Asphalt Manager
Intelligent Compaction
WHAT IS INTELLIGENCE

1) Collect Information

2) Use the Collected Information to Make a Decision

3) Execute the Decision
Surface Covering Compaction Measurement

1983 Terrameter BTM 01 (OMEGA)

1993 Guidelines for Surface Covering Measurements
   National Research Association

1994 ZTVE / TP BF-StB 94, proof methods FDKV/SCCC

1996 Compaction Management System BCM 03

1998 VARIOCONTROL

2001 Measuring device for evaluation of stiffness (Evib)

2004 Modular Measuring System with GPS support
BOMAG Compaction Technology

1996 Variomatic for asphalt rollers
1998 Variocontrol for soil rollers
2000 Evib (MN/m²)
2001 Asphalt Manager
2004 Research project of German DOT (BAST), Oct / Nov. 2004;
VARIOMATIC roller with directed vibration

Control unit

low dynamic energy

Compaction principle
static pressure and dynamic energy which is automatically adjusted to type of material, compactibility, layer thickness and base layer conditions.

high dynamic energy

Applications: asphalt layers, granular bases and subbases.
Worldwide proven design:

Several hundreds Tandem rollers

BW 151 AD-2

BW 174 AD
Non Directed Forces:
Vibration Systems

Rotary exciter

Oscillation

directed
Vibration Systems

Rotary exciter  Oscillation  directed
## Vibration systems / Overview

<table>
<thead>
<tr>
<th>Vibration</th>
<th>Oscillation</th>
<th>Variomatic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Principle</strong></td>
<td>Rotary exciter with</td>
<td>2 rotary exciters with</td>
</tr>
<tr>
<td></td>
<td>unbalanced weight</td>
<td>2 unbalanced weight</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Oscillation</strong></td>
<td>non directed</td>
<td>directed</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>horizontally</td>
</tr>
<tr>
<td><strong>Amplitudes</strong></td>
<td>up to 8</td>
<td>2 fixed amplitudes</td>
</tr>
<tr>
<td></td>
<td>up to 1,3 mm</td>
<td>ca. 1,3 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Frequencies</strong></td>
<td>35 - 70 Hz</td>
<td>33 - 42 Hz</td>
</tr>
<tr>
<td><strong>Control system</strong></td>
<td>manual</td>
<td>manual</td>
</tr>
</tbody>
</table>
Comparison:

**Rotary exciter**
(no infinite variation)

**Variomatic**
(automatic compaction)
Advantages vs. Rotary exciter:

- Better depth effect
- Excellent Asphalt surfaces
  - Eveness
  - Grip / roughness
Benefits for contractors:

- Universal use on
  - Road base
  - Wearing course layers
  - Thin layers
- Higher compaction performance
- Uniform compaction, even on sub-bases with inhomogeneous stiffness
- Better eveness and more uniform surface structure
- Low tendency to scuffing
Compaction of 6 cm asphalt binder course 0/10, RN13 France
Operating weight and compaction technique affect smoothness and eveness

15 t tandem vibratory roller
8 passes

8 t BOMAG VARIOMATIC BW 151 AD
8 passes
Density and roughness measurement on asphalt binder layer

Punctual compaction measurement with portable isotope probe

Continuous compaction measurement with mobile isotope probe
[1 measurement / 10 m]
## Comparison between conventional compaction concept and VARIOMATIC

<table>
<thead>
<tr>
<th>Compaction</th>
<th>Roughness</th>
<th>Sand spot method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable isotope probe</td>
<td>Mobile isotope probe [1 measurement/10 m]</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>X1</td>
<td>( \sigma )</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>4 passes with 25 t rubber tire roller and 4 passes with 15 t tandem vibratory roller</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>92,5 %</td>
<td>1,22</td>
</tr>
<tr>
<td><strong>8 passes with BW 151 AD-2 VARIOMATIC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>92,5 %</td>
<td>0,54</td>
</tr>
</tbody>
</table>

\( n = \) number of measurements, \( X1 = \) mean value of achieved Gyrator test compaction value (93% Gyrator value ~ 98% Marshall value), \( X2 = \) mean value of characteristic roughness value
1996
Variomatic

