

# **Review of Corridors for FlexPLI Dynamic Assembly Certification Tests**

**3<sup>rd</sup> Meeting of the  
Task Force Review and Update Certification Corridors (TF-RUCC)  
of the  
Informal Group GTR9 Phase 2  
May 25<sup>th</sup>, 2012**

**Oliver Zander**

Bundesanstalt für Straßenwesen

**Bundesanstalt für Straßenwesen**

(Federal Highway Research Institute)

---

**Background**

**Inverse test results & analysis**

**Revision of inverse certification corridors**

**Pendulum test results & analysis**

**Revision of pendulum certification corridors**

**Summary**

- **The schedule of TF-RUCC foresees inverse and pendulum testing of three completely overhauled FlexPLI impactors in three different test houses**
- **As impactors, SN01, SN03 and an Engineering Leg have been selected**
- **Test laboratories to perform the tests are JARI, BAST and Bertrandt**
- **The test results are to be validated against the current draft inverse and pendulum certification corridors**
- **If necessary, the draft corridors are to be updated by re-calculation or shifting**
- **As a method to updating the corridors (if necessary), BAST suggest to use the established method as agreed by TEG**
- **An equal weighting (i.e. the same number of test results) of the impactors taken into account is not considered being necessary, because the corridors are based on the achieved minimum and maximum values**
- **This presentation gives an update of the latest test results, including a proposal for revised assembly certification corridors**

## Procedure for determination of certification corridors (as established within TEG):

### 1) Definition of reproducibility corridors

CV calculation of all segments of each impactor

Determination of segments for reproducibility corridor

Requirement:  $CV < 5\%$

Calculation of pooled means of all seven segments with  $CV < 5\%$

Calculation of reproducibility corridors (pooled mean  $\pm 10\%$ )

### 2) Definition of certification corridors

Determination of segments with reproducible test results

All results of corresponding segment supposed to be within reproducibility corridor

Determination of maxima and minima for each segment

Determination of corridor limits

Consideration of scatter: maxima  $+ 5\%$  / minima  $-5\%$

## Revision of Inverse Certification Test

# Inverse test results & analysis



- Up to now, three completely overhauled Flex-GTR impactors have been inverse tested at JARI & BAST (SN01, SN03 and E-Leg)
- As a stable connection of SN01 could not be established at BAST (slack joint of the output cable inside the Slice base module), this impactor was inverse tested at JARI only

## Test result overview:



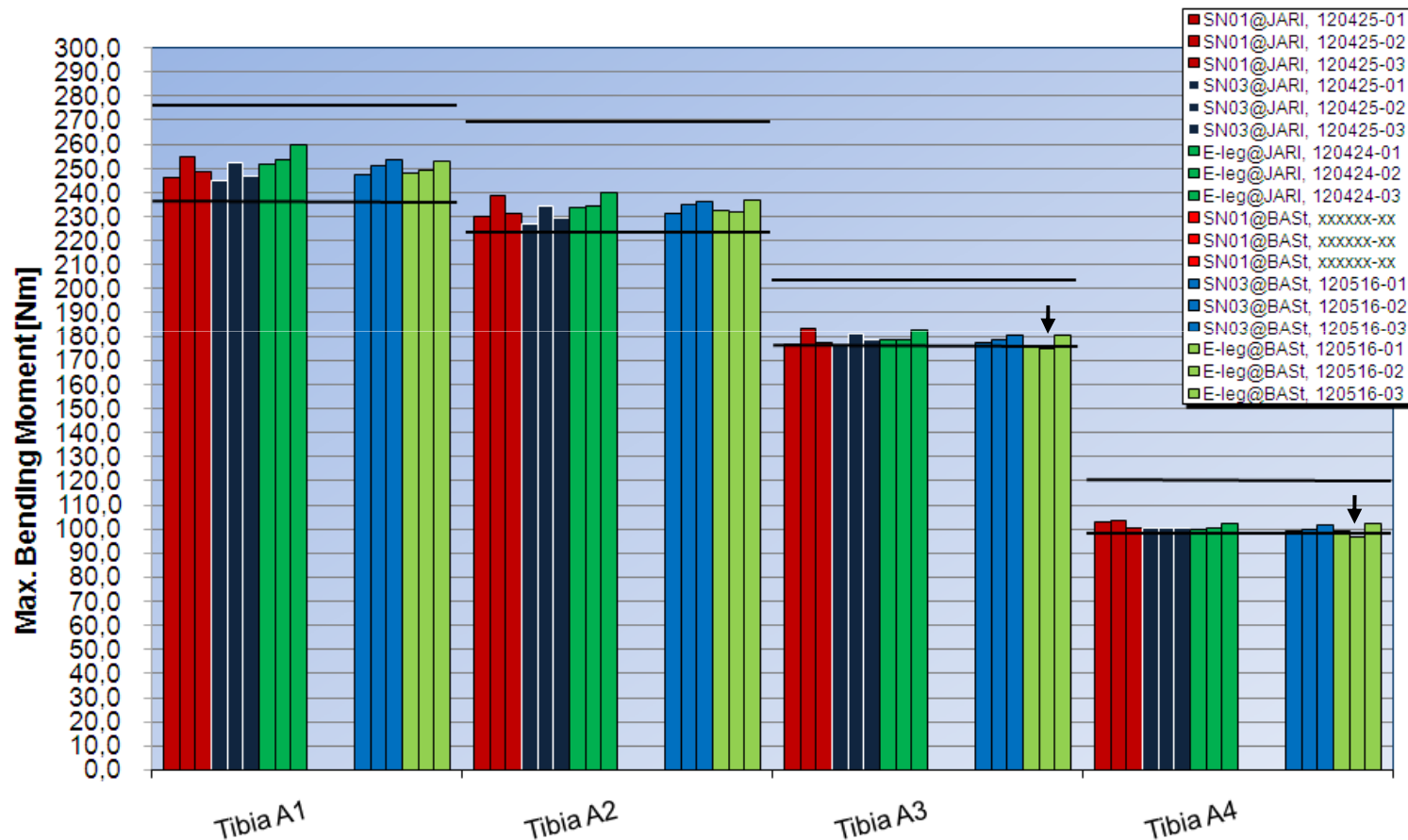
Test #	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
SN01@JARI, 120425-01	245.8	229.9	176.7	103.0	8.6	4.9	19.5
SN01@JARI, 120425-02	254.8	238.7	183.7	103.3	8.5	4.9	19.6
SN01@JARI, 120425-03	248.6	231.1	177.3	100.1	8.6	4.7	19.1
SN03@JARI, 120425-01	245.0	226.8	176.0	100.7	9.0	4.8	19.2
SN03@JARI, 120425-02	252.0	234.6	181.0	100.7	9.0	4.6	18.8
SN03@JARI, 120425-03	247.0	229.5	178.6	100.3	9.3	4.4	18.6
E-leg@JARI, 120424-01	251.9	233.4	178.2	100.1	8.6	5.4	19.8
E-leg@JARI, 120424-02	253.5	234.4	178.4	100.2	8.8	5.3	19.4
E-leg@JARI, 120424-03	260.0	240.1	183.0	102.3	8.8	5.4	19.8
SN01@BAST, xxxxxx-xx	not yet tested !						
SN01@BAST, xxxxxx-xx	not yet tested !						
SN01@BAST, xxxxxx-xx	not yet tested !						
SN03@BAST, 120516-01	247.3	231.5	177.4	99.0	8.4	5.3	18.5
SN03@BAST, 120516-02	250.8	234.9	178.8	100.0	8.9	4.8	18.2
SN03@BAST, 120516-03	253.6	236.0	180.4	101.4	9.4	4.4	18.2
E-leg@BAST, 120516-01	247.9	232.3	176.2	98.9	8.5	5.8	19.5
E-leg@BAST, 120516-02	249.4	232.0	175.0	97.0	8.6	5.7	19.2
E-leg@BAST, 120516-03	252.8	236.8	180.4	102.4	9.1	5.2	19.2

- Only six (out of 105) segments did not pass the current draft inverse corridors !

