TEST REPORT

No. IR5026 Rev1

CYCLIC LOAD TESTING OF SCAFFOLDING SYSTEM

Job No. 4907

PREPARED BY TESTCONSULT
FOR

CCB Scaffolding Supplies Ltd.

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1. INTRODUCTION

Testconsult was instructed by CCB Scaffolding Supplied Ltd (client) to carry out cyclic load testing to the scaffolding system they supplied, at Testconsults' test laboratory in Warrington, Cheshire.

This report describes the testing carried out in accordance with BS EN 12811-3:2002 Temporary work equipment – Part 3: Load testing.

2. TESTING

The following tests were carried out:

- Cyclic loading on ledger to standard connection in both upwards and downwards directions
- Cyclic loading on transom to standard connection in both upwards and downwards directions
- Vibration tests of ledger to standard connection
- Cyclic loading of bracing assembly
- Tensile tests

Table 1 - Test description

Test name	Description
L2S_UP_A1-5	Ledger to Standard connection – Upwards direction
L2S_DN_B1-5	Ledger to Standard connection – Downwards direction
T2S_UP_C1-5	Transom to Standard connection – Upwards direction
T2S_DN_D1-5	Transom to Standard connection – Downwards direction
BRACE	Brace assembly test

2.1 Cyclic Load of Standard to Transom and Ledger to Transom connection

In order to carry out these tests the standard was held vertically to a substantial steel test rig and secured tight enough so that it would not rotate or move in any way. Then the transom or ledger was attached to the locking mechanism and secured using a hammer.

A double acting ram was attached to the transom or ledger and held vertically which was controlled by a hydraulic pump. The load applied by the ram was measured by a bidirectional load cell. Two linear potentiometers we used and positioned parallel at two point of the ledger or transom which measured its' rotation.

All three sensors were wired in to a live MM40 Fylde data logging system. The system provides the basis for applying a highly accurate input voltage to the sensors and measuring an output voltage that is proportional to gauge position or load. A laptop computer was used for real time monitoring and data recording.

Pilot tests were carried out to give characteristic information about the performance of the components and aid design of the rig prior to test commencing.

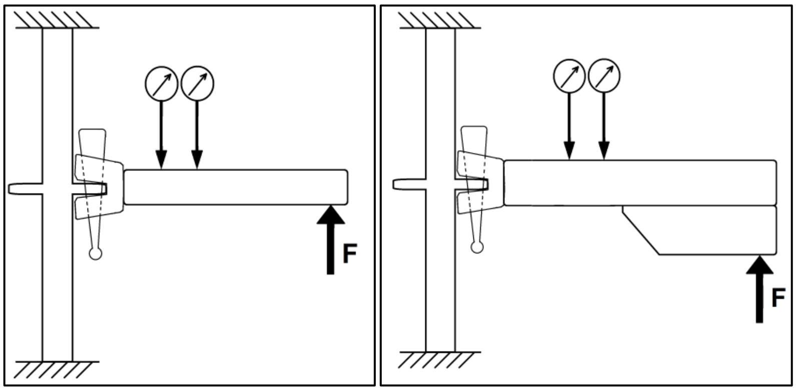

Figure 1 – Diagram of test setup for ledger to standard connection (left) and transom to standard connection (right).

The load regime of the transom to standard and ledger to standard connection in both directions is shown in the table below:

Table 2 – Test Cycle Load Values for Transom to Standard and Ledger to Standard Connections

Test	3 cycles (kNm)	1 cycle (kNm)	1 cycle (kNm)
L2S_UP_A1-5	±1	+1.2 -1	+1.65 -1
L2S_DN_B1-5	±1	+1.2 -1	+1.65 -1
T2S_UP_C1-5	±0.85	+1 -0.85	+1.25 -0.85
T2S_DN_D1-5	±1	+1.2 -1	+1.5 -1

Following these load cycles the arrangement was then tested to failure.

The failure mode on ledger to standard connection in the upwards direction was the bending and shearing of the pin which was wedged using a hammer.

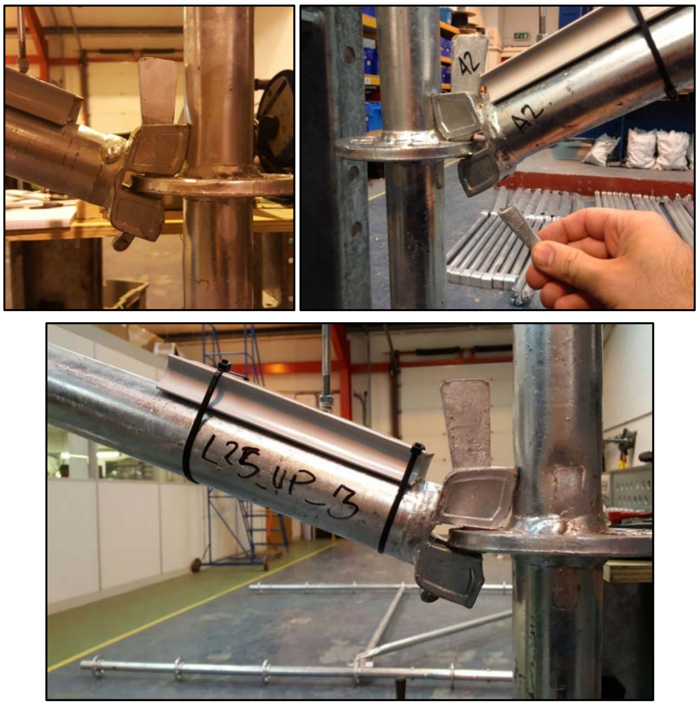

Figure 2 – Failure mode of ledger to standard connection in the upwards direction

The failure mode on transom to standard in the upwards direction was the bending and shearing of the pin which was wedged using a hammer and the shearing of the clamp holding the wedge at its weld points.

Figure 3 - Failure mode of transom to standard connection in the upwards direction

The failure mode on the transom to standard and ledger to standard connection in the downwards direction was the bending and shearing of the pin which was wedged using a hammer, the shearing of the clamp holding the wedge at its weld points and the bending of the connection point to the standard.

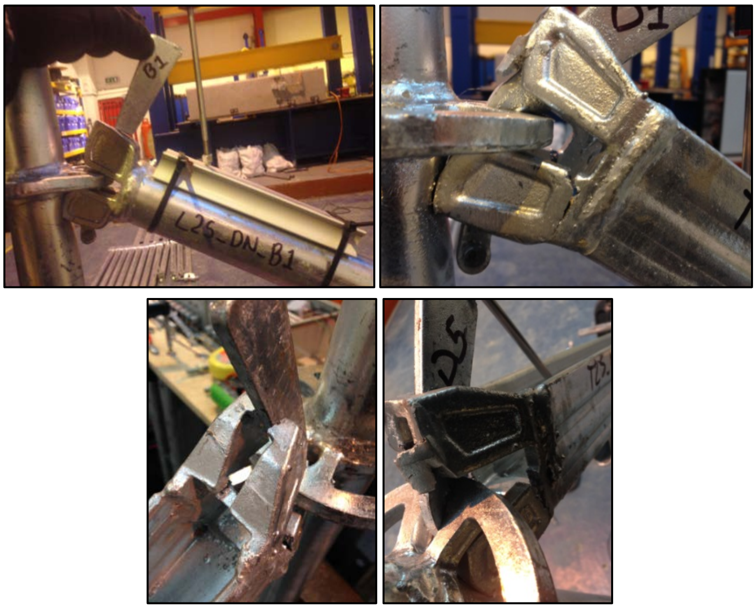

Figure 4 - Failure mode of ledger to standard and transom to standard connection in the downwards direction

Finally in all four test types' indentation was noticed on the standard from the clamp.

Figure 5 – Indentation made to standards during ledger to standard and transom to standard tests in both directions

2.2 Premature Weld Failure during Test D3

The transom to standard connection assembly suffered from a premature failure in the weld due to a weld quality issue. A repeat test was therefore carried out with another test piece D6. The results from test D3 have been disregarded from the calculations but are noted in this report so that manufacturing quality assurance can be addressed.

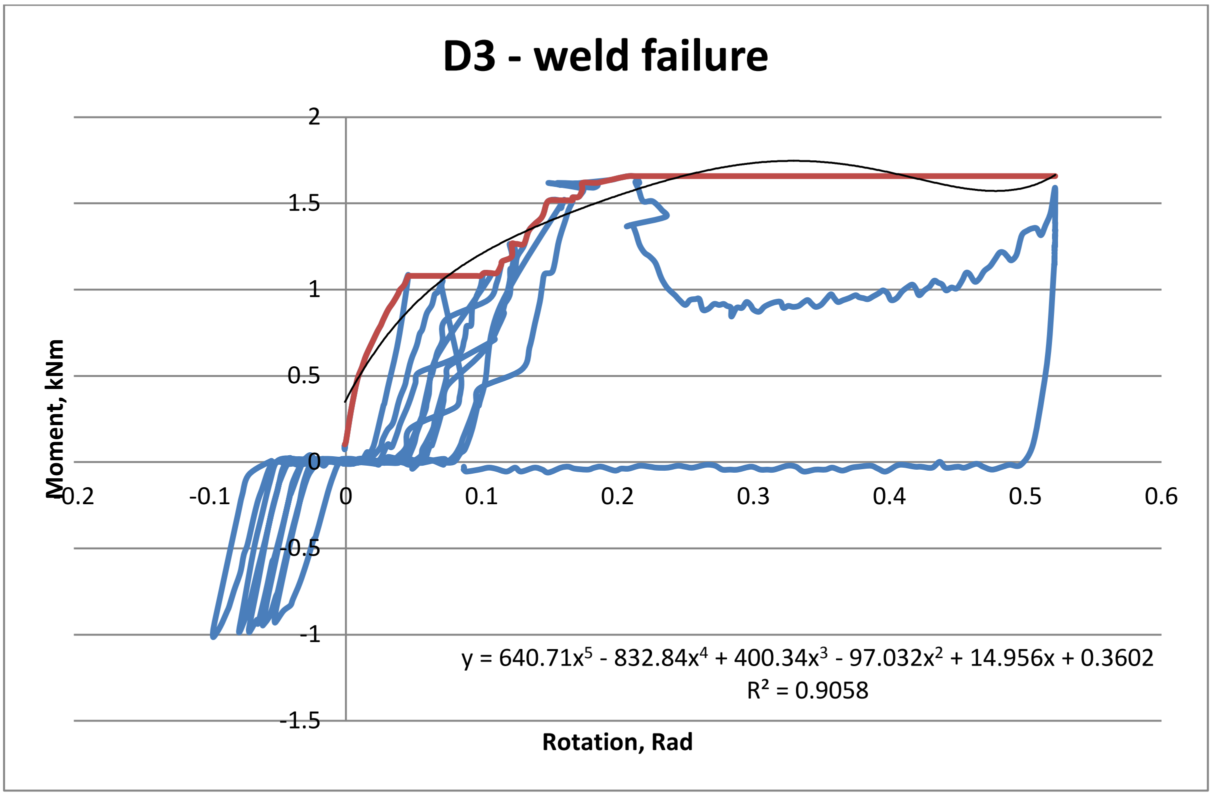

Figure 6 – Premature Weld Failure of the Transom to Standard Connection during test D3

2.3 Cyclic Loading of Brace Assembly

In order to carry out the brace tests, a brace assembly was put together and laid down on a slippery floor. The ends of the two standards, where legs are meant to be installed were allowed only to rotate. Then the ledgers and brace were attached to the locking mechanism and secured using a hammer.

A double acting ram was attached to the one of the ledgers at the point where the brace connected, which was controlled by a hydraulic pump. The load applied by the ram was measured by a bidirectional load cell. Two linear potentiometers we used and positioned parallel at two points of the same standard.

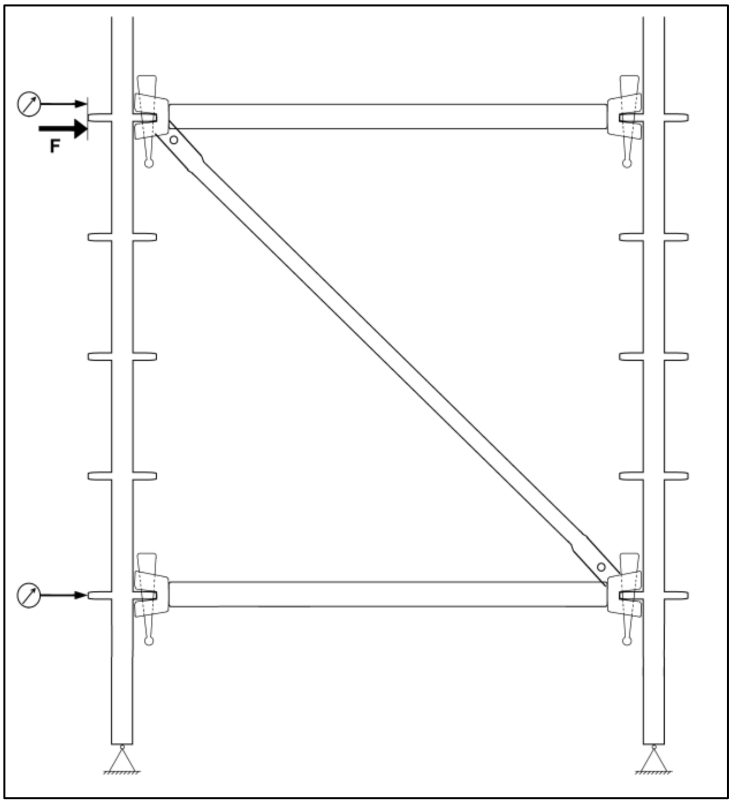

Figure 7 – Diagram of test setup for brace test

As before all three sensors were wired in to a live MM40 Fylde data logging system. The system provides the basis for applying a highly accurate input voltage to the sensors and measuring an output voltage that is proportional to gauge position or load. A laptop computer was used for real time monitoring and data recording.

A pilot test was carried out to give characteristic information about the performance of the components and aid design of the rig prior to test commencing.

The load regime of the brace assembly is shown in the table below:

Table 3 – Test Cycle Load Values for Brace Assembly

Test	3 cycles (kN)	1 cycle (kN)	1 cycle (kN)	1 cycle (kN)
BRACE_1-5	±6	+8 -6	+10 -6	+12 -6

The failure mode on all five tests was the buckling of the brace and a bending of the standards.

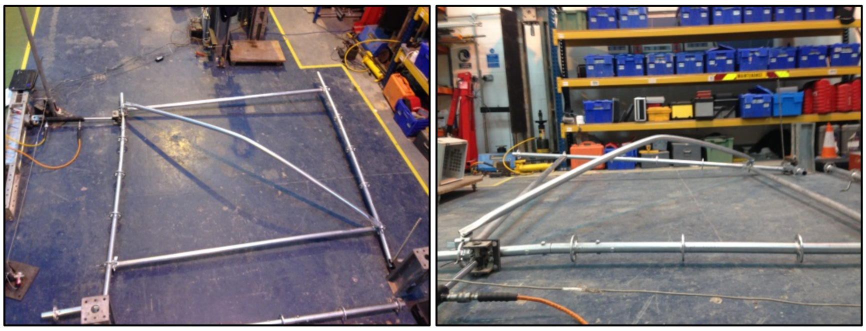

Figure 8 - The failure mode on brace assembly test

2.4 Vibration Tests

Vibration tests were carried out on 5 No. ledger to standard connections using a similar arrangement as to the load testing. The connection was subject to 3100 cycles +/- 0.3kN, (0.1kNm) at 5Hz. No connections showed any indication of the cup locking ring loosening. The transom uses the same coupling arrangement and so is not required to be tested.

2.5 Tensile Tests

Tensile tests were carried out on the weakest link of the arrangement, which was the pin.

