

Fig. 1. Cruciform test configuration and loading arrangement (all dimensions are in mm).



Fig. 2. General test arrangement for major-axis beam-to-column joint Wmj254_2M16_ST1-2.

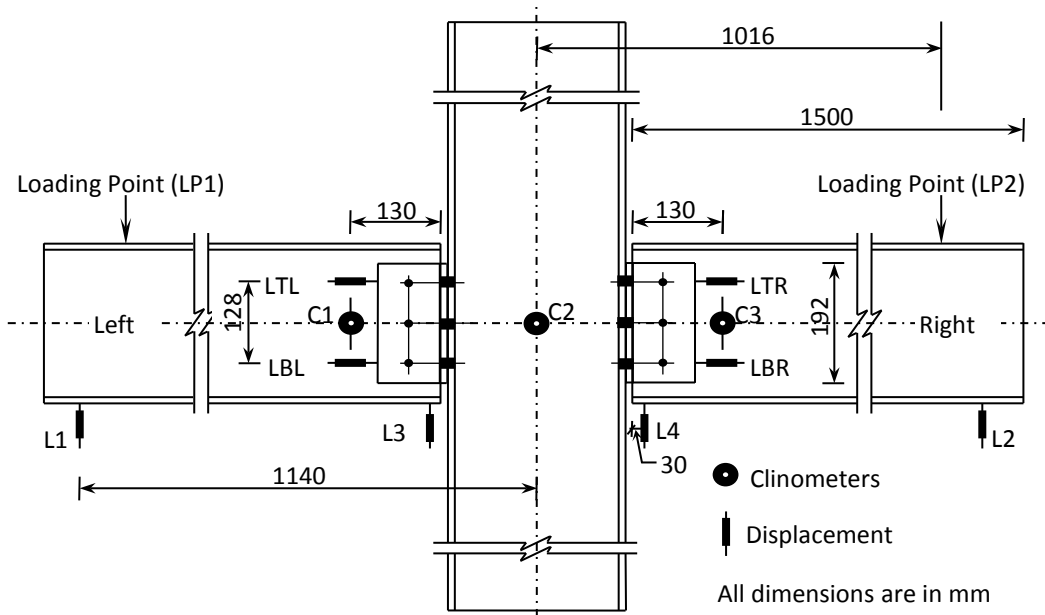


Fig. 3. Location of instrumentation in nominally pinned beam-to-column joint tests (all dimensions are in mm).

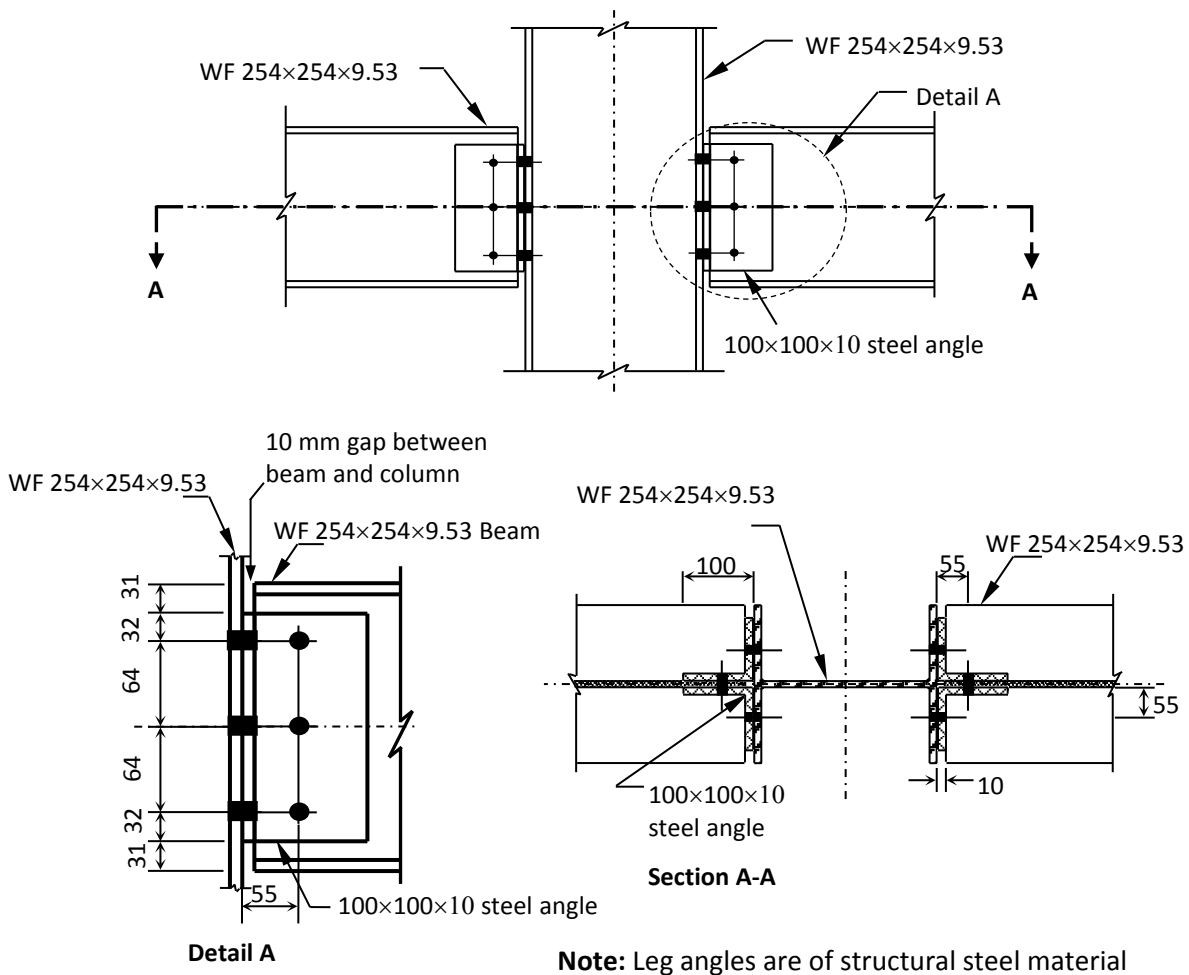


Fig. 4. Connection details for beam-to-column joint tests with structural steel cleats (All dimensions are in mm), adapted from [Fig. 1].