# Inverse test results & analysis



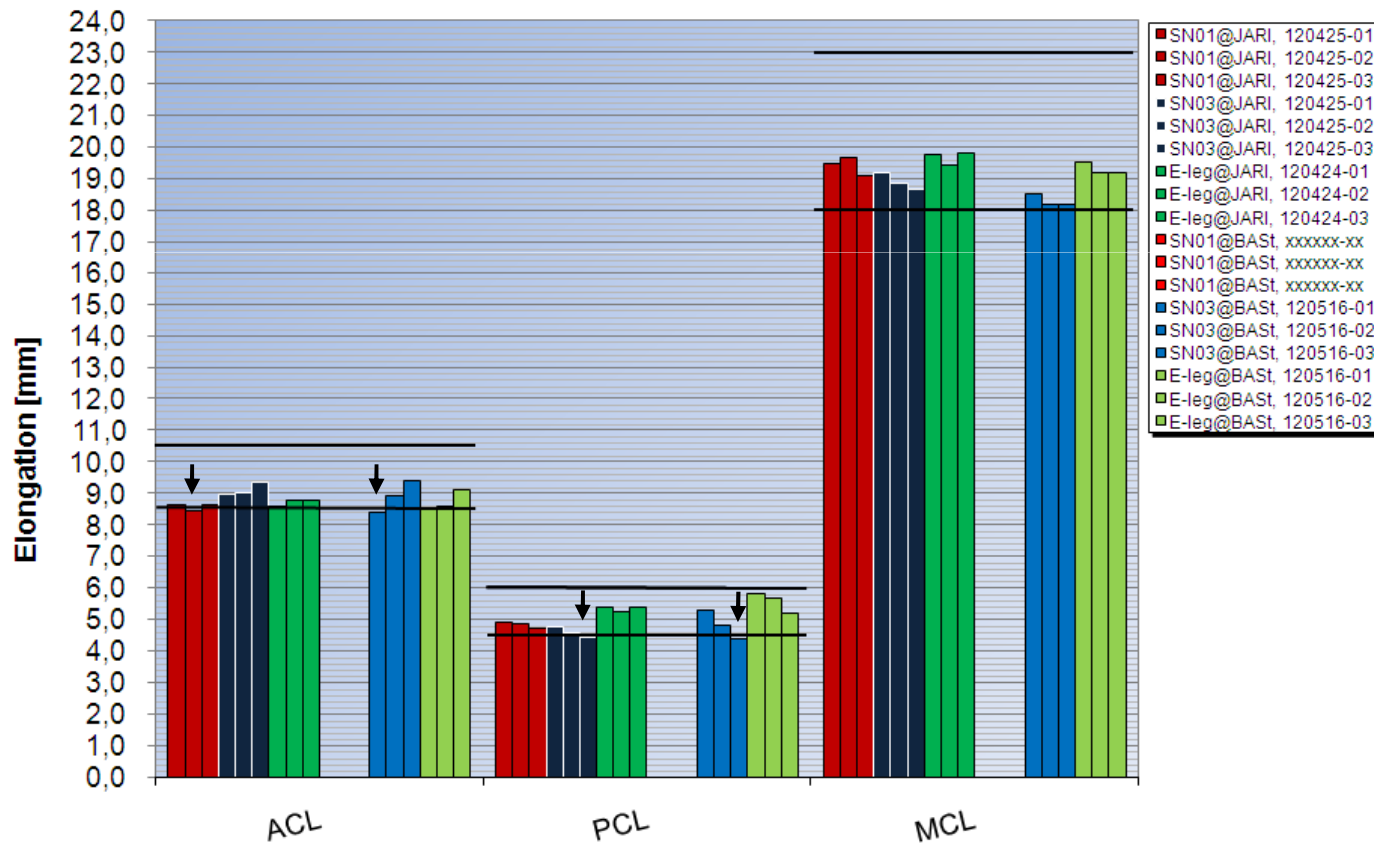
- Tibia A1 and A2 corridors met without any problem during all tests
- Borderline results for tibia A3 and A4 (at the lower end of the corridors)
- Tibia A3 and A4 corridor not met during second test with E-Leg at BAST



# Inverse test results & analysis



- MCL corridors met without any problem during all tests (though at the lower end in two tests)
- Partly borderline results for ACL and PCL (at the lower end of the corridors)
- E-Leg with significantly higher PCL results in both labs
- ACL and PCL corridor not met during two tests each





# Revision of **inverse** corridors



## Coefficients of variation:

(15 inverse test results, thereof five setups with SN01, SN03 and E-Leg)

Segment	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
Setup 1 - SN01 - JARI	1,84	2,04	2,18	1,70	1,08	2,17	1,50
Setup 2 - SN03 - JARI	1,46	1,71	1,38	0,21	2,20	3,47	1,42
Setup 3 - E-leg - JARI	1,68	1,54	1,49	1,21	1,12	1,34	1,13
Setup 4 - SN01 - BASt							
Setup 5 - SN03 - BASt	1,26	1,00	0,84	1,20	5,62	9,33	0,95
Setup 6 - E-leg - BASt	1,00	1,15	1,60	2,75	3,68	5,77	0,90

Most segments with good repeatability (CV < 5%)

Due to repeatability reasons, three segments (out of 35) could not be used for the definition of the reproducibility corridor

# Revision of **inverse** corridors



## Definition of reproducibility corridor:

(Setups and segments with repeatable test results [CV < 5%]):

Segment	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
<b>Setups for Reproducibility Corridor [CV &lt; 5%]</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/6</b>	<b>1/2/3</b>	<b>1/2/3/5/6</b>
Pooled Mean with CV < 5%	250,70	233,47	178,74	100,61	8,78	4,93	19,11
Upper Limit	275,76	256,82	196,61	110,68	9,66	5,42	21,02
Lower Limit	225,63	210,13	160,87	90,55	7,90	4,43	17,20

