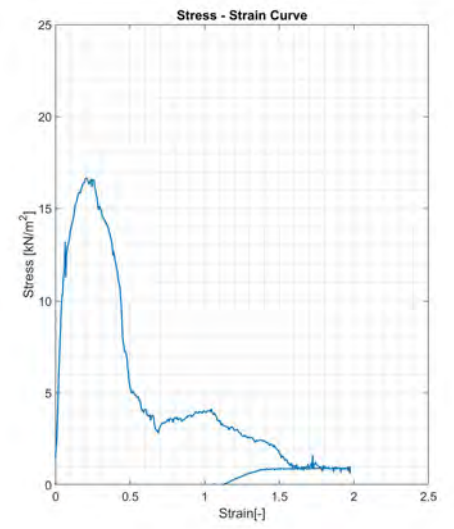
	value 1	value 2	value 3	mean
Date	4-4-2019			
Maximum load [N]	940			
Width Sod [cm]	27			
Weight Sod [N]	50			
Sod Height [cm]	13	10	6	10.1
Root Length [cm]	1	1	6	2
Comments				



Figure 9.20: Pictures of tested grass sod.



Measurement of load and displacement



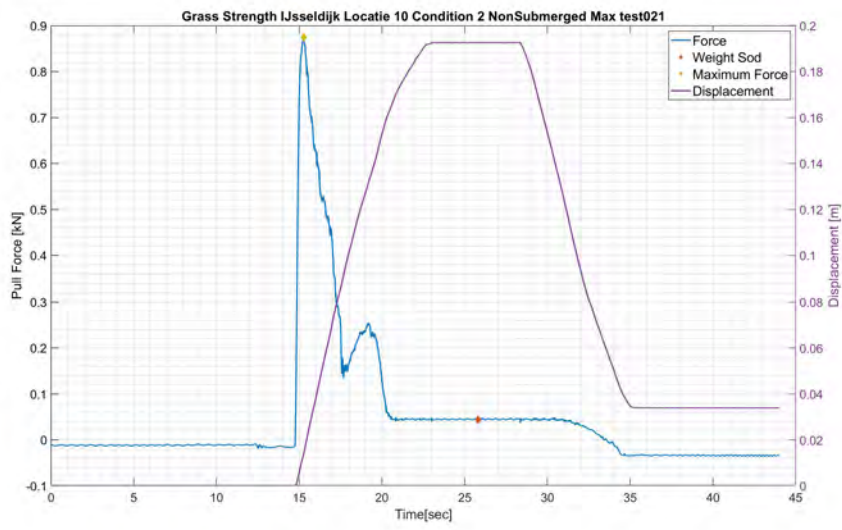
Stress - Strain relation.

test021

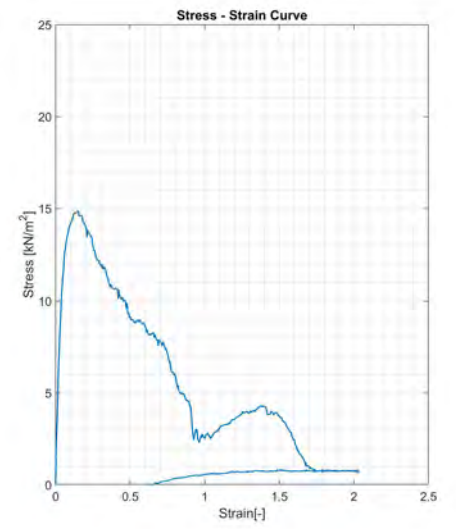
	value 1	value 2	value 3	mean
Date	4-4-2019			
Maximum load [N]	870			
Width Sod [cm]	28			
Weight Sod [N]	44			
Sod Height [cm]	10	9	0	9.5
Root Length [cm]	1	1	0	1
Comments				



Figure 9.21: Pictures of tested grass sod.



Measurement of load and displacement



Stress - Strain relation.