Fig. 5. Details of nominally pinned beam-to-column joint test Wmj254_2M16_ST1-2.

Test Ref: Wmj254_2M16_ST1-2

Test date: 7th December 2011

Moment arm = 1.016 m

| Load Incr | LEFT SIDE | | | | | | | | | | |
|--------------|-------------------------------------|-------------------------------|----------------------------|-----------------------------------|-------------------------------|--|---|---------------------------|---------------------------|--|--|
| | Centre rotation, C2 (CH18) | Load Point, LP1 (CH 21) | Rotation, C1 (CH 17) | Moment =LP1 x moment arm | Joint rotation, (4)-(2) | Slip compensa ted joint rotation, (6)-(12) | End beam deflecti on L1, (CH11) | Slip top, LTL (CH1) | Slip bot, LBL (CH3) | Beam deflecti on near column end, L3 (CH13) | Rotation due to horizontal slip, arctan ((LBL-LTL)/L) |
| | mrad | kN | mrad | kN.m | mrad | mrad | mm | mm | mm | mm | mrad |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | | | | | | | | | | | |
| | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.08 | 0.19 | -0.26 | 0.19 | 0.34 | 0.31 | 0.15 | -0.03 | -0.03 | 0.00 | 0.03 |
| | 0.07 | 0.20 | -0.33 | 0.20 | 0.39 | 0.34 | 0.20 | -0.04 | -0.04 | 0.00 | 0.05 |
| | 0.91 | 0.52 | 0.05 | 0.53 | 0.87 | 0.74 | -0.09 | -0.05 | -0.04 | 0.02 | 0.12 |
| | 0.84 | 0.55 | -0.01 | 0.56 | 0.84 | 0.75 | 0.06 | -0.05 | -0.04 | 0.02 | 0.09 |
| | -0.20 | 1.03 | -2.65 | 1.04 | 2.45 | 2.26 | 2.26 | -0.05 | -0.03 | 0.05 | 0.19 |
| | -0.38 | 1.03 | -2.93 | 1.05 | 2.55 | 2.35 | 2.51 | -0.06 | -0.04 | 0.05 | 0.20 |
| | -0.40 | 1.43 | -4.48 | 1.46 | 4.07 | 3.79 | 3.89 | -0.07 | -0.03 | 0.08 | 0.28 |
| | -0.66 | 1.40 | -4.80 | 1.43 | 4.14 | 3.85 | 4.15 | -0.07 | -0.04 | 0.09 | 0.29 |
| | -0.02 | 1.92 | -7.21 | 1.95 | 7.19 | 6.74 | 6.15 | -0.08 | -0.02 | 0.15 | 0.45 |
| | -0.09 | 1.86 | -7.54 | 1.89 | 7.45 | 7.04 | 6.45 | -0.08 | -0.03 | 0.15 | 0.41 |
| | 0.41 | 2.16 | -8.61 | 2.20 | 9.02 | 8.50 | 7.29 | -0.09 | -0.03 | 0.19 | 0.52 |
| | 0.41 | 2.09 | -8.86 | 2.12 | 9.26 | 8.74 | 7.49 | -0.09 | -0.03 | 0.19 | 0.52 |
| | 1.30 | 2.39 | -10.00 | 2.43 | 11.29 | 10.68 | 8.41 | -0.10 | -0.02 | 0.24 | 0.62 |
| | 1.25 | 2.29 | -10.27 | 2.33 | 11.52 | 10.93 | 8.63 | -0.10 | -0.03 | 0.24 | 0.59 |
| | 0.63 | 2.65 | -15.55 | 2.69 | 16.18 | 15.53 | 13.12 | -0.11 | -0.03 | 0.35 | 0.66 |
| | 0.40 | 2.46 | -15.99 | 2.50 | 16.39 | 15.74 | 13.49 | -0.11 | -0.03 | 0.35 | 0.65 |
| | 0.71 | 2.72 | -18.01 | 2.76 | 18.72 | 18.03 | 15.13 | -0.12 | -0.03 | 0.41 | 0.70 |
| | -10.37 | 0.87 | -19.08 | 0.88 | 8.71 | 8.40 | 16.54 | -0.09 | -0.05 | 0.20 | 0.30 |
| | -4.71 | 0.09 | -8.04 | 0.09 | 3.34 | 3.16 | 6.80 | -0.08 | -0.06 | 0.07 | 0.17 |
| | 0.75 | 2.09 | -14.44 | 2.13 | 15.19 | 14.69 | 12.06 | -0.11 | -0.05 | 0.33 | 0.50 |
| | 0.40 | 2.73 | -19.91 | 2.77 | 20.31 | 19.65 | 16.71 | -0.11 | -0.03 | 0.44 | 0.66 |
| | 0.79 | 2.86 | -22.73 | 2.90 | 23.52 | 22.87 | 19.03 | -0.12 | -0.03 | 0.52 | 0.65 |
| | 0.78 | 2.67 | -23.10 | 2.71 | 23.88 | 23.16 | 19.28 | -0.12 | -0.03 | 0.53 | 0.72 |
| | 1.39 | 3.09 | -27.50 | 3.14 | 28.89 | 28.13 | 22.97 | -0.13 | -0.03 | 0.64 | 0.76 |
| | 1.28 | 2.86 | -28.06 | 2.91 | 29.34 | 28.61 | 23.40 | -0.13 | -0.03 | 0.66 | 0.73 |
| | 0.41 | 0.15 | -6.76 | 0.15 | 7.17 | 6.99 | 5.36 | -0.08 | -0.06 | 0.15 | 0.19 |
| | -0.36 | 1.72 | -19.61 | 1.75 | 19.25 | 18.84 | 16.32 | -0.10 | -0.04 | 0.43 | 0.41 |
| | 0.08 | 3.10 | -31.63 | 3.15 | 31.72 | 30.97 | 26.42 | -0.13 | -0.04 | 0.71 | 0.75 |
| | 1.74 | 3.30 | -40.69 | 3.35 | 42.42 | 41.49 | 33.68 | -0.14 | -0.02 | 0.96 | 0.94 |
| | 0.10 | 3.42 | -49.01 | 3.48 | 49.11 | 48.13 | 40.57 | -0.14 | -0.02 | 1.13 | 0.98 |
| | -0.31 | 3.11 | -49.51 | 3.16 | 49.20 | 48.27 | 40.94 | -0.14 | -0.02 | 1.13 | 0.93 |
| | -3.02 | 3.77 | -63.08 | 3.83 | 60.06 | 58.90 | 52.42 | -0.16 | -0.01 | 1.39 | 1.16 |
| | -3.59 | 3.46 | -63.54 | 3.52 | 59.94 | 58.79 | 52.76 | -0.16 | -0.01 | 1.39 | 1.16 |

