Annex 1:

Technical report:

Brake benchmarking test of A - Vehicle

Performed by:

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Project engineer
Braking systems

Testing period, July - August 2007

This report contains 65 pages
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1 SCOPE

To perform a benchmarking test on a A - Vehicle in order to characterize the main parameters of the brake system.

The tests performed were:

- FSGP test at 50, 100 and high speed
- Straight line stability
- Stopping distances
- Mu-split test

2 MAIN RESULTS

2.1 FSGP test

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>50km/h</td>
<td>6</td>
<td>39</td>
<td>25</td>
<td>12.2</td>
<td>56</td>
<td>52</td>
<td>17.4</td>
<td>71</td>
<td>76</td>
</tr>
<tr>
<td>100 km/h</td>
<td>5.2</td>
<td>37</td>
<td>24</td>
<td>11.2</td>
<td>54</td>
<td>48</td>
<td>17.3</td>
<td>69</td>
<td>75</td>
</tr>
<tr>
<td>200 Km/h</td>
<td>5.5</td>
<td>45</td>
<td>23</td>
<td>11</td>
<td>61</td>
<td>47</td>
<td>18.6</td>
<td>78</td>
<td>80</td>
</tr>
</tbody>
</table>

Table 1. Final results

Graph 1: FSGP main results

Graph showing FSGP - Pedal effort - IBT 100ºC
Graph 2: **FSGP main results**

### FSGP - Pedal stroke - IBT 100°C

<table>
<thead>
<tr>
<th>[g]</th>
<th>0.3 g</th>
<th>0.6 g</th>
<th>0.9 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3 g</td>
<td>39.0</td>
<td>59.0</td>
<td>71.0</td>
</tr>
<tr>
<td>0.6 g</td>
<td>46.0</td>
<td>61.0</td>
<td>78.0</td>
</tr>
<tr>
<td>0.9 g</td>
<td>54.0</td>
<td>69.0</td>
<td>78.0</td>
</tr>
</tbody>
</table>

Graph 3: **FSGP main results**

### FSGP - Front pressure - IBT 100°C

<table>
<thead>
<tr>
<th>[bar]</th>
<th>0.3 g</th>
<th>0.6 g</th>
<th>0.9 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3 g</td>
<td>25</td>
<td>52</td>
<td>76</td>
</tr>
<tr>
<td>0.6 g</td>
<td>24</td>
<td>48</td>
<td>75</td>
</tr>
<tr>
<td>0.9 g</td>
<td>23</td>
<td>57</td>
<td>80</td>
</tr>
</tbody>
</table>
Graph 4:  

**FSGP – Speed sensibility comparison - IBT 100°C**

- **Ped. effort [daN]**
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9
  - 10
  - 11
  - 12

- **Decel. [m/s²]**
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9
  - 10
  - 11
  - 12

- **Ped. stroke [mm]**
  - 0
  - 10
  - 20
  - 30
  - 40
  - 50
  - 60
  - 70
  - 80
  - 90

- **Decel. [m/s²]**
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9
  - 10
  - 11

- **Ped. effort [daN]**
  - 0
  - 10
  - 20
  - 30
  - 40
  - 50
  - 60
  - 70
  - 80
  - 90

- **Decel. [m/s²]**
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9
  - 10

- **Ped. stroke [mm]**
  - 0
  - 10
  - 20
  - 30
  - 40
  - 50
  - 60
  - 70
  - 80
  - 90

- **50 km/h**
- **100 km/h**
- **200 km/h**
Graph 5: **FSGP – Speed sensibility comparison - IBT 100ºC**

- **Ped. effort [daN]**: 0 2 4 6 8 10 12 14 16 18 20 22 24
- **Ped. stroke [mm]**: 0 10 20 30 40 50
- **M/C press [bar]**: 0 1 2 3 4 5 6 7 8 9 10 11 12
- **Decel. [m/s²]**: 0 1 2 3 4 5 6 7 8 9 10 11 12

- **50 km/h**
- **100 km/h**
- **200 km/h**
### 2.2 Straight line stability

<table>
<thead>
<tr>
<th>Initial brake speed [km/h]</th>
<th>Weight [kg]</th>
<th>Application [g/s]</th>
<th>Maximum drift until 50% Vi [m]</th>
<th>Max yaw rate after 1s [º/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>140</td>
<td>DOW</td>
<td>1</td>
<td>0.2</td>
<td>-0.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.6</td>
<td>-0.39</td>
</tr>
<tr>
<td></td>
<td>DOW</td>
<td>3</td>
<td>0.3</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.3</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>DOW</td>
<td>5*</td>
<td>0.8</td>
<td>-0.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.5</td>
<td>0.06</td>
</tr>
<tr>
<td>200</td>
<td>DOW</td>
<td>1</td>
<td>0.9</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.1</td>
<td>-0.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>0.7</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.3</td>
<td>-0.87</td>
</tr>
</tbody>
</table>