Submerged Condition 2 Constant

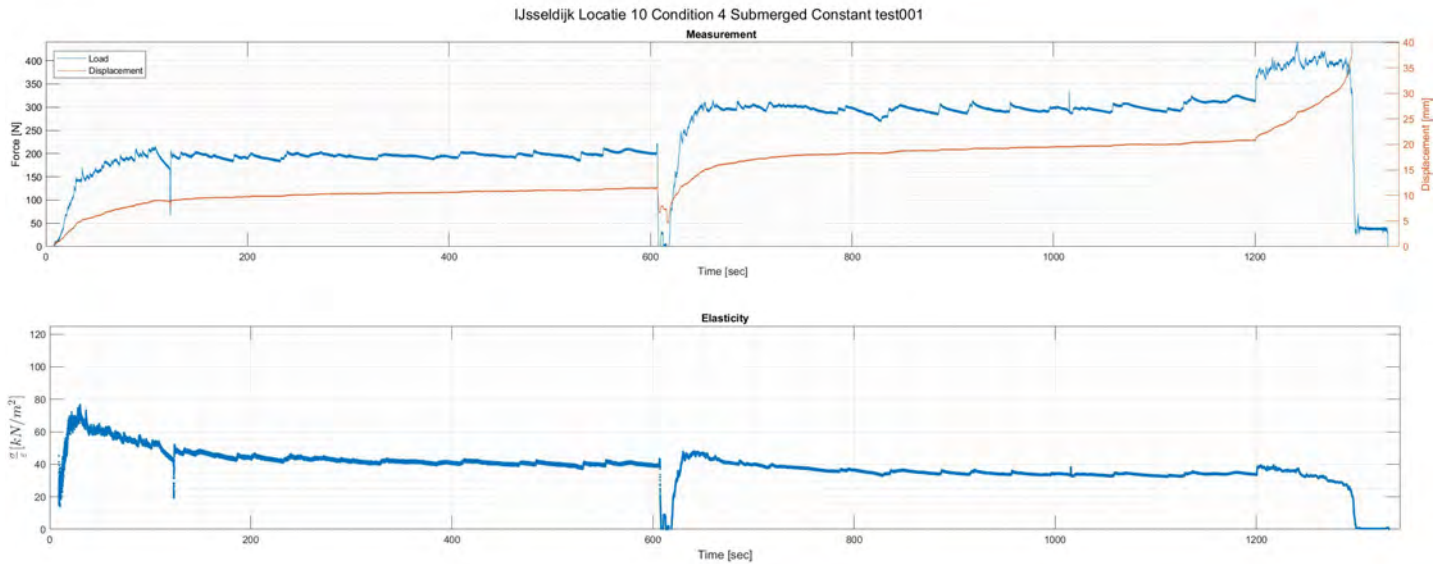
	Time to reach 80% of displacement [<i>sec</i>]	E [kN/m^2]	Weight Sod [kg]	Width Sod [cm]	Mean Height Sod [cm]	Mean Root Length [cm]
test004	52	42.78	3.8	21.0	9.4	3.8
test003	133	37.35	6.8	21.0	8.9	3.9
test002	31	36.59	3.0	21.0	8.0	5.8
test001	92	39.09	4.1	21.0	8.8	4.8
mean	77	38.95	4.4	21.0	8.8	4.6
median	72	38.22	4.0	21.0	8.8	4.4
75 th percentile	112	40.93	5.4	21.0	9.1	5.3
25 th percentile	42	36.97	3.4	21.0	8.4	3.8

test001

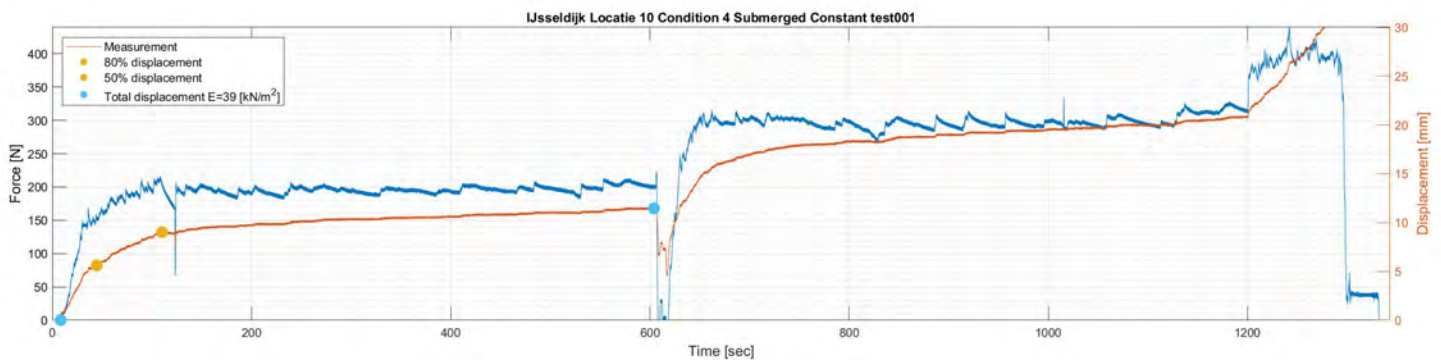
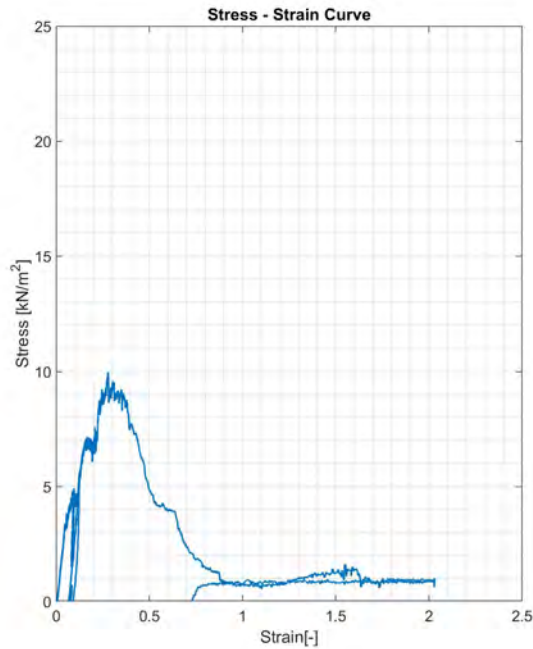
	value 1	value 2	value 3	mean
Date	25-4-2019			
E	39.09			
Time to reach 80% of displacement	92			
Width Sod	21			
Weight Sod	38			
Sod Height	13	10	4	9.4
Root Length	3	4	4	3.8
Comments				