1998
Variomatic 2

advanced, more powerful
also for split drums!
Latest developments of compaction technology

1996  Variomatic for asphalt rollers

1998  Variocontrol for soil rollers

2000  Evib (MN/m²)

2001  Asphalt Manager
Directed Exciter System

Vibration motor

Exciter housing (slewable)

Unbalanced weights (counter rotating)
inner: No. 2 + 3
outer: No. 1 + 4

Compaction force

Travel motor

Slewing motor

Slide 19
Force Direction Control:
Infinite adjustment of exciter housing from horizontal to vertical.
Dynamischer Steifigkeitsmodul "Evib"
as flächendeckende Verdichtungskontrolle beim Fahren

Indikatordiagramm

Bodenkraft [kN]

Evib in [MNm²]

Schwingweg [mm]
$F_K \quad \rightarrow \quad E_{VIB}$

- $E_{VIB} = 242$ MN/m² (6. Übergang)
- $E_{VIB} = 158$ MN/m² (3. Übergang)
- $E_{VIB} = 86$ MN/m² (1. Übergang)
Continous compaction control for soil compaction

Exchange of energy between roller and soil
Asphalt Manager with new measuring value $E_{\text{VIB}}$ [MN/m$^2$] and temperature gauge
Acceleration meters

Force direction control
Benefits for Operators:

No critical decisions required

All operators achieve better results:
- good and uniform compaction

Continuous information on
- asphalt temperature
- compaction increase
Asphalt Manager: Easy to understand
<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>BW 141 / 151 AD AM</th>
<th>BW 190 / 203 AD AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oper. weight kg</td>
<td>8.000</td>
<td>8.400</td>
</tr>
<tr>
<td>Drum width in</td>
<td>59</td>
<td>66</td>
</tr>
<tr>
<td>Amplitudes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>front mm</td>
<td>0.96</td>
<td>0.95</td>
</tr>
<tr>
<td>rear mm</td>
<td>0.64 / 0.27</td>
<td>0.6 / 0.25</td>
</tr>
<tr>
<td>Frequencies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>front / rear Hz</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Centr. force kN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>front kN</td>
<td>160</td>
<td>168</td>
</tr>
<tr>
<td>rear kN</td>
<td>80 / 34</td>
<td>80 / 34</td>
</tr>
</tbody>
</table>

Front: AM    Rear: Std. Exciter
Bomag Operational Panel

Compaction Modes

Manual - Auto

Fixed vs. Variable

<table>
<thead>
<tr>
<th>Fixed</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,2 mm</td>
<td>0 - 0,2 mm</td>
</tr>
<tr>
<td>0,4</td>
<td>0 - 0,6</td>
</tr>
<tr>
<td>0,6</td>
<td>0 - 0,93</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fixed</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,08 in</td>
<td>0,08 in</td>
</tr>
<tr>
<td>0,24 in</td>
<td>0,24 in</td>
</tr>
<tr>
<td>0,37 in</td>
<td>0,37 in</td>
</tr>
</tbody>
</table>

Manual - Auto Compaction Modes

6 x | 3 x
Bomag Operational Panel

- Printer
  - Start
  - Stop
  - Print out
  - Delete

Test procedure:
- Mark the track to be compacted
- „Manual operation mode“ with
- Fixed amplitude
- Fixed working speed
Bomag Operational Panel

SETTINGS
- Escape
- Enter
Printer
$E_{\text{VIB}}$ Max. / $E_{\text{VIB}}$ Min.

$E_{\text{VIB}}$ Average

Frequency

Average Speed

Track length

Temperature
$E_{\text{VIB}}$ and Density as function of passes; BW 174 AD Asphalt Manager, Automatic mode; Asphalt Base 0/32 CS B65, Nürnberg A3
$E_{\text{VIB}}$ and Density as function of passes; BW 174 AD Asphalt Manager, Manual mode 4; Wearing course SMA 0/11S PmB45, Nürnberg A3

- $E_{\text{VIB}}$ [MN/m²], [°C]
- Evib
- Surface temp.
- Core temp.
- Troxler density

