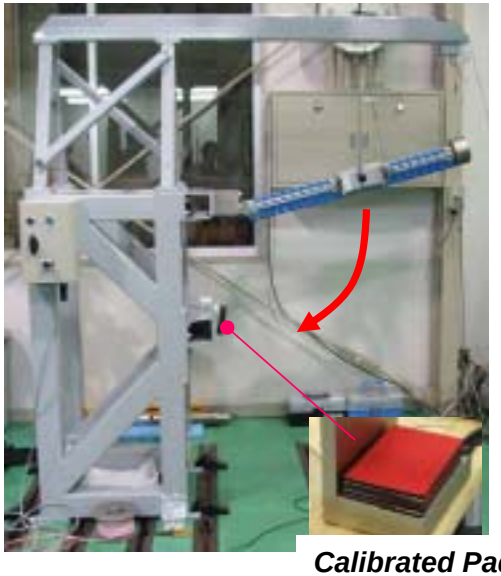
JAMA-JARI Study for the Inverse Test

Back Grounds

- Up to now, two different calibration test methods for Flex-PLI were proposed.
- One is Pendulum Test Method, and the other is Inverse Test Method.
- BASt/BGS strongly supported the Inverse Test Method, because 1) it can detect additional mass effect very well and 2) its loading speed to the impactor is comparable with that of during a car test.
- However, non of the other organizations had any experiences to conduct the inverses test, so it is difficult to judge the inverse test method is better than the pendulum test without conducting any inverse tests.
- JAMA-JARI therefore conducted the Inverse Tests by themselves at JARI.

Pendulum Test

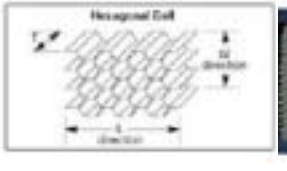


Calibrated Pad

Inverse Test

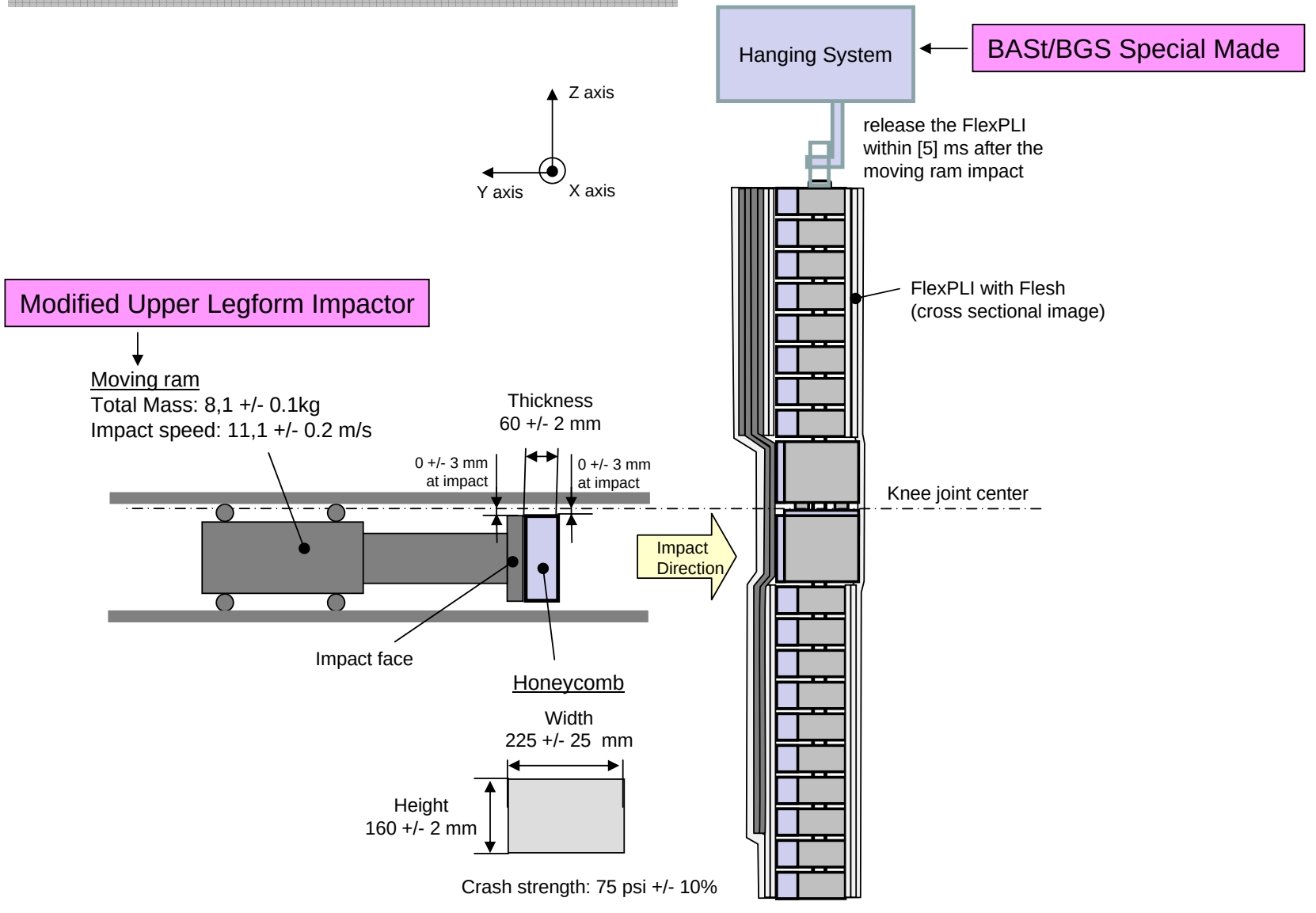
Flex-GT inverse testing

Honeycomb



Materials and Methodology

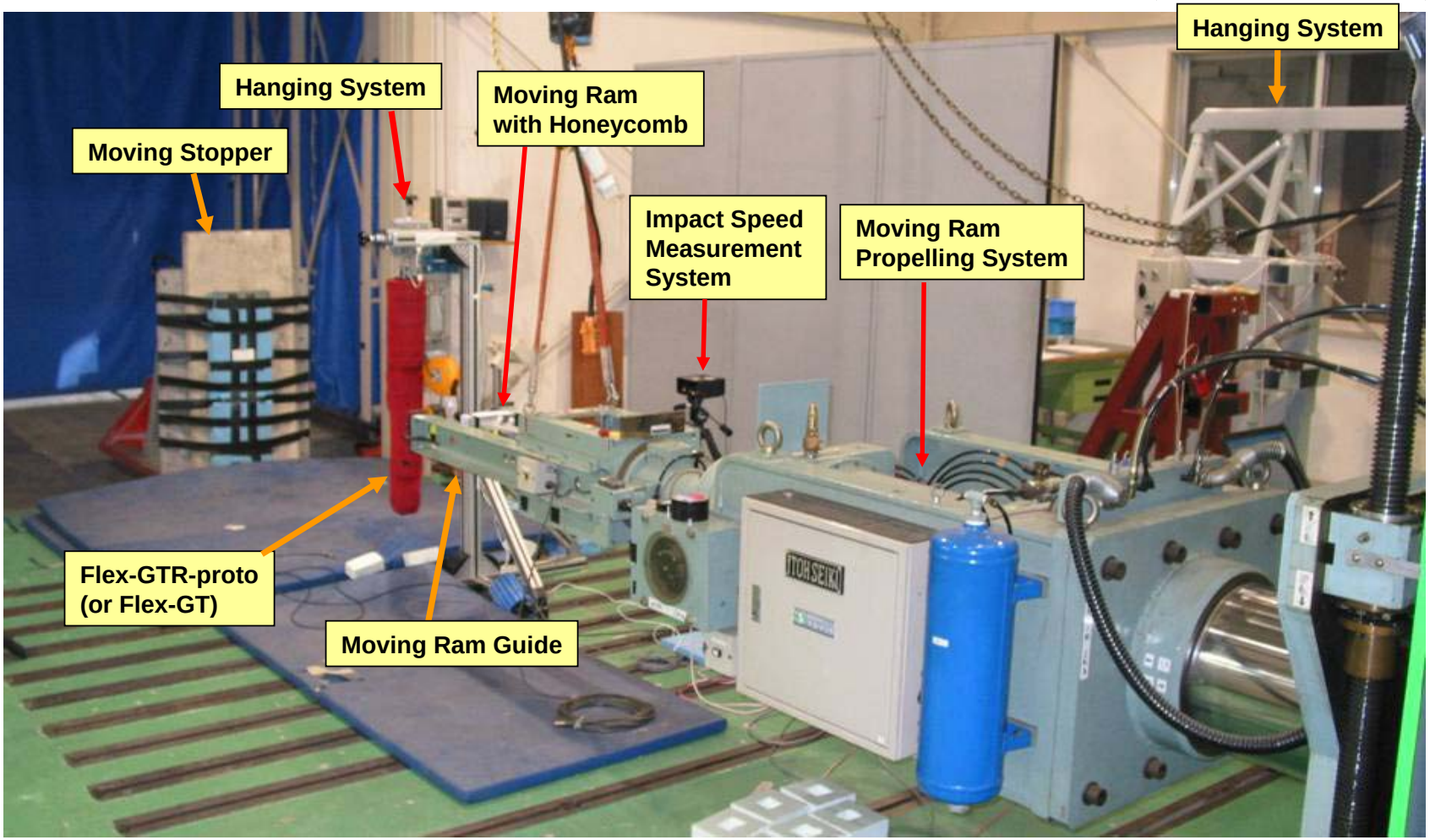
Inverse Test
Schematic Diagram of the Test Conditions