Figure 10.1: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



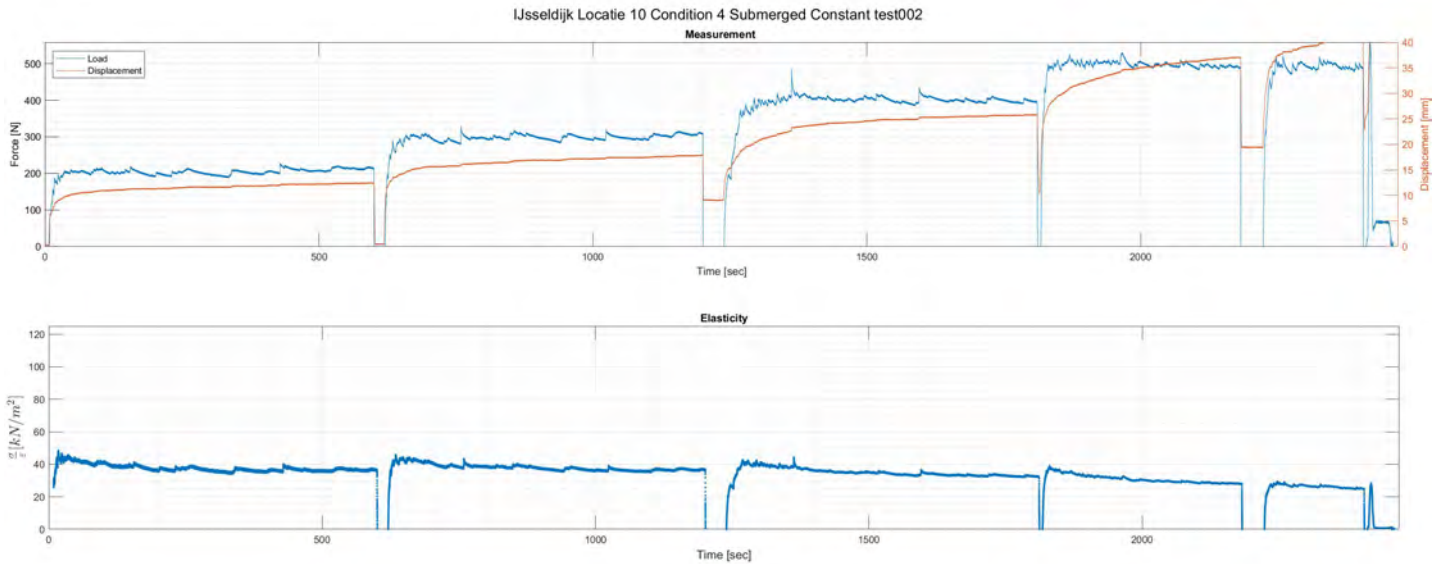
Displacement rate under step increased strain constant loading. The blue dots indicate the total or final displacement as result of the induced load during the first 600 seconds of loading. The yellow dot indicates 80% of the final displacement

test002

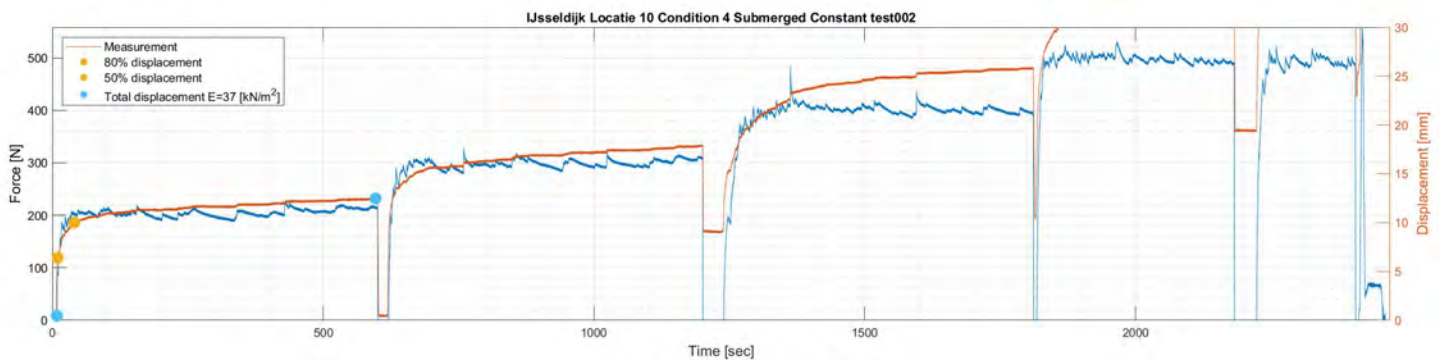
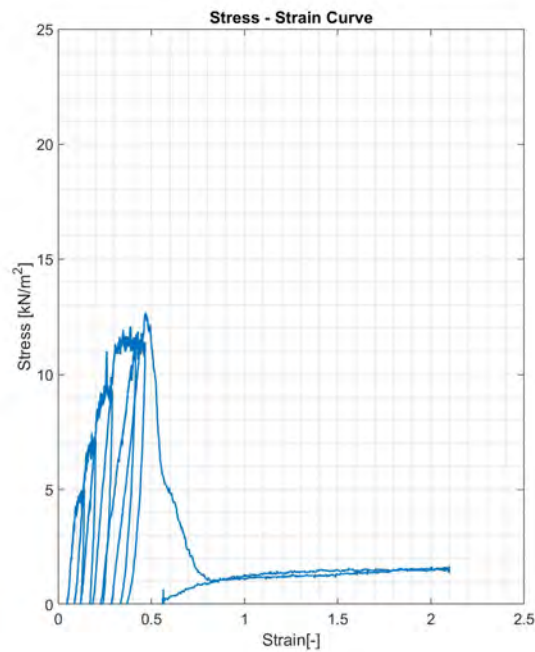
	value 1	value 2	value 3	mean
Date	25-4-2019			
E	36.59 $[kN/m^2]$			
Time to reach 80% of displacement	31 $[sec]$			
Width Sod	21 $[cm]$			
Weight Sod	68 $[N]$			
Sod Height	13	9	6	8.9
Root Length	3	3	6	3.9
Comments				