Passes

- 4 cm SMA 0/11 S
- 8 cm Binder 0/22
- > 10 cm ATS 0/32
Advantages:

- Immediate determination of dynamic stiffness in MN/m² ($E_{VIB}$)
- $E_{VIB}$ can be correlated with the increase of compaction
- $E_{VIB}$ is widely independent from roller parameters
- $E_{VIB}$ printouts for area covering compaction control

In Development:

- Target $E_{VIB}$ values to be pre-selectable
- „Ready“ indication if target value is achieved (red light)
- „Ready“ indication if no further compaction is possible (red light)
### Number of passes with vibratory rollers

#### Recommended figures:

<table>
<thead>
<tr>
<th>Layer thickness \ d [cm]</th>
<th>No. of passes with vibration of different tandem rollers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 t</td>
</tr>
<tr>
<td>2</td>
<td>2 - 4</td>
</tr>
<tr>
<td>4</td>
<td>4 - 6</td>
</tr>
<tr>
<td>6</td>
<td>4 - 8</td>
</tr>
<tr>
<td>10</td>
<td>6 - 8</td>
</tr>
<tr>
<td>14</td>
<td>--</td>
</tr>
<tr>
<td>18</td>
<td>--</td>
</tr>
<tr>
<td>SMA (Stone mastix) \ d = 2</td>
<td>--</td>
</tr>
<tr>
<td>Porous asphalt \ d = 4</td>
<td>--</td>
</tr>
</tbody>
</table>

L = low amplitude, H = high amplitude

Assumption: Compaction temperature > 100°C

3 t = Machine with only the amplitude
Further advantages:
better gradability - less shoving effect

Automatic force adaption with travel direction
Evib (MN/m²) Vibration modulus

Equivalent for dynamic Stiffness;

Directly picked up by the roller;

Physical value for compaction increase on asphalt.
Benefits for Contractors: Investment for Profit

Compaction
- Uniform and predictable results while rolling
- Avoids under / overcompaction
- Better eveness and roughness
- Eliminates drum bouncing

Economical and quality aspects
- More efficient roller utilization with fewer passes
- Reduced shock loads in sensitive environment
  e.g. buildings, bridges
- Area coverage method
Temperature development

Base course - Temperature profile vs. No. of passes

Temperature [°C] vs. No. of passes

Thickness [mm]

Compaction test on asphalt wearing course (stone mastix asphalt)

Perfect correlation:
Evib + Marshall density

Adequate conditions:
- Temperature between (170-120 °C)
- Asphalt layer on solid ground
Compaction test on asphalt wearing course (stone mastix asphalt)

Increase of Evib = Increase of compaction
Comfort + Quality:

Compaction of joints hot against cold

- avoids shock loads
- no bouncing
- better eveness
Leipzig:

“Augustusplatz”

Compaction on a parking roof top;

Alternatives:

15 t static roller - 15 cm layers
With BVM - 40 cm layers
Avoids shock loads on bridges and near buildings

Depth control via force adjustment

• 3 automatic control ranges
• 6 manual force directions (fixed)
<table>
<thead>
<tr>
<th>FEATURES</th>
<th>BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modular Design Principle:</td>
<td>Less Expenses for Warehousing, Training, and Logistics;</td>
</tr>
<tr>
<td>- Operator Platform</td>
<td></td>
</tr>
<tr>
<td>- Central Electric System</td>
<td></td>
</tr>
<tr>
<td>- Travel- / Vibration Pumps</td>
<td></td>
</tr>
<tr>
<td>and Motors</td>
<td></td>
</tr>
<tr>
<td>- Support Legs</td>
<td></td>
</tr>
</tbody>
</table>
Racing Course „Sachsenring“

Perfect Results:

- Roughness
- Eveness
**Application soil compaction**

Support for compaction works and measuring paths on sub-grade, frost blanket layers and non-bonded bearing layers: the $E_{vib}$ value increases with increasing compaction. Weak spots are localized.

**Application asphalt compaction**

Support for compaction works on asphalt layers. If compaction is performed within a narrow temperature range (e.g. 120° – 150°C) and the sub base is of sufficient stability, $E_{vib}$ will show the increase in compaction. A direct statement on the density is only possible after performing comparison measurements with an isotope probe (Troxler). Compaction force and depth effect can be adapted to the layer to be compacted and to the substrate (see matrix of recommended applications).