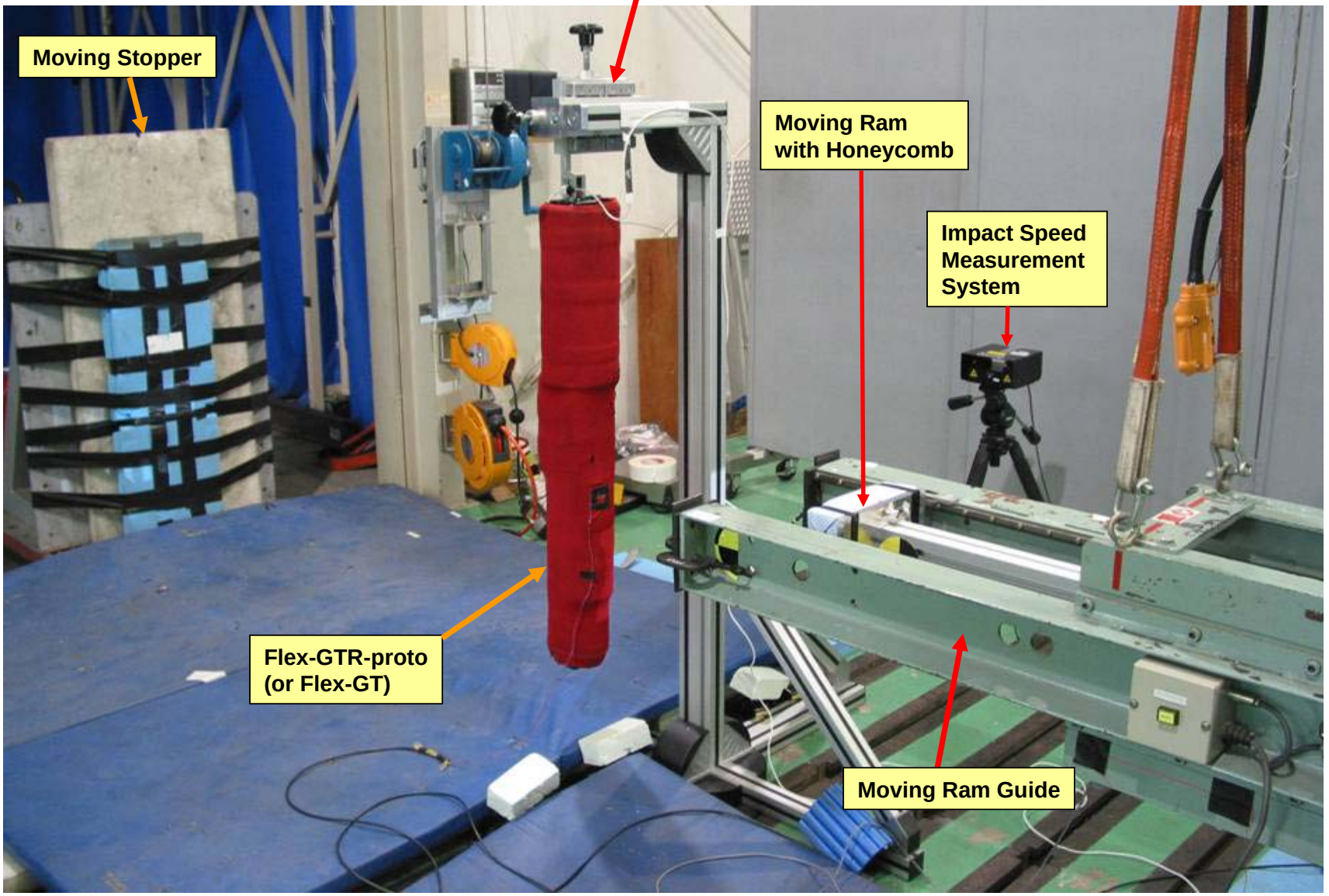
Comparison of the Test Equipments
Inverse Test and Pendulum Test