Tensile Test – BS EN ISO 6892 – A:16 A224						
	Thickness x Width	**GL (mm)**	**Rp0.20 (N/mm^2)**	**UTS (N/mm^2)**	**%El**	**Temp (°C)**
1	4.40 x 6.02	25.00	412	559	34.0	23.0
2	4.38 x 6.01	25.00	418	573	32.0	23.0
3	4.30 x 6.00	25.00	415	591	32.0	23.0
4	4.35 x 6.02	25.00	402	553	33.0	23.0
5	4.35 x 6.01	25.00	398	556	33.0	23.0

3 ANALYSIS OF TEST RESULTS

The cyclic test results were analysed by considering the third of three cycles to the approximate service moment. Curve fitting was carried out using Excel to produce a polynomial to the maximum, the maximum is then held for greater rotations.

In case of the brace assembly the buckling failure mode gave a graph of displacement against load where the first maximum reduces sharply after failure and then levels of after a displacement of approximately 170mm. The design curve has is represented by a polynomial up to 170mm and then represented by a straight line. It is felt that this demonstrates more closely the performance of the arrangement.

Values of q_e were found for each test and the value used for further calculation in accordance with BS EN 12811-3:2002.

There was significant looseness in all assemblies, this was measured and the average value was produced for using in the design.

The results graphs show separate results graphs for each component assembly.

Rotations and loads have been normalised to the so that the predominant direction of load is shown as positive.

Table 4 – Summary of Properties

Property	Unit	Ledger		Transom		Brace Assembly	
		A, Up	B, Down	C, Up	D, Down	Unit	Z, Brace
Char Rk,nom	**kNm**	1.63	1.68	1.33	1.470	**kN**	11.660
Theta @ Rk,nom	**rad**	0.170	0.191	0.107	0.124	**mm**	48.461
serv Rk,nom	**kNm**	0.990	1.019	0.805	0.893	**kN**	7.068
Theta @ serv	**rad**	0.052	0.057	0.030	0.042	**mm**	24.26
Initial Slope	**kNm/rad**	27.60	22.18	27.83	21.85	**kN/mm**	0.181
Design Slope	**kNm/rad**	25.58	24.09	30.97	28.45	**kN/mm**	0.359
Final Slope	**kNm/rad**	5.46	4.94	6.79	7.05	**kN/mm**	0.190
Total Looseness	**rad**	0.027	0.029	0.008	0.021	**mm**	5.050
Mean Looseness	**rad**	0.000	0.000	0.000	0.000	**mm**	2.050

Table 5 – Polynomial Coefficients

Test	x^5	x^4	x^3	x^2	x^1	x^0
A	1.24E+03	-1.63E+03	8.25E+02	-2.05E+02	2.76E+01	5.74E-03
B	6.50E+02	-9.39E+02	5.30E+02	-1.45E+02	2.22E+01	1.40E-01
C	2.17E+03	-2.62E+03	1.20E+03	-2.60E+02	2.78E+01	1.73E-01
D	1.08E+03	-1.42E+03	6.94E+02	-1.61E+02	2.18E+01	2.14E-01
Z	-1.37E-08	3.77E-06	-3.55E-04	1.11E-02	1.81E-01	1.65E-03

4 CONCLUSION

This report describes the tests made on the system scaffolding in accordance with the procedures and recommendations of BS EN 12811-3. The findings are set out in the tables, Summary of properties and Polynomial coefficients in Table 5.

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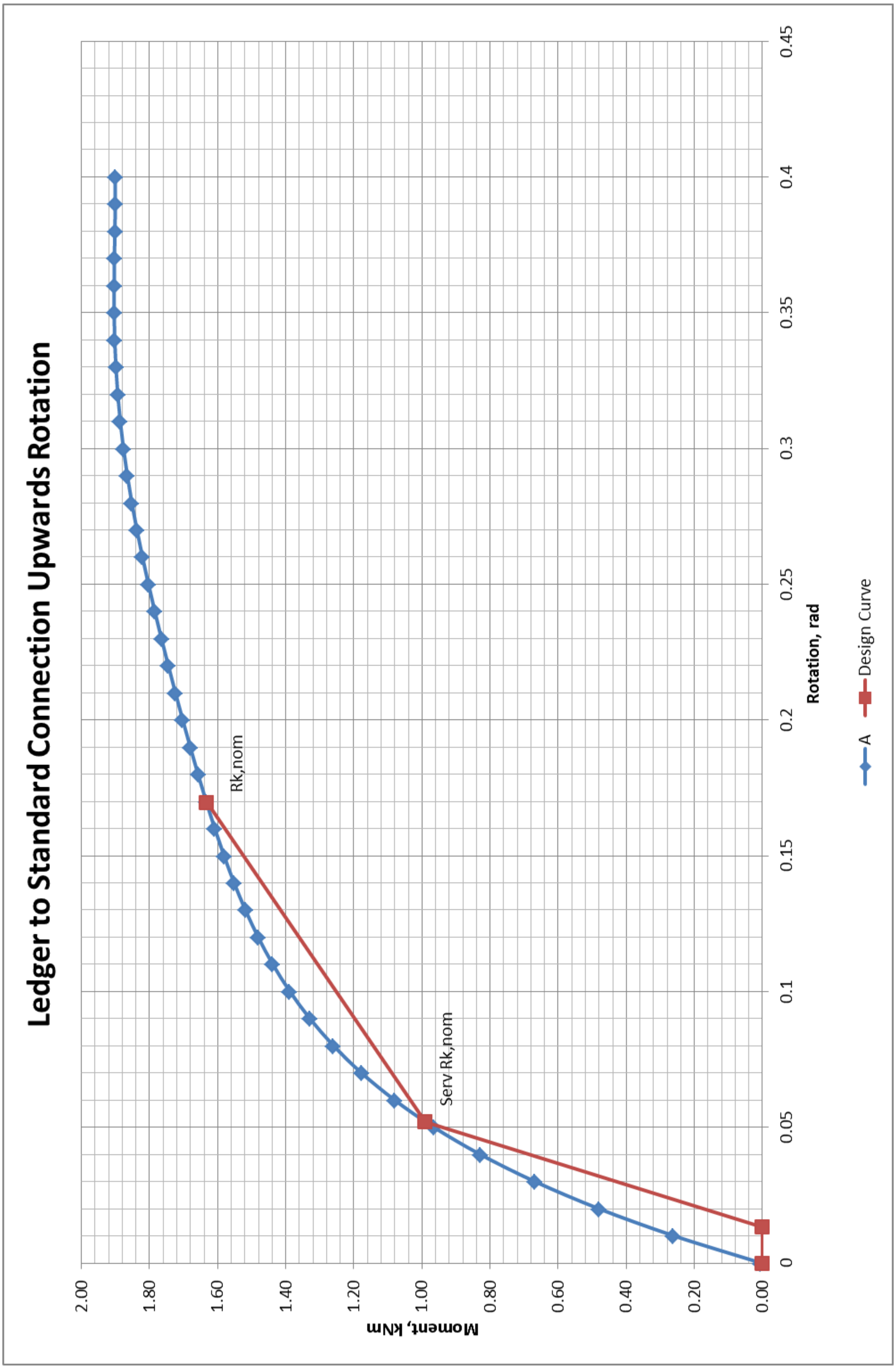
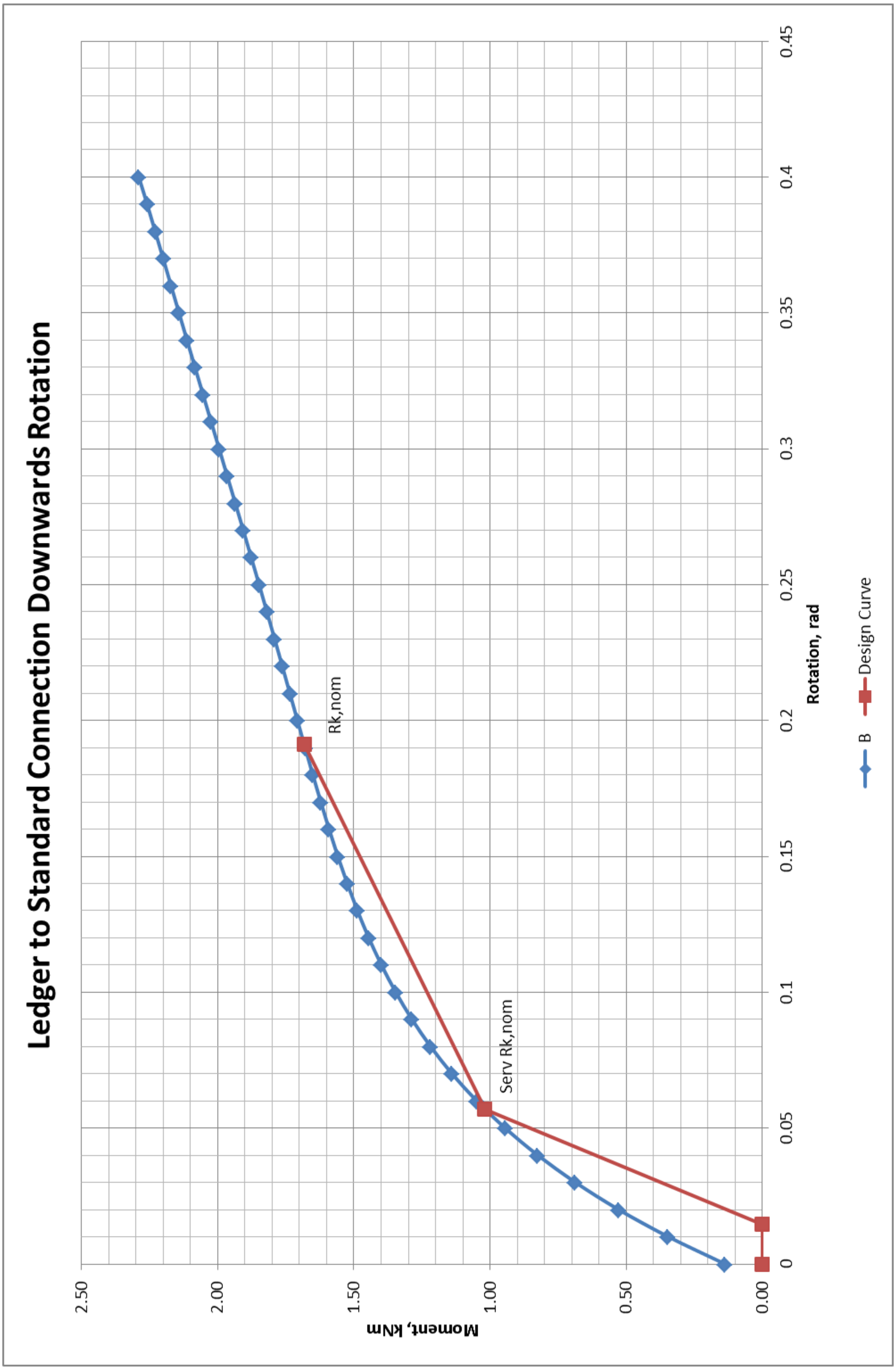
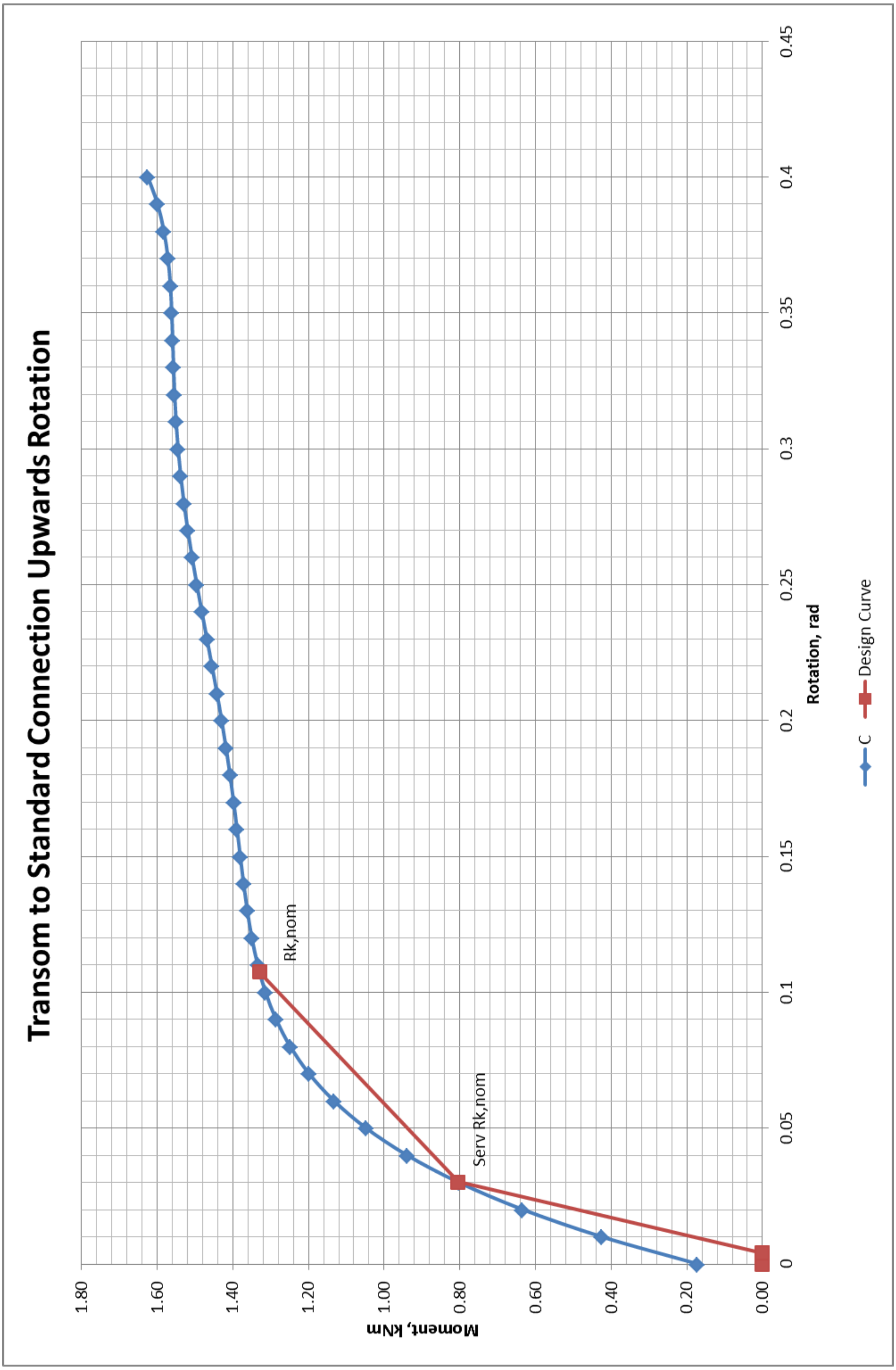
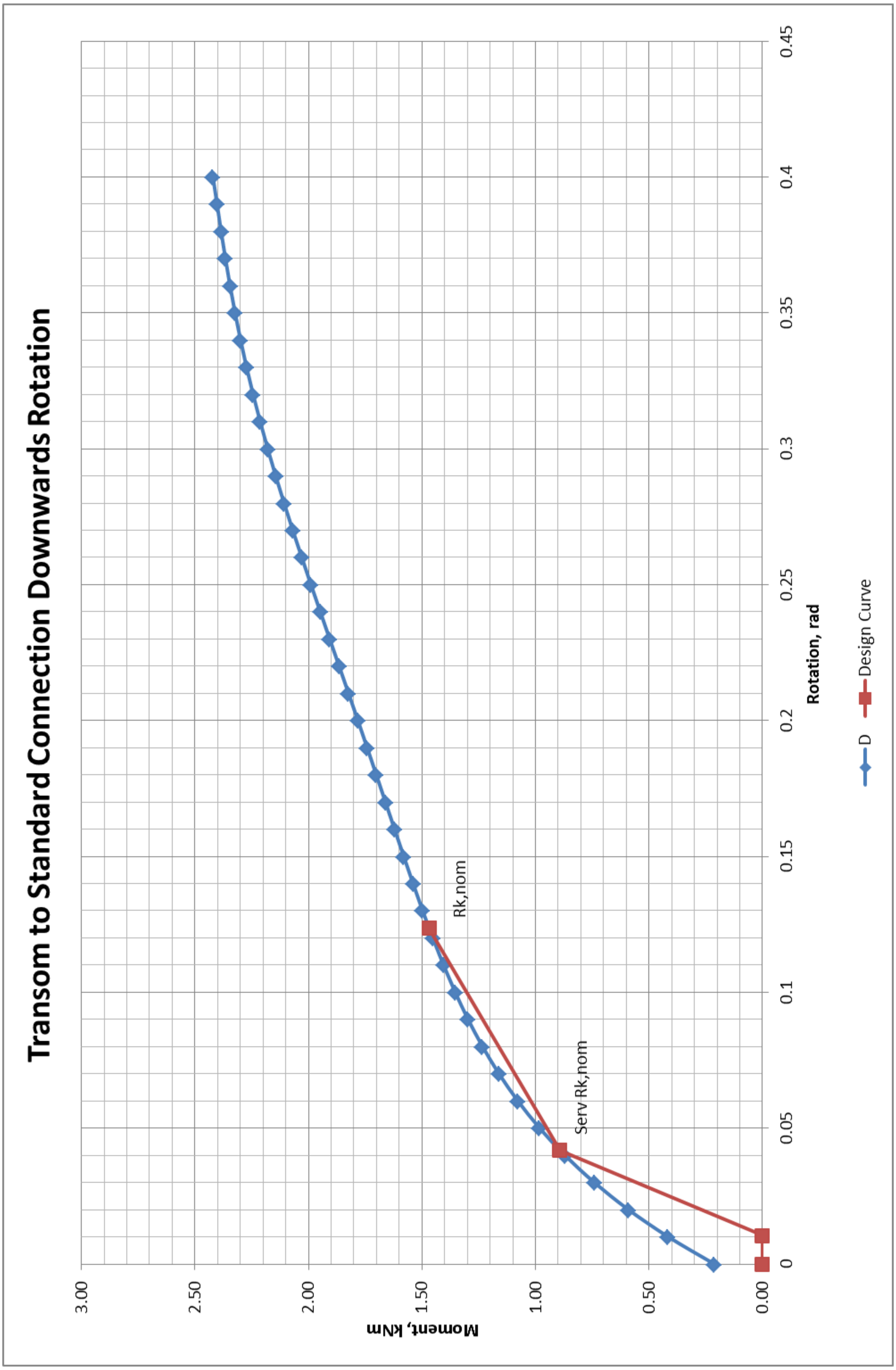
Tim Neat
Project Engineer
For and on behalf of TESTCONSULT