## Determination of setups and segments with reproducible test results:

Setup / Segment	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
Setup 1 - SN01 - JARI - MAX	254,78	238,67	183,73	103,27	8,63	4,92	19,64
Setup 1 - SN01 - JARI - MIN	245,82	229,89	176,67	100,13	8,47	4,71	19,07
Setup 2 - SN03 - JARI - MAX	252,03	234,59	180,96	100,67	9,33	4,77	19,17
Setup 2 - SN03 - JARI - MIN	245,04	226,85	176,04	100,29	8,96	4,45	18,65
Setup 3 - E-leg - JARI - MAX	259,98	240,13	182,95	102,25	8,79	5,40	19,79
Setup 3 - E-leg - JARI - MIN	251,90	233,39	178,23	100,06	8,61	5,27	19,40
Setup 4 - SN01 - BASt - MAX							
Setup 4 - SN01 - BASt - MIN							
Setup 5 - SN03 - BASt - MAX	253,60	236,00	180,40	101,40	9,40	5,30	18,50
Setup 5 - SN03 - BASt - MIN	247,30	231,50	177,40	99,00	8,40	4,40	18,20
Setup 6 - E-leg - BASt - MAX	252,80	236,80	180,40	102,40	9,10	5,80	19,50
Setup 6 - E-leg - BASt - MIN	247,90	232,00	175,00	97,00	8,50	5,20	19,20
<b>Reproducible test results (Setups and segments within Reproducibility Corridor)</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3</b>	<b>1/2/3/5/6</b>

# Revision of **inverse** corridors



**Definition of certification corridor:**  
**(Setups and segments with reproducible test results):**

Setup / Segment	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
Setup 1 - SN01 - JARI - MAX	254,78	238,67	183,73	103,27	8,63	4,92	19,64
Setup 1 - SN01 - JARI - MIN	245,82	229,89	176,67	100,13	8,47	4,71	19,07
Setup 2 - SN03 - JARI - MAX	252,03	234,59	180,96	100,67	9,33	4,77	19,17
Setup 2 - SN03 - JARI - MIN	245,04	226,85	176,04	100,29	8,96	4,45	18,65
Setup 3 - E-leg - JARI - MAX	259,98	240,13	182,95	102,25	8,79	5,40	19,79
Setup 3 - E-leg - JARI - MIN	251,90	233,39	178,23	100,06	8,61	5,27	19,40
Setup 4 - SN01 - BASt - MAX							
Setup 4 - SN01 - BASt - MIN							
Setup 5 - SN03 - BASt - MAX	253,60	236,00	180,40	101,40	9,40		18,50
Setup 5 - SN03 - BASt - MIN	247,30	231,50	177,40	99,00	8,40		18,20
Setup 6 - E-leg - BASt - MAX	252,80	236,80	180,40	102,40	9,10		19,50
Setup 6 - E-leg - BASt - MIN	247,90	232,00	175,00	97,00	8,50		19,20
Maximum	259,98	240,13	183,73	103,27	9,40	5,40	19,79
Minimum	245,04	226,85	175,00	97,00	8,40	4,45	18,20
Max * 1,05 (Consideration of scatter)	272,98	252,14	192,92	108,44	9,87	5,67	20,78
Min * 0,95 (Consideration of scatter)	232,79	215,51	166,25	92,15	7,98	4,23	17,29
Certification Corridor Upper Limit	272	252	192	108	10	6	21
Certification Corridor Lower Limit	233	216	167	93	8	4	17

**Calculated tibia values have been rounded in a way such that the corridors are kept tight.**

**For feasibility reasons, the ligament corridors have been widened slightly.**

# Revision of **inverse** corridors



Verification of certification corridors (Application to 15 Flex-GTR tests):

Test #	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
SN01@JARI, 120425-01	245.8	229.9	176.7	103.0	8.6	4.9	19.5
SN01@JARI, 120425-02	254.8	238.7	183.7	103.3	8.5	4.9	19.6
SN01@JARI, 120425-03	248.6	231.1	177.3	100.1	8.6	4.7	19.1
SN03@JARI, 120425-01	245.0	226.8	176.0	100.7	9.0	4.8	19.2
SN03@JARI, 120425-02	252.0	234.6	181.0	100.7	9.0	4.6	18.8
SN03@JARI, 120425-03	247.0	229.5	178.6	100.3	9.3	4.4	18.6
E-leg@JARI, 120424-01	251.9	233.4	178.2	100.1	8.6	5.4	19.8
E-leg@JARI, 120424-02	253.5	234.4	178.4	100.2	8.8	5.3	19.4
E-leg@JARI, 120424-03	260.0	240.1	183.0	102.3	8.8	5.4	19.8
SN01@BAsT, xxxxxx-xx							
SN01@BAsT, xxxxxx-xx							
SN01@BAsT, xxxxxx-xx							
SN03@BAsT, 120516-01	247.3	231.5	177.4	99.0	8.4	5.3	18.5
SN03@BAsT, 120516-02	250.8	234.9	178.8	100.0	8.9	4.8	18.2
SN03@BAsT, 120516-03	253.6	236.0	180.4	101.4	9.4	4.4	18.2
E-leg@BAsT, 120516-01	247.9	232.3	176.2	98.9	8.5	5.8	19.5
E-leg@BAsT, 120516-02	249.4	232.0	175.0	97.0	8.6	5.7	19.2
E-leg@BAsT, 120516-03	252.8	236.8	180.4	102.4	9.1	5.2	19.2

- All certification tests passed the complete set of defined draft inverse criteria