* maximum speed application before panic brake assistant activation

** drift on the left positive

*** Yaw rate positive counter clockwise

**Table 2. Final results**
2.3 Stopping distance test

<table>
<thead>
<tr>
<th>Stopping distances</th>
<th>Dry asphalt</th>
<th>Wet asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distance [m]</td>
<td>Std dev [m]</td>
</tr>
<tr>
<td>Tyre bedding</td>
<td>42.7</td>
<td>0.49</td>
</tr>
<tr>
<td>Low Temperature</td>
<td>41.3</td>
<td>0.34</td>
</tr>
<tr>
<td>High temperature</td>
<td>41.8</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Table 3. Final results

Graph 6: Stopping distances comparison
2.4 Mu-split test

STOPPING DISTANCE AT 100 Km/h
Initial speed 100 ± 3 km/h, initial brake temperature 100ºC

<table>
<thead>
<tr>
<th>Measured</th>
<th>Calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Va (km/h) Sa (m) Aa (m/s²)</td>
<td>S100 (m)</td>
</tr>
<tr>
<td>17 99.8 108.0 3.55</td>
<td>108.8</td>
</tr>
<tr>
<td>18 100.5 110.4 3.52</td>
<td>109.6</td>
</tr>
<tr>
<td>19 100.6 114.5 3.40</td>
<td>113.5</td>
</tr>
<tr>
<td>20 99.4 108.8 3.50</td>
<td>110.3</td>
</tr>
<tr>
<td>21 101.2 117.6 3.35</td>
<td>115.2</td>
</tr>
<tr>
<td>22 100.9 115.8 3.38</td>
<td>114.1</td>
</tr>
<tr>
<td>23 99.5 114.8 3.32</td>
<td>116.3</td>
</tr>
<tr>
<td>24 98.6 116.2 3.22</td>
<td>119.9</td>
</tr>
<tr>
<td>29 99.8 120.9 3.17</td>
<td>121.7</td>
</tr>
</tbody>
</table>

Mean 114.4
Std. Deviation: 4.48 Asphalt Temperature: 26 ºC

STOPPING DISTANCE AT 100 km/h 114.4 m

Test analysis (according to ISO Straight-line braking procedure)

The average deceleration $a_a$ is calculated between $t_1$ and $t_f$.

$$A_a = \frac{V_a^2 - V_s^2}{2 \cdot S_a}$$

$t_1$ (beginning of braking, 5N trigger or lower)
$t_f$ (5 km/h)

where:

$V_a$ is the longitudinal entry velocity at time $t_1$ (m/s), taking 10N on pedal effort

$S_a$ is the measured longitudinal braking distance between $t_1$ and time $t_f$

Then the corrected longitudinal braking distance in meters is calculated using the following formula.

$$S_{norm(100)} = \frac{V_{norm}^2}{2 \cdot A_a}$$

where:

$V_{norm}$ Nominal entry velocity for the test in m/s (100/3.6)

$S_{norm(100)}$ Standardised braking distance
Mu-SPLIT BRAKING DISTANCES

STOPPING DISTANCE AT 100 Km/h
Initial speed 100 ± 3 km/h, initial brake temperature 100ºC

<table>
<thead>
<tr>
<th>No.</th>
<th>Measured</th>
<th>Calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Va (km/h)</td>
<td>Sa (m)</td>
</tr>
<tr>
<td>19</td>
<td>100.6</td>
<td>114.5</td>
</tr>
<tr>
<td>20</td>
<td>99.4</td>
<td>108.8</td>
</tr>
<tr>
<td>21</td>
<td>101.2</td>
<td>117.6</td>
</tr>
<tr>
<td>22</td>
<td>100.9</td>
<td>115.8</td>
</tr>
<tr>
<td>23</td>
<td>99.5</td>
<td>114.8</td>
</tr>
</tbody>
</table>

Mean: 113.9
Std. Deviation: 2.28

Asphalt Temperature: 26.0 ºC

STOPPING DISTANCE AT 100 Km/h 113.9 m

Fast application (> 500 mm/s)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>State</th>
<th>Measurement No.</th>
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<tbody>
<tr>
<td>Controlability</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>build-up-state</td>
<td>3+</td>
<td>3.5</td>
</tr>
<tr>
<td>steady-state</td>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td>final-state</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Predictability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>build-up-state</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>steady-state</td>
<td>3+</td>
<td>3.5</td>
</tr>
<tr>
<td>final-state</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Directional Stability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>build-up-state</td>
<td>3+</td>
<td>3+</td>
</tr>
<tr>
<td>steady-state</td>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td>final-state</td>
<td>3+</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Table 4. Final results

<table>
<thead>
<tr>
<th>Stability Rating</th>
<th>Rating</th>
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</thead>
<tbody>
<tr>
<td>Vehicle very difficult even for skilled driver</td>
<td>2</td>
</tr>
<tr>
<td>Vehicle difficult even for skilled driver</td>
<td>2.5</td>
</tr>
<tr>
<td>Difficult for skilled driver</td>
<td>3-</td>
</tr>
<tr>
<td>Difficult for average driver</td>
<td>3</td>
</tr>
<tr>
<td>Controlable for average driver</td>
<td>3+</td>
</tr>
<tr>
<td>Very easy to control</td>
<td>3.5</td>
</tr>
<tr>
<td>Straight line without any control</td>
<td>4</td>
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</table>
### GENERAL BRAKE SPECIFICATIONS