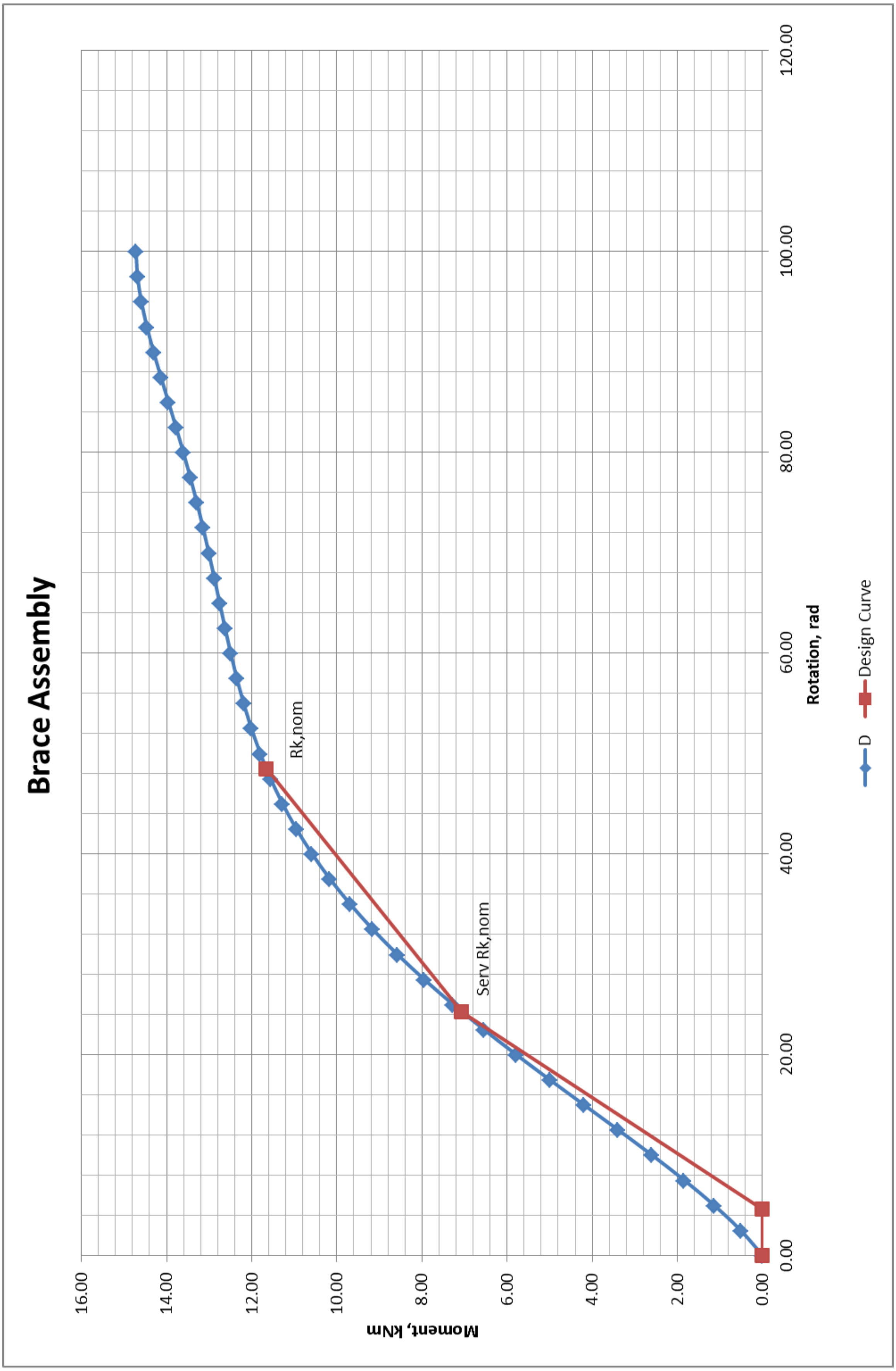
APPENDIX A – DESIGN CURVES


Ledger to Standard Connection Upwards Rotation
Moment, kNm
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Rotation, rad
Rk,nom
Serv Rk,nom
A
Design Curve


Ledger to Standard Connection Downwards Rotation
Moment, kNm
0.00
0.50
1.00
1.50
2.00
2.50
Rotation, rad
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Rk,nom
Serv Rk,nom
B
Design Curve

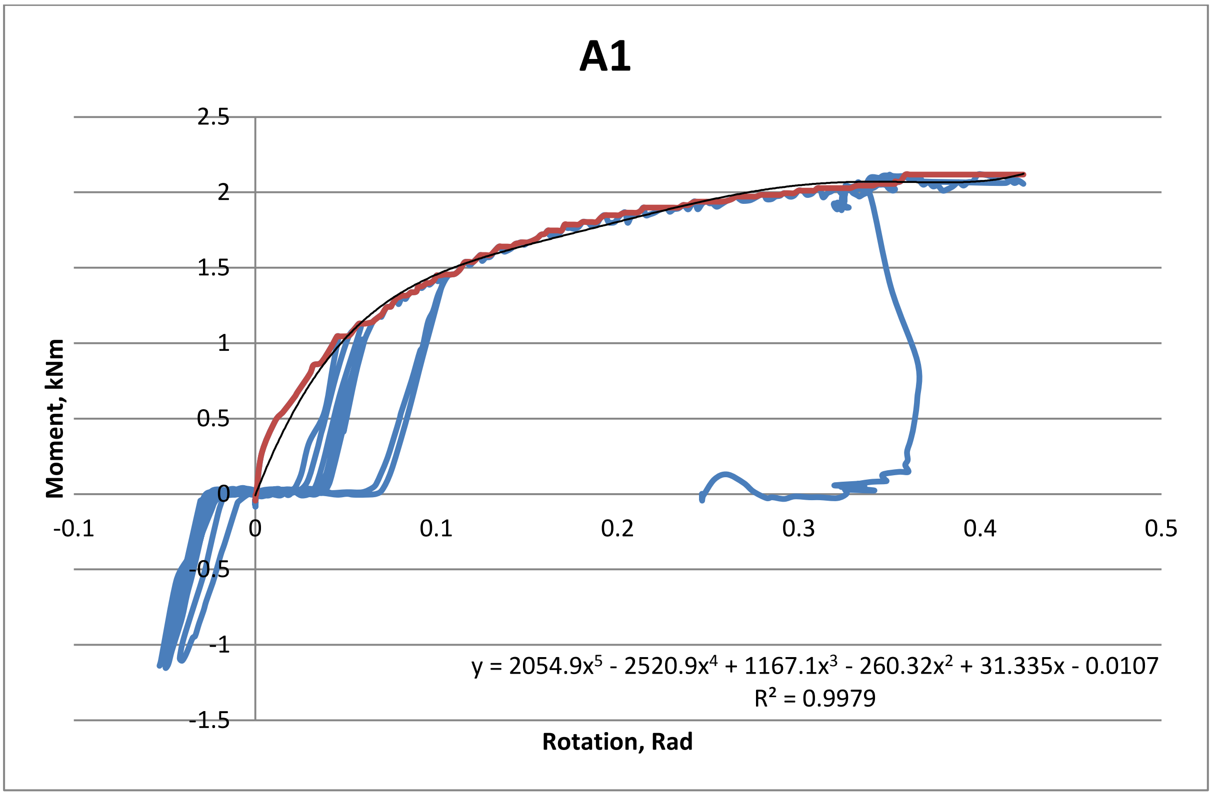

Transom to Standard Connection Upwards Rotation
Moment, kNm
Rotation, rad
Rk,nom
Serv Rk,nom
C
Design Curve
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45

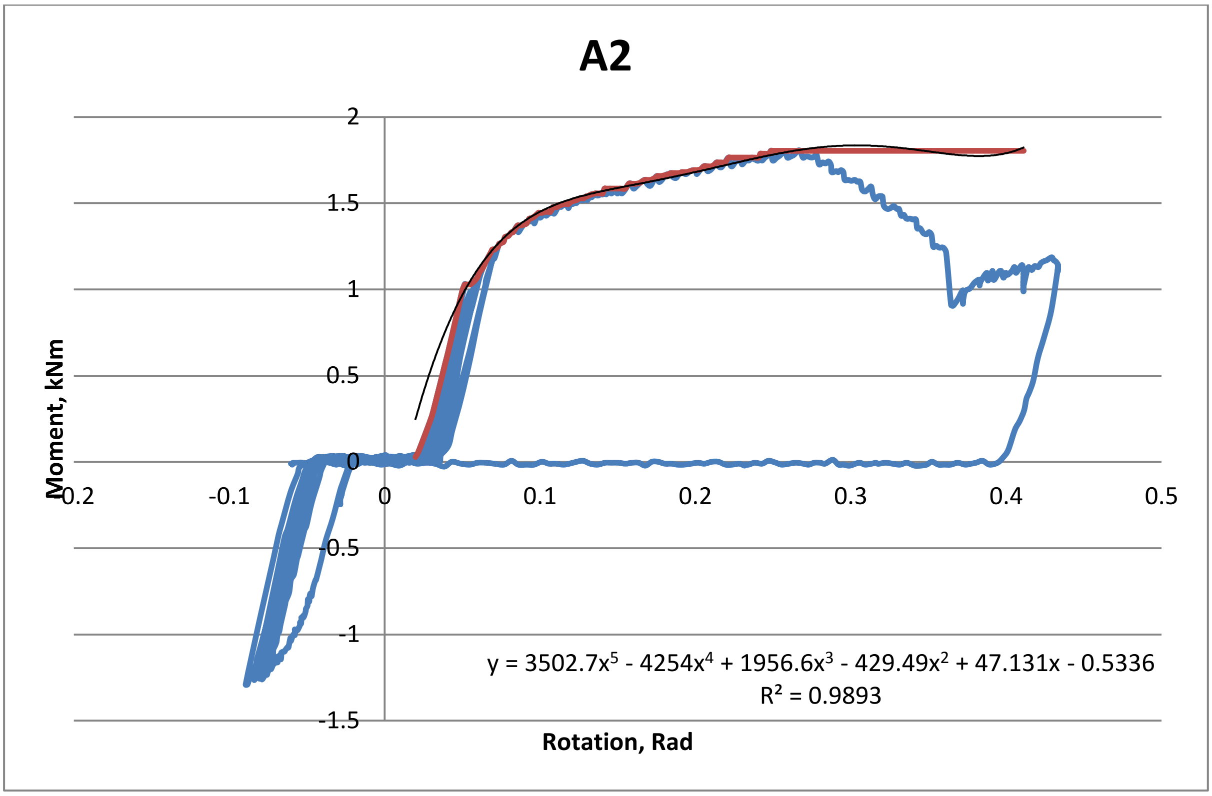

Transom to Standard Connection Downwards Rotation
Moment, kNm
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Rotation, rad
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Rk,nom
Serv Rk,nom
D
Design Curve

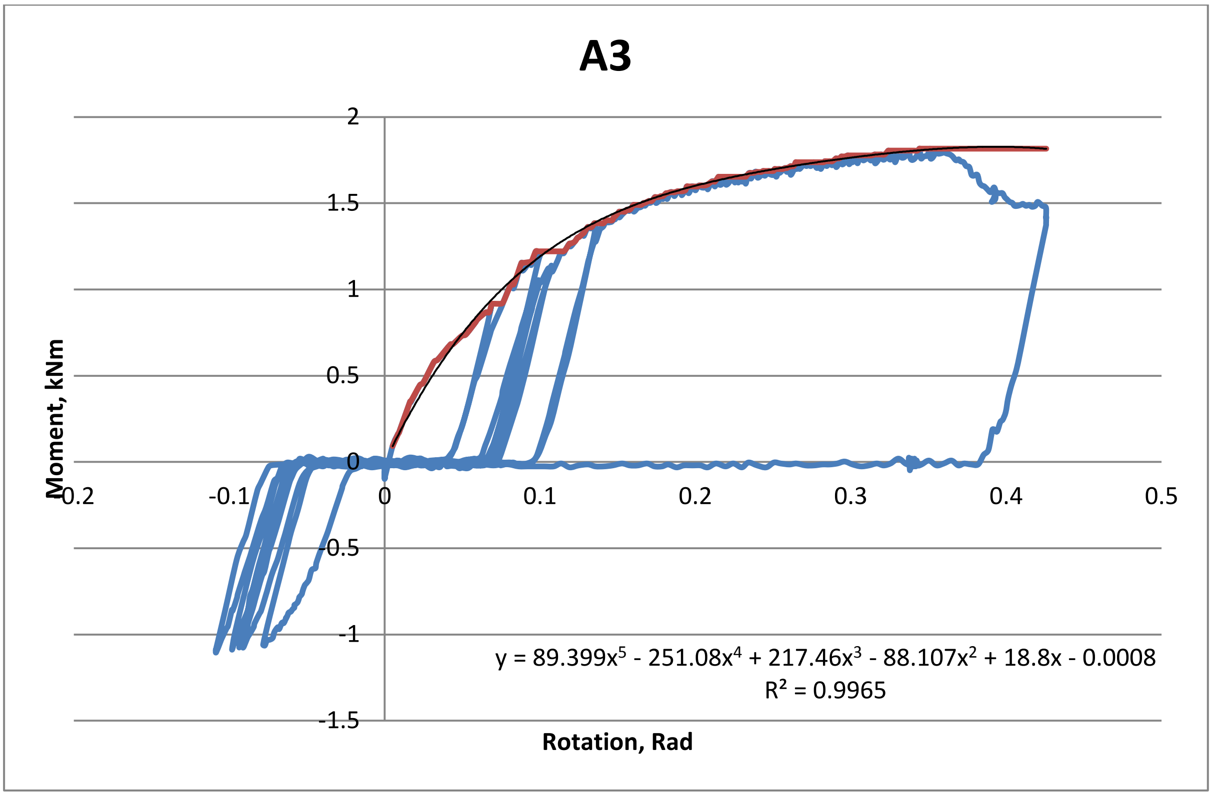

Brace Assembly
Moment, kNm
Rotation, rad
Rk,nom
Serv Rk,nom
D
Design Curve
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
20.00
40.00
60.00
80.00
100.00
120.00