| | | | | | | | | | | | |
|--|-------|------|--------|------|-------|-------|-------|-------|-------|------|------|
| | -0.33 | 3.92 | -65.82 | 3.98 | 65.49 | 64.27 | 54.55 | -0.16 | -0.01 | 1.51 | 1.23 |
| | -0.37 | 3.67 | -65.98 | 3.73 | 65.61 | 64.40 | 54.65 | -0.16 | -0.01 | 1.52 | 1.20 |
| | 0.07 | 0.21 | -20.80 | 0.21 | 20.87 | 20.42 | 16.93 | -0.11 | -0.05 | 0.46 | 0.45 |
| | -3.41 | 0.03 | -19.03 | 0.03 | 15.62 | 15.27 | 15.71 | -0.11 | -0.06 | 0.34 | 0.34 |

Note: L is vertical separation between two horizontal displacement transducers on the web cleat = 128 mm

Green: indicates linear elastic joint properties

Red: shows joint properties at damage onset*

Blue: indicates joint properties at maximum moment

***Damage Onset** is defined in following two ways:

1. When audible loud cracking noise is first heard.
2. When width of column near centreline of top bolt increases by 1% of its width before loading.
(refer worksheet **col data**)

In col data worksheet, width of column near top bolt increases by 1% when load is 2 kN.

From moment rotation curves, the joint properties at damage onset are as under:

| M | ϕ (with slip) | ϕ (Compensated for slip) |
|------|--------------------|-------------------------------|
| 2.03 | 8.00 | 7.50 |

Test Ref: Wmj254_2M16_ST1-2

Test date: 7th December 2011

Moment arm =

1.016 m

| RIGHT SIDE | | | | | | | | | |
|-------------------------|---------------------|--------------------------|--------------------------|--|-------------------------------|---------------------|---------------------|--|---|
| Load Point, LP2 (CH 22) | Rotation C3 (CH 19) | Moment =LP2 x moment arm | Joint rotation, (14)-(2) | Slip compensated joint rotation, (16)-(22) | End beam deflection L2, (CH9) | Slip top, LTR (CH5) | Slip bot, LBR (CH7) | Beam deflection near column end, L4 (CH15) | Rotation due to horizontal slip, arctan ((LBL-LTL)/L) |
| kN | mrad | kN.m | mrad | mrad | mm | mm | mm | mm | mrad |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.19 | 0.49 | 0.19 | 0.41 | 0.39 | 0.53 | -0.03 | -0.04 | 0.00 | 0.02 |
| 0.20 | 0.49 | 0.20 | 0.43 | 0.37 | 0.54 | -0.04 | -0.05 | 0.00 | 0.05 |
| 0.52 | 2.22 | 0.53 | 1.31 | 1.27 | 2.11 | -0.05 | -0.05 | 0.02 | 0.03 |
| 0.55 | 2.31 | 0.56 | 1.47 | 1.45 | 2.16 | -0.05 | -0.05 | 0.02 | 0.02 |
| 1.03 | 2.86 | 1.05 | 3.06 | 2.98 | 2.60 | -0.06 | -0.05 | 0.06 | 0.08 |
| 1.03 | 2.85 | 1.05 | 3.23 | 3.10 | 2.60 | -0.06 | -0.05 | 0.06 | 0.13 |
| 1.43 | 4.38 | 1.45 | 4.79 | 4.59 | 3.93 | -0.07 | -0.04 | 0.09 | 0.20 |
| 1.40 | 4.45 | 1.42 | 5.12 | 4.87 | 3.97 | -0.08 | -0.04 | 0.09 | 0.25 |
| 1.92 | 8.08 | 1.95 | 8.09 | 7.80 | 7.13 | -0.08 | -0.05 | 0.15 | 0.30 |
| 1.87 | 8.20 | 1.89 | 8.29 | 7.98 | 7.20 | -0.09 | -0.05 | 0.15 | 0.31 |
| 2.17 | 10.34 | 2.20 | 9.93 | 9.57 | 9.10 | -0.10 | -0.05 | 0.18 | 0.37 |
| 2.09 | 10.45 | 2.12 | 10.04 | 9.66 | 9.18 | -0.10 | -0.05 | 0.18 | 0.38 |
| 2.40 | 13.21 | 2.44 | 11.91 | 11.50 | 11.65 | -0.11 | -0.05 | 0.22 | 0.41 |
| 2.29 | 13.34 | 2.33 | 12.09 | 11.71 | 11.74 | -0.10 | -0.05 | 0.23 | 0.37 |
| 2.64 | 17.96 | 2.68 | 17.33 | 16.87 | 15.49 | -0.11 | -0.05 | 0.33 | 0.45 |
| 2.46 | 18.27 | 2.50 | 17.87 | 17.45 | 15.63 | -0.11 | -0.06 | 0.35 | 0.41 |
| 2.71 | 21.51 | 2.75 | 20.80 | 20.25 | 18.27 | -0.11 | -0.04 | 0.40 | 0.55 |
| 0.88 | 0.86 | 0.90 | 11.23 | 11.03 | 0.11 | -0.09 | -0.07 | 0.20 | 0.20 |
| 0.11 | 0.61 | 0.11 | 5.31 | 5.29 | 0.20 | -0.08 | -0.08 | 0.10 | 0.02 |
| 2.09 | 17.62 | 2.12 | 16.87 | 16.57 | 15.11 | -0.10 | -0.06 | 0.33 | 0.30 |
| 2.72 | 23.04 | 2.77 | 22.64 | 22.18 | 19.41 | -0.11 | -0.05 | 0.44 | 0.46 |
| 2.85 | 26.68 | 2.89 | 25.89 | 25.38 | 22.36 | -0.11 | -0.05 | 0.51 | 0.52 |
| 2.66 | 26.87 | 2.70 | 26.09 | 25.57 | 22.47 | -0.11 | -0.05 | 0.51 | 0.52 |
| 3.08 | 32.35 | 3.13 | 30.96 | 30.35 | 27.02 | -0.12 | -0.05 | 0.61 | 0.61 |
| 2.85 | 32.65 | 2.89 | 31.38 | 30.81 | 27.22 | -0.12 | -0.05 | 0.62 | 0.57 |
| 0.16 | 8.75 | 0.16 | 8.35 | 8.28 | 7.37 | -0.07 | -0.06 | 0.17 | 0.06 |
| 1.72 | 20.69 | 1.75 | 21.05 | 20.82 | 17.26 | -0.09 | -0.06 | 0.42 | 0.23 |
| 3.09 | 34.10 | 3.14 | 34.01 | 33.45 | 28.43 | -0.12 | -0.05 | 0.67 | 0.56 |
| 3.30 | 42.02 | 3.35 | 40.29 | 39.64 | 34.91 | -0.13 | -0.05 | 0.80 | 0.65 |
| 3.40 | 44.94 | 3.46 | 44.84 | 44.14 | 37.24 | -0.13 | -0.04 | 0.89 | 0.70 |
| 3.10 | 45.21 | 3.15 | 45.52 | 44.84 | 37.38 | -0.14 | -0.05 | 0.91 | 0.68 |
| 3.74 | 58.76 | 3.80 | 61.78 | 60.93 | 48.53 | -0.15 | -0.04 | 1.25 | 0.85 |
| 3.45 | 59.13 | 3.51 | 62.72 | 61.88 | 48.76 | -0.15 | -0.04 | 1.27 | 0.84 |