<table>
<thead>
<tr>
<th>GENERAL</th>
<th>A - Vehicle</th>
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<tbody>
<tr>
<td>Model</td>
<td>A - Vehicle</td>
</tr>
<tr>
<td>VIN</td>
<td>---</td>
</tr>
<tr>
<td>Engine</td>
<td>6.0 petrol</td>
</tr>
<tr>
<td>Transmission</td>
<td>Automatic</td>
</tr>
<tr>
<td>Body</td>
<td>4 doors</td>
</tr>
</tbody>
</table>

#### CHASSIS
- Wheel Base [mm] 3165
- Wheels 18” aluminium
- Tyres (reference) Continental SportContact2
  - FR: 255/45 R18 99Y
  - RR: 275/45 R18 103Y
- Tyres (Batch number)
  - FR: 2307
  - RR: 1007
- Weights used in the tests
  - DOW (Fr/Rr = Total) [kg] 1,240 Kg / 1,127 Kg = 2,367 Kg
  - PTW (Total) [kg] 2,590 Kg

#### BRAKE SPECIFICATION

<table>
<thead>
<tr>
<th>Type of circuit</th>
<th>I – I</th>
</tr>
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<tbody>
<tr>
<td>ABS SYSTEM</td>
<td>Teves MK25 E5</td>
</tr>
<tr>
<td>No. Sensor / No. channels</td>
<td>4/4</td>
</tr>
</tbody>
</table>

#### FRONT BRAKE
- No. Cylinder / ∅ [mm] 6 / 32-30-28
- Rotor type Ventilated (with holes on the rotor)
  - ∅Ext.xThick / R. Effective [mm] 360 x 36 / 145
- Friction material Jurid 652GF
  - Grove / Chamfer No / no
  - Anti-noise Yes
- Splash-guard Yes

#### REAR BRAKE
- No. Cylinder / ∅ [mm] 4 / 26-22
- Rotor type Ventilated
  - ∅Ext.xThick / R. Effective [mm] 330 x 26 / 140
- Friction material Jurid 681 GF
  - Grove / Chamfer No / Yes
  - Anti-noise Yes
- Splash-guard Yes

#### APPLICATION
- Booster size Tandem (10 + 10)"
  - Jump-in (bar) / ratio 16 / 6
- Master cylinder diameter [mm] 25 / 20
- Brake fluid DOT 4

#### PARKING BRAKE SYSTEM (PKB)
- Type Drum in hat
- Friction material Jurid 559 HG

Table 6. Technical data
## TEST CONDITIONS

### Brake benchmarking test of A - Vehicle

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Conditions</th>
<th>Vehicle weight (kg)</th>
<th>Front final speed (km/h)</th>
<th>Rear final speed (km/h)</th>
<th>BHT (ºC)</th>
<th>Speed application (m/s²)</th>
<th>Max. of braking</th>
<th>Brake angle</th>
<th>Brake position</th>
<th>Instrumentation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brake bedding</td>
<td>DC109</td>
<td>70</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>3.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Subjective pedal feeling</td>
<td>DC106</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Basic instrumentation</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Static test</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>FSGP 50 &amp; 100km Pitch &amp; dive evaluation</td>
<td>DC102</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>3.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Acceleration build up</td>
<td>DC210</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>--</td>
<td>2 g/s</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Straight line stability</td>
<td>DC210</td>
<td>140</td>
<td>60</td>
<td>0.5°/50 ms</td>
<td>0</td>
<td>2 g/s</td>
<td>Fixed</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Change tyre &amp; Tyre run in</td>
<td>DC210</td>
<td>140</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
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</tbody>
</table>

### Brake deceleration

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Conditions</th>
<th>Vehicle weight (kg)</th>
<th>Front final speed (km/h)</th>
<th>Rear final speed (km/h)</th>
<th>BHT (ºC)</th>
<th>Speed application (m/s²)</th>
<th>Max. of braking</th>
<th>Brake angle</th>
<th>Brake position</th>
<th>Instrumentation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBT Speed application</td>
<td>DC210</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>3.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>IBT Speed application</td>
<td>DC210</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>3.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>IBT Speed application</td>
<td>DC210</td>
<td>50</td>
<td>50% width V</td>
<td>0.5°/50 ms</td>
<td>0</td>
<td>2 g/s</td>
<td>Fixed</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>IBT Speed application</td>
<td>DC210</td>
<td>50</td>
<td>50% width V</td>
<td>0.5°/50 ms</td>
<td>0</td>
<td>2 g/s</td>
<td>Fixed</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

### Table 7. Test conditions
5 TEST ANALYSIS

5.1 Brake bedding evolution

Graph 7: Pressure – Deceleration Vs Number of Stops

![Graph showing brake bedding evolution](image-url)
5.2 FSGP

5.2.1 Static test measurement

Graph 8: Booster characteristic curve

Graph 9: Pedal effort vs. pedal stroke
5.2.2 FSGP 50 km/h

Graph 10:

<table>
<thead>
<tr>
<th>FSGP 50 km/h</th>
<th>Pad Temp. = 50°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_{init.}(50-0) km/h</td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing brake performance data for FSGP 50 km/h]
Brake benchmarking test of
A - Vehicle