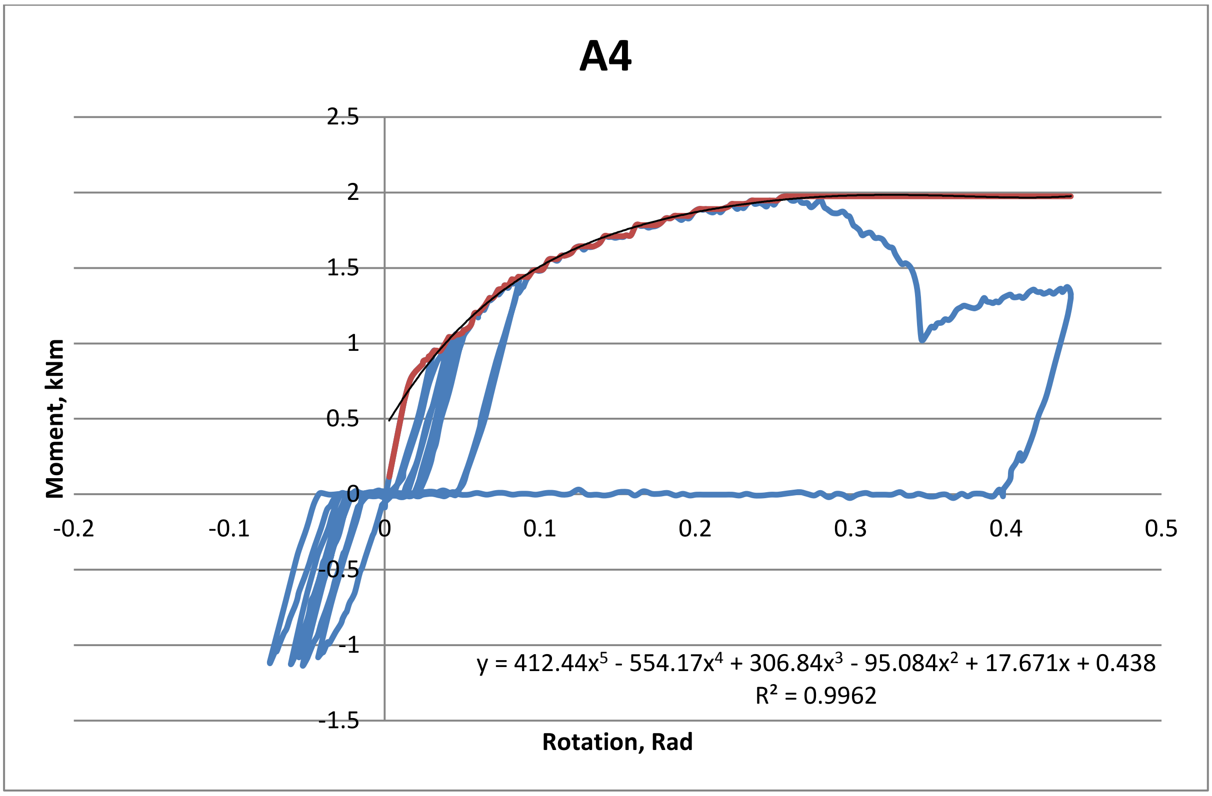
APPENDIX B – RESULTS GRAPHS

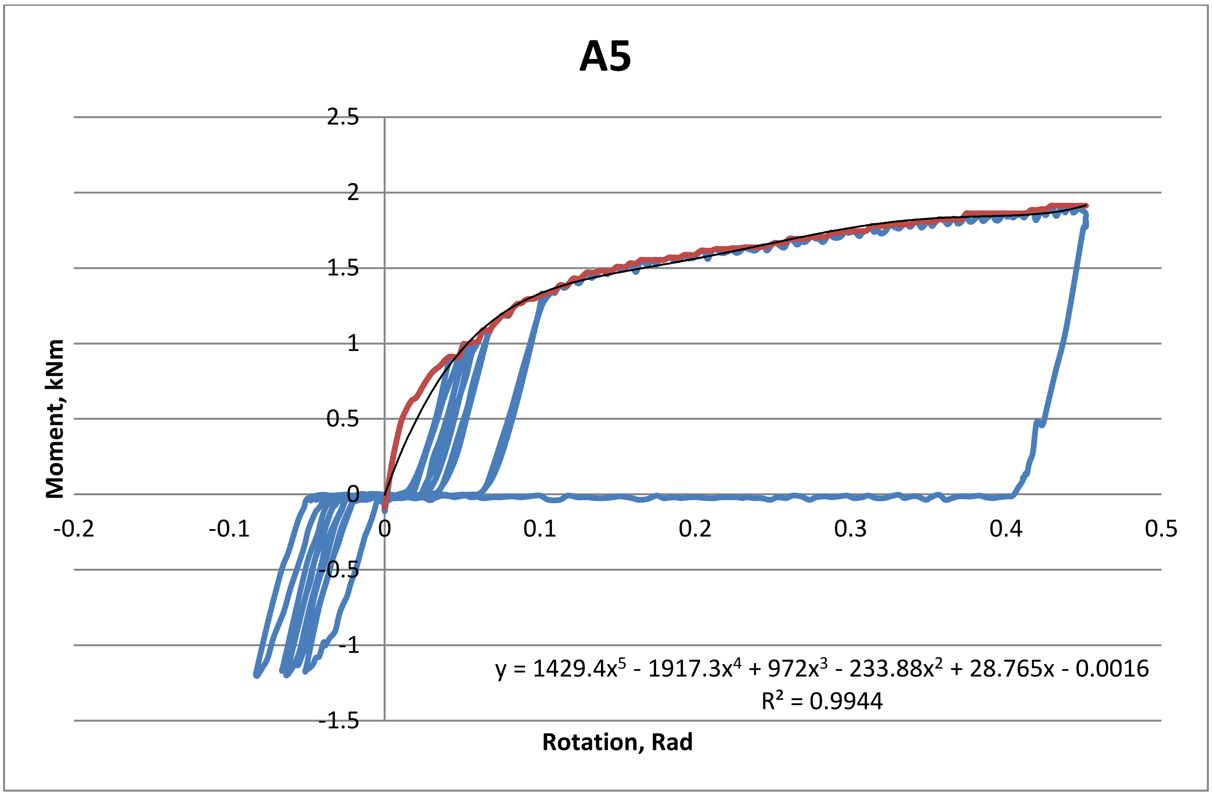
Ledger to Standard Connection in the Upwards Direction – L2S_UP_A1-5



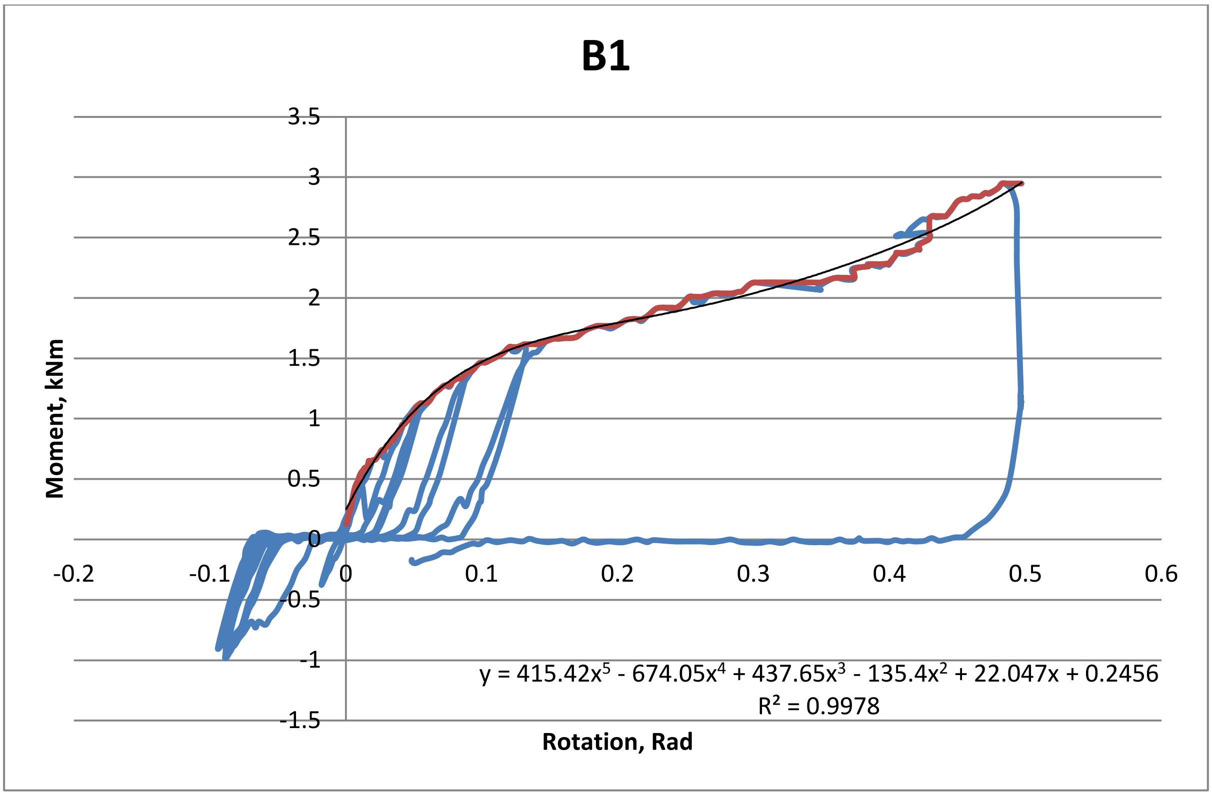


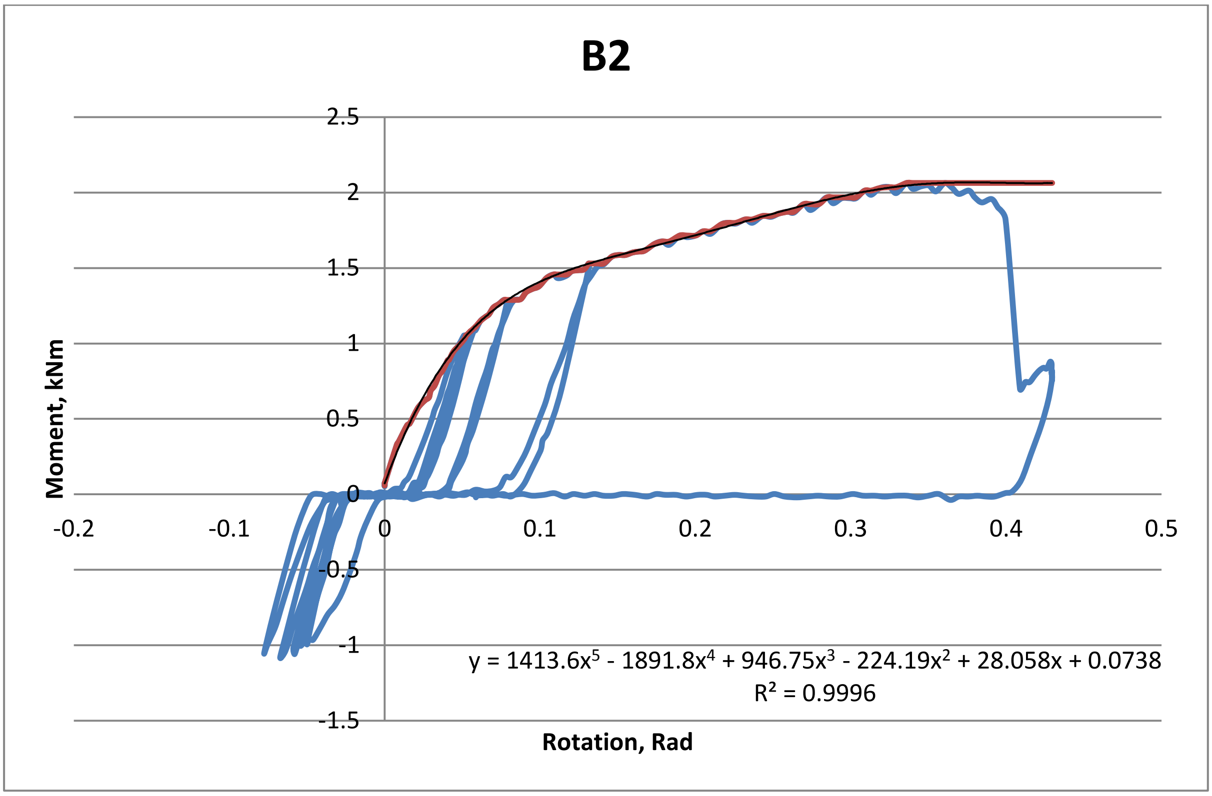

A3
Moment, kNm
Rotation, Rad
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
y = 89.399x⁵ - 251.08x⁴ + 217.46x³ - 88.107x² + 18.8x - 0.0008
R² = 0.9965

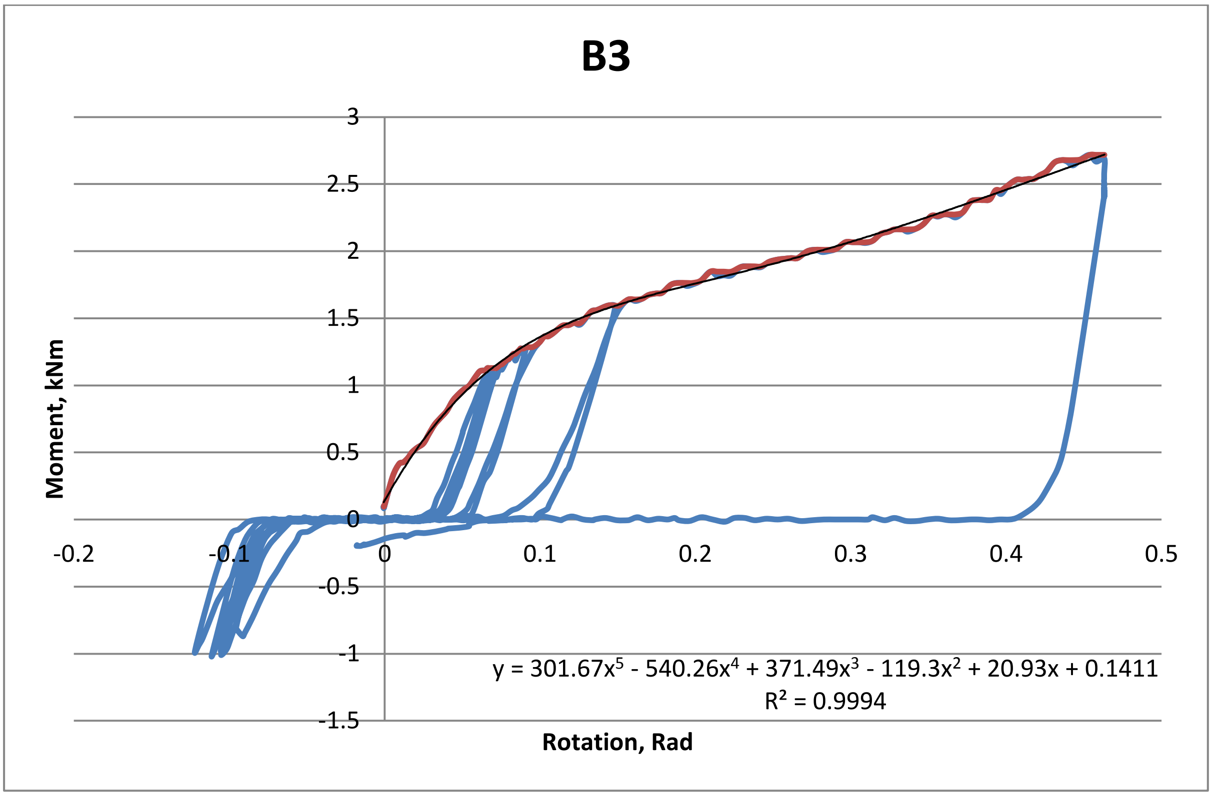

A4
Moment, kNm
Rotation, Rad
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
y = 412.44x⁵ - 554.17x⁴ + 306.84x³ - 95.084x² + 17.671x + 0.438
R² = 0.9962