100 % passed

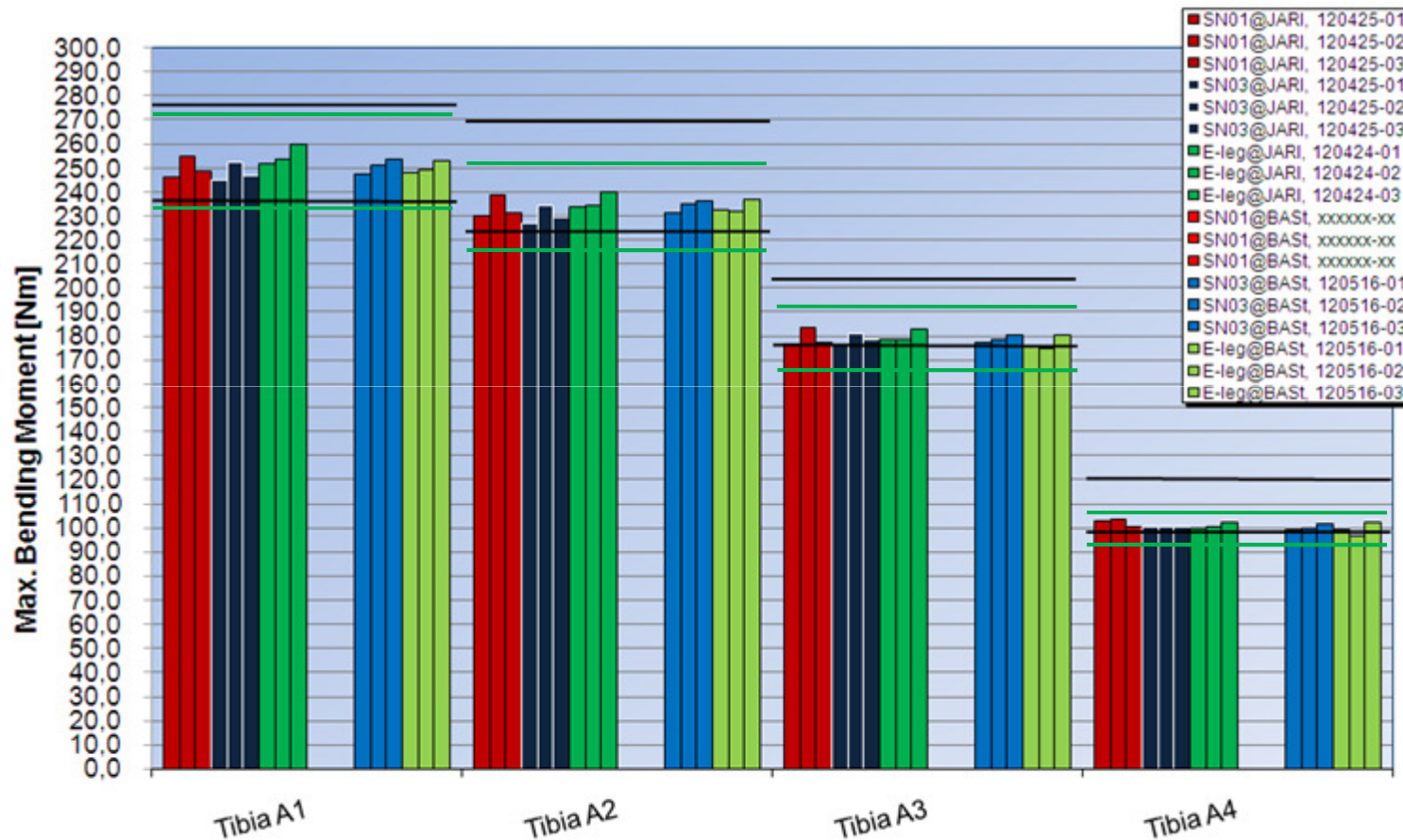
0 % failed

Upper Limit	272	252	192	108	10	6	21
Lower Limit	233	216	167	93	8	4	17

# Revision of **inverse** corridors



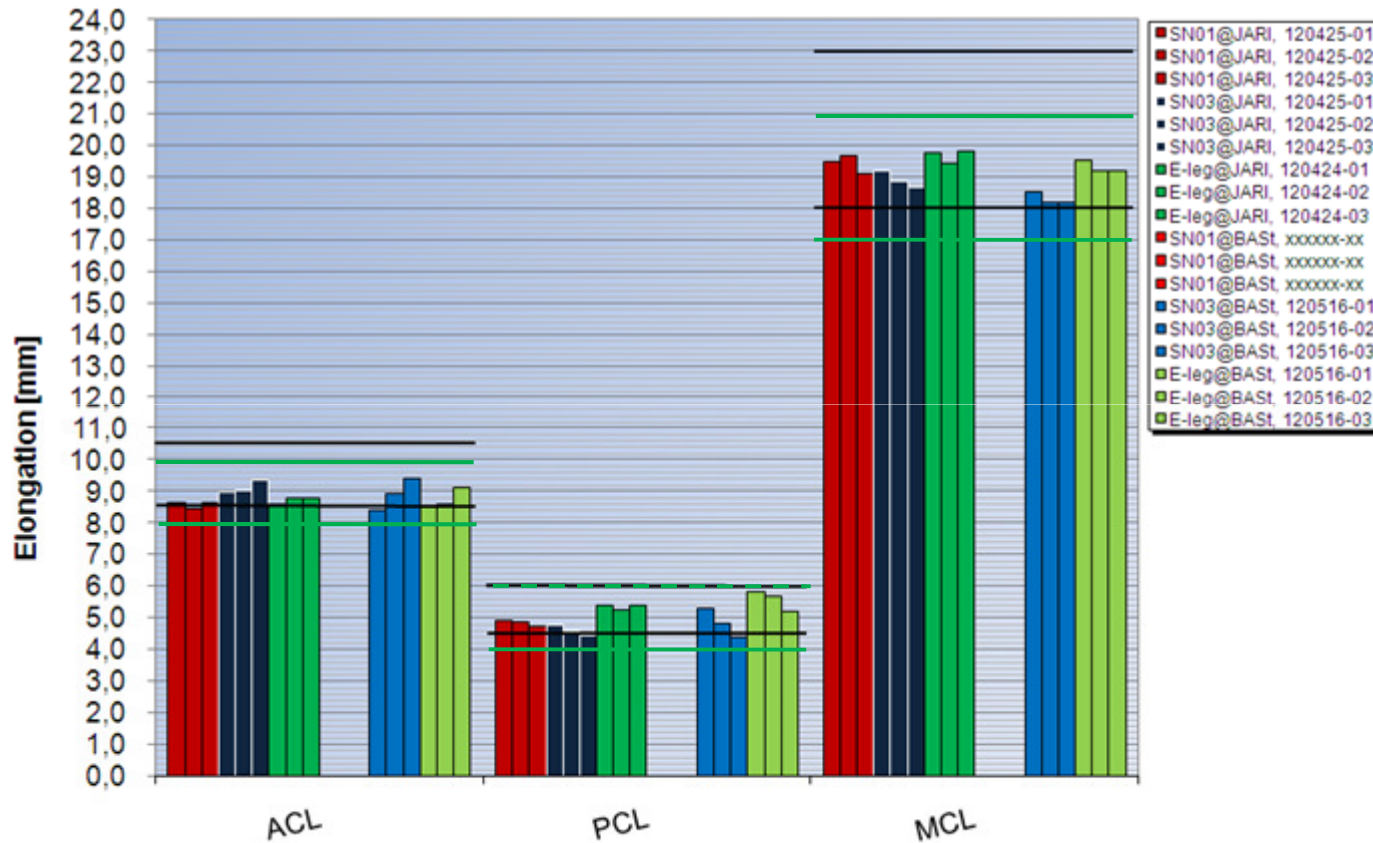
Verification of certification corridors (Application to 15 Flex-GTR tests):



# Revision of **inverse** corridors



Verification of certification corridors (Application to 15 Flex-GTR tests):



# Comparison of **inverse** corridors



## Old draft inverse certification corridors:

	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
upper	277	269	204	120	10,5	6	23
lower	237	223	176	98	8,5	4,5	18
average	257	246	190	109	9,5	5,25	20,5
range	40	46	28	22	2	1,5	5

## Revised draft inverse certification corridors:

	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
upper	272	252	192	108	10	6	21
lower	233	216	167	93	8	4	17
average	252,5	234	179,5	100,5	9	5	19
range	39	36	25	15	2	2	4

## Average shift old → new:

	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
Average shift [abs]:	-4,5	-12	-10,5	-8,5	-0,5	-0,25	-1,5
Average shift [%]:	-1,75	-4,88	-5,53	-7,80	-5,26	-4,76	-7,32

Draft proposal for modification of ECE/TRANS/WP.29/GRSP/2011/13:

***8.2.3.3.1. When the Lower legform II is used for the test specified in paragraph 8.2.3.4., the maximum bending moment of the tibia at tibia-1 shall be not more than 272 Nm and not less than 233 Nm, the maximum bending moment at tibia-2 shall be not more than 252 Nm and not less than 216 Nm, the maximum bending moment at tibia-3 shall be not more than 192 Nm and not less than 167 Nm, and the maximum bending moment at tibia-4 shall be not more than 108 Nm and not less than 93 Nm.***  
***The maximum elongation of the MCL shall be not more than 21 mm and not less than 17 mm, that of the ACL shall be not more than 10 mm and not less than 8 mm, and that of the PCL shall be not more than 6 mm and not less than 4 mm [...]***



## Revision of Pendulum Certification Test

# Pendulum test results & analysis



- Up to now, three completely overhauled Flex-GTR impactors have been pendulum tested at JARI & BAST (SN01, SN03 and E-Leg)
- As a stable connection of SN01 could not be established at BAST (slack joint of the output cable inside the Slice base module), this impactor was inverse tested at JARI only

## Test result overview:

Rounded up values



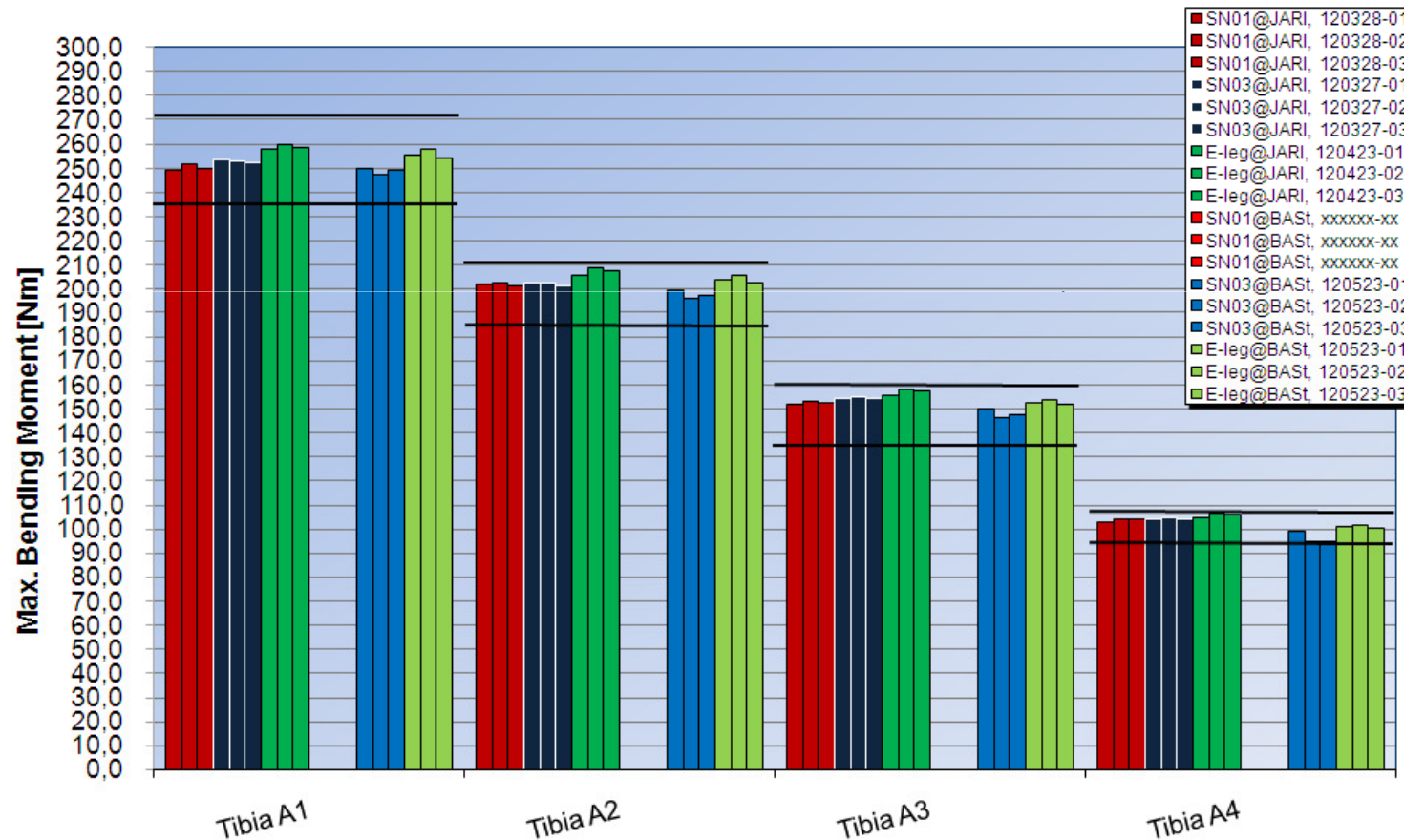
Test #	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
SN01@JARI, 120328-01	249,4	201,8	151,7	102,6	8,9	4,4	22,6
SN01@JARI, 120328-02	251,6	202,9	152,9	103,9	8,9	4,5	22,8
SN01@JARI, 120328-03	249,8	201,2	152,3	103,9	8,9	4,5	22,5
SN03@JARI, 120327-01	253,4	202,6	154,2	104,4	9,0	4,4	22,1
SN03@JARI, 120327-02	252,8	202,9	155,0	104,6	9,0	4,4	22,2
SN03@JARI, 120327-03	252,0	201,5	154,3	104,3	9,0	4,4	22,3
E-leg@JARI, 120423-01	258,0	205,6	155,6	105,0	9,2	4,6	22,4
E-leg@JARI, 120423-02	259,9	208,8	158,3	106,4	9,2	4,8	22,8
E-leg@JARI, 120423-03	258,7	207,6	157,5	106,1	9,4	4,4	22,4
SN01@BAST, xxxxxx-xx	not yet tested !						
SN01@BAST, xxxxxx-xx							
SN01@BAST, xxxxxx-xx							
SN03@BAST, 120523-01	250,0	199,4	150,1	99,2	9,7	3,8	22,1
SN03@BAST, 120523-02	247,3	195,8	146,1	94,7	9,7	3,7	22,0
SN03@BAST, 120523-03	249,1	196,8	147,5	95,0	9,7	3,7	22,1
E-leg@BAST, 120523-01	255,1	203,8	152,5	101,1	9,9	4,1	22,3
E-leg@BAST, 120523-02	257,6	206,0	153,8	101,9	9,8	4,2	22,4
E-leg@BAST, 120523-03	254,0	202,9	151,7	100,3	9,6	4,0	21,9

- All MCL and some ACL/PCL segments did not pass the current draft pendulum corridors !