Graph 11: FSGP 50 km/h

<table>
<thead>
<tr>
<th>Ped. stroke [mm]</th>
<th>Ped. effort [daN]</th>
<th>Decel. [m/s²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>15</td>
<td>7</td>
<td>8</td>
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<tr>
<td>20</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>25</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>

Pad Temp. = 50°C
Graph 12: 

**FSGP 50 km/h**

| V_{inl.}(50-0)km/h | Pad Temp. = 100 °C |

---

![Graph showing brake performance metrics](image-url)
Graph 13: FSGP 50 km/h

<table>
<thead>
<tr>
<th>V_{inl}(50-0)km/h</th>
<th>Pad Temp. = 100 °C</th>
</tr>
</thead>
</table>

Ped. stroke [mm]

Ped. effort [daN]

Decel. [m/s²]

M/C press [bar]
5.2.3 FSGP 100 km/h

Graph 14:

<table>
<thead>
<tr>
<th>V_{\text{ini.}} (100-0) km/h</th>
<th>Pad Temp. = 50°C</th>
</tr>
</thead>
</table>

Decel. [m/s²] vs. Ped. effort [daN]

Decel. [m/s²] vs. Ped. stroke [mm]
Brake benchmarking test of
A - Vehicle

Graph 15:

**FSGP 100 km/h**

<table>
<thead>
<tr>
<th>Ped. effort [daN]</th>
<th>M/C press [bar]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
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<td>3</td>
<td>3</td>
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<td>4</td>
<td>4</td>
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<td>11</td>
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<tr>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ped. stroke [mm]</th>
<th>Decel. [m/s²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
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<tr>
<td>10</td>
<td>1</td>
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<tr>
<td>90</td>
<td>9</td>
</tr>
<tr>
<td>100</td>
<td>10</td>
</tr>
</tbody>
</table>
Graph 16: FSGP 100 km/h

V_{in}(100-0) km/h

Pad Temp. = 100 °C

Decel. [m/s²] vs Ped. effort [daN]

Decel. [m/s²] vs Ped. stroke [mm]
5.2.4 FSGP high speed

Graph 18:

<table>
<thead>
<tr>
<th>V\text{init.}(200-0) km/h</th>
<th>Pad Temp. = 50°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSGP 200 km/h</td>
<td></td>
</tr>
</tbody>
</table>

Ped. effort [daN]

Decel. [m/s²]

Ped. stroke [mm]

Decel. [m/s²]
Graph 19: FSGP 200 km/h

<table>
<thead>
<tr>
<th>V_{inl.}(200-0) km/h</th>
<th>Pad Temp. = 50°C</th>
</tr>
</thead>
</table>

- Ped. effort [daN]
- Ped. stroke [mm]
- M/C press [bar]
- Decel. [m/s²]

Legend:
- Blue line
- Red line
- Green line
- Black line

Note: Graph showing the relationship between pedal effort, stroke, M/C press, and deceleration for a vehicle under FSGP 200 km/h conditions with pad temperature at 50°C.
Graph 20:

FSGP 200 km/h

V_{inl.}(200-0)km/h  Pad Temp. = 100 °C

Decel. [m/s²] vs Ped. effort [daN]

Decel. [m/s²] vs Ped. stroke [mm]
Graph 21: FSGP 200 km/h

<table>
<thead>
<tr>
<th>$V_{init}(200-0)$ km/h</th>
<th>Pad Temp. = 100 °C</th>
</tr>
</thead>
</table>

Ped. effort [daN]

Decel. [m/s²]

Ped. stroke [mm]

M/C press [bar]
5.2.5 Pitch and dive evaluation during FSGP

Graph 22: FSGP 50 km/h – brake stop No.1

| Pad Temp. | 100 °C |

\[
\begin{array}{c}
\text{Distance to driver (mm)} \\
-600 & -400 & -200 & 0 & 200 & 400 & 600 \\
\end{array}
\]

\[
\begin{array}{c}
\text{Decel (m/s}^2) \\
-6 & -4 & -2 & 0 & 2 & 4 \\
\end{array}
\]

\[
\begin{array}{c}
\text{Pitch (deg)} \\
-5 & -2.5 & 0 & 2.5 & 5 \\
\end{array}
\]

\[
\begin{array}{c}
\text{Dec (m/s}^2) \\
-1 & 0 & 1 & 2 & 3 \\
\end{array}
\]

\[
\begin{array}{c}
\text{Pitch_Rate (deg/s)} \\
-0.5 & 0 & 0.5 & 1 \\
\end{array}
\]

\[
\begin{array}{c}
\text{Vhc_spd (m/s)} \\
0 & 2 & 4 & 6 & 8 & 10 & 12 \\
\end{array}
\]

\[
\begin{array}{c}
\text{Vhc_dec (m/s}^2) \\
-0.5 & 0 & 0.5 & 1 \\
\end{array}
\]

\[
\begin{array}{c}
\text{MC_press (bar)} \\
0 & 2 & 4 & 6 & 8 & 10 \\
\end{array}
\]