Figure 10.2: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



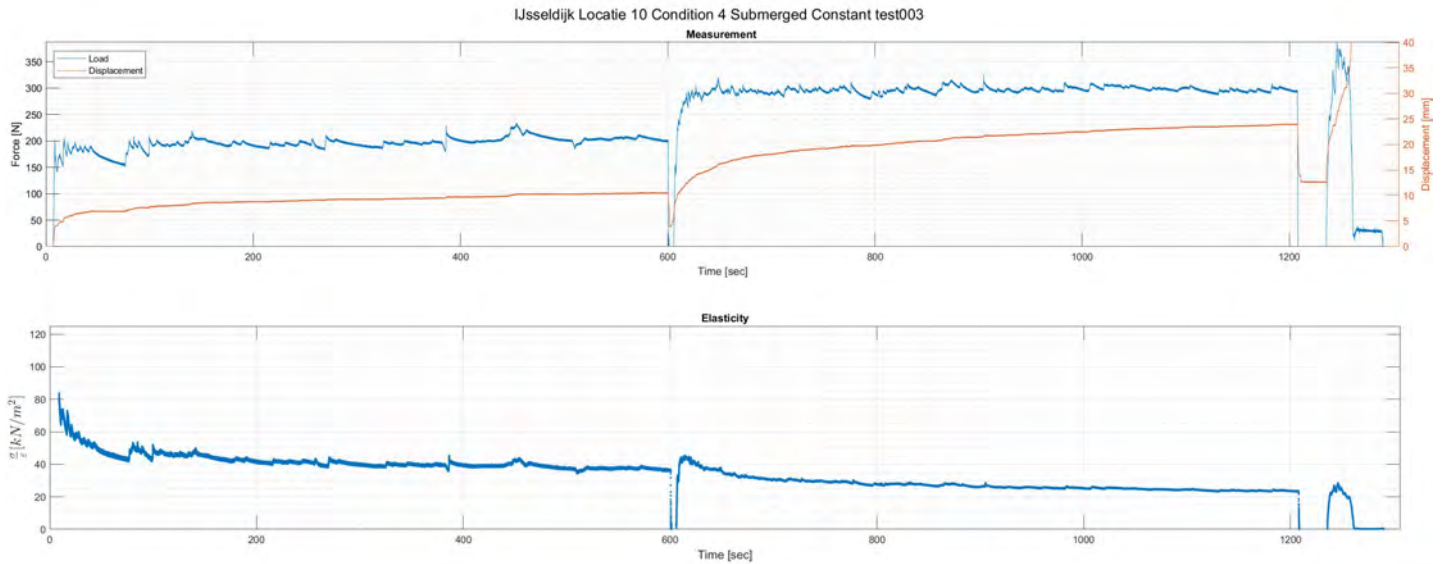
Displacement rate under step increased constant loading. The blue dots indicate the total or final displacement as result of the induced load during the first 600 seconds of loading. The yellow dot indicates 80% of the final displacement

test003

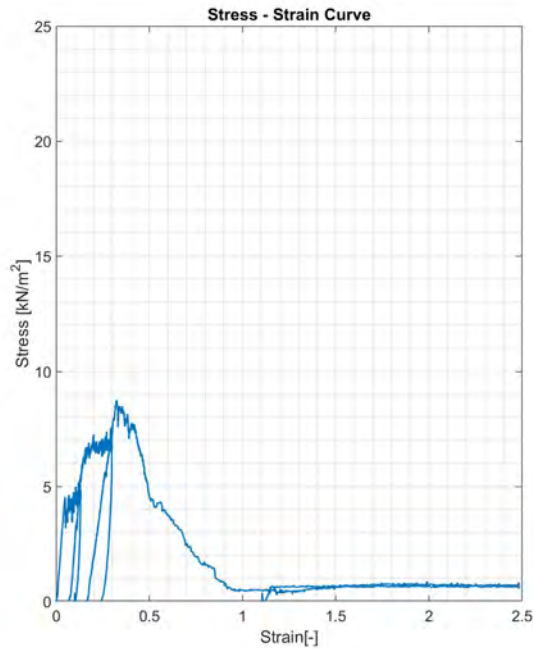
	value 1	value 2	value 3	mean
Date	25-4-2019			
E	37.35			
Time to reach 80% of displacement	133			
Width Sod	21			
Weight Sod	30			
Sod Height	9	7	7	8
Root Length	5	6	7	5.8
Comments				



Figure 10.3: Pictures of tested grass sod.