Inverse Test Equipments

Pendulum Test Equipment

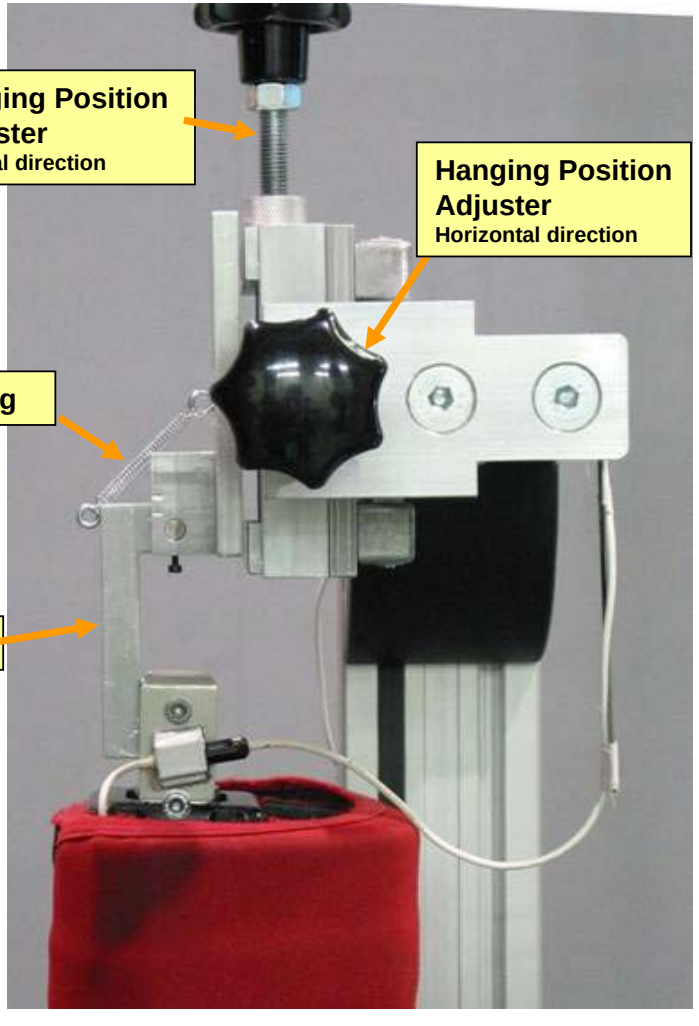


Test Equipments
Inverse Test: Overall

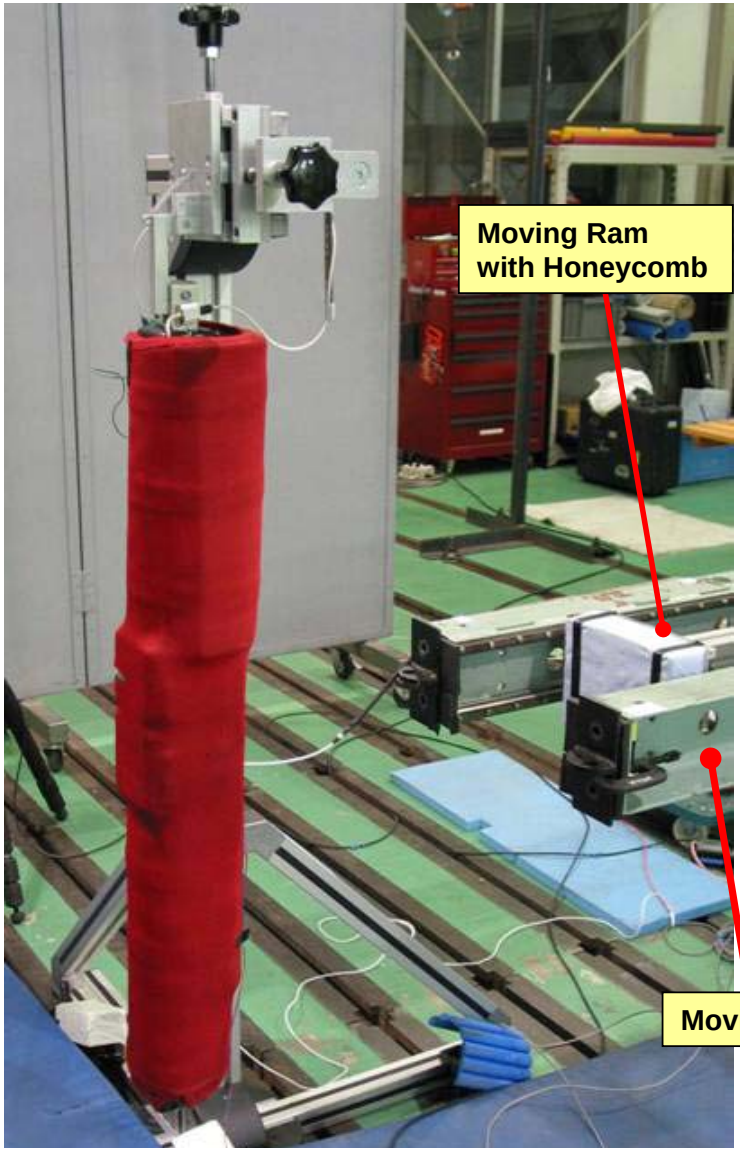


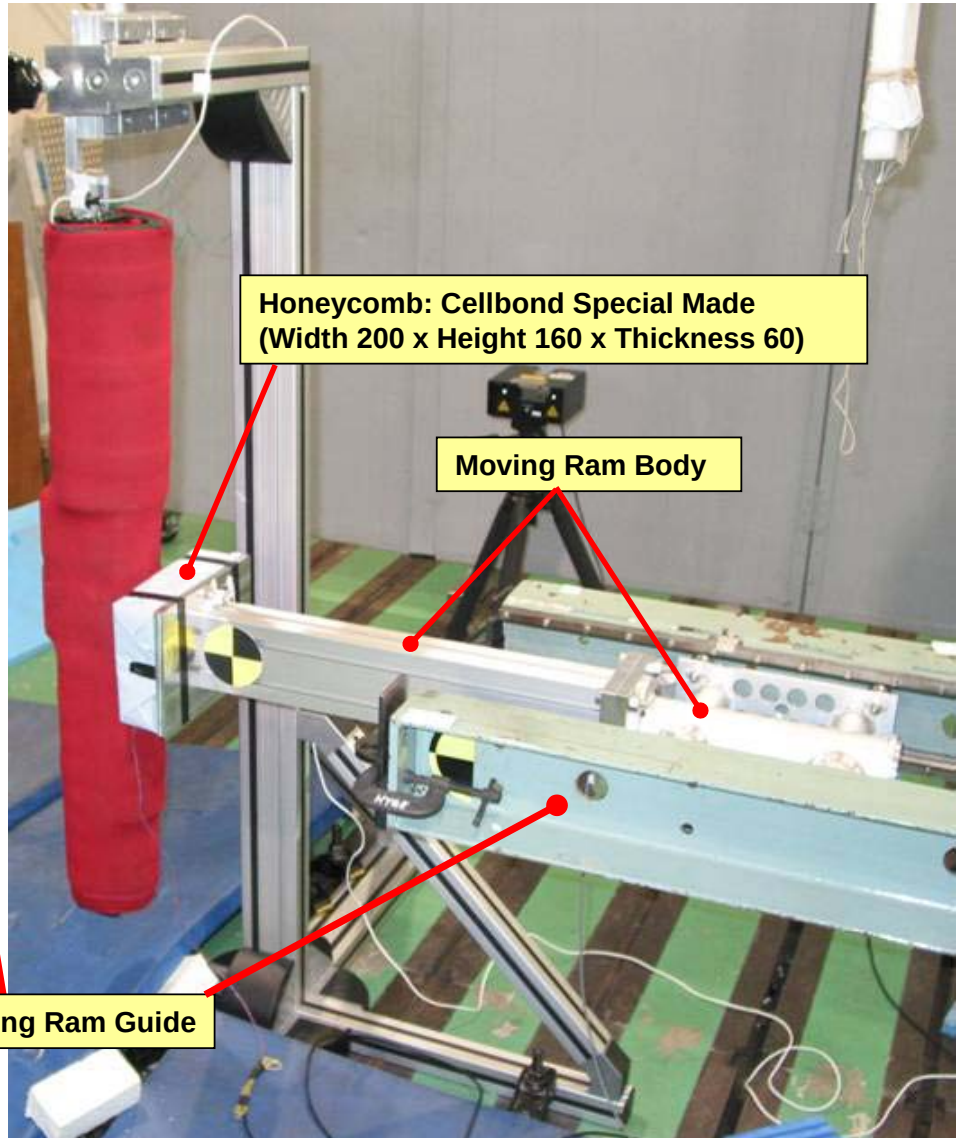
Test Equipments
Inverse Test: Hanging System

Hanging System



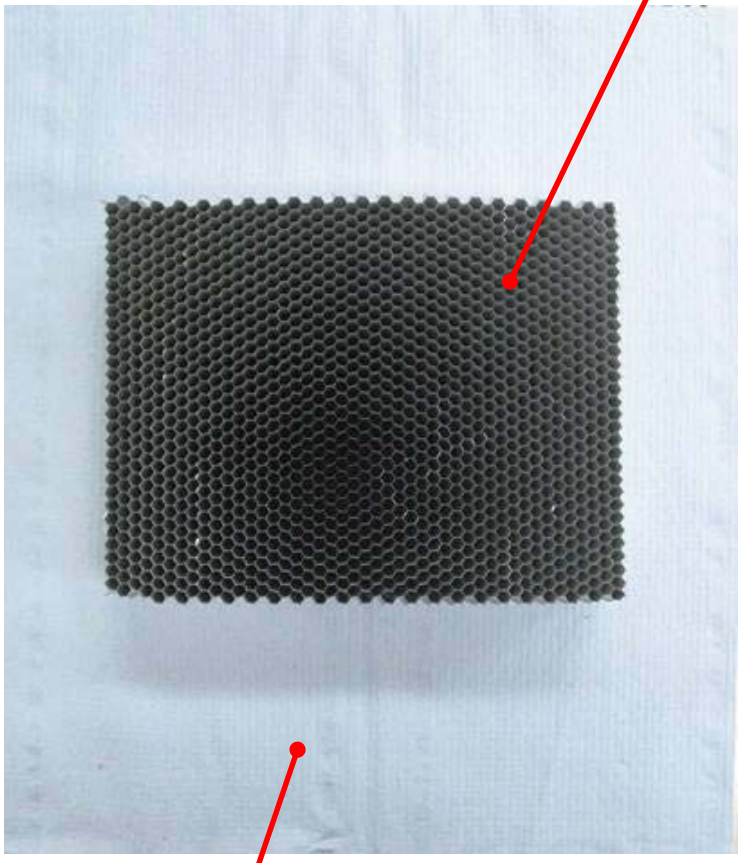
Test Equipments
Inverse Test: Moving Ram with Honeycomb





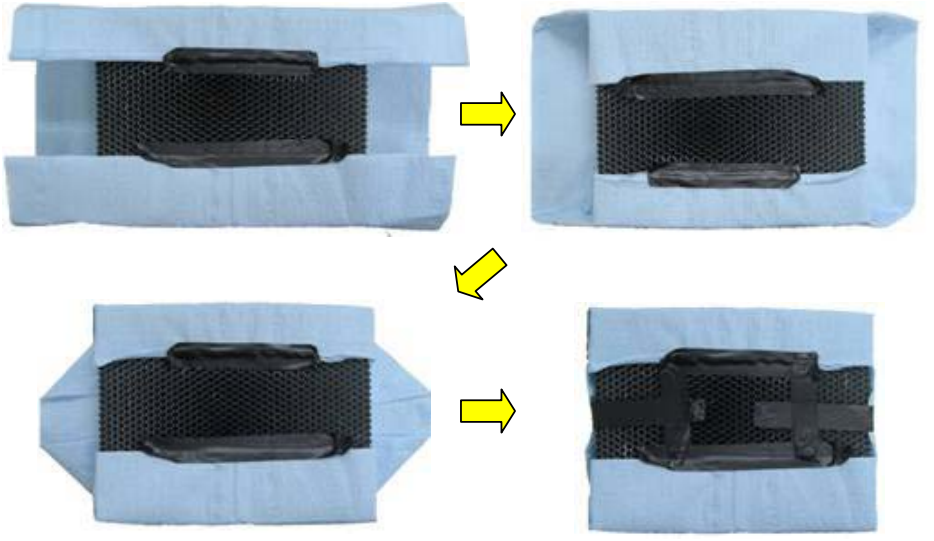
Test Equipments
Inverse Test: Honeycomb

Honeycomb: Cellbond Special Made
(Width 200 x Height 160 x Thickness 60)