\[
\begin{array}{c}
\text{Ped_strk (mm)} \\
-5 & -2.5 & 0 & 2.5 & 5 \\
\end{array}
\]

\[
\begin{array}{c}
\text{Ped_eff (mm)} \\
-5 & -2.5 & 0 & 2.5 & 5 \\
\end{array}
\]

\[
\begin{array}{c}
\text{Front_top} \\
\text{Front_axle} \\
\text{Driver} \\
\text{Rear_axle} \\
\text{Rear_top} \\
\end{array}
\]

\[
\begin{array}{c}
\text{High_1m/s}^2 \\
\text{High_2m/s}^2 \\
\text{High_3m/s}^2 \\
\text{High_4m/s}^2 \\
\text{High_5m/s}^2 \\
\text{High_6m/s}^2 \\
\text{High_7m/s}^2 \\
\text{High_8m/s}^2 \\
\end{array}
\]
Graph 23: FSGP 50 km/h – brake stop No.2

$V_{\text{ini.}} (50-0) \text{km/h}$

Pad Temp. = 100 °C
Graph 24: FSGP 50 km/h – brake stop No.3

$V_{inl.}(50-0) km/h$  
Pad Temp. = 100 °C
Graph 25: 

**FSGP 100 km/h – brake stop No.1**

| Vinit.(100-0)km/h | Pad Temp. = 100 °C |

![Graph showing various measurements including vehicle speed, pressure, and other parameters over time and distance to driver.](image-url)
Graph 26: FSGP 100 km/h – brake stop No.2
V_{init.}\ (100-0)\ km/h \hspace{1cm} \text{Pad Temp.} = 100\ ^\circ\ C
Graph 27: FSGP 100 km/h – brake stop No.3

V Init.(100-0)km/h  Pad Temp. = 100 °C
Graph 28: FSGP 200 km/h – brake stop No.1

V_{init}(200-0) km/h | Pad Temp. = 100 °C

---

Vhc_spd  Vhc_dec  MC_press  Ped_strk  Ped_eff  Pitch  Pitch_Rate  Front_axle  Rear_axle

Front_top  Front_axle  Driver  Rear_axle  Rear_top

Pitch  Pitch_Rate

---

High_1m/s2  High_2m/s2  High_3m/s2  High_4m/s2  High_5m/s2  High_6m/s2  High_7m/s2  High_8m/s2
Graph 29: FSGP 200 km/h – brake stop No.2
V_{init.}(200-0) km/h  Pad Temp. = 100 °C

Vhc_spd  Vhc_dec  MC_press  Ped_strk  Ped_eff
Front_top
Front_axle
Driver
Rear_axle
Rear_top
Pitch
Pitch_Rate
Front_axle
Rear_axle

High (mm)
Dec (m/s^2)
Vhc_spd
Vhc_dec
MC_press
Ped_strk
Ped_eff
High_1m/s^2
High_2m/s^2
High_3m/s^2
High_4m/s^2
High_5m/s^2
High_6m/s^2
High_7m/s^2
High_8m/s^2

Distance to driver (mm)
Graph 30: FSGP 200 km/h – brake stop No.3

\[ V_{ini.}(200-0) \text{km/h} \quad \text{Pad Temp.} = 100 \, ^\circ \text{C} \]
5.2.6 Deceleration build-up

Graph 31: Friction increase with constant pressure

$V_{inl.}(60-0)\text{km/h}$  Pad Temp. = $100^\circ\text{C}$
5.3 *Straight line stability*

**Graph 32:**

*Straight line stability test - brake stop No.1*

\[ V_{\text{ini.}} (140-0) \text{km/h} - \text{DOW} \]

*Application speed 1g/s*

- **Position X (m)**
- **Position Y (m)**
- **Time (s)**
- **vx**
- **Ped_eff**
- **MC_press**
- **FL_press**
- **FR_press**
- **RL_press**
- **RR_press**

**Max. Dev. = 0.2 m**

**Track mapping**

Point at 70 km/h

Braking point

SBE_05
Graph 33: Straight line stability test - brake stop No.2

V_{init.} (140-0) km/h - DOW

Application speed 1g/s

Max. Dev. = 0.6 m

Braking point

Track mapping

Point at 70 km/h

vx
Ped_eff
MC_press
FL_press
FR_press
RL_press
RR_press

pos_Yc
yawR

Vhc_dec

yaw rate at 1s.: -0.39 deg/s

Brake benchmarking test of
A - Vehicle

SBE_09
Graph 34: Straight line stability test - brake stop No.1

V<sub>ini</sub>.(140-0)km/h - DOW | Application speed 3 g/s

Brake benchmarking test of
A - Vehicle

Track mapping
Max. Dev.= 0.3 m

SBE_22
Graph 35: **Straight line stability test - brake stop No.2**

\[ V_{init}(140-0) \text{km/h} - \text{DOW} \quad \text{Application speed 3 g/s} \]

- **Position X (m)**: -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5
- **Position Y (m)**: 1, 2, 3, 4, 5, 6
- **Time (s)**: 0, 50, 100, 150, 200