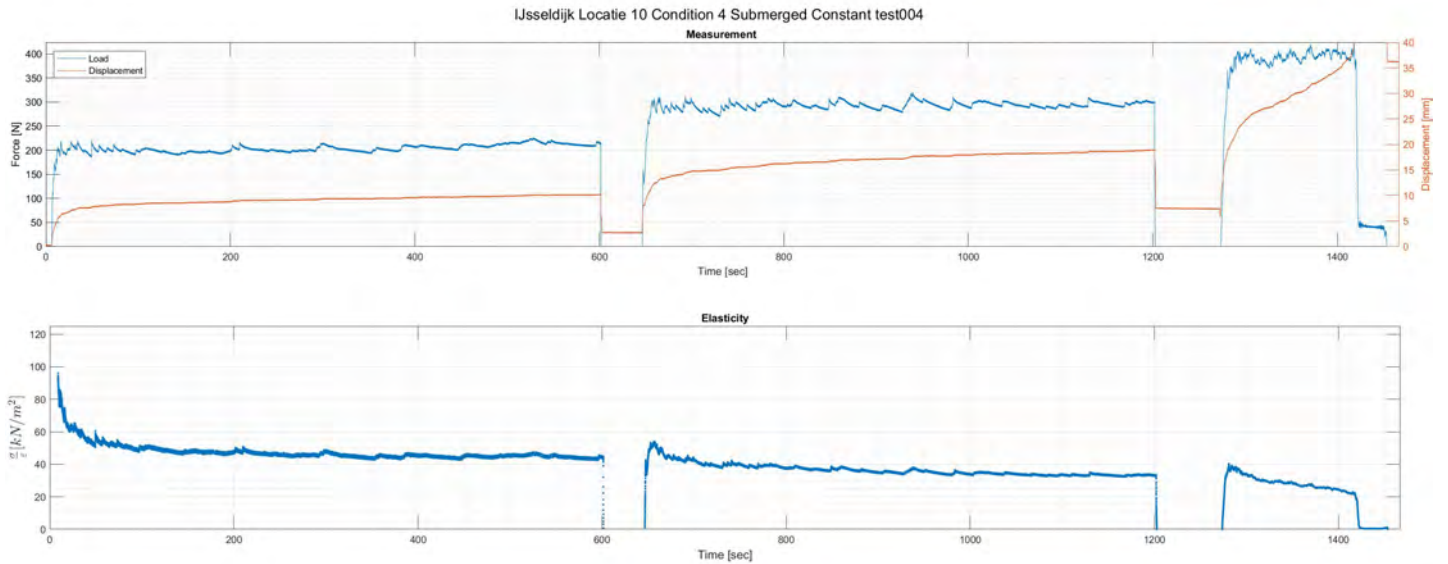
Measurement of load and displacement and resulting elasticity.



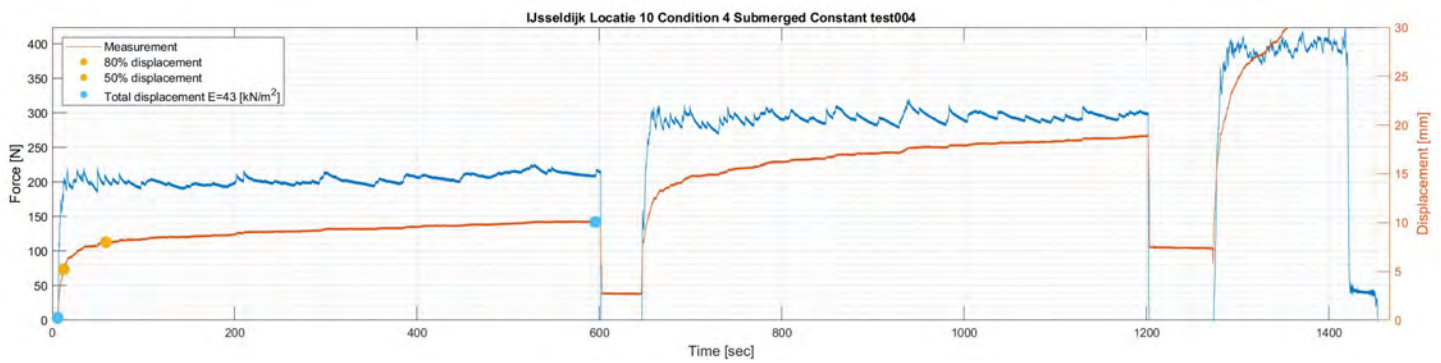
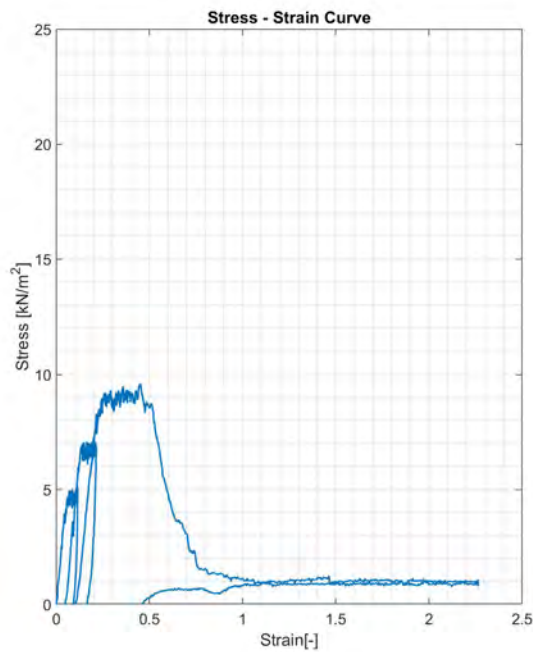
Displacement rate under step increased strain constant loading. The blue dots indicate the total or final displacement as result of the induced load during the first 600 seconds of loading. The yellow dot indicates 80% of the final displacement

test004

	value 1	value 2	value 3	mean
Date	25-4-2019			
<i>E</i>	42.78			
Time to reach 80% of displacement	52			
Width Sod	21			
Weight Sod	41			
Sod Height	10	7	0	8.8
Root Length	4	6	0	4.8
Comments	COM			



Measurement of load and displacement and resulting elasticity.