# Pendulum test results & analysis



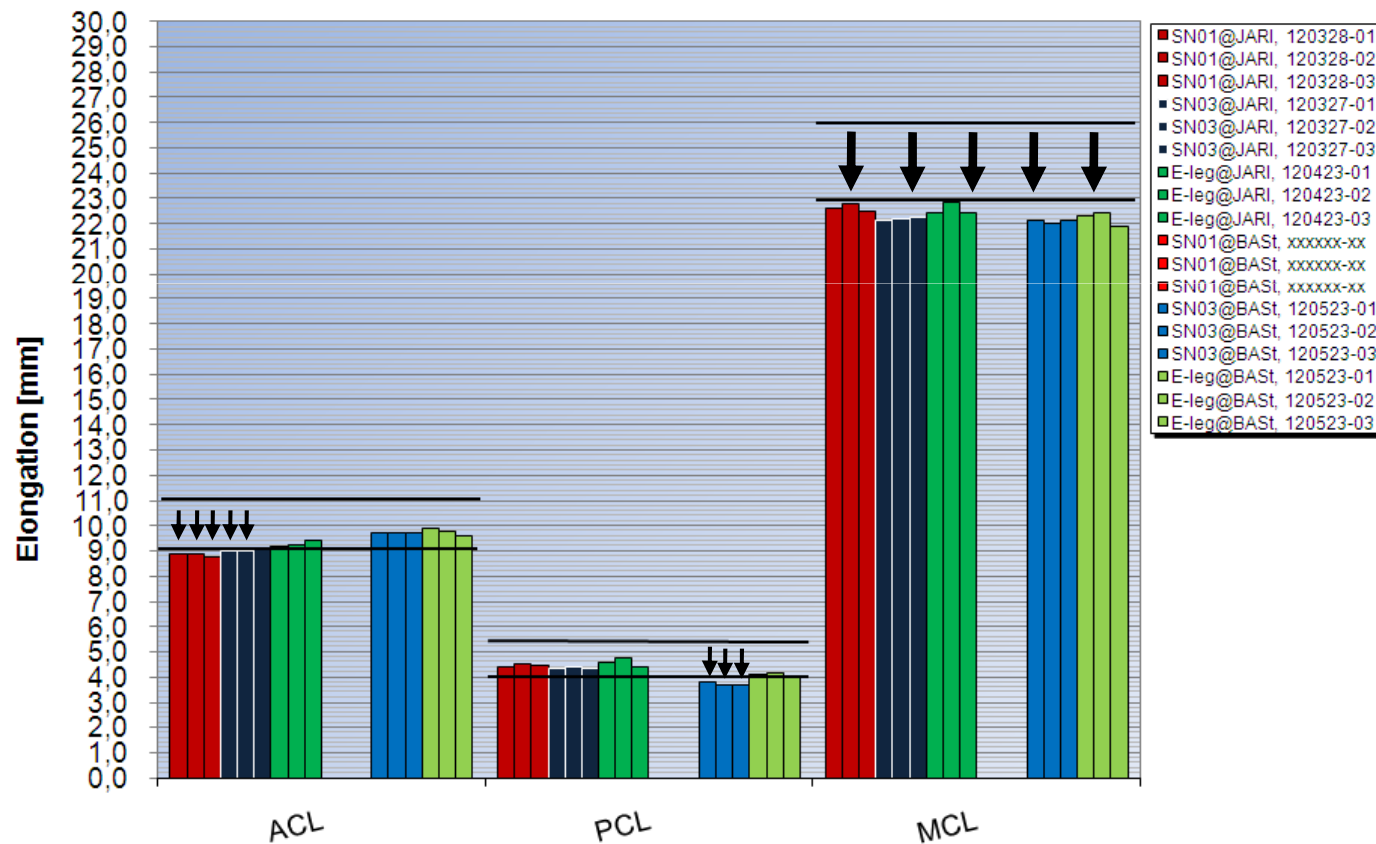
- All tibia corridors met during all tests
- Partly borderline results for tibia A4 (at the upper end of the corridors in lab #1 but at the lower end in lab #2)
- E-leg with highest tibia results in both test houses



# Pendulum test results & analysis



- All MCL corridors not met during all tests (low out)
- Partly borderline results for ACL and PCL (at the lower end of / outside the corridors)



# Revision of pendulum corridors



## Coefficients of variation:

(15 pendulum test results, thereof five setups with SN01, SN03 and E-Leg)

Segment	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
Setup 1 - SN01 - JARI	0,47	0,42	0,40	0,70	0,79	1,19	0,78
Setup 2 - SN03 - JARI	0,28	0,36	0,26	0,14	0,38	0,16	0,25
Setup 3 - E-leg - JARI	0,39	0,78	0,87	0,71	1,28	4,05	1,03
Setup 4 - SN01 - BASt							
Setup 5 - SN03 - BASt	0,55	0,94	1,37	2,61	0,00	1,55	0,26
Setup 6 - E-leg - BASt	0,72	0,78	0,69	0,79	1,56	2,44	1,19

All segments with good repeatability ( $CV < 5\%$ )

Thus, all 35 segments could be used for the definition of the reproducibility corridors

# Revision of **pendulum** corridors



## Definition of reproducibility corridor:

(Setups and segments with repeatable test results [CV < 5%]):

Segment	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
<b>Setups for Reproducibility Corridor [CV &lt; 5%]</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>
Pooled Mean with CV < 5%	253,25	202,64	152,90	102,22	9,32	4,25	22,33
Upper Limit	278,57	222,91	168,19	112,45	10,25	4,68	24,56
Lower Limit	227,92	182,38	137,61	92,00	8,39	3,83	20,09

## Determination of setups and segments with reproducible test results:

Setup / Segment	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
Setup 1 - SN01 - JARI - MAX	251,59	202,88	152,91	103,92	8,88	4,51	22,81
Setup 1 - SN01 - JARI - MIN	249,38	201,23	151,68	102,63	8,75	4,40	22,46
Setup 2 - SN03 - JARI - MAX	253,43	202,89	154,97	104,57	9,04	4,39	22,25
Setup 2 - SN03 - JARI - MIN	252,01	201,51	154,24	104,26	8,98	4,38	22,14
Setup 3 - E-leg - JARI - MAX	259,94	208,81	158,31	106,39	9,42	4,79	22,82
Setup 3 - E-leg - JARI - MIN	257,96	205,61	155,62	104,97	9,19	4,41	22,40
Setup 4 - SN01 - BASt - MAX							
Setup 4 - SN01 - BASt - MIN							
Setup 5 - SN03 - BASt - MAX	250,00	199,40	150,10	99,20	9,70	3,80	22,10
Setup 5 - SN03 - BASt - MIN	247,30	195,80	146,10	94,70	9,70	3,70	22,00
Setup 6 - E-leg - BASt - MAX	257,60	206,00	153,80	101,90	9,90	4,20	22,40
Setup 6 - E-leg - BASt - MIN	254,00	202,90	151,70	100,30	9,60	4,00	21,90
<b>Reproducible test results (Setups and segments within Reproducibility Corridor)</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/3/5/6</b>	<b>1/2/6</b>	<b>1/2/3/5/6</b>

# Revision of pendulum corridors



## Definition of certification corridor:

(Setups and segments with reproducible test results):