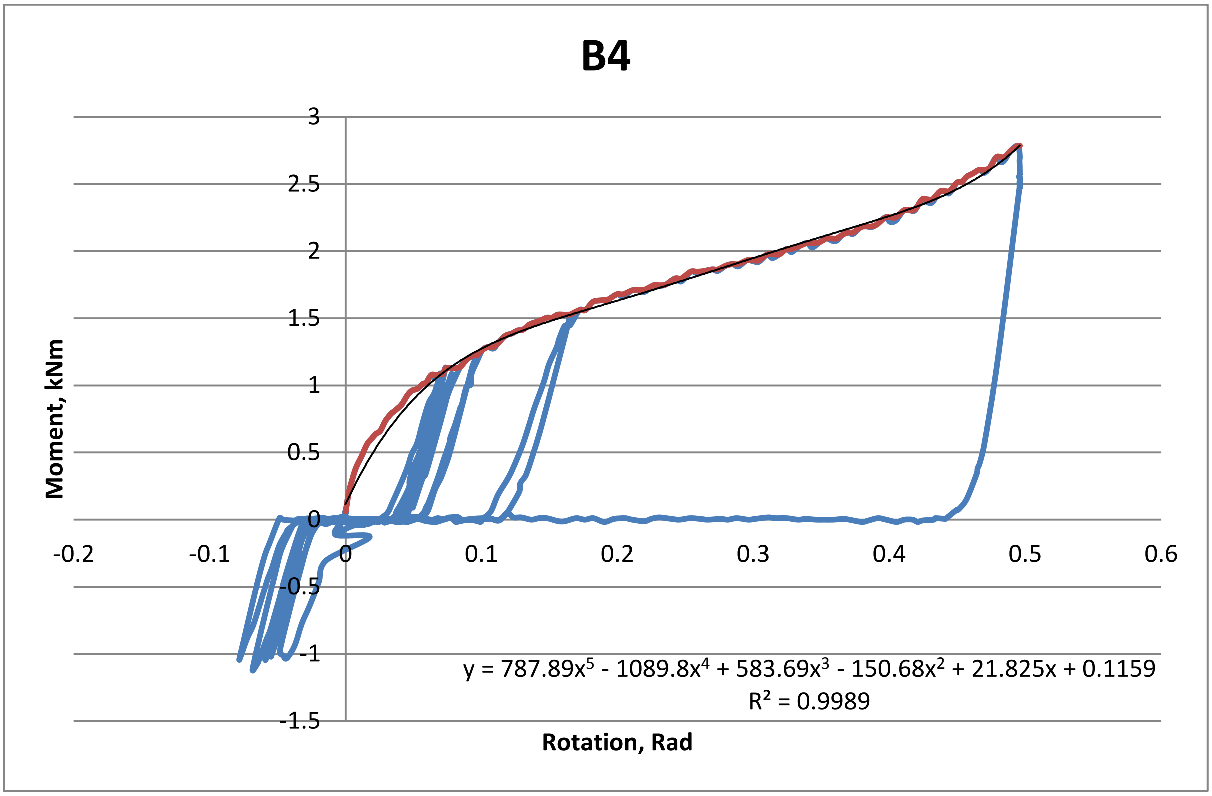


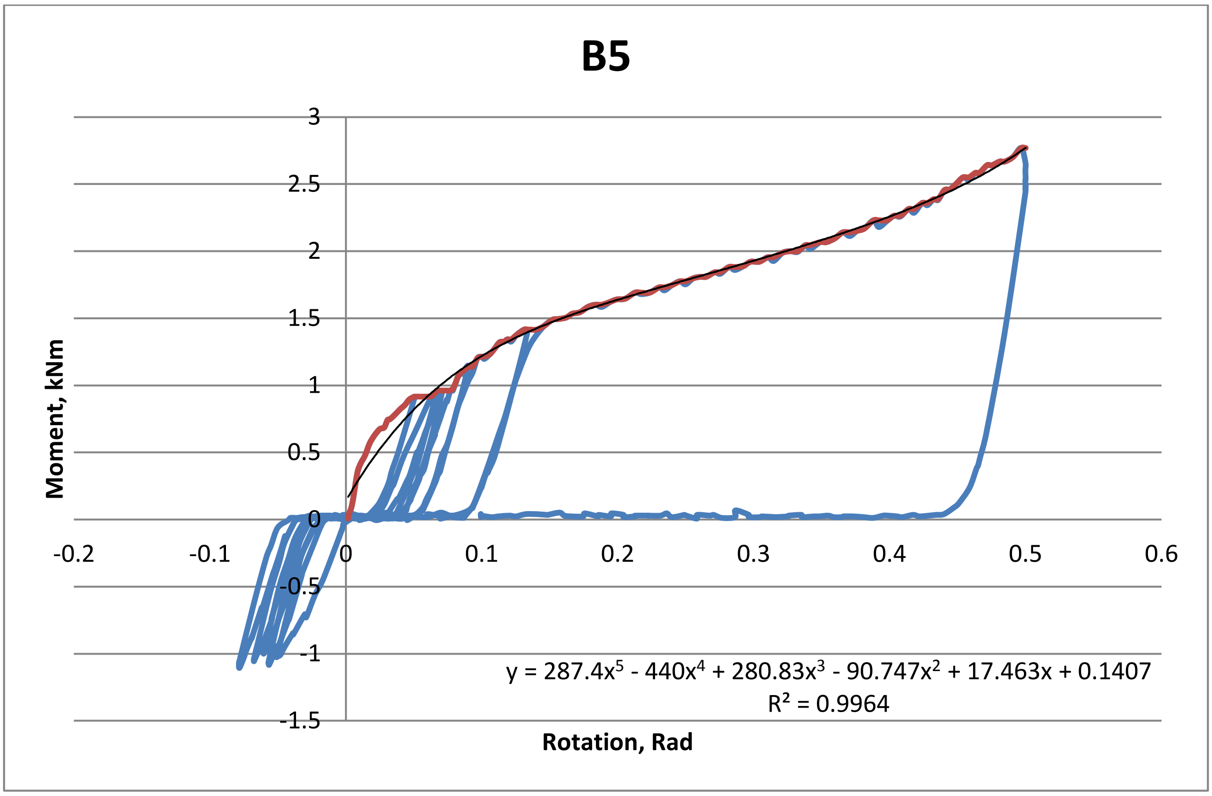
Ledger to Standard Connection in the Downwards Direction – L2S_DN_B1-5



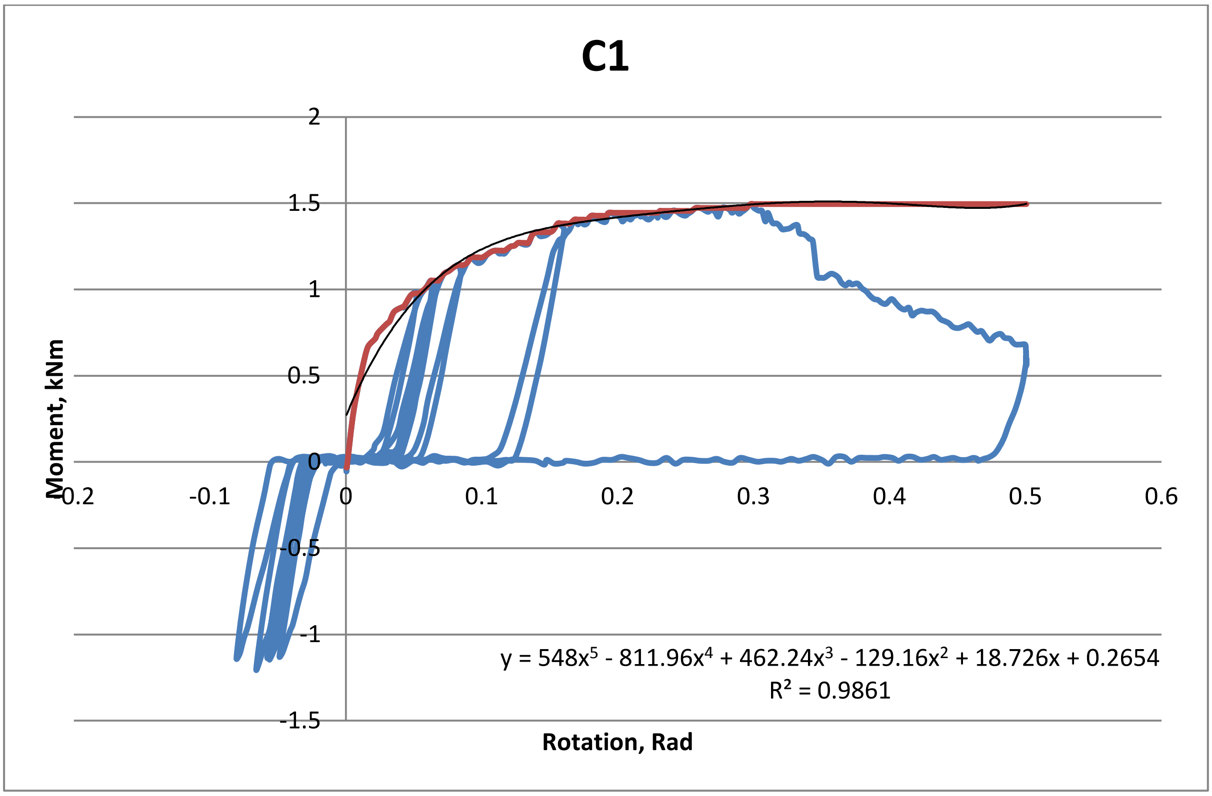

B2
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Moment, kNm
y = 1413.6x5 - 1891.8x4 + 946.75x3 - 224.19x2 + 28.058x + 0.0738
R2 = 0.9996
Rotation, Rad

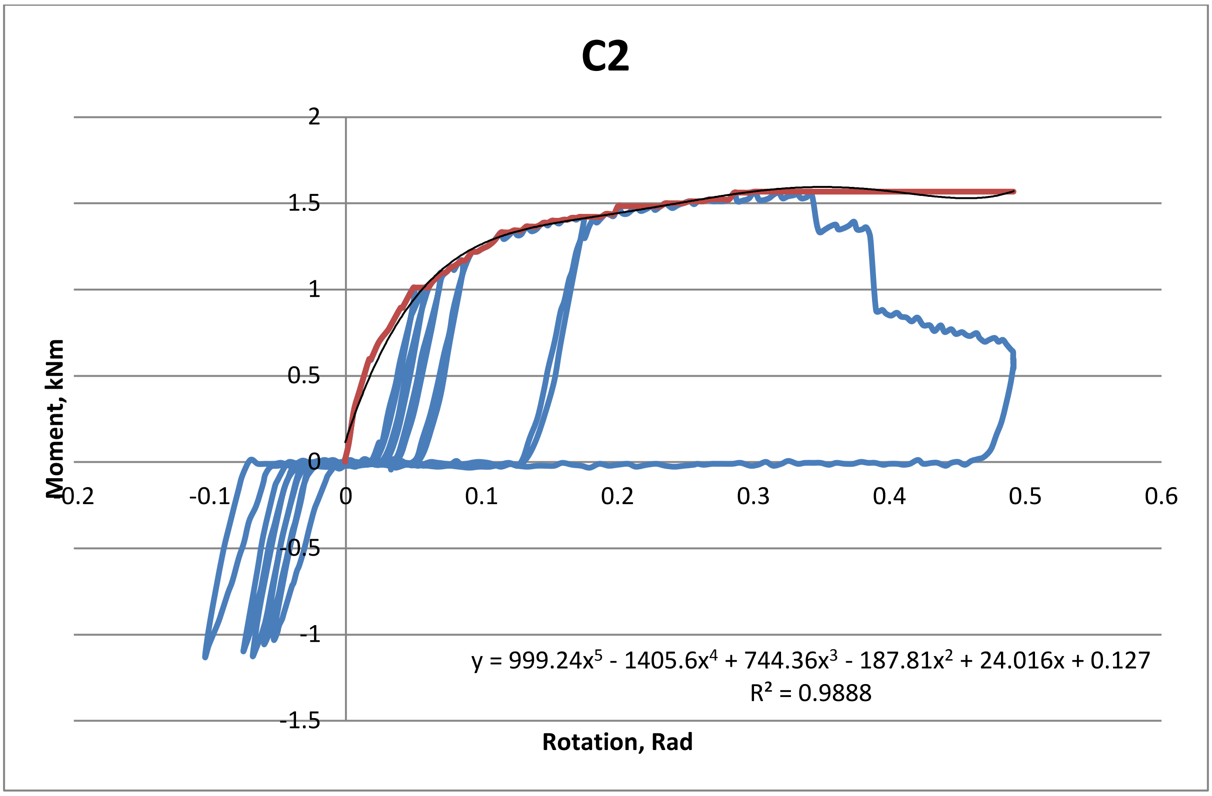

B3
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Moment, kNm
y = 301.67x5 - 540.26x4 + 371.49x3 - 119.3x2 + 20.93x + 0.1411
R2 = 0.9994
Rotation, Rad

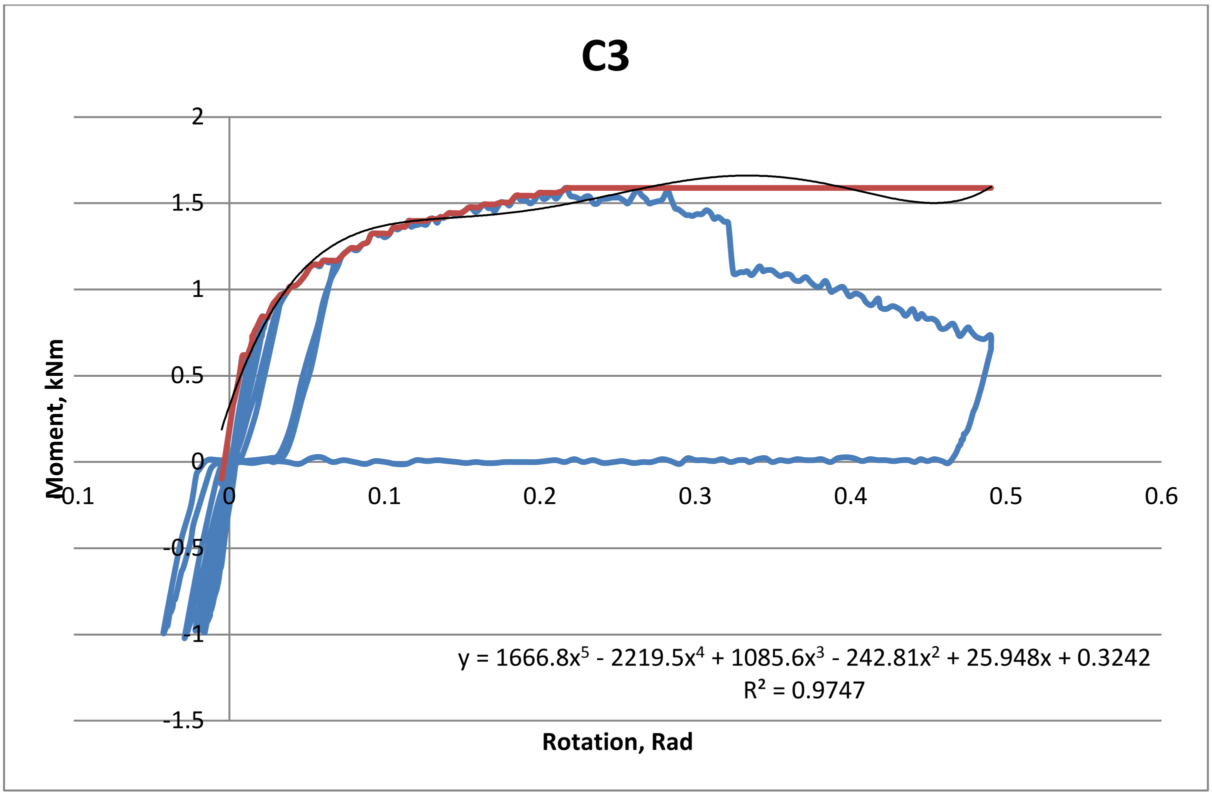

B4
Moment, kNm
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
y = 787.89x⁵ - 1089.8x⁴ + 583.69x³ - 150.68x² + 21.825x + 0.1159
R² = 0.9989
Rotation, Rad