Blue Paper Sheet to Cover the Honeycomb

How to hold the blue paper

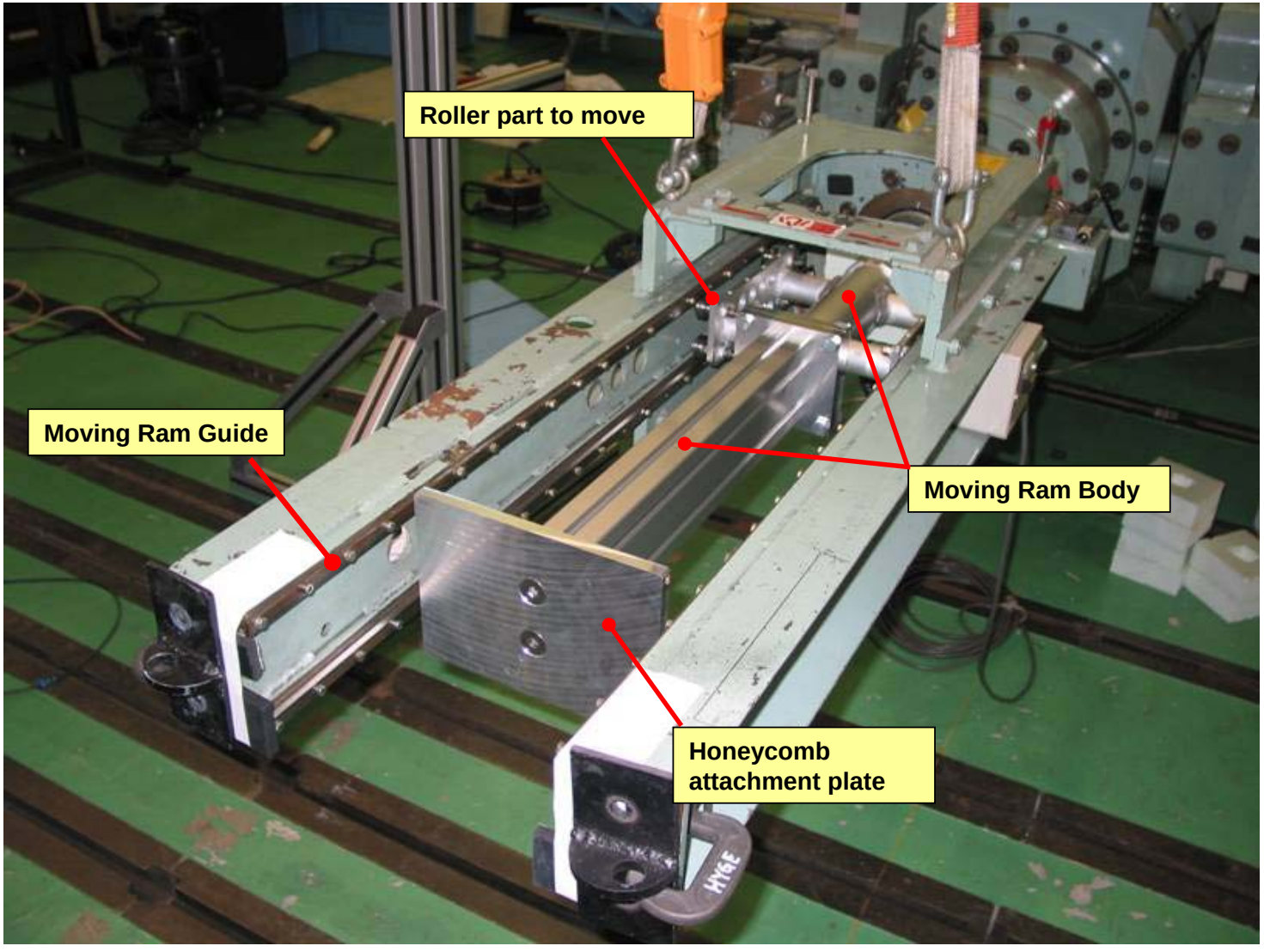


Outlook

Back side

Front/Impact side

Test Equipments
Inverse Test: Moving Ram Body and Guide System

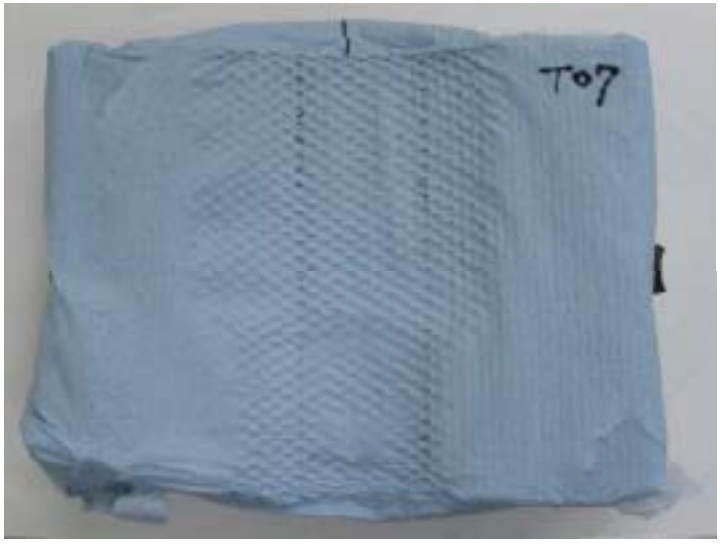


Test Equipments
Inverse Test: Honeycomb Deformation

After the Inverse Test example

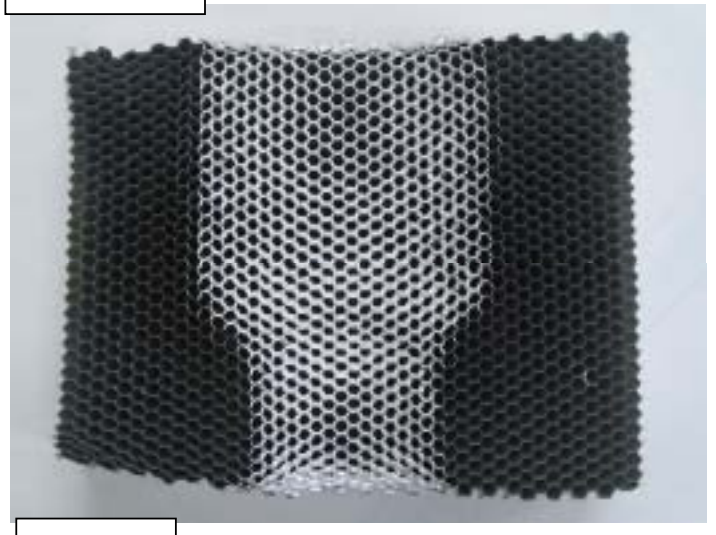
With blue paper sheet

Frontal view



Without blue paper sheet

Frontal view



Top view

Top-Frontal view

Inverse Test
Test Conditions

Test ID	Flex-PLI			Impact Speed		Temperature	Relative Humidity
	type	SN	Modification	(m/s)	(km/h)	(degrees C)	(%)
T-01	Flex-GT	11	None	No data	No data	20.3	48
T-02	Flex-GT	11	None	11.11	39.98	20.8	47
T-03	Flex-GTR-proto	3	None	11.23	40.41	21.6	35
T-04	Flex-GTR-proto	3	None	11.10	39.96	22.2	34
T-05	Flex-GTR-proto	3	None	11.01	39.62	22.2	33
T-06	Flex-GTR-proto	3	Add Mass	11.16	40.18	21.5	26
T-07	Flex-GTR-proto	3	Add Mass	11.04	39.75	21.9	26
T-08	Flex-GTR-proto	3	Add Mass	11.01	39.64	21.4	29
T-09	Flex-GTR-proto	3	None	10.93	39.34	21.5	28
T-10	Flex-GTR-proto	3	None	No data	No data	21.2	28
T-11	Flex-GTR-proto	3	None	10.77	38.78	20.7	29
T-12	Flex-GTR-proto	3	None	11.17	40.21	20.6	30
T-13	Flex-GTR-proto	3	None	11.21	40.35	20.7	31
T-14	Flex-GTR-proto	3	None	11.09	39.91	20.5	34
T-15	Flex-GTR-proto	3	None	11.20	40.31	20.5	35
T-16	Flex-GTR-proto	3	None	11.18	40.25	18.9	41
T-17	Flex-GTR-proto	3	None	11.30	40.67	20.2	34
T-18	Flex-GTR-proto	3	None	11.25	40.5	21.5	29

* SN: Serial Number, Add Mass: Added 100g mass at the top and botom of the impactor

Pendulum Test
Test Conditions

Test ID	Flex-PLI			Temperature	Relative Humidity
	type	SN	Modification	(degrees C)	(%)
PT-01	Flex-GTR-proto	3	None	No data	No data
PT-02	Flex-GTR-proto	3	None	No data	No data
PT-03	Flex-GTR-proto	3	None	No data	No data
PT-04	Flex-GTR-proto	3	None	21.6	35
PT-05	Flex-GTR-proto	3	None	22.2	34
PT-06	Flex-GTR-proto	3	None	22.2	33
PT-07	Flex-GTR-proto	3	Add Mass	21.5	26
PT-08	Flex-GTR-proto	3	Add Mass	21.9	26
PT-09	Flex-GTR-proto	3	Add Mass	21.4	29
PT-10	Flex-GTR-proto	3	None	21.5	28
PT-11	Flex-GTR-proto	3	None	21.2	28
PT-12	Flex-GTR-proto	3	None	20.7	29
PT-13	Flex-GTR-proto	3	None	20.6	30
PT-14	Flex-GTR-proto	3	None	20.7	31
PT-15	Flex-GTR-proto	3	None	20.5	34
PT-16	Flex-GTR-proto	3	None	18.9	41
PT-17	Flex-GTR-proto	3	None	18.9	41
PT-18	Flex-GTR-proto	3	None	20.2	34
PT-19	Flex-GTR-proto	3	None	21.5	29

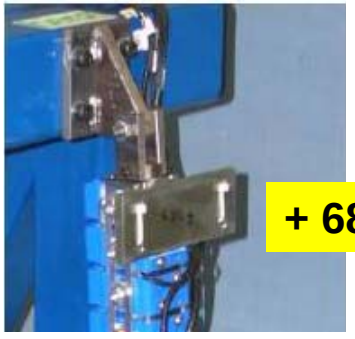
* SN: Serial Number, Add Mass: Added 100g mass at the top and botom of the impactor

Flex-GTR-prototype (SN03)
Additional Mass

Additional Mass in this study
+ 100 g for femur top
+ 100 g for tibia bottom

Current gtr 9 tolerance:
Femur Mass Tolerance
+/- 100g
Tibia Mass Tolerance
+/- 100g