Displacement rate under step increased strain constant loading. The blue dots indicate the total or final displacement as result of the induced load during the first 600 seconds of loading. The yellow dot indicates 80% of the final displacement

NonSubmerged Condition 4 Cyclic

		Growth rate $\frac{\Delta U}{n}$ [mm]						Load					
Load block		Plastic deformation			Maximum deformation			Mean		Mean maximum			
		0-600	600-1200	1200-1800	0-600	600-1200	1200-1800	0-600	600-1200	0-600	600-1200	1200-1800	1200-1800
test001		5.56e-04	1.10e-01	NaN	1.27e-03	1.32e-01	NaN	1.07e+02	2.35e+02	NaN	2.24e+02	4.61e+02	NaN
mean		5.56e-04	1.10e-01	NaN	1.27e-03	1.32e-01	NaN	1.07e+02	2.35e+02	NaN	2.24e+02	4.61e+02	NaN
median		5.56e-04	1.10e-01	NaN	1.27e-03	1.32e-01	NaN	1.07e+02	2.35e+02	NaN	2.24e+02	4.61e+02	NaN
75 th percentile		5.56e-04	1.10e-01	NaN	1.27e-03	1.32e-01	NaN	1.07e+02	2.35e+02	NaN	2.24e+02	4.61e+02	NaN
25 th percentile		5.56e-04	1.10e-01	NaN	1.27e-03	1.32e-01	NaN	1.07e+02	2.35e+02	NaN	2.24e+02	4.61e+02	NaN

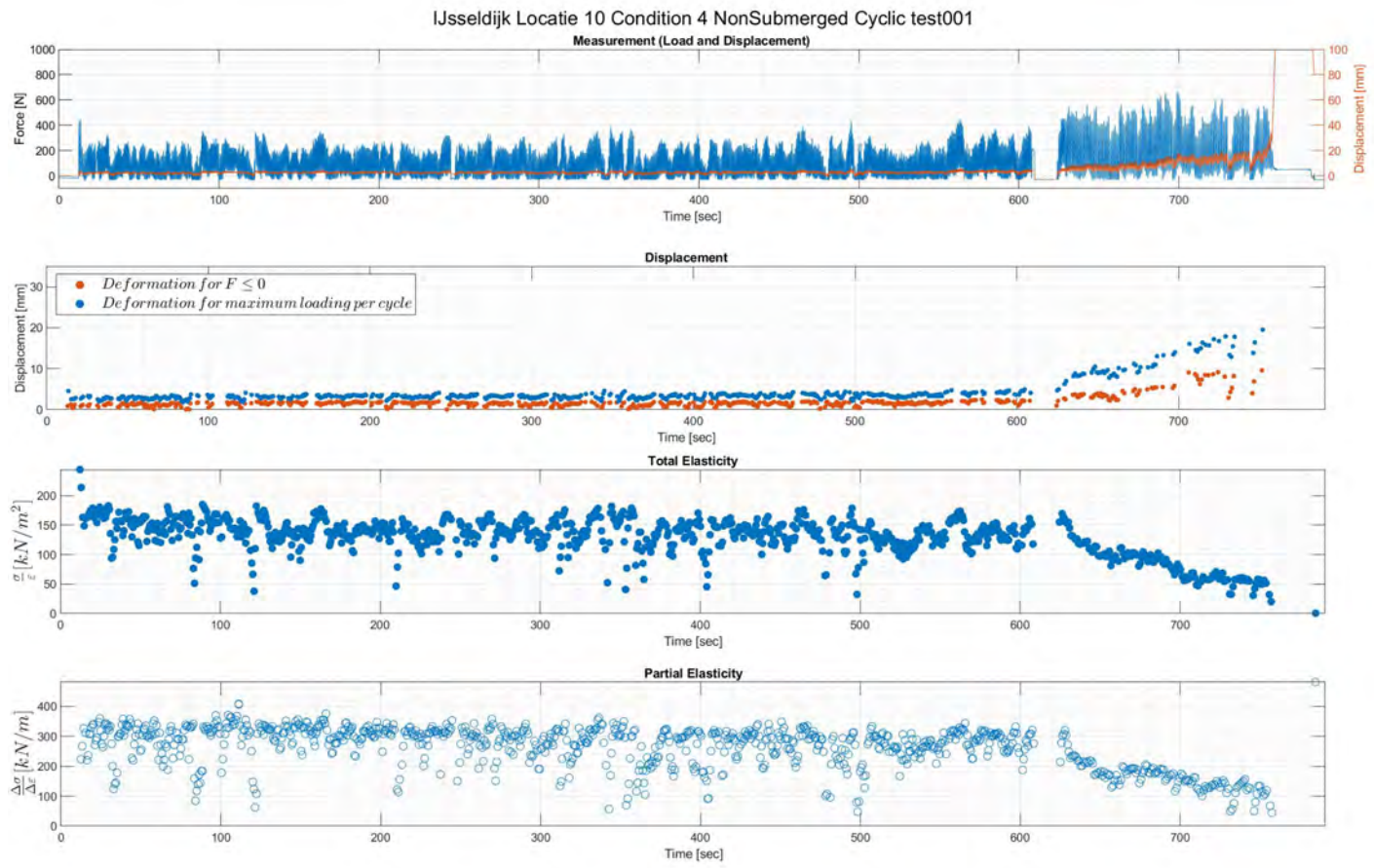
	Weight Sod [kg]	Width Sod [cm]	Mean Height Sod [cm]	Mean Root Length [cm]
test001	4.9	21.0	9.6	2.0
Mean	4.9	21	9.6	2
Median	4.9	21	9.6	2
75 th percentile	4.9	21	9.6	2
25 th percentile	4.9	21	9.6	2