<table>
<thead>
<tr>
<th>Condition of the substrate</th>
<th>Setting</th>
<th>Asphalt bearing course</th>
<th>Asphalt binder</th>
<th>Asphalt pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Easy to compact</td>
<td>Difficult to compact</td>
</tr>
<tr>
<td>evenly firm (stable)</td>
<td>Automatic: Force level</td>
<td>3</td>
<td>2-3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>alternative: Manual*: Position</td>
<td>6-3</td>
<td>4-3</td>
<td>5-3</td>
</tr>
<tr>
<td></td>
<td>Compaction temperature</td>
<td>&gt; 80°C</td>
<td>&gt; 80°C</td>
<td>&gt; 100°C</td>
</tr>
<tr>
<td>yielding (soft)</td>
<td>Automatic: Force level</td>
<td>2</td>
<td>1-2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>alternative: Manual*: Position</td>
<td>4-2</td>
<td>3-2</td>
<td>3-2</td>
</tr>
<tr>
<td></td>
<td>Compaction temperature</td>
<td>&gt; 80°C</td>
<td>&gt; 80°C</td>
<td>&gt; 100°C</td>
</tr>
<tr>
<td>Layers on bridges</td>
<td>Automatic: Force level</td>
<td>1-2</td>
<td>1-2</td>
<td>1-2</td>
</tr>
<tr>
<td></td>
<td>alternative: Manual*: Position</td>
<td>3-2</td>
<td>2-1</td>
<td>2-1</td>
</tr>
<tr>
<td></td>
<td>Compaction temperature</td>
<td>&gt; 80°C</td>
<td>&gt; 80°C</td>
<td>&gt; 100°C</td>
</tr>
</tbody>
</table>

Temperature specifications related to the asphalt surface, * in manual mode start with higher level first, and reduce after.
Display, direction of vibrations

EVIB display

Temperature gauge

Emergency switch

Display of vibration direction and amplitude
shows the direction of drum vibration and the size of the vertical amplitude

EVIB display
EVIB shows the dynamic stiffness of the material to be compacted in MN/m²
- EVIB responds to changes in density. With increasing density the asphalt becomes firmer (stiffer). The EVIB value increases.
- EVIB responds to temperature changes. With dropping temperature the asphalt becomes firmer (stiffer), even if the end of compaction is not yet reached. EVIB increases with decreasing temperature.
- EVIB responds to deviations in the stiffness of the substrate (base layer). On a soft substrate and with a pre-selected high force level the EVIB may remain low.

Temperature gauge
The temperature is permanently detected as asphalt surface temperature. Depending on layer thickness, ambient temperature and wind force the mix temperature inside the core of the layer may be up to 40°C higher. At a surface temperature of 80°C compaction should be completed.

Emergency switch
In case of an electronics failure the emergency switch enables the selection of two vibration directions: horizontal (left) or vertical (right)
Asphalt Manager + BOMAG GPS System

- Surface covering compaction control on asphalt layers
- GPS receiver
- GPS reference station
- Roller PC for data managing and graphical representation of roller position and stiffness values
- Position accuracy: better than 10 cm
- CAD based evaluation program
Roller positioning with total station (Geodimeter) for continuous compaction control on asphalt layers
Evib Messung mit GPS-Unterstützung
Determination of roller positions with GPS

Reference station on the job site
  High accuracy: up to 5 cm

GPS Reference service with reference satellite
  Accuracy: up to 100 cm
  > OmniSTAR (world wide) ~ 1500,- Euro annual charge
  > EGNOS (Europe, not yet in operation) free of charge
  > WAAS (North America)

Local Reference network (reference service)
  High accuracy: up to 5 cm (depending on service)
  > Ascos (since 2001, Ruhrgas / Germany,
    (only available in Rhine Area)
GPS / positioning with Reference Station

- Two GPS Antenna
- Reference station (Trimble)
- High accuracy (5cm)
- RTK (real time)
- BCM 05 positioning software