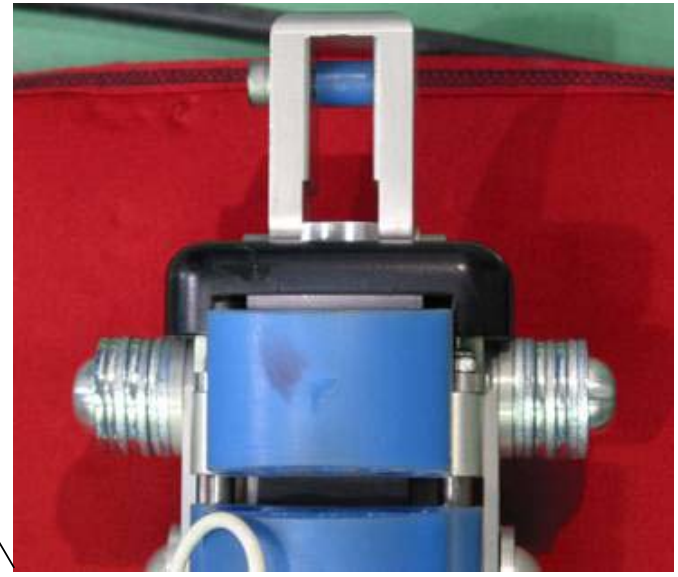
BASt/BGS Add Mass
+ 680g for femur top
+ 680 g for tibia bottom



+ 680 g

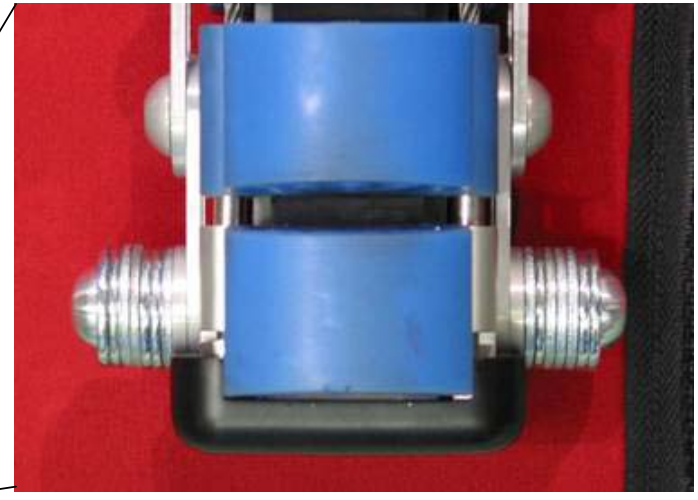
+ 680 g

Can not be allowed to attach the 680 g masses



+ 100 g (Femur Top)

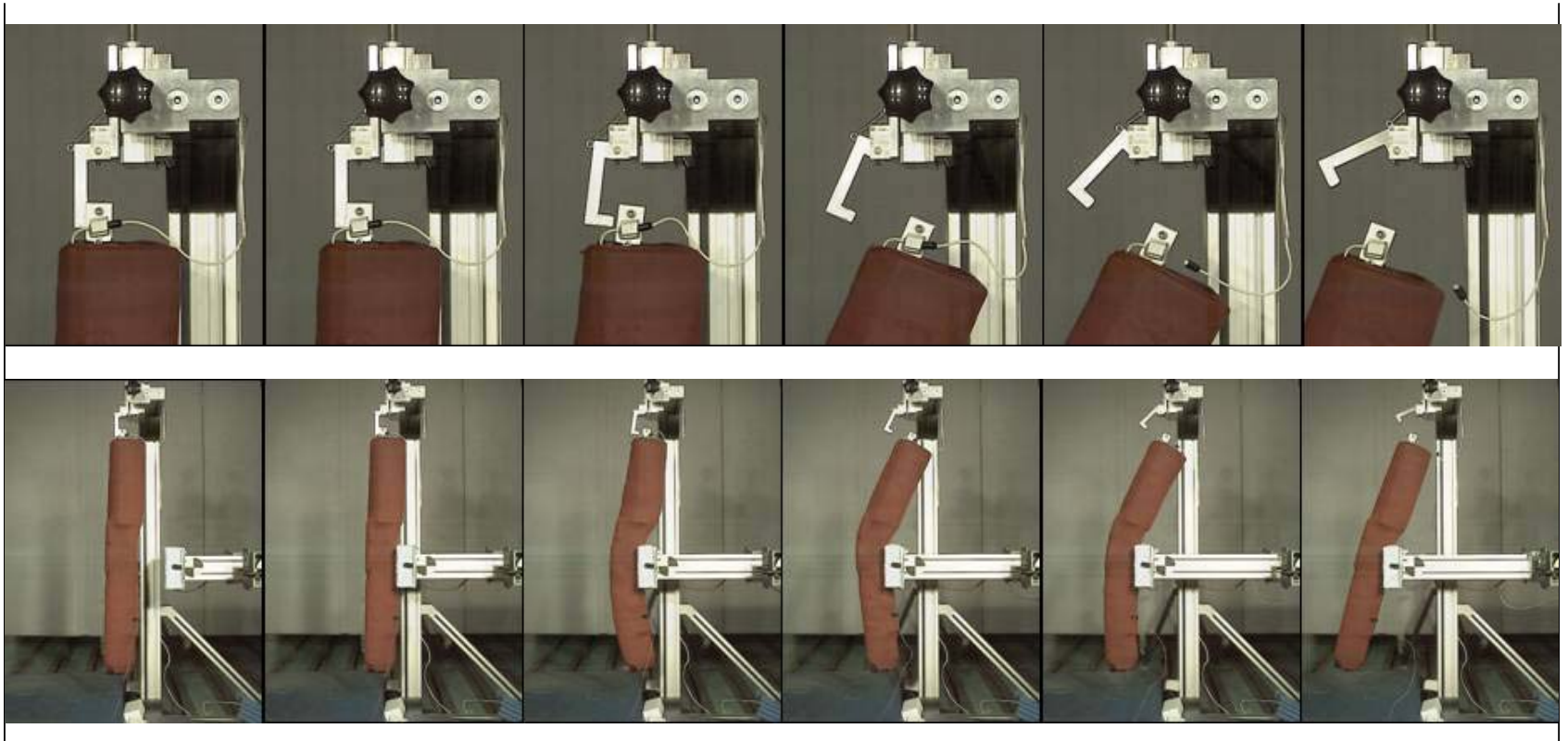
+100 g (Tibia Bottom)



Results

Inverse Test Results
Kinematics (example)

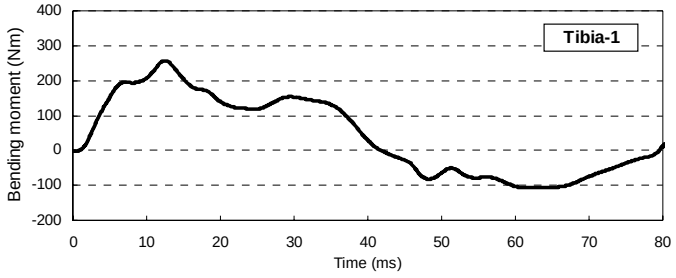
- The hanging part was released immediately after the impact.

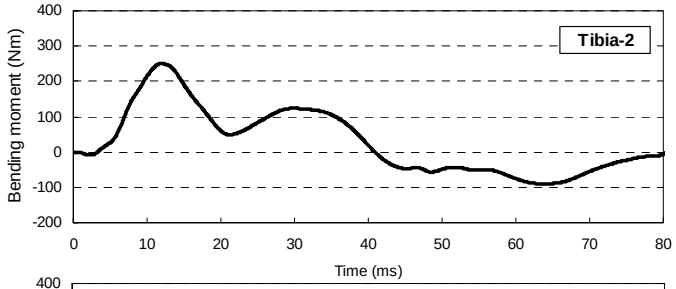


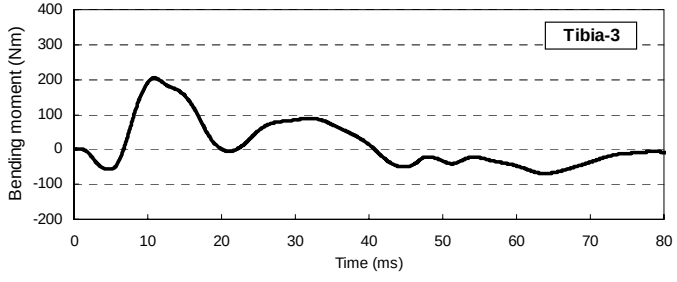
- 10 ms | 0 ms | 10 ms | 20 ms | 30 ms | 40 ms

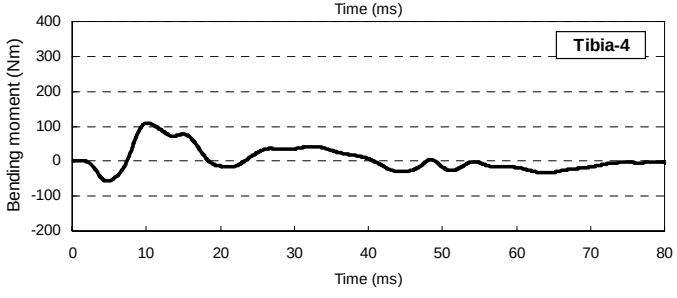
Inverse Test Results
Waveforms (example)