| | | | | | | | | | |
|------|-------|------|-------|-------|-------|-------|-------|------|------|
| 3.94 | 68.64 | 4.00 | 68.97 | 68.06 | 56.90 | -0.16 | -0.04 | 1.40 | 0.91 |
| 3.67 | 68.90 | 3.73 | 69.27 | 68.36 | 57.06 | -0.16 | -0.05 | 1.41 | 0.91 |
| 0.22 | 24.20 | 0.22 | 24.13 | 23.96 | 19.78 | -0.10 | -0.08 | 0.47 | 0.17 |
| 0.02 | 14.89 | 0.02 | 18.30 | 18.22 | 11.99 | -0.10 | -0.08 | 0.35 | 0.09 |

***Damage Onset is defined in following two ways:**

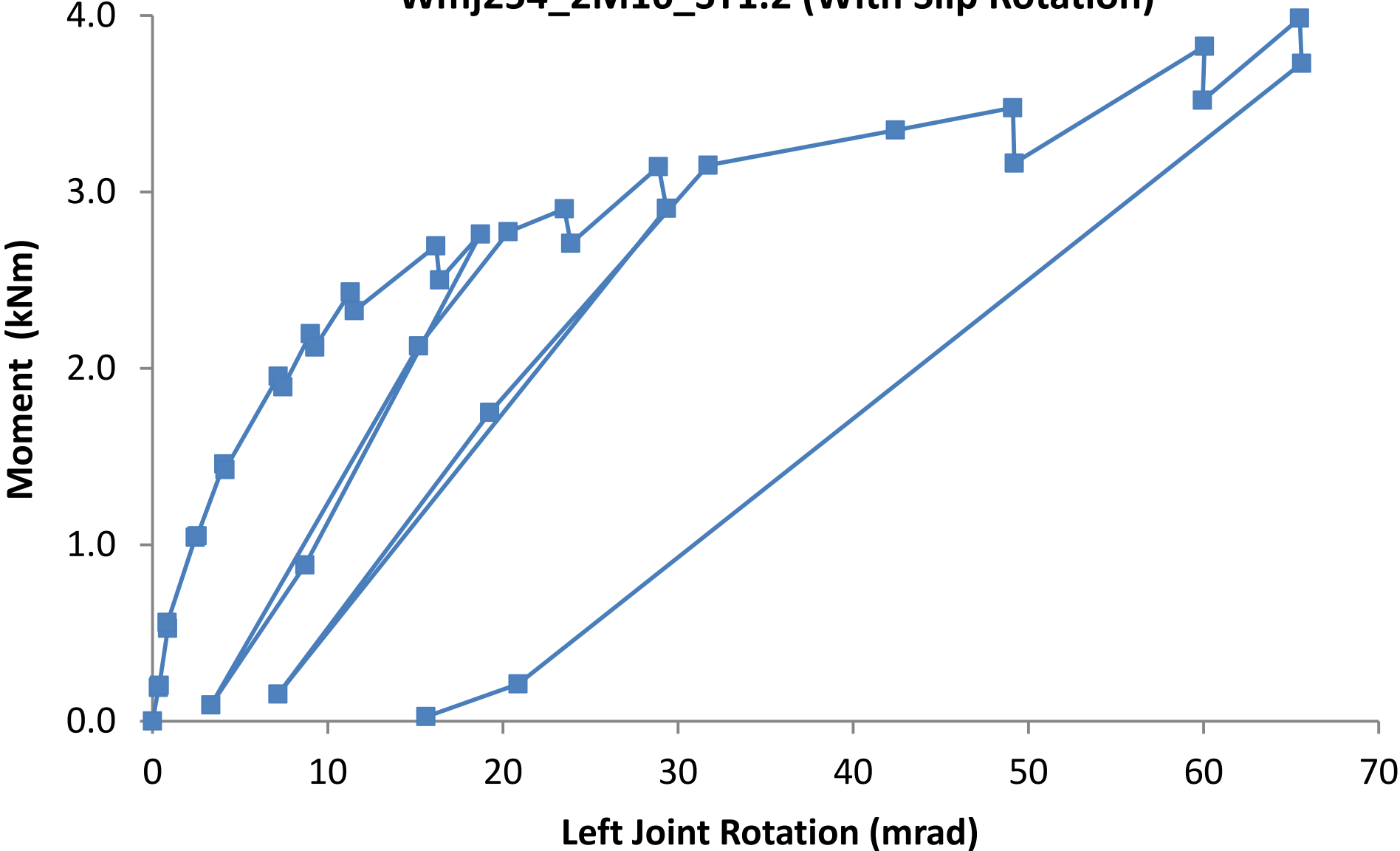
1. When audible loud cracking noise is first heard.
2. When width of column near centreline of top bolt increases by 1% of its width before loading.
(refer worksheet **col data**)