- **Braking point**: Point at 70 km/h
- **Track mapping**: Max. Dev. = 0.3 m

- **Values**:
  - \( v_x \)
  - \( \text{Ped eff} \)
  - \( \text{MC press} \)
  - \( \text{FL press} \)
  - \( \text{FR press} \)
  - \( \text{RL press} \)
  - \( \text{RR press} \)
  - \( \text{pos_Yc} \)
  - \( \text{yawR} \)
  - \( \text{Vhc dec} \)

---

**Brake benchmarking test of A - Vehicle**

*SBE_25*
Graph 36: Straight line stability test - brake stop No.1

V_{init}(140-0)km/h - DOW  Application speed 5 g/s

- Braking point: Point at 70 km/h
- Track mapping:
  - Max. Dev. = 0.8 m

Pos. X (m) | Pos. Y (m) | Max. Dev. = 0.8 m

- Yaw rate at 1s.: -0.37 deg/s

- Position X (m): -5 to 5
- Position Y (m): -5 to 5
- Time (s): 0 to 200
Graph 37: Straight line stability test - brake stop No.2
V_{init.}(140-0)km/h - DOW  Application speed 5 g/s

- **vx**
- **Ped_eff**
- **MC_press**
- **FL_press**
- **FR_press**
- **RL_press**
- **RR_press**

**Track mapping**
- Braking point: Point at 70 km/h
- Max. Dev.: 0.5 m

**Braking point**
- Position Y (m)
- Position X (m)

**Track mapping**
- Position Y (m)
- Position X (m)
Graph 38: Straight line stability test - brake stop No.1

V_{inl.}(200-0)km/h - DOW  
Application speed 1 g/s

---

Graph 38:

**Straight line stability test - brake stop No.1**

<table>
<thead>
<tr>
<th>V_{inl.}(200-0)km/h - DOW</th>
<th>Application speed 1 g/s</th>
</tr>
</thead>
</table>

---

**Graph Details:**

- **Braking point:** Point at 100 km/h
- **Track mapping:**
  - Maximum Deviation: 0.9 m

---

Graph 38:

- **Graph 1:**
  - **Vx:**
  - **Ped_eff:**
  - **MC_press:**
  - **FL_press:**
  - **FR_press:**
  - **RL_press:**
  - **RR_press:**

- **Graph 2:**
  - **Pos_Yc:**
  - **yawR:**

- **Graph 3:**
  - **Vhc_dec:**

---

**Graph Analysis:**

- **Max. Dev.:** 0.9 m

---

SBE_32
Graph 39: Straight line stability test - brake stop No. 2

\( V_{inl.}(200-0) \text{km/h} - \text{DOW} \)  
Application speed 1 g/s

- Track mapping
  - Braking point
  - Track mapping Point at 100 km/h
  - Max. Dev. = 1.1 m

- Yaw rate at 1s.: -0.94 deg/s

- Yaw rate at 1s.: -0.94 deg/s

- Vhc dec

- Track mapping
  - Braking point
  - Track mapping Point at 100 km/h
  - Max. Dev. = 1.1 m

SBE_34
Graph 40: Straight line stability test - brake stop No.1

| V_{inl.}(200-0)km/h - DOW | Application speed 3 g/s |

- Braking point: Point at 100 km/h
- Track mapping: Max. Dev. = 0.7 m
- Yaw rate at 1s.: 0.73 deg/s
- Track mapping: Max. Dev. = 0.7 m

SBE_29
Brake benchmarking test of
A - Vehicle

Graph 41: Straight line stability test - brake stop No.2
V_{int.}(200-0)km/h - DOW
Application speed 3 g/s

Observable parameters:
- \(v_x\)
- \(\text{Ped}_{\text{eff}}\)
- MC_press
- FL_press
- FR_press
- RL_press
- RR_press

Graphs:
1. \(v_x\) vs. time (s)
2. Yaw rate at 1s: -0.87 deg/s vs. time (s)
3. \(V_{hc\_dec}\) vs. time (s)
4. Track mapping: Braking point at 100 km/h

Track mapping:
- Max. Dev. = 0.3 m

SBE_31
5.4 Stopping distance test

Graph 42: Test sequence

A - Vehicle - Stopping distances

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>48.7</td>
<td>29.1</td>
<td>23.0</td>
<td>42.3</td>
<td>31.0</td>
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<tr>
<td>Wet</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Graph 43: Temperature and wet effect