Setup / Segment	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
Setup 1 - SN01 - JARI - MAX	251,59	202,88	152,91	103,92	8,88	4,51	22,81
Setup 1 - SN01 - JARI - MIN	249,38	201,23	151,68	102,63	8,75	4,40	22,46
Setup 2 - SN03 - JARI - MAX	253,43	202,89	154,97	104,57	9,04	4,39	22,25
Setup 2 - SN03 - JARI - MIN	252,01	201,51	154,24	104,26	8,98	4,38	22,14
Setup 3 - E-leg - JARI - MAX	259,94	208,81	158,31	106,39	9,42		22,82
Setup 3 - E-leg - JARI - MIN	257,96	205,61	155,62	104,97	9,19		22,40
Setup 4 - SN01 - BASt - MAX							
Setup 4 - SN01 - BASt - MIN							
Setup 5 - SN03 - BASt - MAX	250,00	199,40	150,10	99,20	9,70		22,10
Setup 5 - SN03 - BASt - MIN	247,30	195,80	146,10	94,70	9,70		22,00
Setup 6 - E-leg - BASt - MAX	257,60	206,00	153,80	101,90	9,90	4,20	22,40
Setup 6 - E-leg - BASt - MIN	254,00	202,90	151,70	100,30	9,60	4,00	21,90
Maximum	259,94	208,81	158,31	106,39	9,90	4,51	22,82
Minimum	247,30	195,80	146,10	94,70	8,75	4,00	21,90
Max * 1,05 (Consideration of scatter)	272,94	219,25	166,22	111,71	10,40	4,73	23,96
Min * 0,95 (Consideration of scatter)	234,94	186,01	138,80	89,97	8,31	3,80	20,81
Certification Corridor Upper Limit	272	219	166	111	10,5	5	24
Certification Corridor Lower Limit	235	187	139	90	8	3,5	20,5

Calculated tibia values have been rounded in a way such that the corridors are kept tight.

For feasibility reasons, the ligament corridors have been widened slightly.

# Revision of pendulum corridors



Verification of certification corridors (Application to 15 Flex-GTR tests):

Test #	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
SN01@JARI, 120328-01	249.4	201.8	151.7	102.6	8.9	4.4	22.6
SN01@JARI, 120328-02	251.6	202.9	152.9	103.9	8.9	4.5	22.8
SN01@JARI, 120328-03	249.8	201.2	152.3	103.9	8.8	4.5	22.5
SN03@JARI, 120327-01	253.4	202.6	154.2	104.4	9.0	4.4	22.1
SN03@JARI, 120327-02	252.8	202.9	155.0	104.6	9.0	4.4	22.2
SN03@JARI, 120327-03	252.0	201.5	154.3	104.3	9.0	4.4	22.3
E-leg@JARI, 120423-01	258.0	205.6	155.6	105.0	9.2	4.6	22.4
E-leg@JARI, 120423-02	259.9	208.8	158.3	106.4	9.2	4.8	22.8
E-leg@JARI, 120423-03	258.7	207.6	157.5	106.1	9.4	4.4	22.4
SN01@BAsT, xxxxxx-xx							
SN01@BAsT, xxxxxx-xx							
SN01@BAsT, xxxxxx-xx							
SN03@BAsT, 120523-01	250.0	199.4	150.1	99.2	9.7	3.8	22.1
SN03@BAsT, 120523-02	247.3	195.8	146.1	94.7	9.7	3.7	22.0
SN03@BAsT, 120523-03	249.1	196.8	147.5	95.0	9.7	3.7	22.1
E-leg@BAsT, 120523-01	255.1	203.8	152.5	101.1	9.9	4.1	22.3
E-leg@BAsT, 120523-02	257.6	206.0	153.8	101.9	9.8	4.2	22.4
E-leg@BAsT, 120523-03	254.0	202.9	151.7	100.3	9.6	4.0	21.9

- All certification tests passed the complete set of defined draft pendulum criteria

100 % passed

0 % failed

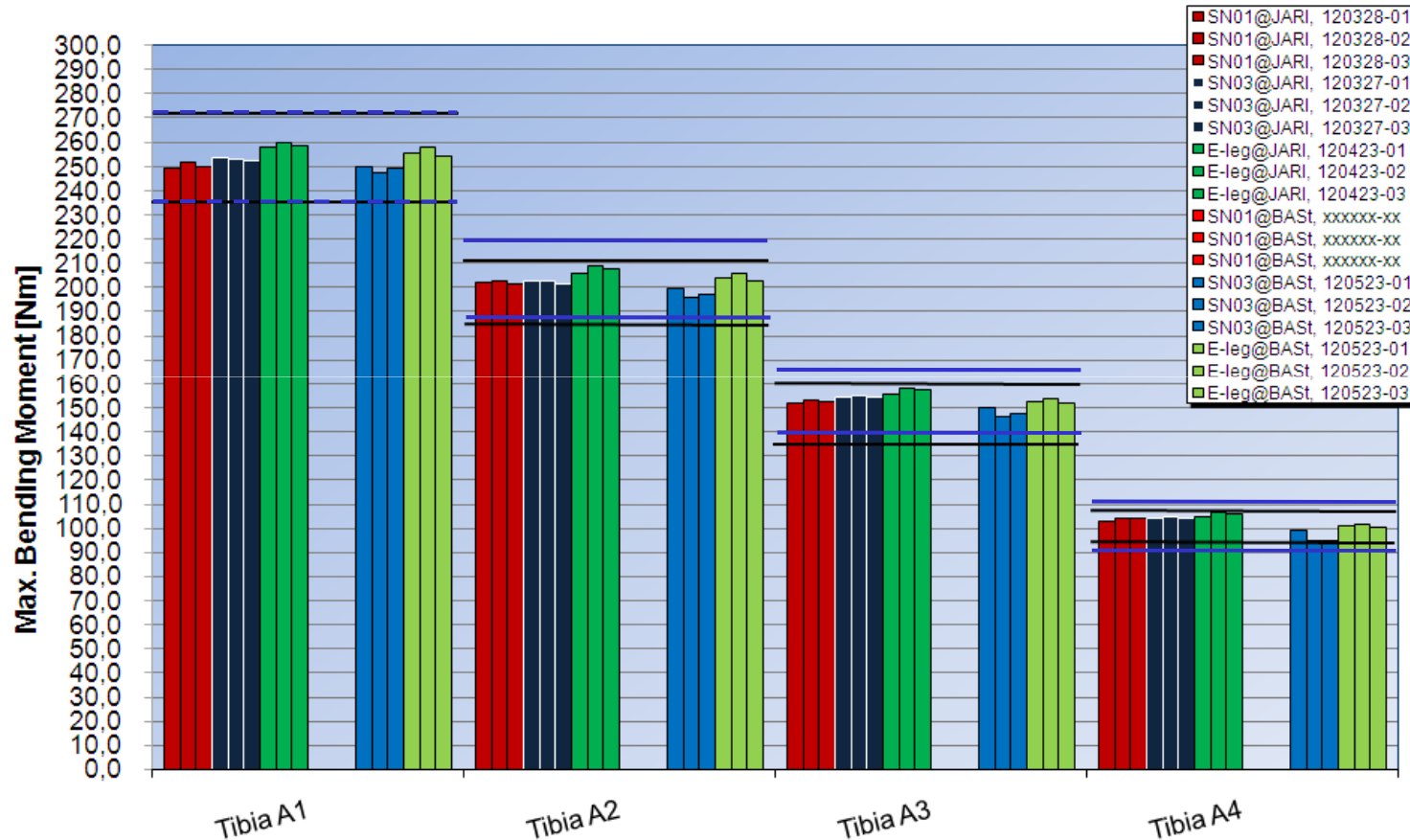
Upper Limit	272	219	166	111	10,5	5	24
Lower Limit	235	187	139	90	8	3,5	20,5