In col data worksheet, width of column near top bolt increases by 1% when load is 2 kN.

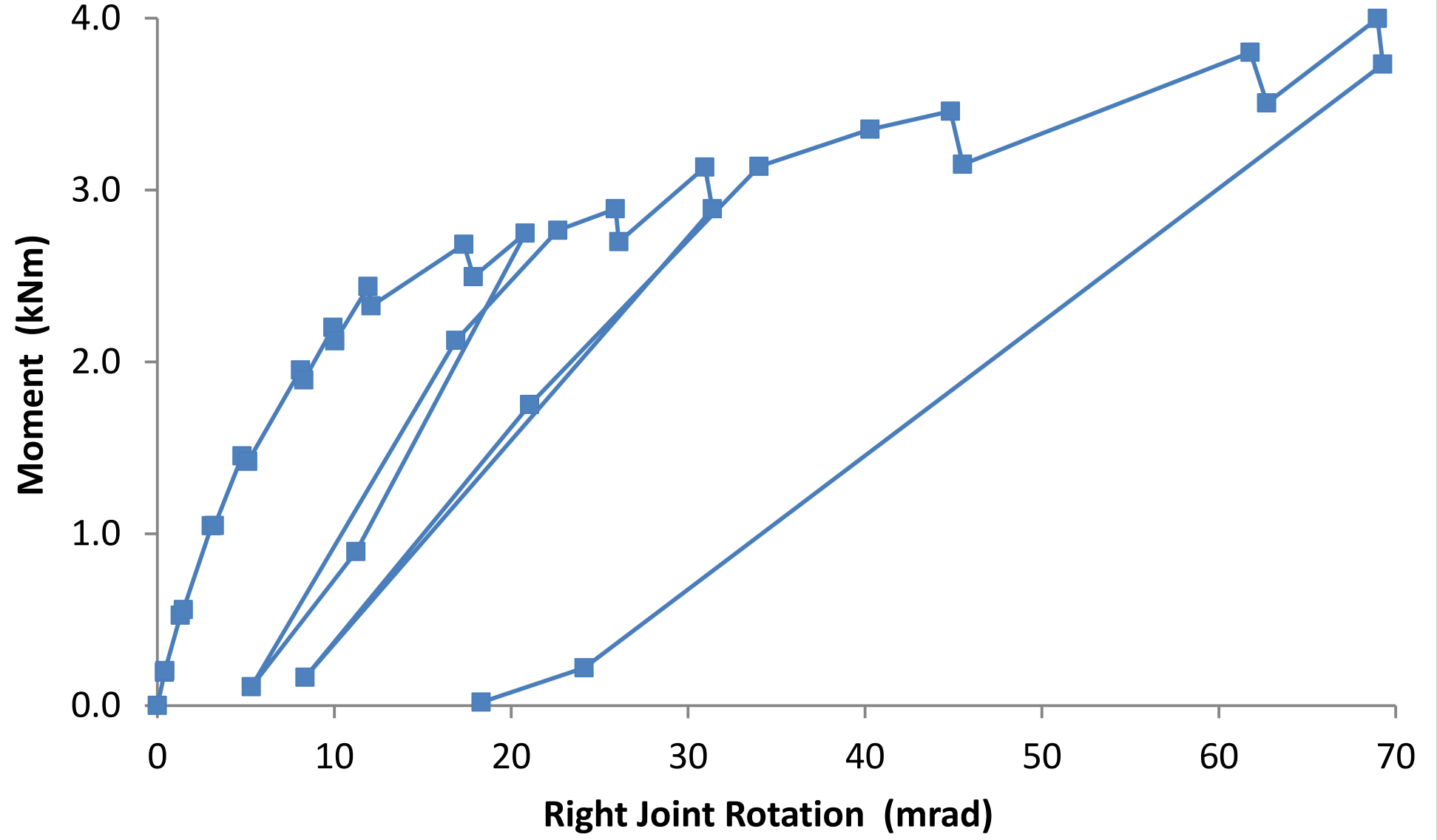
From moment rotation curves, the joint properties at damage onset are as under:

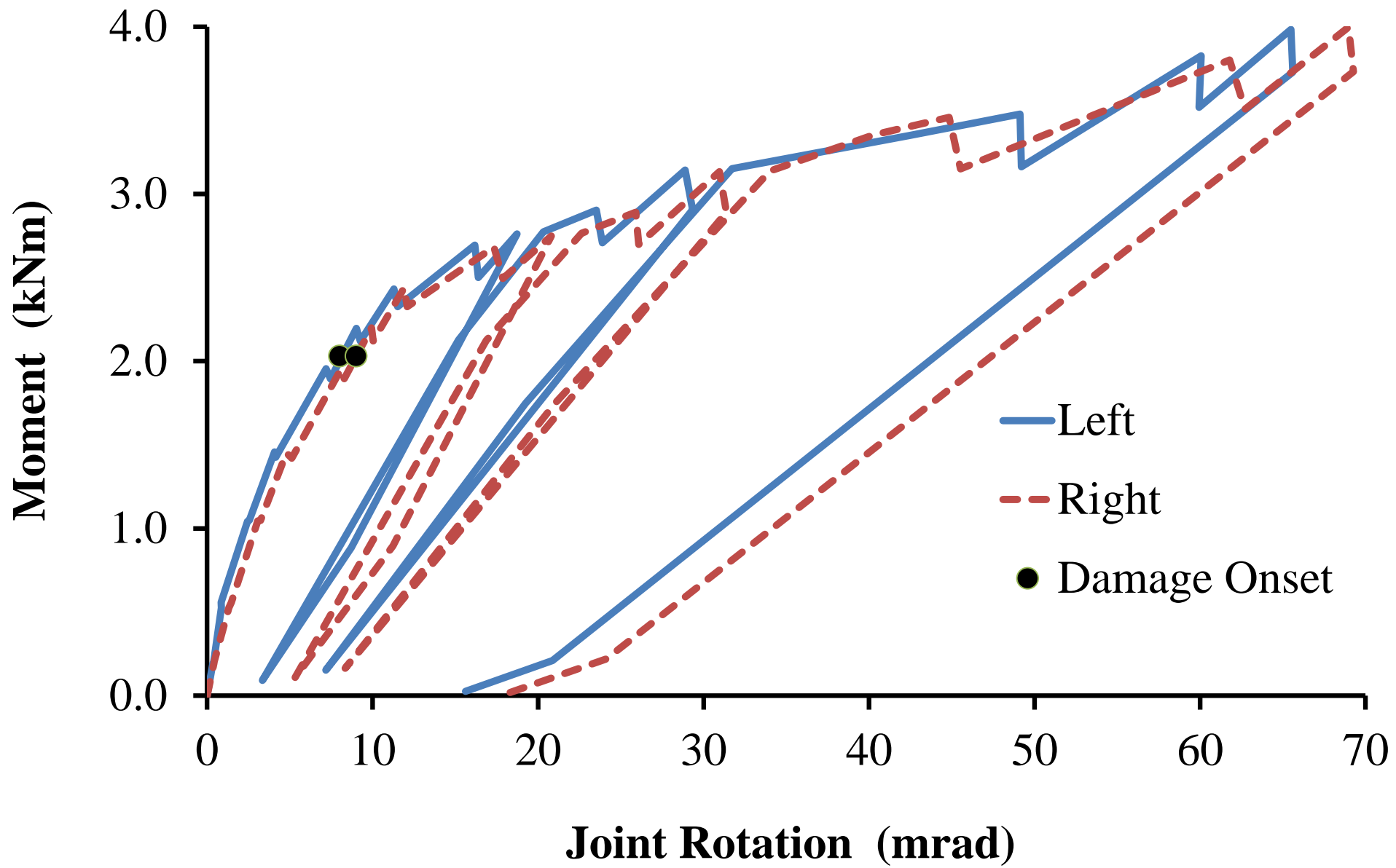
| M | ϕ (with slip) | ϕ (Compensated for slip) |
|------|--------------------|-------------------------------|
| 2.03 | 9.00 | 8.50 |

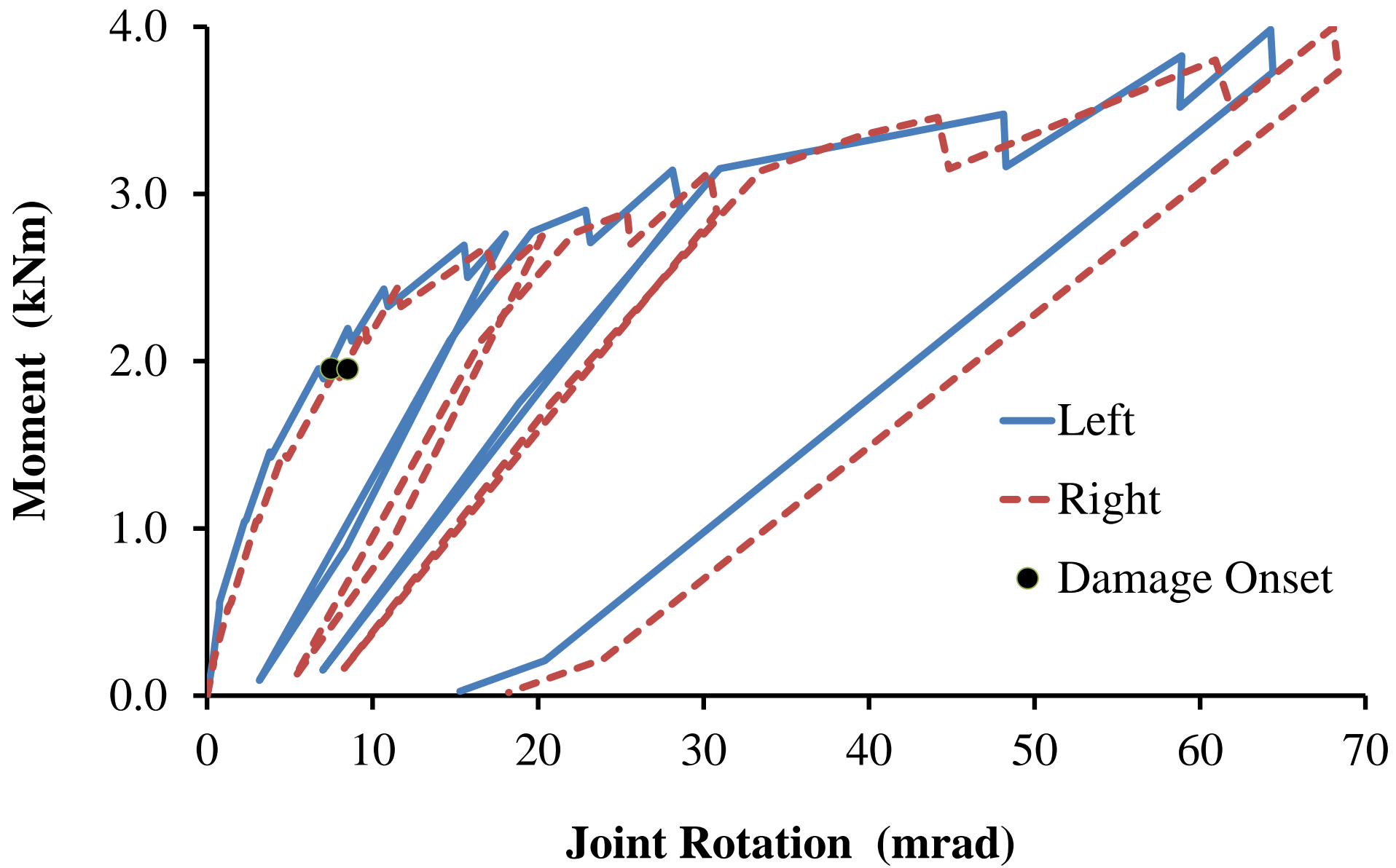
Wmj254_2M16_ST1.2 (With Slip Rotation)