- Tibia-1
- Tibia-2
- Tibia-3
- Tibia-4

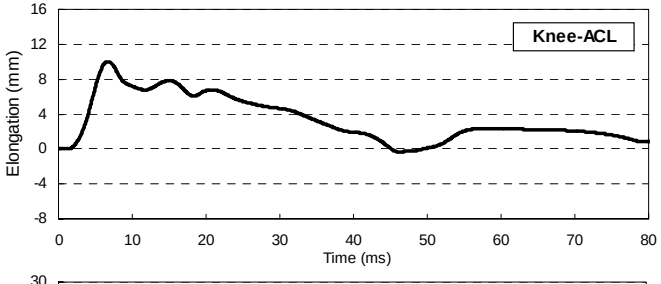


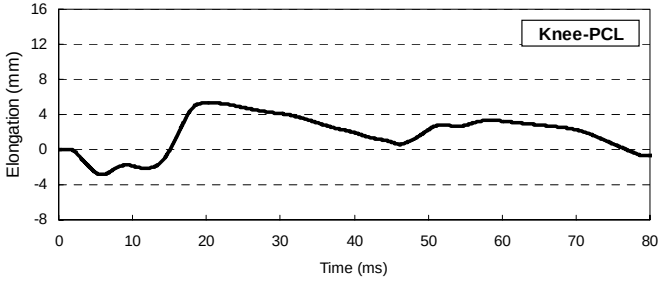


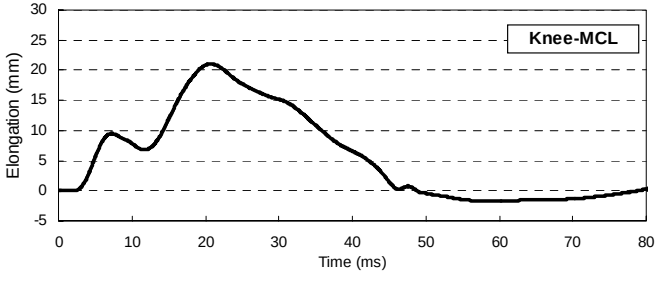




- Knee-ACL
- Knee-PCL
- Knee-MCL

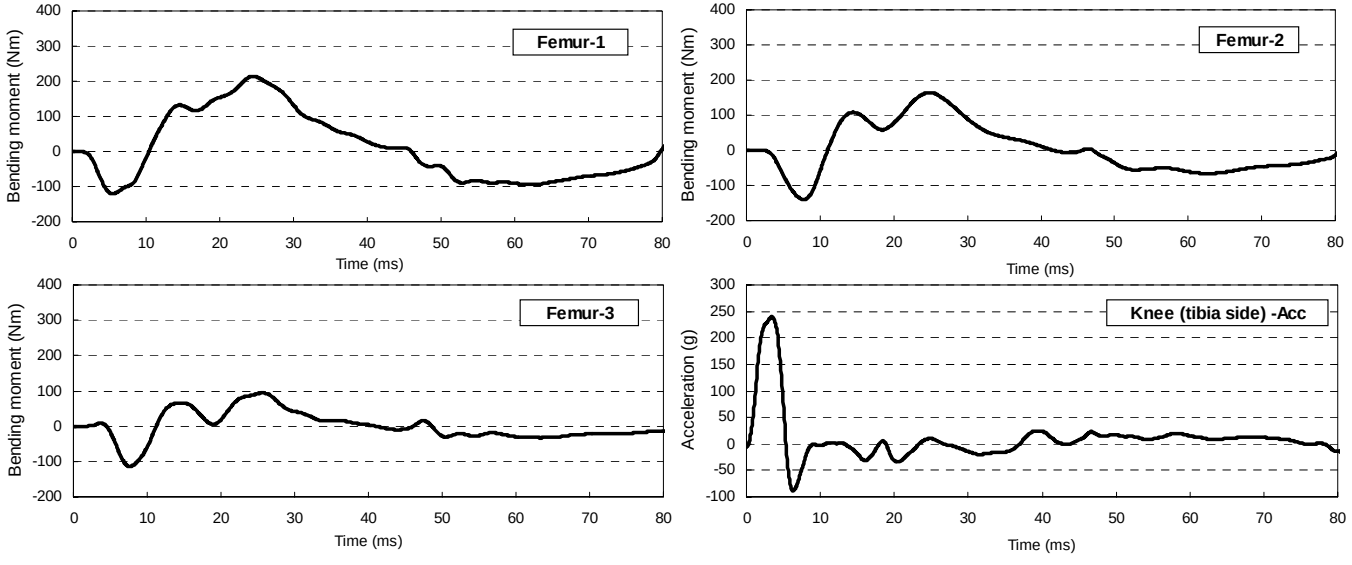






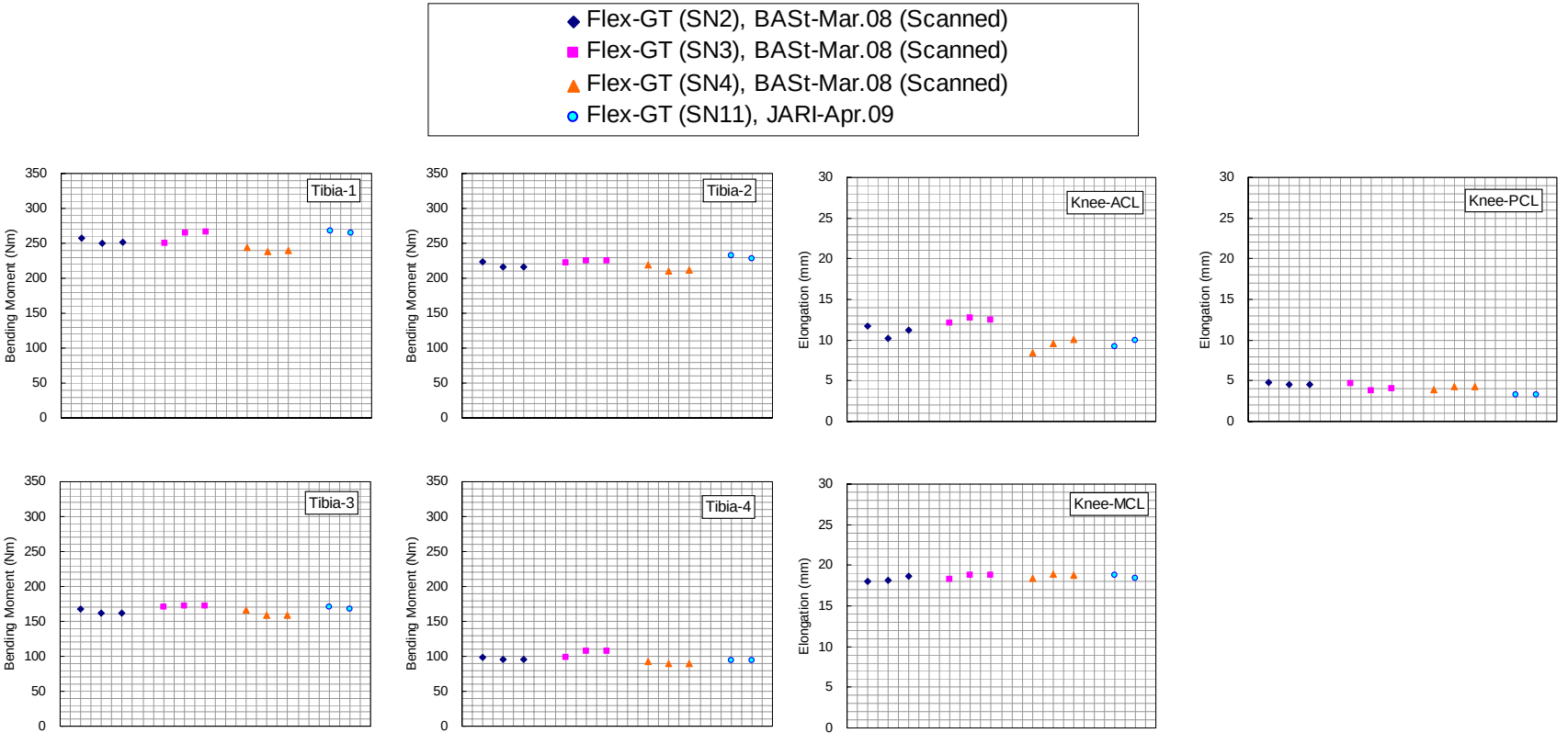
Inverse Test Results
Waveforms (example)

- Femur-1
- Femur-2
- Femur-3
- Knee (tibia side) -Acc



Inverse Test Results
Comparability with BASt Test Results (Flex-GT)

- Based on the Flex-GT test results, BASt and JARI test results were looked as comparable.