A - Vehicle - Stopping distances

- Dry: 0.110 m/ºC
- Wet: 0.032 m/ºC
### 5.4.1 Tyre bedding

#### Graph 44: Tyre bedding

<table>
<thead>
<tr>
<th>Measured</th>
<th>Calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Vx (km/h) dx (m) ax (m/s²) dcx (m)</td>
<td></td>
</tr>
<tr>
<td>1 99.9 43.5 8.86 43.6</td>
<td></td>
</tr>
<tr>
<td>2 99.9 42.7 9.02 42.8</td>
<td></td>
</tr>
<tr>
<td>3 99.0 42.0 9.00 42.9</td>
<td></td>
</tr>
<tr>
<td>4 99.5 42.4 9.00 42.9</td>
<td></td>
</tr>
<tr>
<td>5 100.3 43.5 8.93 43.2</td>
<td></td>
</tr>
<tr>
<td>6 100.7 43.8 8.93 43.2</td>
<td></td>
</tr>
<tr>
<td>7 100.6 43.0 9.08 42.5</td>
<td></td>
</tr>
<tr>
<td>8 100.2 43.0 9.00 42.9</td>
<td></td>
</tr>
<tr>
<td>9 100.5 43.1 9.03 42.7</td>
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</tr>
<tr>
<td>10 100.7 43.8 8.93 43.2</td>
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<tr>
<td>11 100.3 43.0 9.01 42.9</td>
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<tr>
<td>12 99.8 41.6 9.24 41.7</td>
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<td>13 100.3 42.2 9.18 42.0</td>
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<tr>
<td>14 100.2 42.8 9.05 42.6</td>
<td></td>
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<tr>
<td>15 99.8 42.0 9.15 42.2</td>
<td></td>
</tr>
</tbody>
</table>

Mean: Vx: 9.03 dx: 42.7
Means: Tasph: 49 ºC Tamb: 29 ºC Hum %: 47 Wind vel = 4.8 m/s
Std. Deviation: 0.10 dx: 0.49

#### Table 8: Tyre bedding data

<table>
<thead>
<tr>
<th>No.</th>
<th>Vx1 V1</th>
<th>dxm</th>
<th>Δv V10</th>
<th>V2</th>
<th>Δv V10</th>
<th>Spd Ap (10-5)</th>
<th>Fm</th>
<th>dm</th>
<th>Init. Temp.</th>
<th>Init. Temp.</th>
<th>Time</th>
<th>Asphalt T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km/h</td>
<td>m</td>
<td>km/h</td>
<td>m</td>
<td>m</td>
<td>daN/s daN m/s² °C °C s ºC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>99.9</td>
<td>43.5</td>
<td>89.9</td>
<td>4.9</td>
<td>12.3</td>
<td>30.9 336.6 104.5 10.1 128.2 85.3 0.282 49.0</td>
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<tr>
<td>2</td>
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<td>42.7</td>
<td>89.8</td>
<td>5.0</td>
<td>11.8</td>
<td>30.5 480.0 108.0 10.2 93.2 61.7 0.260 48.3</td>
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<td>42.0</td>
<td>88.8</td>
<td>5.0</td>
<td>11.5</td>
<td>30.1 358.2 101.8 10.1 106.8 74.0 0.280 49.8</td>
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<td>99.5</td>
<td>42.4</td>
<td>89.4</td>
<td>4.9</td>
<td>12.0</td>
<td>30.1 363.7 111.5 10.2 116.0 84.5 0.266 49.4</td>
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<tr>
<td>5</td>
<td>100.3</td>
<td>43.5</td>
<td>90.3</td>
<td>4.9</td>
<td>12.5</td>
<td>30.7 292.9 111.5 10.4 119.2 85.8 0.280 49.0</td>
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<tr>
<td>6</td>
<td>100.7</td>
<td>43.8</td>
<td>90.6</td>
<td>5.0</td>
<td>12.8</td>
<td>30.6 250.8 105.6 10.4 101.8 72.4 0.290 49.0</td>
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<tr>
<td>7</td>
<td>100.6</td>
<td>43.0</td>
<td>90.6</td>
<td>4.9</td>
<td>11.8</td>
<td>30.8 388.4 119.7 10.4 110.3 79.1 0.246 49.0</td>
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<tr>
<td>8</td>
<td>100.2</td>
<td>43.0</td>
<td>90.1</td>
<td>5.0</td>
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<td>30.6 327.5 120.8 10.2 114.5 83.3 0.268 49.2</td>
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5.4.2 Stopping distance: dry asphalt

Graph 45:

**Dry asphalt**

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Mean: 9.35, 41.3

Std. Deviation: 0.08, 0.34

Means: Tasph = 29 ºC, Tamb = 25 ºC, Hum % = 52, Wind vel = 0.6 m/s

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**Dry asphalt (LOWEST TEMPERATURE)**

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Mean: 9.23, 41.8

Std. Deviation: 0.05, 0.21

Means: Tasph = 42 ºC, Tamb = 29 ºC, Hum % = 47, Wind vel = 4.0 m/s

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**Tab 9:**

**Stopping distance data on dry asphalt**

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**Dry asphalt**

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5.4.3 Stopping distance: wet asphalt

Graph 46:

**WET ABS TRACK (LOWEST TEMPERATURE)**

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Mean: 7.67 50.3

Means: Tasph= 23 ºC Tamb= 20 ºC Hum %= 69 Wind vel = 0.6 m/s

Std. Deviation: 0.09

**WET ABS TRACK (HIGHEST TEMPERATURE)**

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Mean: 7.54 51.1

Means: Tasph= 31 ºC Tamb= 29 ºC Hum %= 43 Wind vel = 3.9 m/s

Std. Deviation: 0.12

**Tab 10:** Stopping distance data on wet asphalt

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5.5 \( \mu \)-split

5.5.1 Close loop test

**Graph 47.** \( \mu \)-split close loop test – brake stop 1

![Graph showing \( \mu \)-split close loop test results](image)