# Revision of **pendulum** corridors



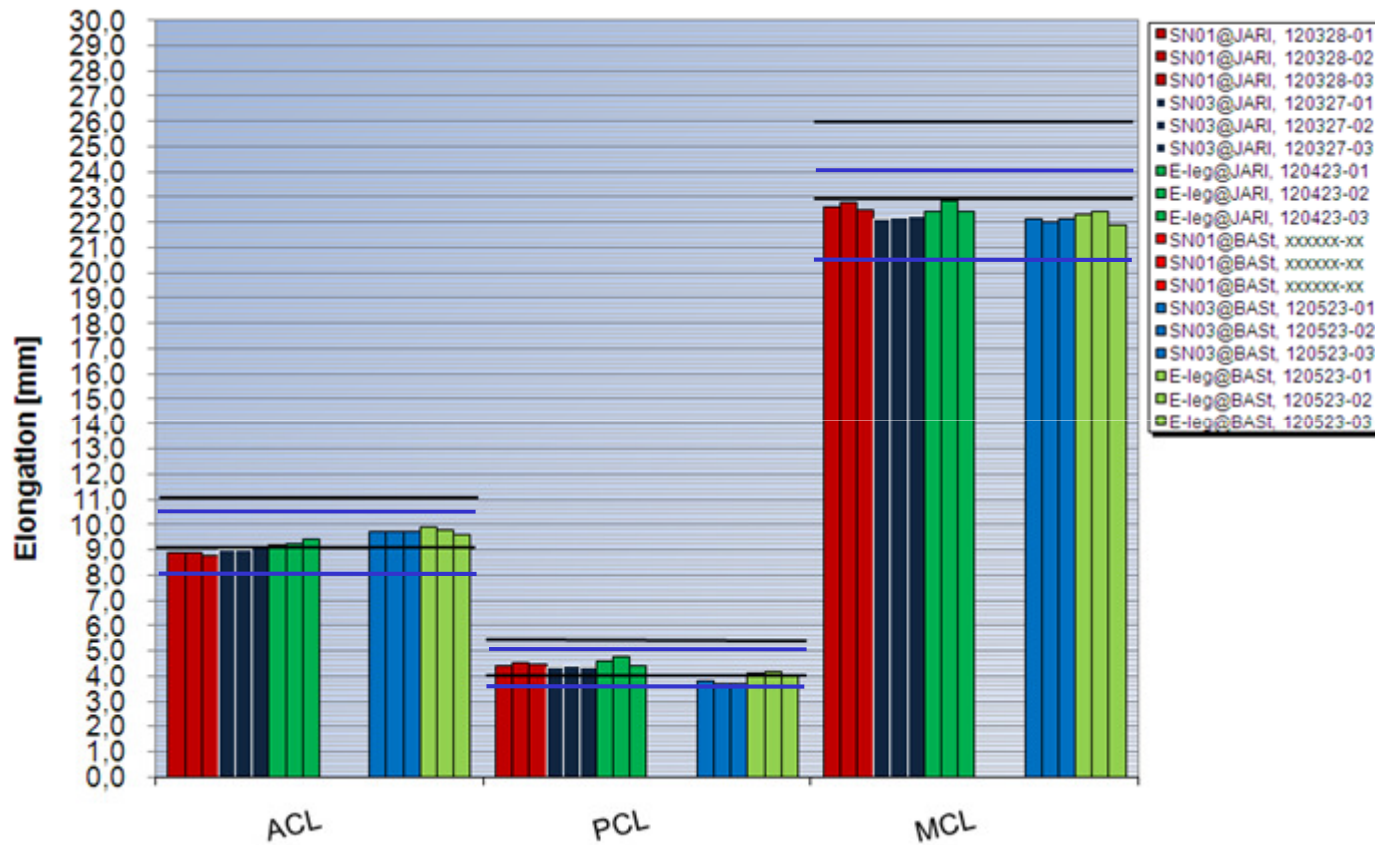
Verification of certification corridors (Application to 15 Flex-GTR tests):



# Revision of pendulum corridors



Verification of certification corridors (Application to 15 Flex-GTR tests):



# Comparison of pendulum corridors



## Old draft pendulum certification corridors:

	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
upper	272	211	160	108	11	5,4	26
lower	235	185	135	94	9	4	23
average	253,5	198	147,5	101	10	4,7	24,5
range	37	26	25	14	2	1,4	3

## Revised draft pendulum certification corridors:

	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
upper	272	219	166	111	10,5	5	24
lower	235	187	139	90	8	3,5	20,5
average	253,5	203	152,5	100,5	9,25	4,25	22,25
range	37	32	27	21	2,5	1,5	3,5

## Average shift old → new:

	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
Average shift [abs]:	0	5	5	-0,5	-0,75	-0,45	-2,25
Average shift [%]:	0,00	2,53	3,39	-0,50	-7,50	-9,57	-9,18

Draft proposal for modification of ECE/TRANS/WP.29/GRSP/2011/13:

**8.2.2.3.1** *When the Lower legform II is used for a test as specified in paragraph 8.2.2.4., the maximum bending moment of the tibia at tibia-1 shall be not more than 272 Nm and not less than 235 Nm, the maximum bending moment at tibia-2 shall be not more than 219 Nm and not less than 187 Nm, the maximum bending moment at tibia-3 shall be not more than 166 Nm and not less than 139 Nm, and the maximum bending moment at tibia-4 shall be not more than 111 Nm and not less than 90 Nm. The maximum elongation of MCL shall be not more than 24 mm and not less than 20.5 mm, the maximum elongation of ACL shall be not more than 10.5 mm and not less than 8.0 mm, and the maximum elongation of PCL shall be not more than 5 mm and not less than 3.5 mm [...]*

- **The inverse and pendulum certification corridors have been revised, taking into account all available and provided test data (up to now 2\*15 tests in total, using three impactors)**
- **As a method to updating the corridors, the established method as agreed by TEG was used**
- **An equal weighting (i.e. the same number of test results) of the impactors taken into account is not really necessary, because the corridors are based on the achieved minimum and maximum values**
- **Based on the available test data, the revised draft inverse corridors have been further tightened (exception: ACL/PCL)**
- **Based on the available test data, the revised draft pendulum corridors had to be partly widened (exception: tibia A1)**
- **Based on the available tests, the inverse mid corridor for all segments was shifted downwards (between 1,75 and 7,8 percent)**
- **Based on the available tests, the pendulum mid corridor for all ligaments was shifted downwards (between 7,5 and 9,5 percent), for two tibia segments upwards (2,5 and 3,4 percent), for two tibia segments almost unchanged**
- **Tests with SN01 @ BAST and all tests @ Betrandt for completion of assembly certification corridors outstanding**

Thank you !

Bundesanstalt für Straßenwesen

(Federal Highway Research Institute)