test001

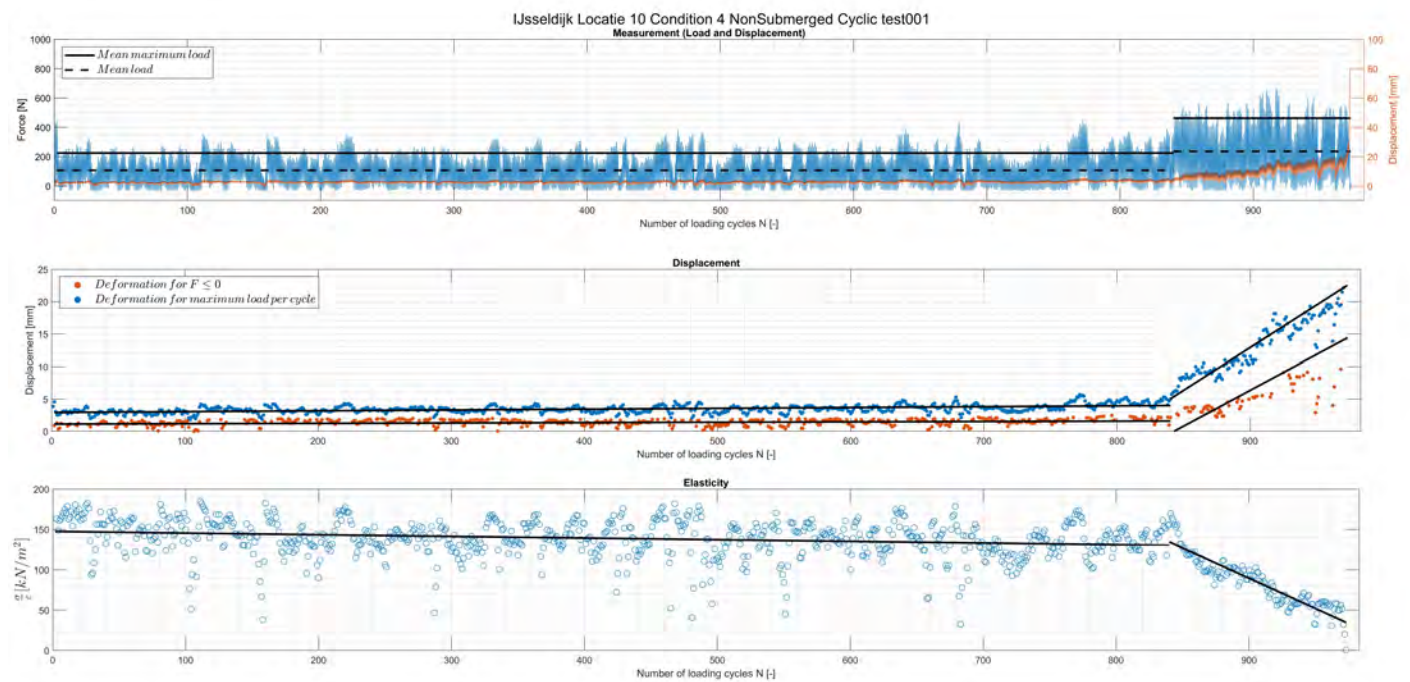
		value 1	value 2	value 3	mean
Date		8-4-2019			
Mean load	[N]	1.07e+02	2.35e+02		1.71e+02
Mean maximum load	[N]	2.24e+02	4.61e+02		3.43e+02
Growth rate Plastic deformation	$\frac{\Delta U}{n}$ [mm]	5.56e-04	1.10e-01		
Growth rate Maximum deformation	$\frac{\Delta U}{n}$ [mm]	1.27e-03	1.32e-01		
Width Sod	[cm]	21			
Weight Sod	[N]	49			
Sod Height	[cm]	12	10	4	9.6
Root Length	[cm]	1	2	4	2
Comments					



Figure 11.1: Pictures of tested grass sod.



Measurement of load and displacement and resulting elasticity.



Development of displacement and elasticity are shown as function of number of cycles.