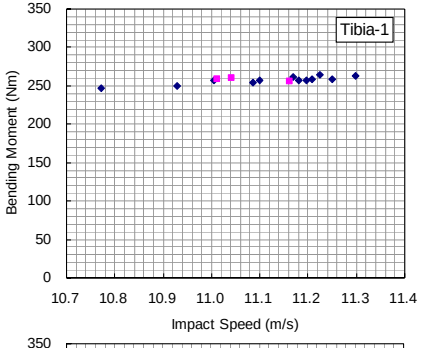


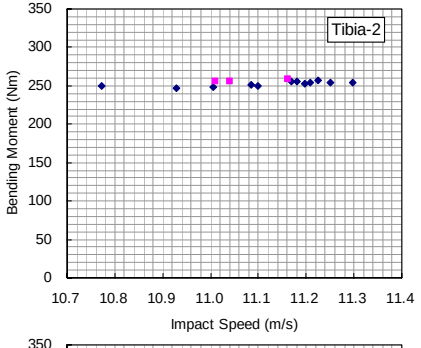
Inverse Test Results
Additional Mass Effect

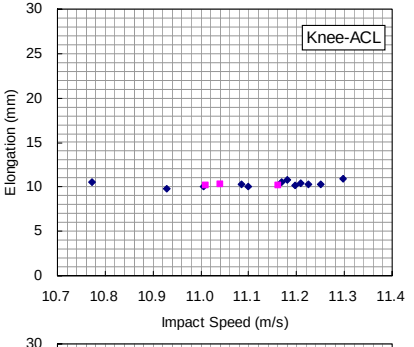
- Additional mass (+ 100 g for femur top and tibia bottom) effect was insignificant in the Inverse Test.

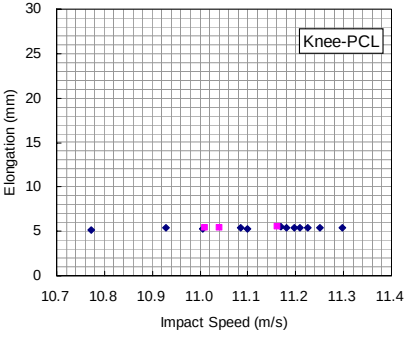
◆ Flex-GTR-proto (SN03), JARI-Apr.09

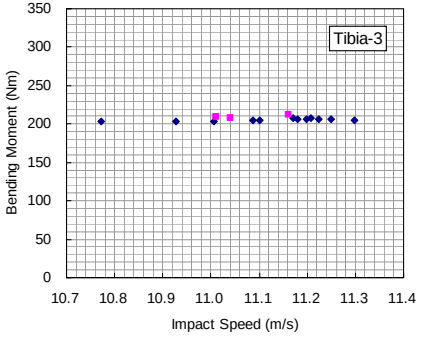
■ Flex-GTR-proto (SN03)-Add Mass, JARI-Apr.09

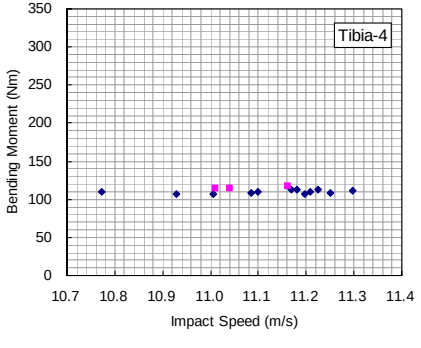


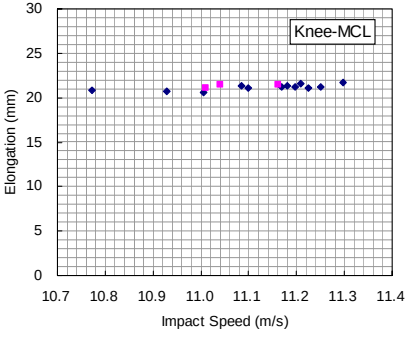






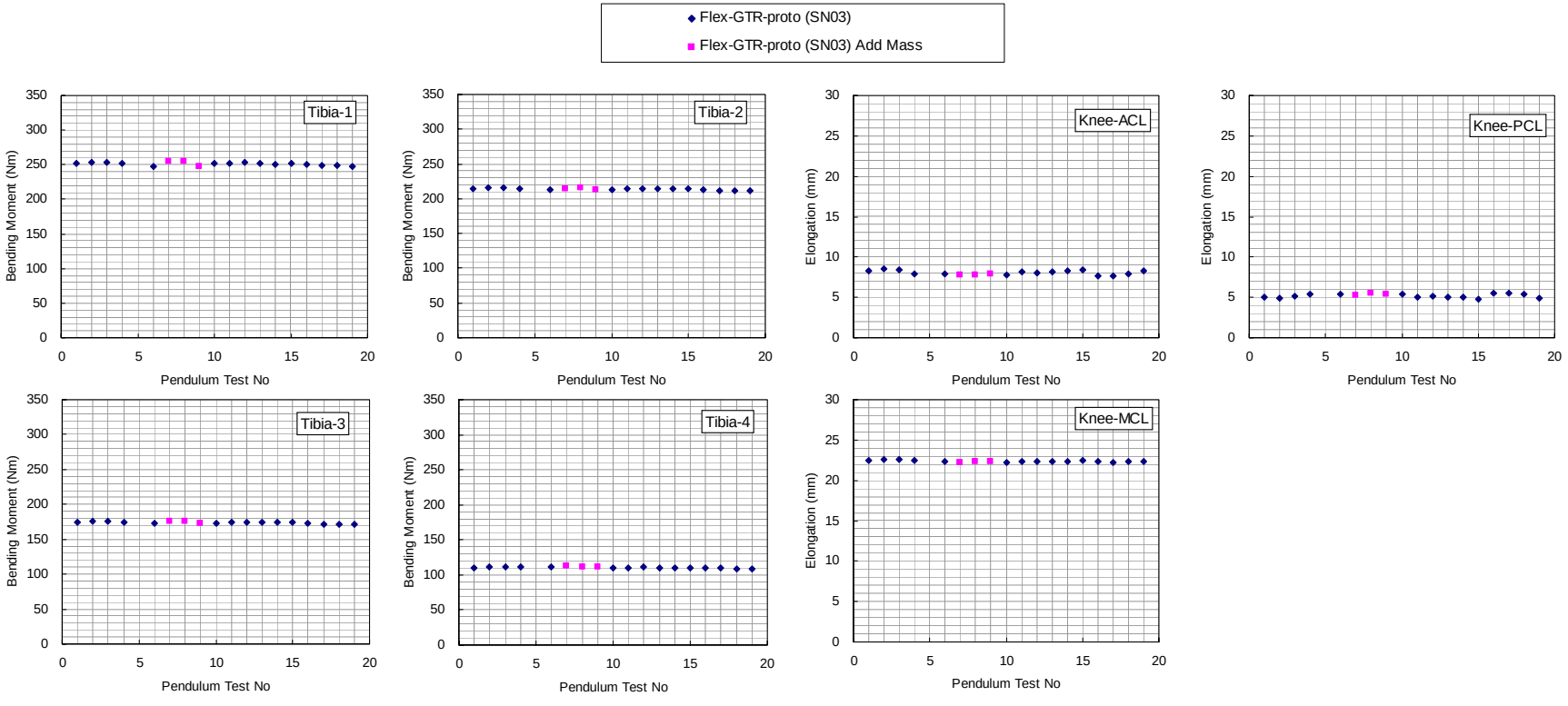






Pendulum Test Results
Additional Mass Effect

- Additional mass (+ 100 g for femur top and tibia bottom) effect was also insignificant in the pendulum test.



Discussions

- JAMA-JARI conducted the Inverse Tests at JARI in order to investigate its detail.
- Efforts to conduct single certification test:
  - ✓ Almost one day is needed to conduct the inverse test.
  - ✓ Especially, preparation of a lot of test equipments were took much time.
  - ✓ Expensive and Non-Reusable Special Honeycomb was required.
- Impact Condition:
  - ✓Hard impact, around 250 g (CFC180) was observed at Knee joint level during the Inverse Test, compare to that of the pendulum test (around 80 g).
  - ✓The Impactor was impacted to the stopper wall under a severe impact condition, therefore, it has a chance to be damage the impactor and/or measurement cables during the Inverse Test.
  - ✓Moving Ram has to be stopped suddenly from the 11.1 m/s impact speed condition, therefore, it has a chance to be damaged the Moving Ram under the sudden stop condition.
- Additional Mass Effect:
  - ✓Additional 100 g masses, at the top of Femur and at the bottom of Tibia, effect were insignificant in the Inverse Test.
  - ✓Basically, to add 680 g masses, at the top of Femur and bottom of Tibia are not allowed by the gtr 9 mass tolerances (Flex-PLI can be used same tolerances).
  - ✓Additional mass and/or inertia influences can be controlled by tolerances for the Mass, CoG and Moment of Inertia of the impactor.
  - ✓We therefore need not concern these effects seriously by using the inverse test method.

Discussions, contd.

- Loading Speed:
  - ✓Loading speed of the Inverse Test is close to that of a car impact test.
  - ✓However, the main parts of the Flex-GTR, bone cores and knee springs, are made with low rate sensitive materials (see appendix).
  - ✓Loading speed is therefore not essential items for the Flex-PLI certification test, whereas, applied loading level is important.
  - ✓Applied loading level is comparable between the Inverse Test and Pendulum Test, therefore, no concerns on this issues for the Pendulum test.