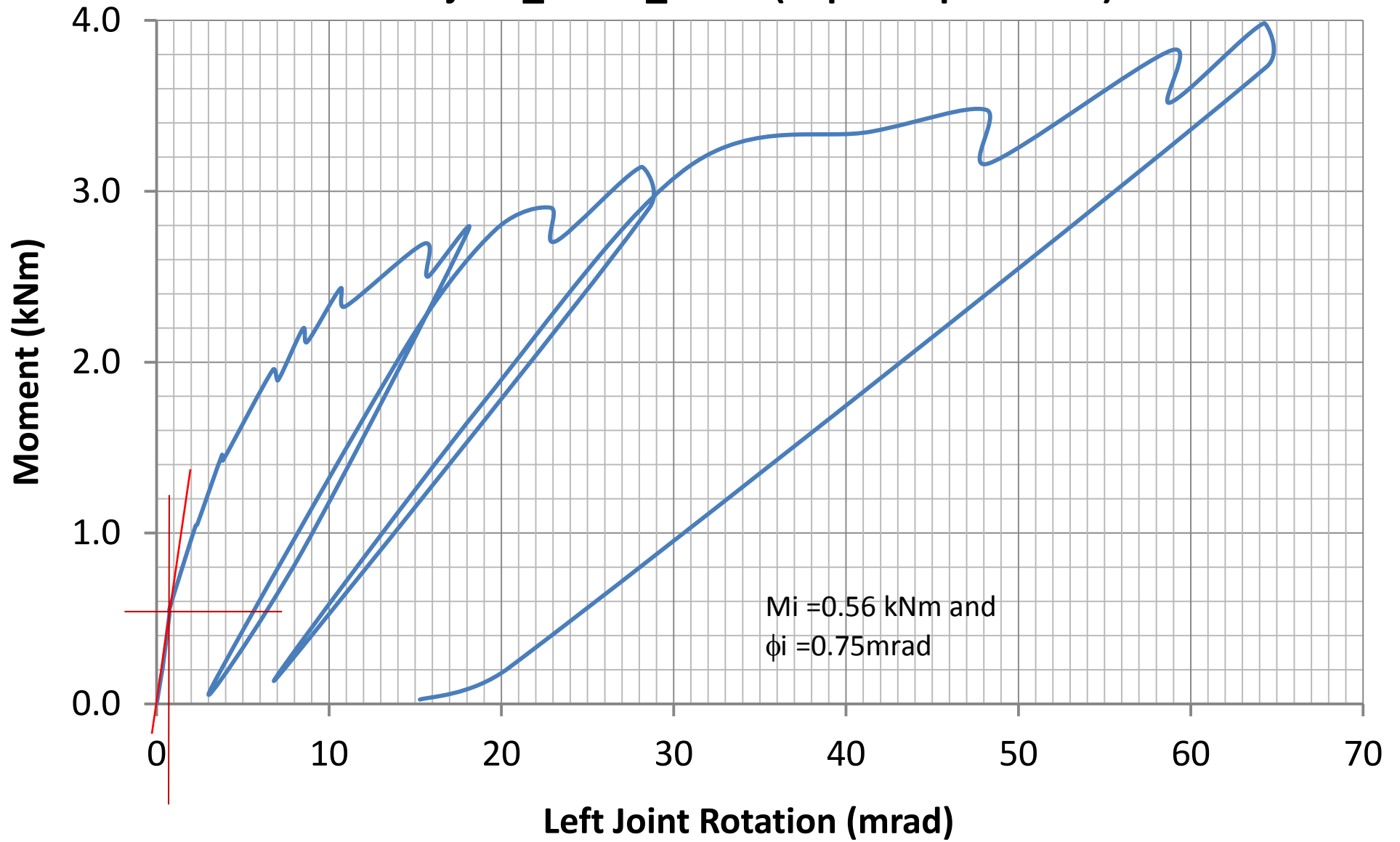
Wmj254_2M16_ST1.2 (With Slip Rotation)