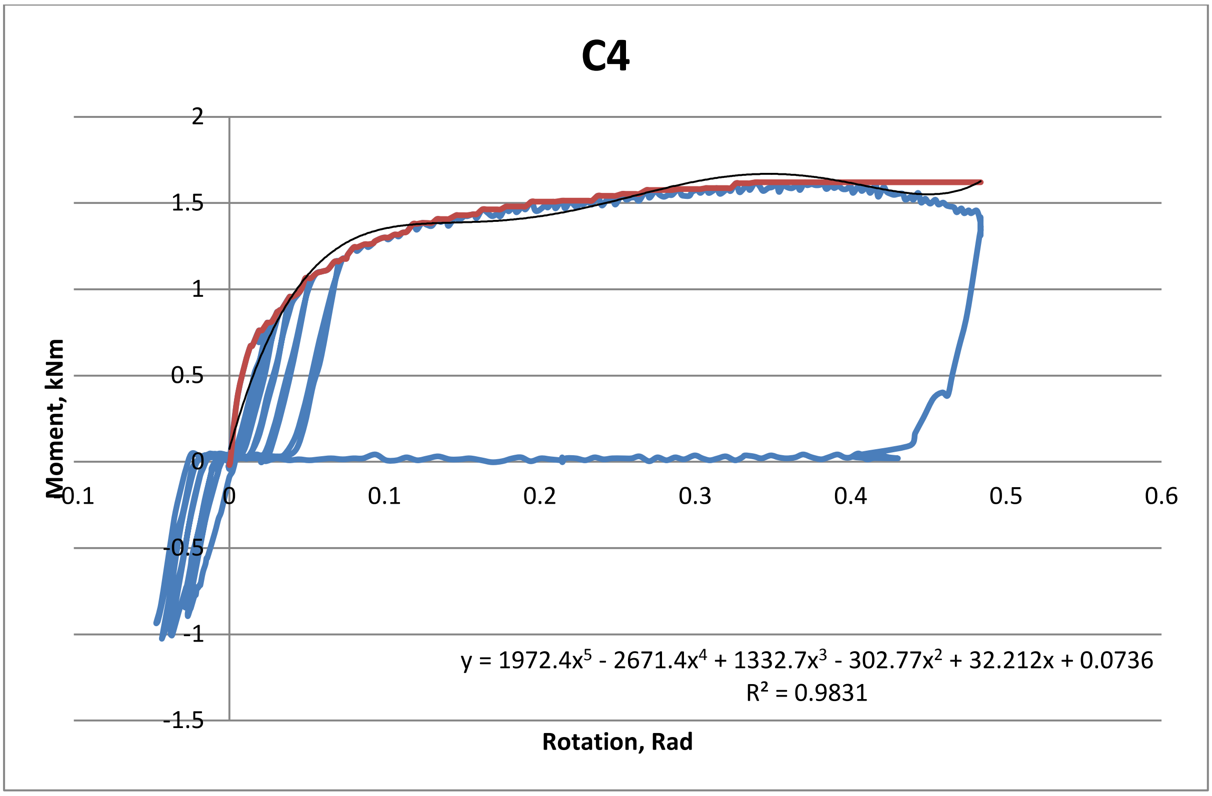

B5
Moment, kNm
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
y = 287.4x⁵ - 440x⁴ + 280.83x³ - 90.747x² + 17.463x + 0.1407
R² = 0.9964
Rotation, Rad

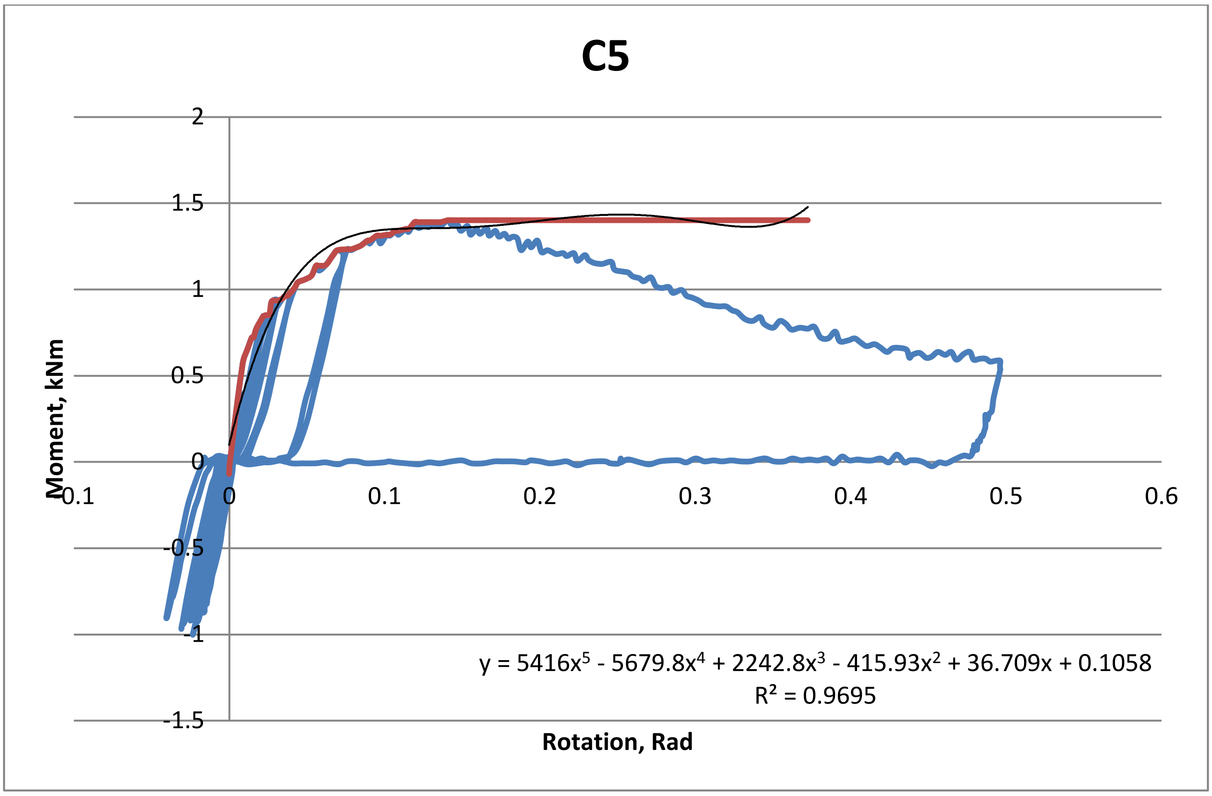
Transom to Standard Connection in the Upwards Direction – T2S_UP_C1-5



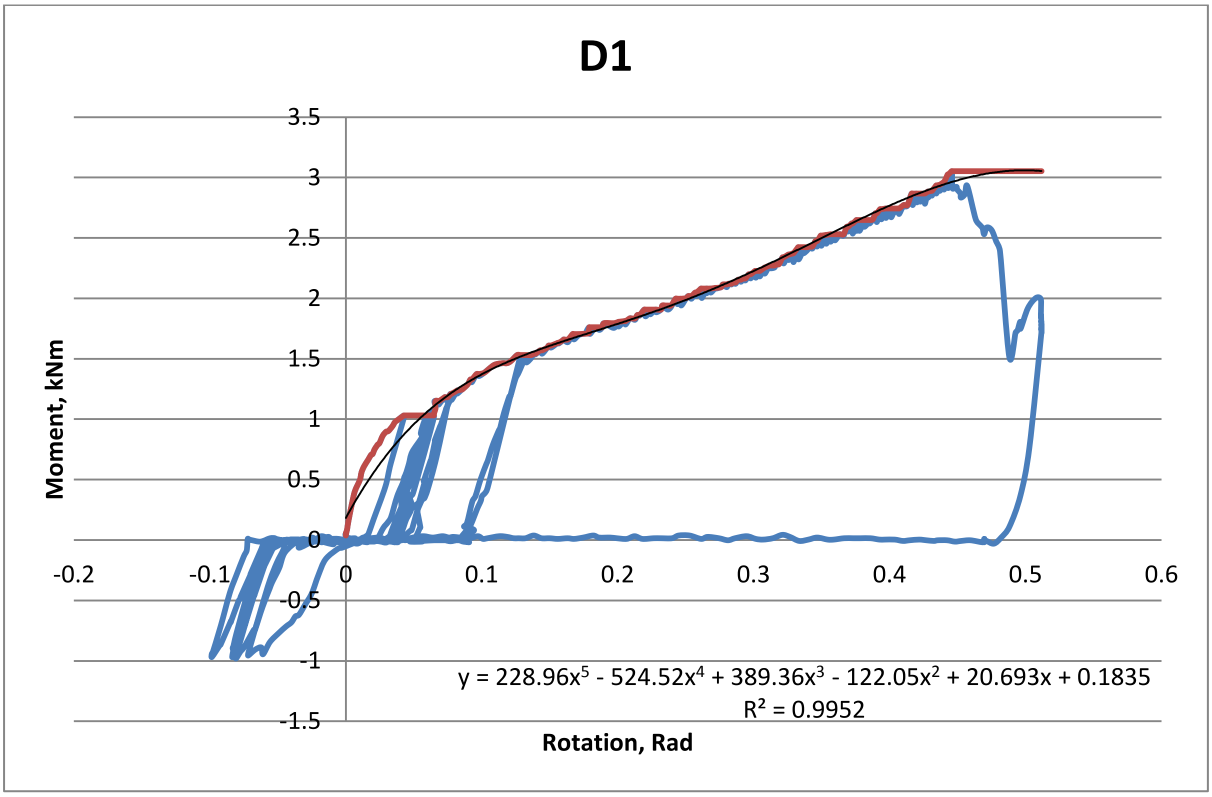


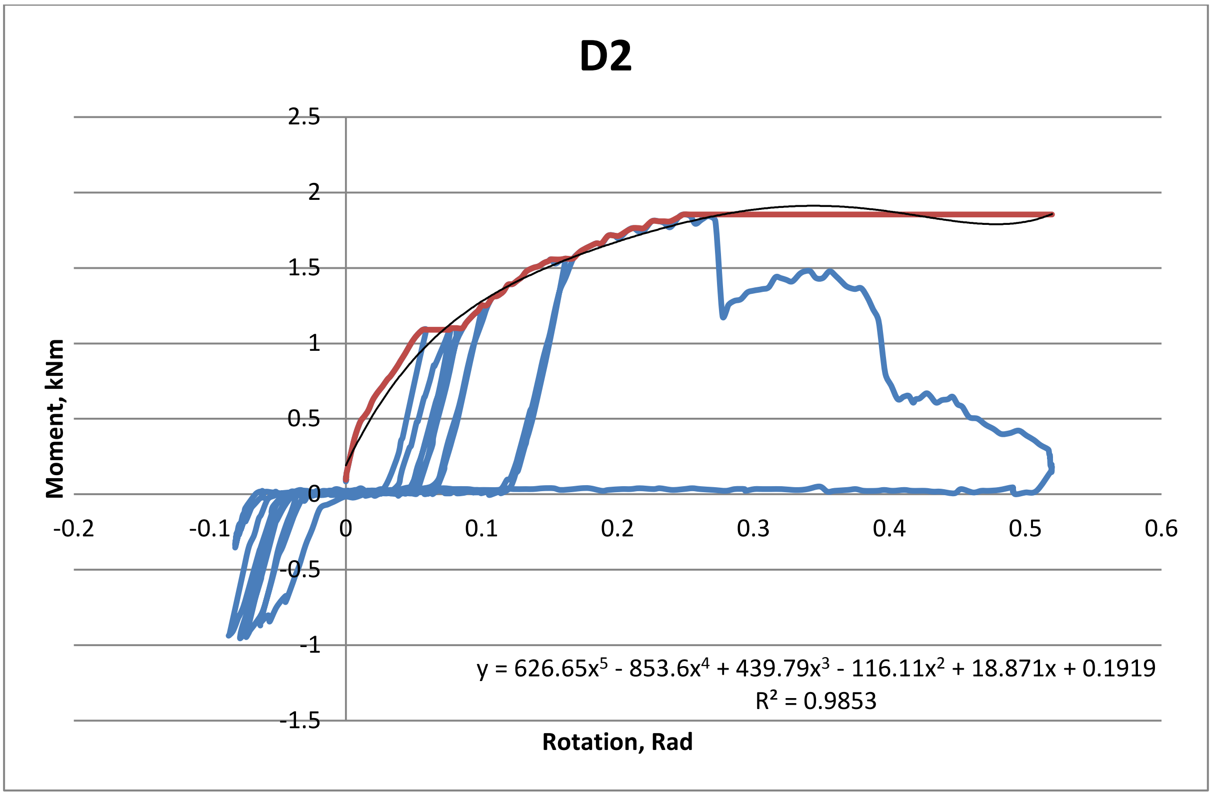

C3
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
Moment, kNm
Rotation, Rad
y = 1666.8x5 - 2219.5x4 + 1085.6x3 - 242.81x2 + 25.948x + 0.3242
R2 = 0.9747

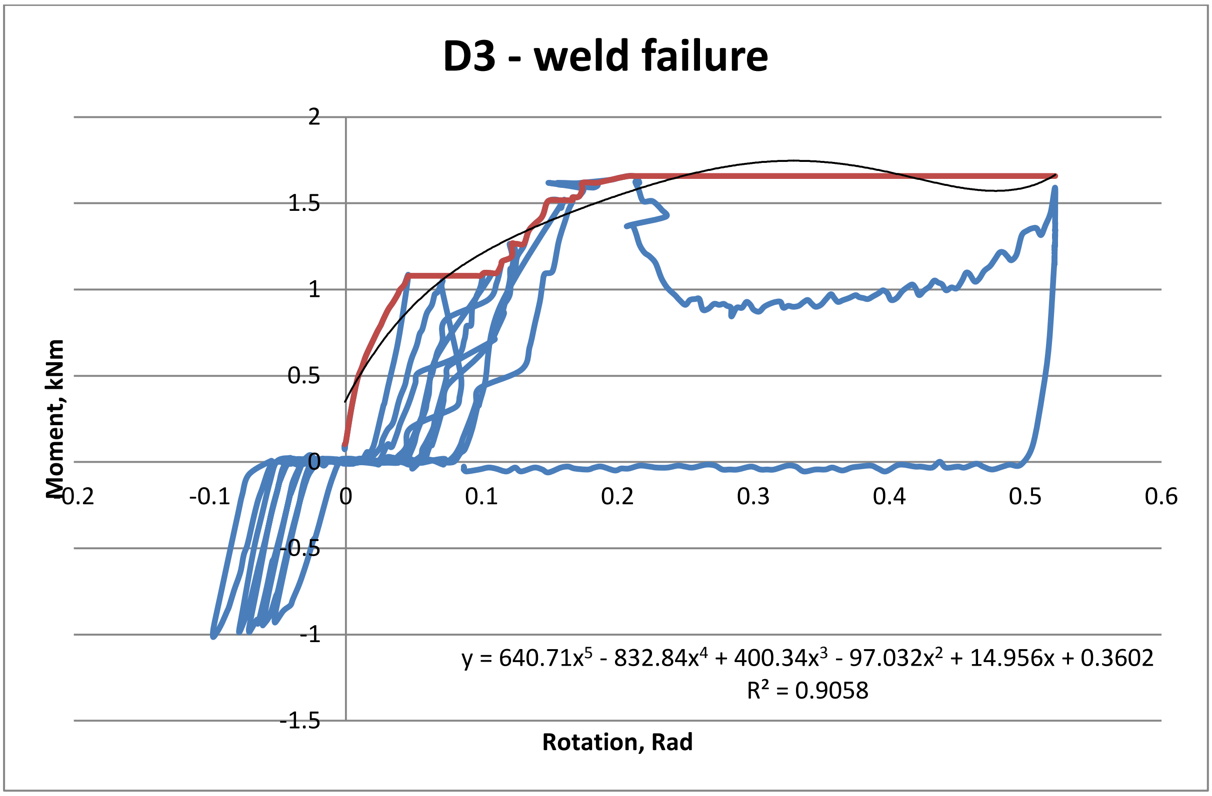

C4
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
Moment, kNm
Rotation, Rad
y = 1972.4x5 - 2671.4x4 + 1332.7x3 - 302.77x2 + 32.212x + 0.0736
R2 = 0.9831