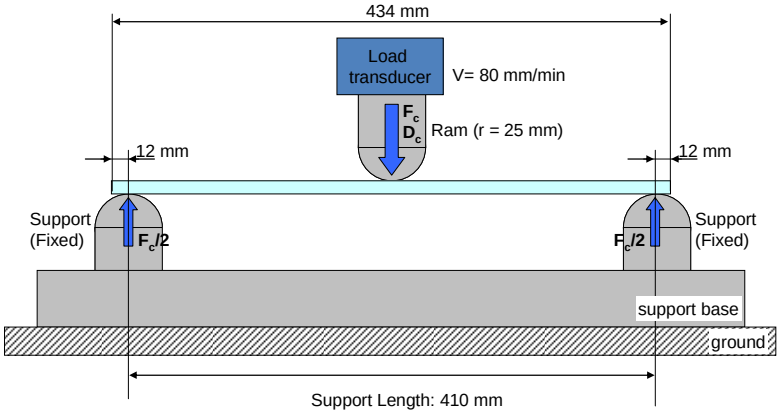
Conclusions

- JAMA-JARI conducted the Inverse Tests at JARI in order to investigate its detail.
- After the investigation, JAMA-JARI recommend to use Pendulum Test for a certification test of the Flex-PLI by following reasons,
  - ✓Efforts to conduct single Inverse test is significant for the Inverse Test (much effort is needed to conduct a single test compare to the pendulum test, even if the test is needed per 20 car impact tests). Pendulum Test is much Easy and Simple.
  - ✓Impact condition of Inverse test is severe (around 250 g, i.e. upper limit level of the current gtr 9), and the impactor impacted to a stopper wall directly, therefore, it has a chance to be damaged the impactor and/or measurement cables during the inverse test. Pendulum Test has no concerns on this issue.
  - ✓Additional Masses Effect (add 100 g masses) was insignificant , therefore, we need not to check the additional effect by the inverse test per 20 car impact tests. (requirement of the tolerance of mass, CoG, moment of inertia are enough to control on this issues)
  - ✓Loading Speed is not essential because the Flex-PLI main parts are made with low rate sensitive materials.
  - ✓Applied load level is important and the loading level is comparable between the Inverse test and the Pendulum test
  - ✓Merits of the Inverse Test are not significant whereas it is required much efforts to conduct the test.

Appendix

- Low Rate Sensitivity of the Bone Cores of the Flex-PLI.

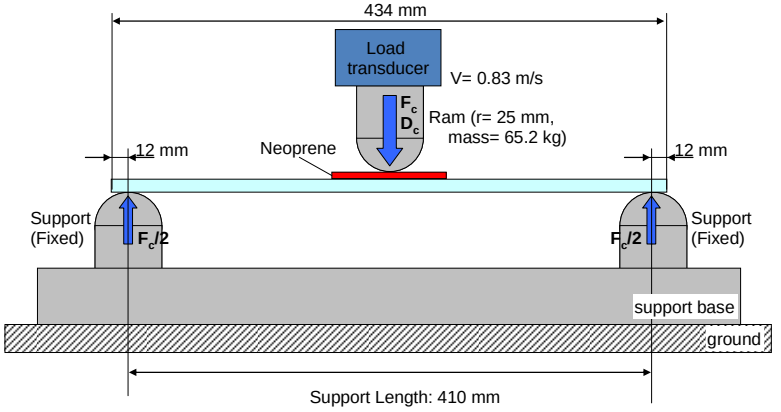
Tibia Bone Core
Quasi-static 3-Point Bending Test



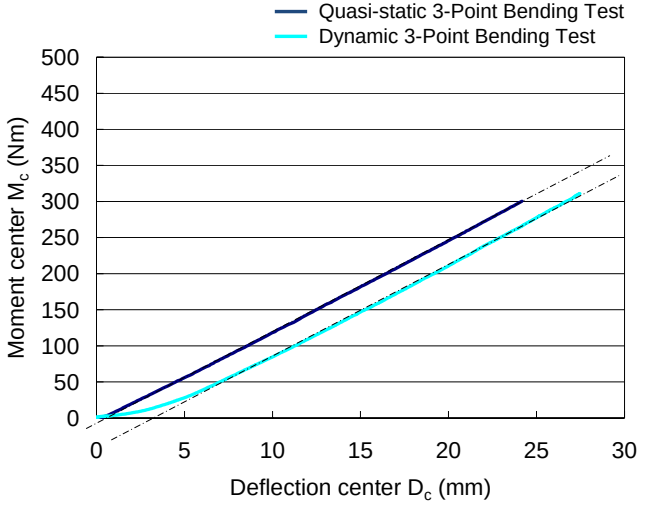
F_c: Force Center, D_c: Deflection Center
M_c : Moment Center (Nm) = F_c/2 (N) x 0.205 (m)

Tibia Bone Core
Dynamic 3-Point Bending Test

Loading speed of the bone core during a car test: around 1.5 m/s

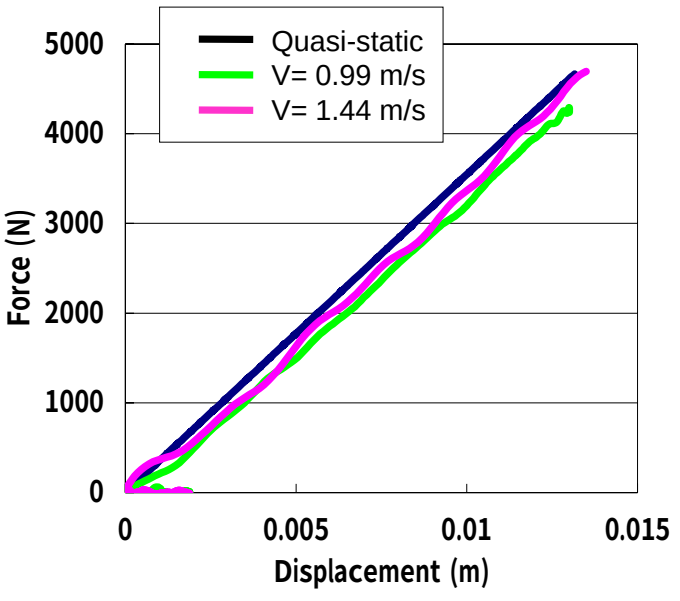


F_c: Force Center, D_c: Deflection Center
M_c : Moment Center (Nm) = F_c/2 (N) x 0.205 (m)

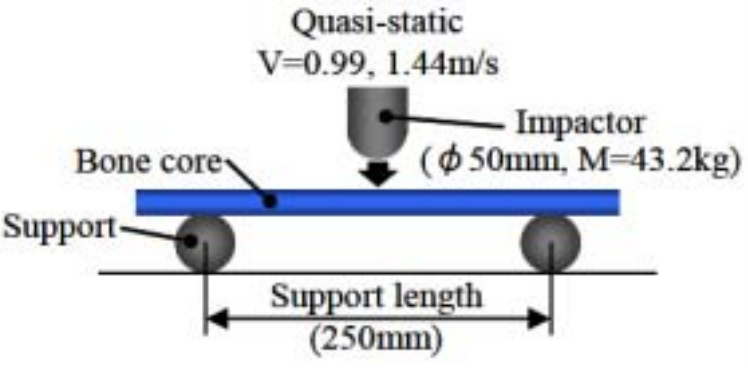


Appendix

- Low Rate Sensitivity of the Bone Cores of the Flex-PLI.



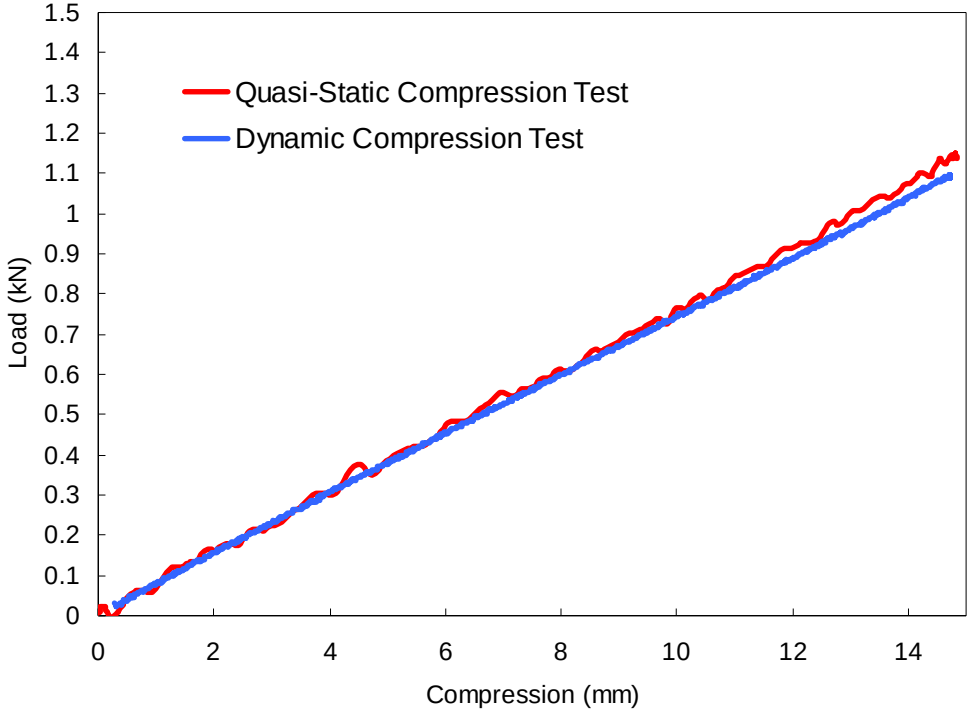
Loading speed of the bone core
during a car test: around 1.5 m/s



Direct impact to the bone cores

Appendix

- Low Rate Sensitivity of the Knee Springs of the Flex-PLI.



Loading speed during the dynamic compression test: 0.3 m/s
Loading speed of the knee spring during a car test: around 0.5 m/s