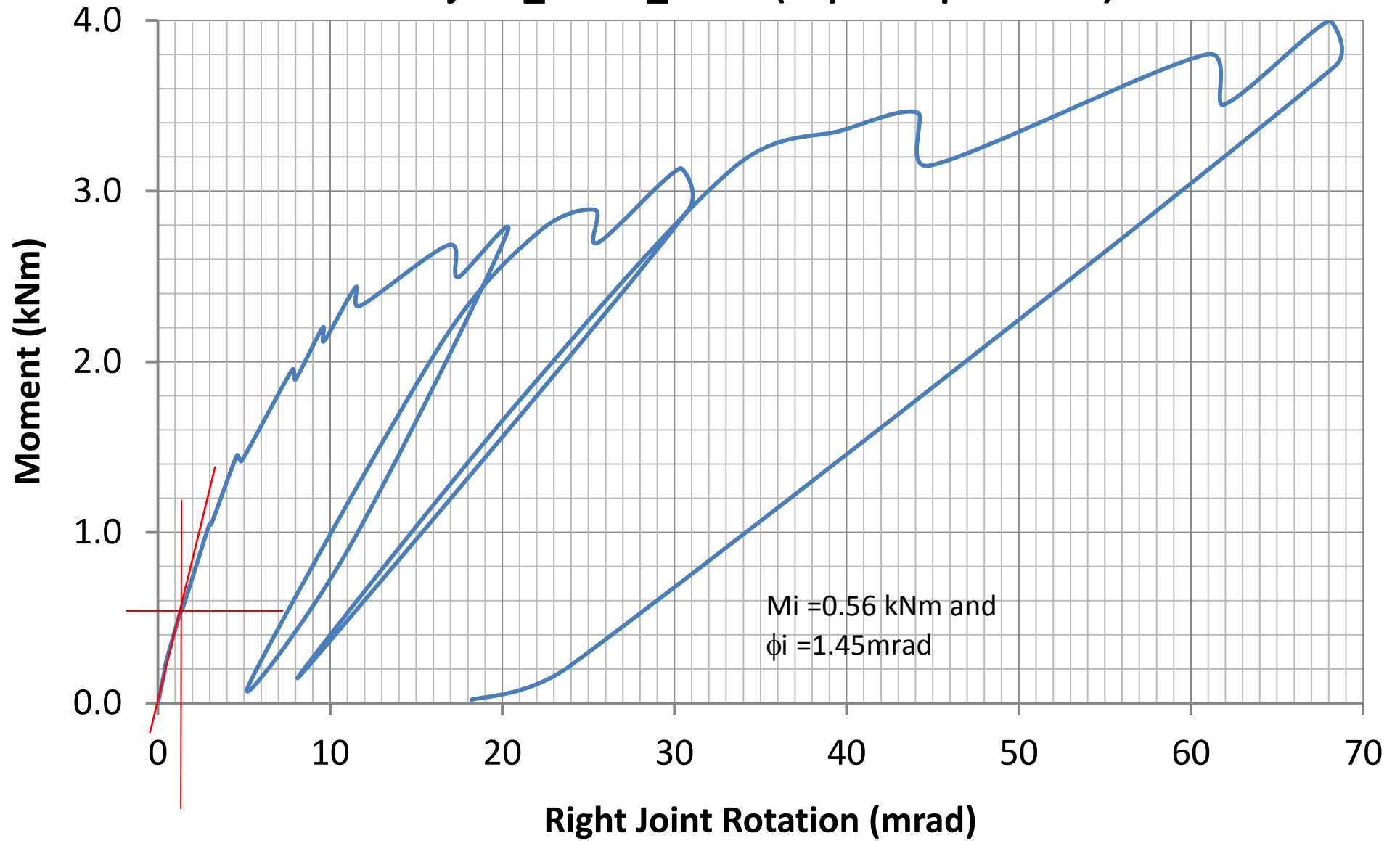




Wmj254_2M16_ST1.2 (Slip Compensated)



Wmj254_2M16_ST1.2 (Slip Compensated)



Moment = Applied Load × Moment Arm
 Moment Arm = 1.016 m

Width of the column at TOP web cleat = TOP
 Width of the column at BOTTOM web cleat = BOT

| | Load (kN) | Moment (kNm) | TOP (mm) | BOT (mm) | % increase TOP | % increase BOT | |
|--------------------------|--------------|-----------------|--------------|--------------|----------------|----------------|---------------------|
| Before start of test | 0.00 | 0.00 | 254.5 | 253.7 | | | |
| | 0.25 | 0.25 | 254.5 | 253.7 | 0.0% | 0.0% | |
| | 0.60 | 0.61 | 254.8 | 253.7 | 0.1% | 0.0% | |
| | 1.10 | 1.12 | 255.4 | 253.7 | 0.4% | 0.0% | |
| | 1.50 | 1.52 | 255.9 | 253.7 | 0.6% | 0.0% | |
| Loud cracking noise | 2.00 | 2.03 | 257.1 | 253.8 | 1.0% | 0.0% | damage onset |
| | 2.25 | 2.29 | 257.8 | 253.8 | 1.3% | 0.0% | |
| | 2.50 | 2.54 | 258.5 | 253.8 | 1.6% | 0.0% | |
| | 2.75 | 2.79 | 260.4 | 254.0 | 2.3% | 0.1% | |
| | 3.00 | 3.05 | 262.9 | 254.0 | 3.3% | 0.1% | |
| | 3.20 | 3.25 | 264.7 | 254.0 | 4.0% | 0.1% | |
| Very loud cracking noise | 3.50 | 3.56 | 271.2 | 254.4 | 6.6% | 0.3% | |
| Very loud cracking noise | 3.80 | 3.86 | 275.9 | 254.5 | 8.4% | 0.3% | |
| Very loud cracking noise | 3.94 | 4.00 | 278.0 | 254.5 | 9.2% | 0.3% | |
| After unloading | 0.00 | 0.00 | 261.4 | 254.4 | 2.7% | 0.3% | |