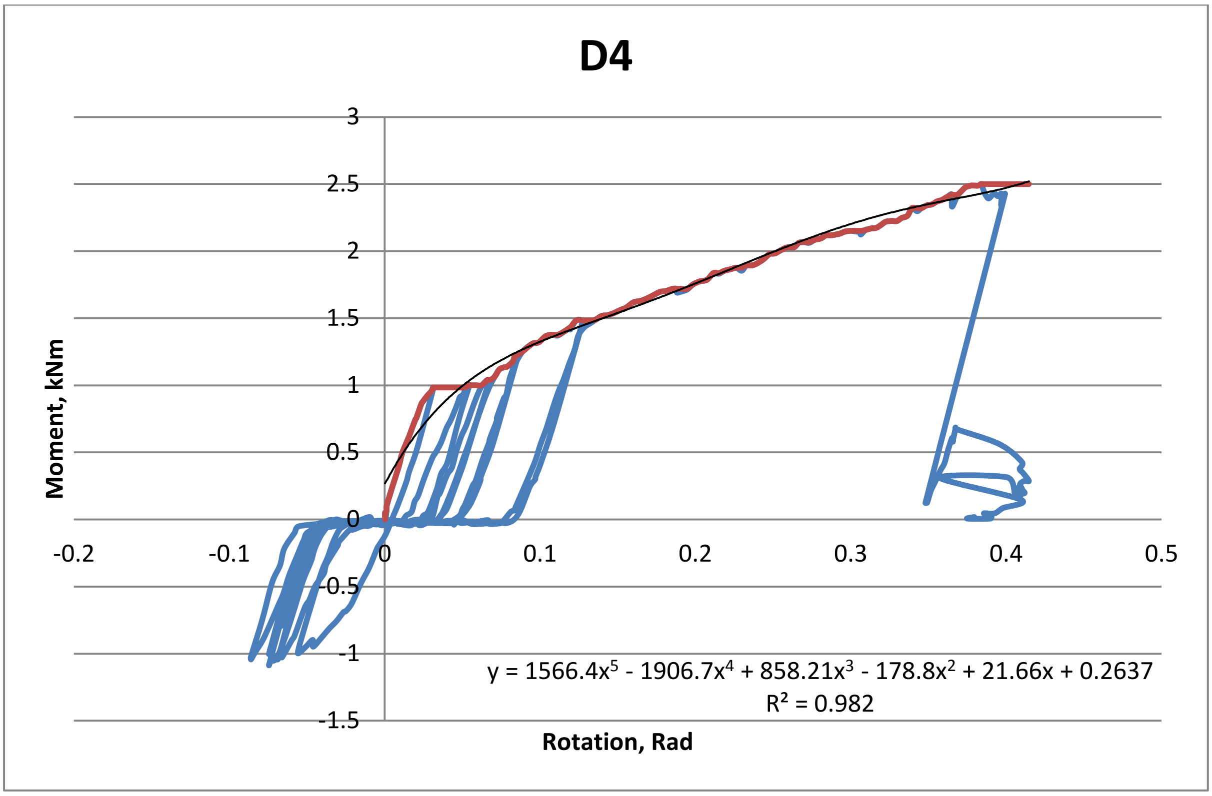


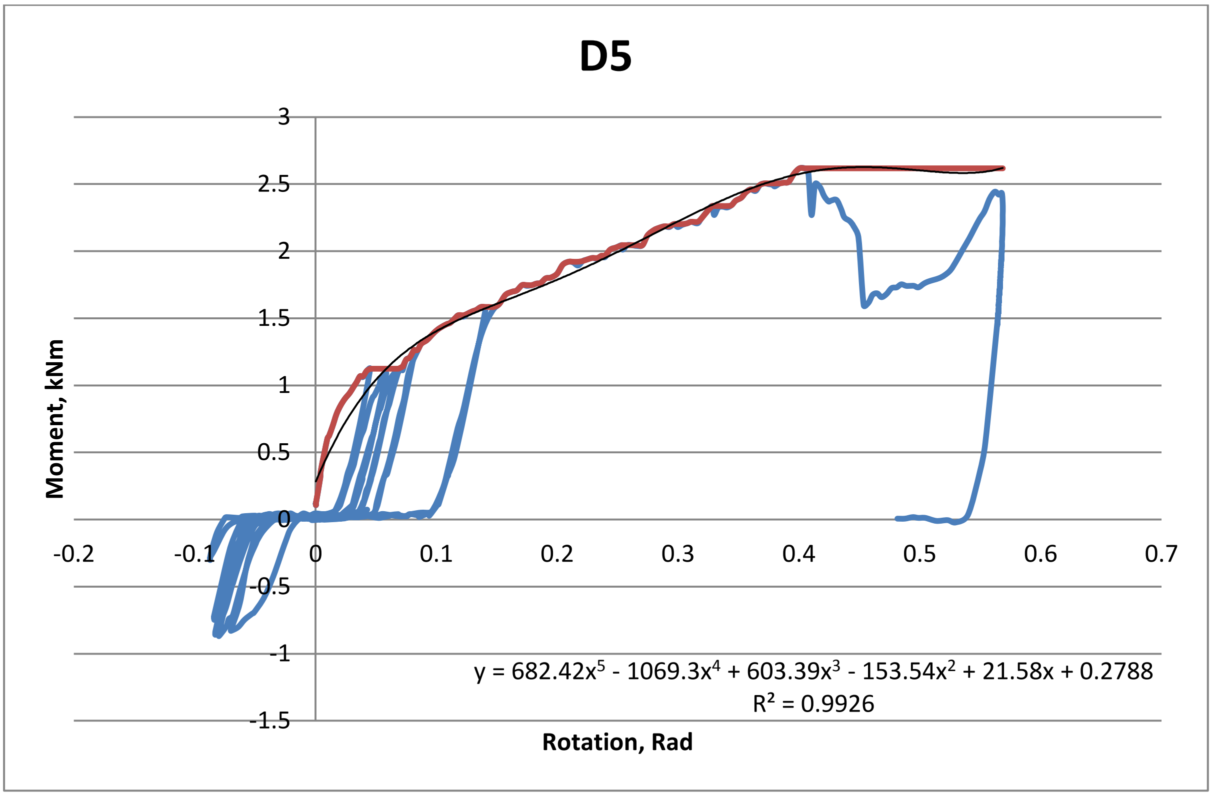
Transom to Standard Connection in the Downwards Direction – T2S_DN_D1-5

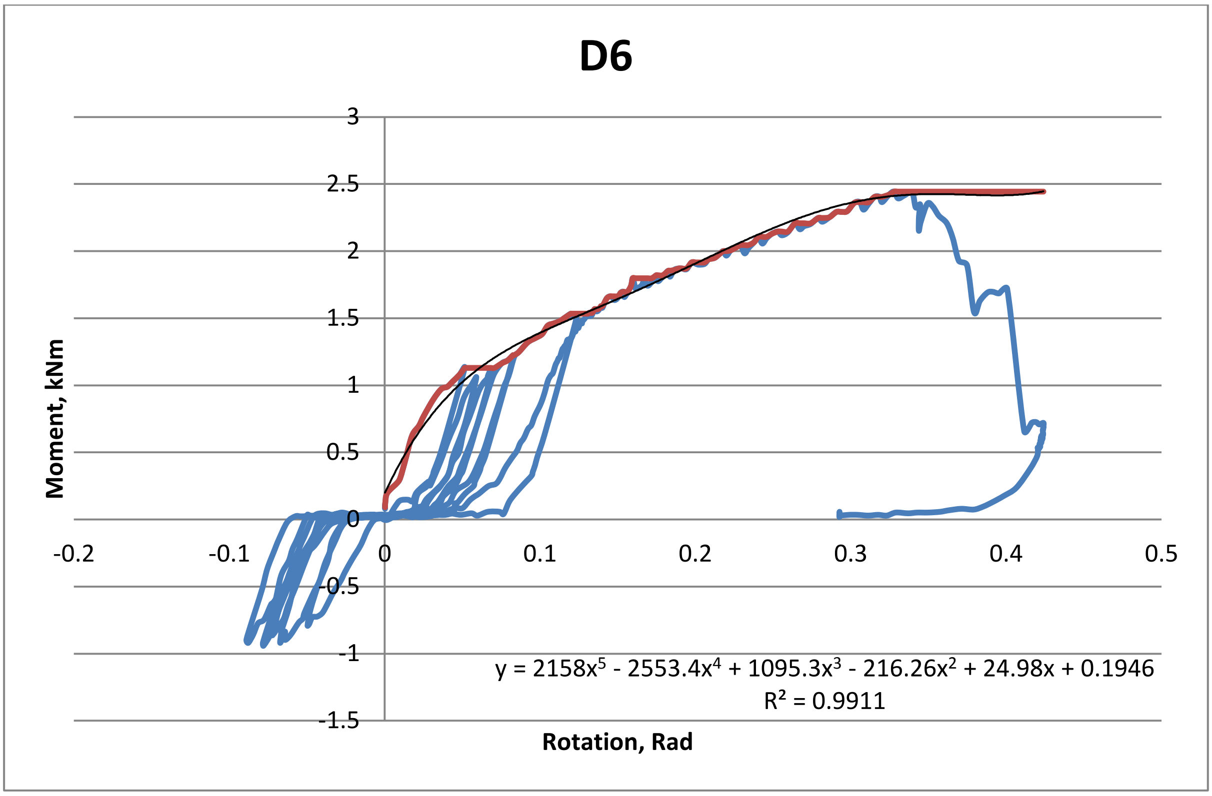



D2
Moment, kNm
Rotation, Rad
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
y = 626.65x⁵ - 853.6x⁴ + 439.79x³ - 116.11x² + 18.871x + 0.1919
R² = 0.9853

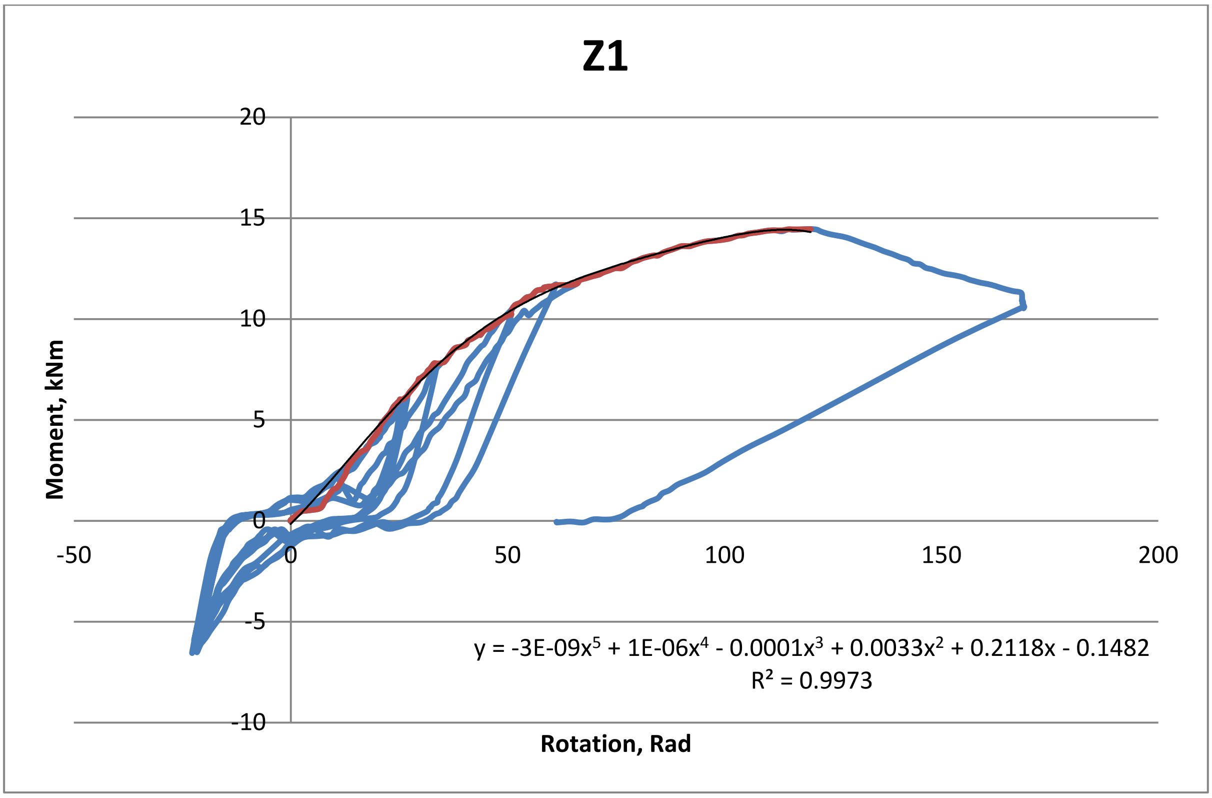

D3 - weld failure
Moment, kNm
Rotation, Rad
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
y = 640.71x⁵ - 832.84x⁴ + 400.34x³ - 97.032x² + 14.956x + 0.3602
R² = 0.9058