- **vx**
- **Ped_eff**
- **Ped_strk**
- **MC_press**
- **FL_press**
- **FR_press**
- **RL_press**
- **RR_press**

- **pos_Yc**
- **yawR**

- **Steering angle**
- **Vhc_dec**

- **Braking point**
- **Track mapping**
Graph 48.  **ABS μ-split close loop test - brake stop 2**

[Graph showing various parameters over time, including:
- vx
- Ped_eff
- Ped_strk
- MC_press
- FL_press
- FR_press
- RL_press
- RR_press
- pos_Yc
- yawR
- Steering angle
- Vhc_dec
- Braking point
- Track mapping]
Graph 49. **ABS μ-split close loop test – brake stop 3**

**Graph Details:**
- **Graph 2:** pos_Yc, yawR over time.
- **Graph 3:** Steering angle, Vhc_dec over time.
- **Graph 4:** Position Y, Track mapping over Position X.

**Graph Titles:**
- Braking point
- Track mapping

**Graph Legend:**
- vx
- Ped_eff
- Ped_strk
- MC_press
- FL_press
- FR_press
- RL_press
- RR_press
- pos_Yc
- yawR
- Steering angle
- Vhc_dec

**Graph Axes:**
- Position X (m)
- Position Y (m)
- time (s)
- (deg/s)
- (deg)
- (m/s²)

**Graph Units:**
- Bar, km/h, daN
- (bar, km/h, daN)
- (deg/s)
- (deg)
- (m/s²)
Graph 50.  **ABS μ-split close loop test - brake stop 4**

![Graph of ABS μ-split close loop test - brake stop 4]
Graph 51.  **ABS µ-split close loop test - brake stop 5**

- vx
- Ped_eff
- Ped_strk
- MC_press
- FL_press
- FR_press
- RL_press
- RR_press
- pos_Yc
- yawR
- Steering angle
- Vhc_dec
- Braking point
- Track mapping

**musplit_023**
### 5.5.2 Close loop test (slow application)

#### Slow application (100 - 150 mm/s)

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<th>State</th>
<th>Measurement No.</th>
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*Table 11. Final results*

#### Medium application (250 - 300 mm/s)

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</table>

*Table 12. Final results*
Graph 52.  

ABS µ-split close loop test (100-150 mm/s) – brake stop 1

[Graph showing various parameters over time, including vx, Ped_eff, Ped_strk, MC_press, FL_press, FR_press, RL_press, RR_press, pos_Yc, yawR, Steering angle, Vhc_dec, Braking point, Track mapping, musplit_025]
Graph 53. **ABS μ-split close loop test (100-150 mm/s) – brake stop 2**

[Graph showing various test parameters and data, including:
- vx
- Ped_eff
- Ped_strk
- MC_press
- FL_press
- FR_press
- RL_press
- RR_press
- pos_Yc
- yawR
- Steering angle
- Vhc_dec
- Braking point
- Track mapping]
Graph 54. ABS μ-split close loop test (100-150 mm/s) – brake stop 3

Braking point
Track mapping

musplit_032
Graph 55. ABS µ-split close loop test (250-300 mm/s) – brake stop 1

Braking point  Track mapping
Graph 56. **ABS μ-split close loop test (250-300 mm/s) – brake stop 2**

|----|--------|---------|----------|----------|----------|----------|----------|

<table>
<thead>
<tr>
<th>pos_Yc</th>
<th>yawR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steering angle</td>
<td>Vhc_dec</td>
</tr>
</tbody>
</table>

**Braking point**

**Track mapping**

musplit_031
Graph 57. **ABS μ-split close loop test (250-300 mm/s) –brake stop 3**

**Graph Details:**
- **Graphs:**
  - Top graph: shows various parameters over time, including brake pressure, steering angle, and vehicle deceleration.
  - Middle graphs: focus on specific parameters like position and yaw rate.
  - Bottom graph: illustrates track mapping with braking points marked.

**Parameters:**
- **Parameters Monitored:**
  - vx
  - Ped_eff
  - Ped_strk
  - MC_press
  - FL_press
  - FR_press
  - RL_press
  - RR_press
  - pos_Yc
  - yawR
  - Steering angle
  - Vhc_dec
  - Braking point
  - Track mapping
  - musplit_035


5.5.3 Open loop test

Graph 58. **ABS µ-split open loop test – brake stop 1**

Graph 59. **ABS µ-split open loop test – brake stop 2**
Graph 60. **ABS µ-split open loop test – brake stop 3**

- FL pressure at 1s.: 42.7 bar
- RL pressure at 1s.: 17.2 bar
- Yaw rate at 1s.: 10.5 deg/s

Graph 61. **ABS µ-split open loop test – brake stop 4**

- FL pressure at 1s.: 38.7 bar
- RL pressure at 1s.: 16.5 bar
- Yaw rate at 1s.: 11 deg/s
Graph 62.  **ABS µ-split open loop test – brake stop 5**

**FL pressure at 1s.: 23 bar**  
**RL pressure at 1s.: 10.9 bar**

**Yaw rate at 1s.: 10.5 deg/s**  
**Steering angle**