NonSubmerged Condition 4 Max

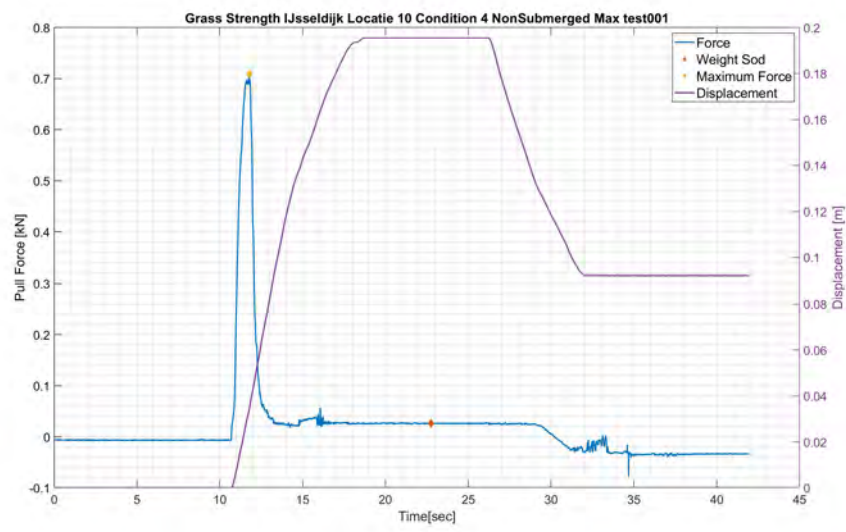
	F max [N]	Weight Sod [kg]	Width Sod [cm]	Mean Height Sod [cm]	Mean Root Length [cm]
test001	701	2.8	21	9.2	3.3
test002	563	3.8	21	9.6	2.2
Mean	632	3.3	21	9.4	2.8
Median	632	3.3	21	9	3
75 th percentile	701	3.8	21	10	3
25 th percentile	563	2.8	21	9	2

test001

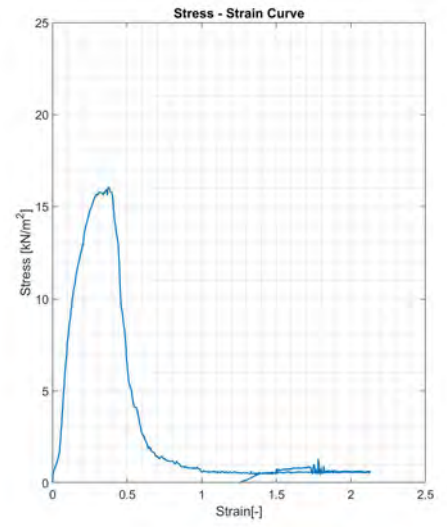
	value 1	value 2	value 3	mean
Date	5-4-2019			
Maximum load [N]	700			
Width Sod [cm]	21			
Weight Sod [N]	28			
Sod Height [cm]	12	8	4	9.2
Root Length [cm]	2	5	4	3.3
Comments				



Figure 12.1: Pictures of tested grass sod.



Measurement of load and displacement



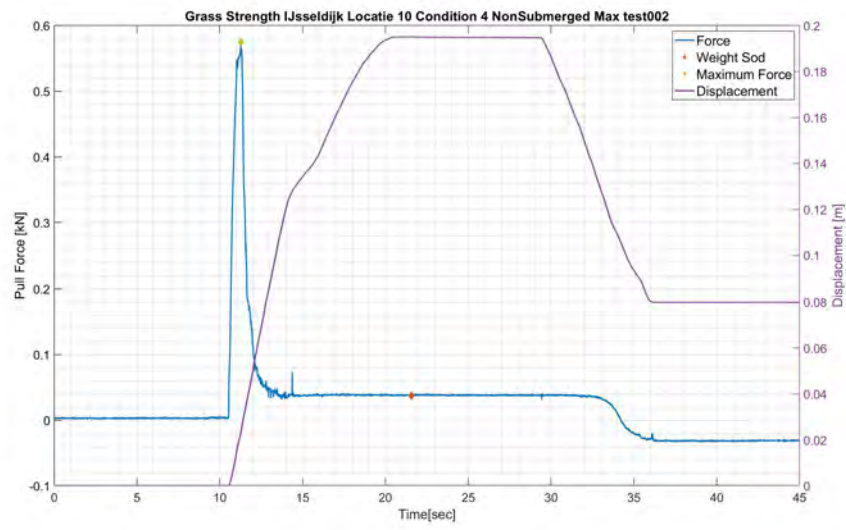
Stress - Strain relation.

test002

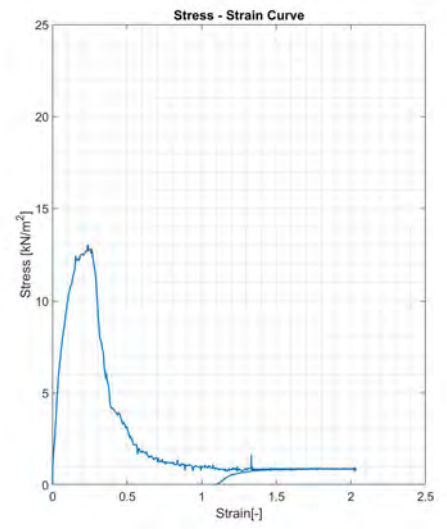
	value 1	value 2	value 3	mean
Date	5-4-2019			
Maximum load [N]	563			
Width Sod [cm]	21			
Weight Sod [N]	38			
Sod Height [cm]	10	8	0	9.6
Root Length [cm]	2	3	0	2.2
Comments				



Figure 12.2: Pictures of tested grass sod.



Measurement of load and displacement



Stress - Strain relation.