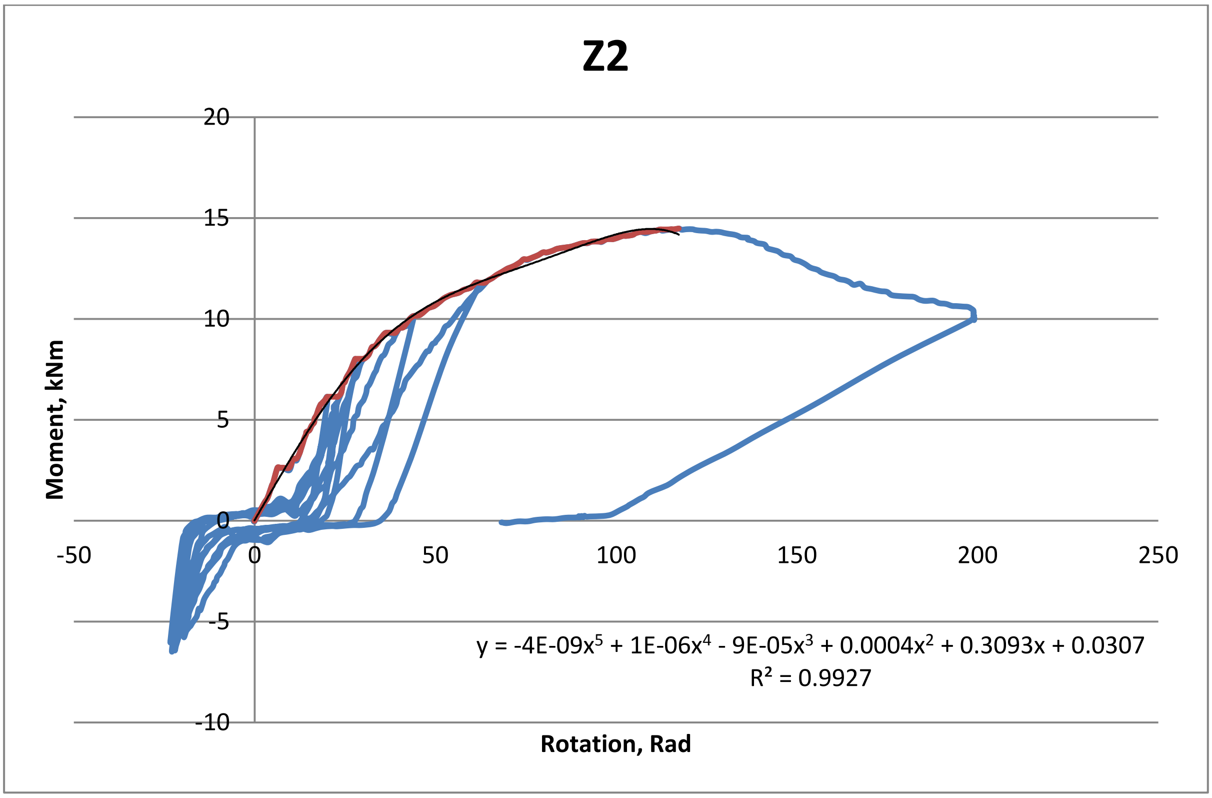

D4
Moment, kNm
Rotation, Rad
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
y = 1566.4x⁵ - 1906.7x⁴ + 858.21x³ - 178.8x² + 21.66x + 0.2637
R² = 0.982

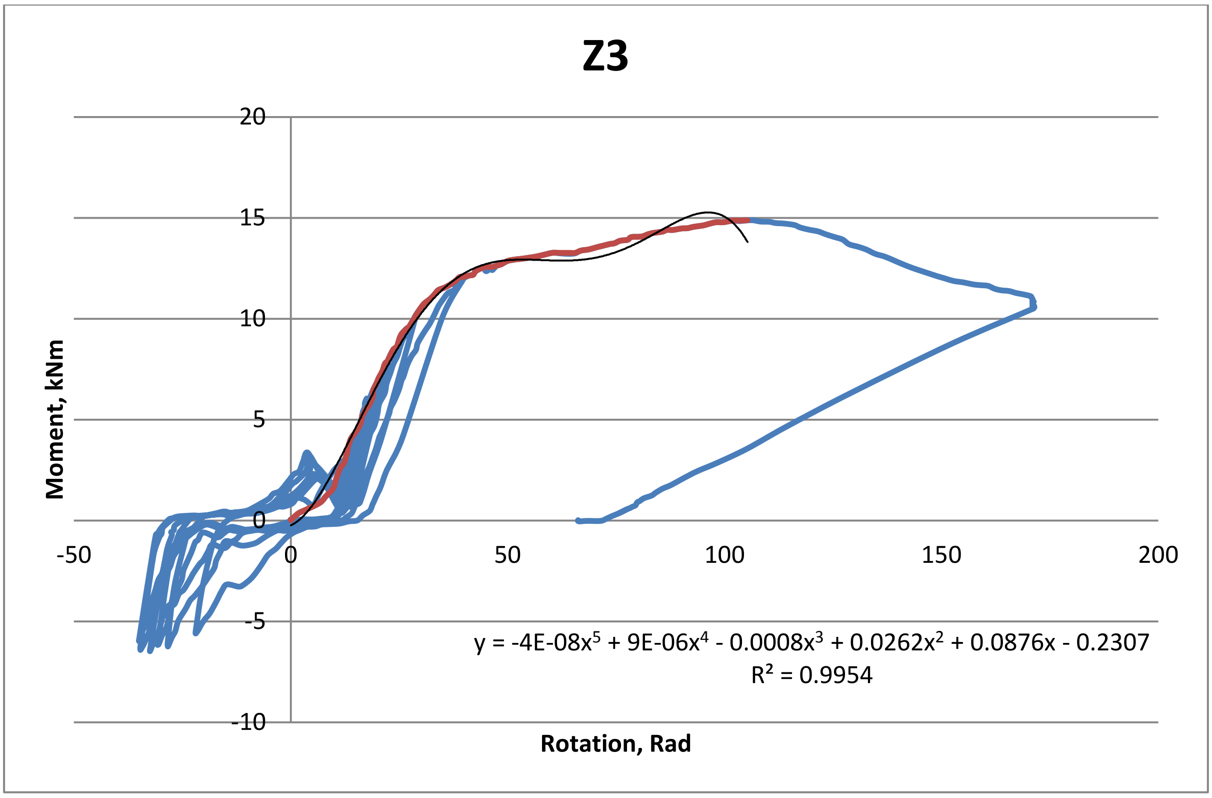

D5
Moment, kNm
Rotation, Rad
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
y = 682.42x⁵ - 1069.3x⁴ + 603.39x³ - 153.54x² + 21.58x + 0.2788
R² = 0.9926

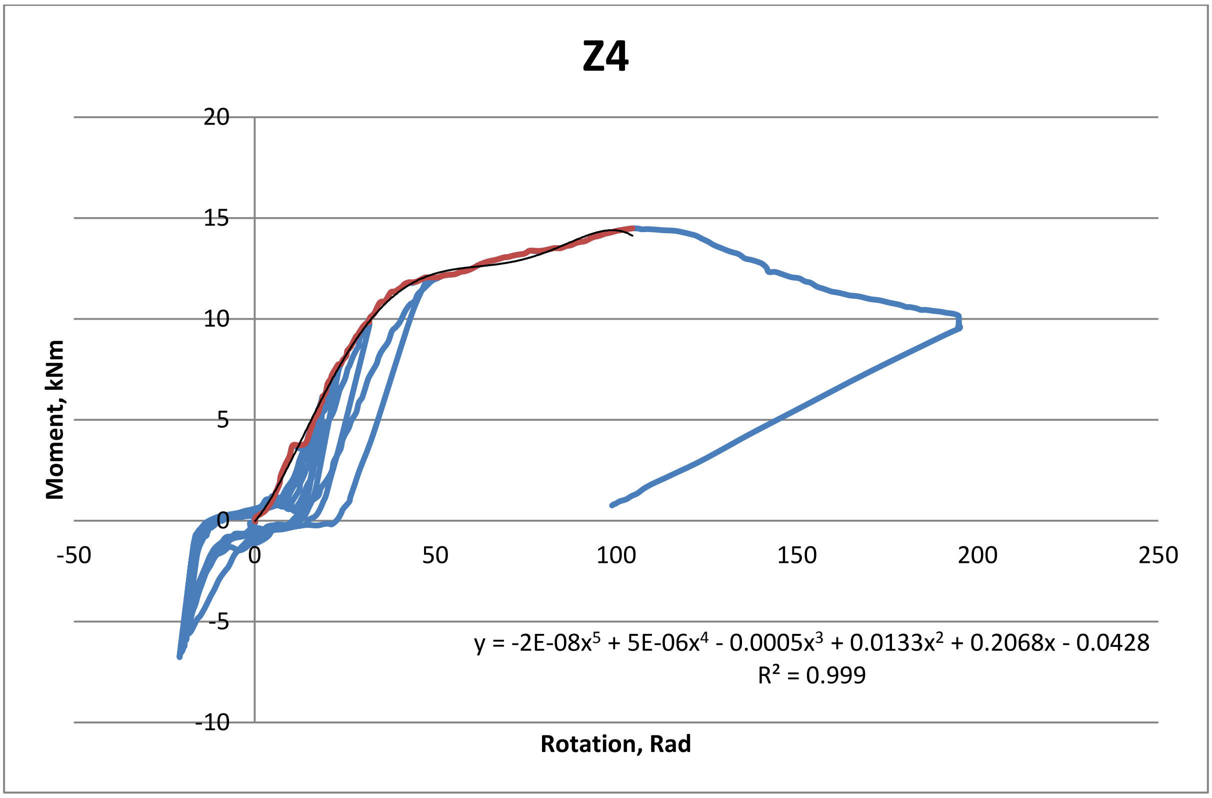


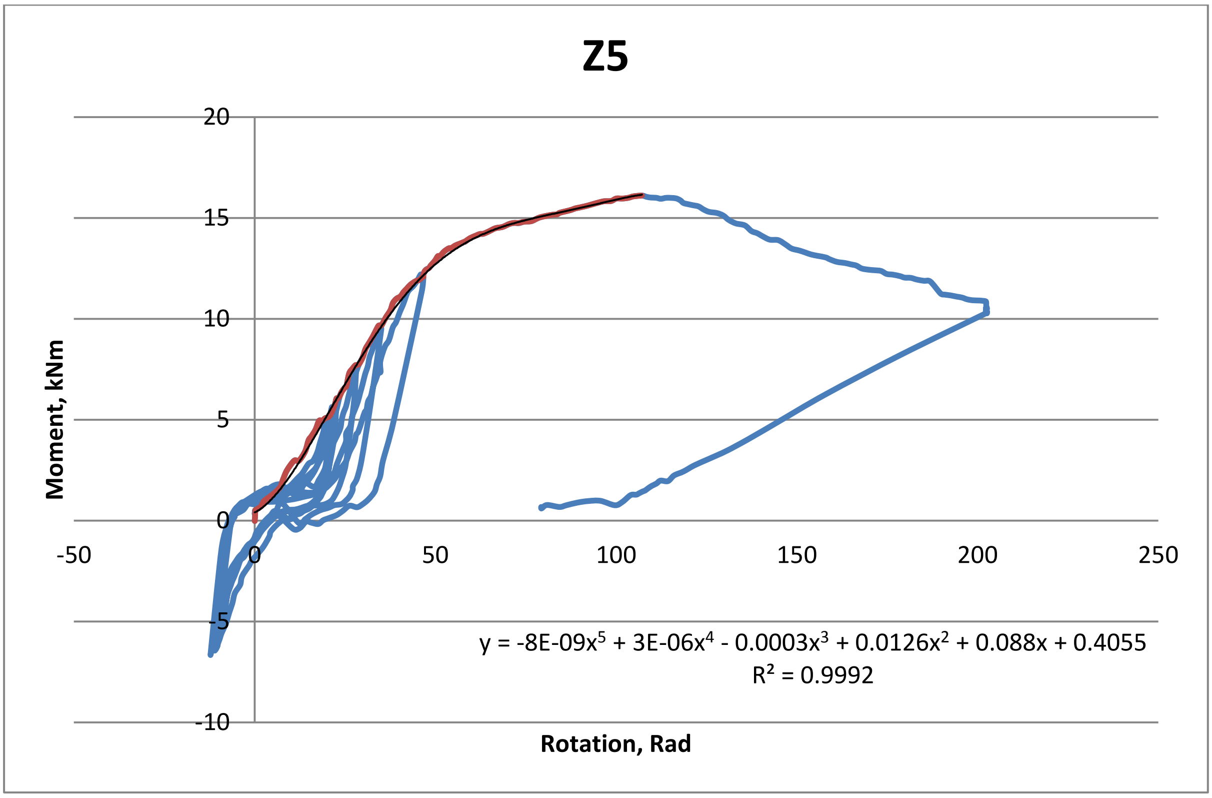
Brace Assembly – BRACE_1-5




Z2
Moment, kNm
Rotation, Rad
20
15
10
5
0
-5
-10
-50
0
50
100
150
200
250
y = -4E-09x⁵ + 1E-06x⁴ - 9E-05x³ + 0.0004x² + 0.3093x + 0.0307
R² = 0.9927


Z3
Moment, kNm
Rotation, Rad
20
15
10
5
0
-5
-10
-50
0
50
100
150
200
y = -4E-08x⁵ + 9E-06x⁴ - 0.0008x³ + 0.0262x² + 0.0876x - 0.2307
R² = 0.9954

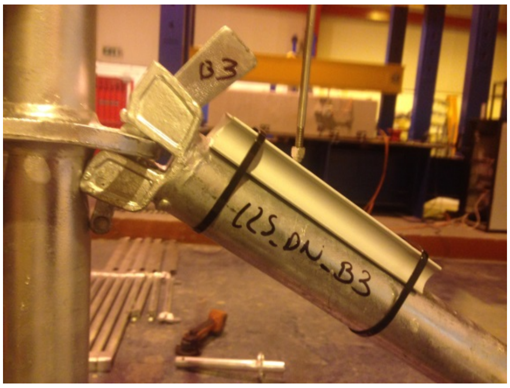

Z4
20
15
10
5
0
-5
-10
-50
0
50
100
150
200
250
Moment, kNm
Rotation, Rad
y = -2E-08x⁵ + 5E-06x⁴ - 0.0005x³ + 0.0133x² + 0.2068x - 0.0428
R² = 0.999

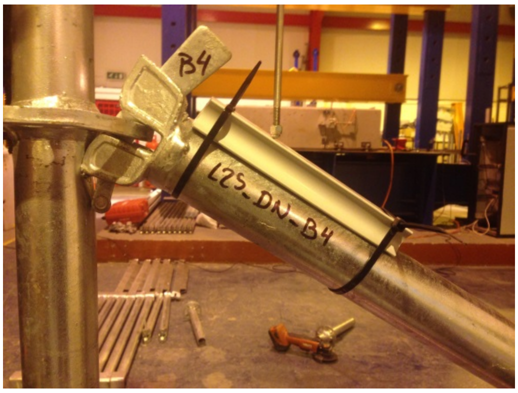

Z5
20
15
10
5
0
-5
-10
-50
0
50
100
150
200
250
Moment, kNm
Rotation, Rad
y = -8E-09x⁵ + 3E-06x⁴ - 0.0003x³ + 0.0126x² + 0.088x + 0.4055
R² = 0.9992

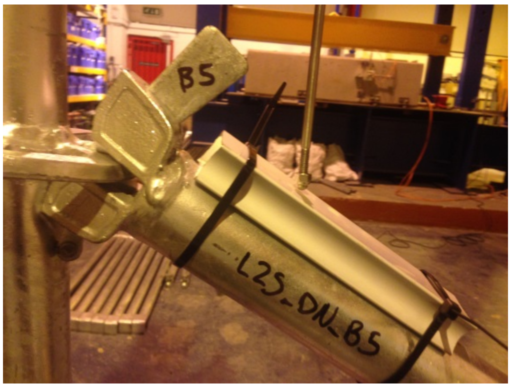
APPENDIX C – PHOTOGRAPHIC RECORDS

Ledger to Standard Connection in the Upwards Direction – L2S_UP_A1-5

Ledger to Standard Connection in the Downwards Direction – L2S_DN_B1-5

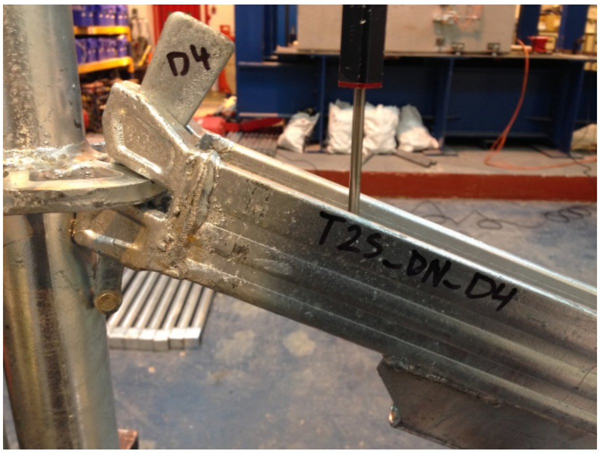






Transom to Standard Connection in the Upwards Direction – T2S_UP_C1-5

Transom to Standard Connection in the Downwards Direction – T2S_DN_D1-5



Brace Assembly – BRACE_1-5