

# Basic Principles of Asphalt Compaction

Compaction methods  
Compaction equipment  
Rolling technique



### **Masthead**

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# Foreword

The asphalt layers of a road pavement should be able to reliably carry the traffic loads and to discharge these to the substructure or subbase, in order to prevent harmful deformation. This equally applies for load burdens resulting from weather and temperature stress. Besides the mix composition and the paving, the compaction of the mix is of utmost importance with respect to the quality and the service life of the road. On the construction site successful compaction mainly depends on the compaction technique, the knowledge and the experience of the roller driver.

In this book we present an overview of compaction techniques and equipment. It contains explanations to the different rolling patterns and a number of basic rules and notes for successful compaction of rolled asphalt. The BOMAG Asphalt Compaction Handbook should serve as source of information for practitioners involved in pavement construction and facilitate the use of compaction equipment in asphalt construction.

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# 1. Basic principles of asphalt compaction

## 1.1 Principles

Rolled asphalts are divided into base courses, asphalt binder courses and asphalt wearing courses. Asphalt concrete, stone mastic asphalt and porous asphalts are used for asphalt wearing courses.

The laid mix must be compacted to such a degree that an increase in density or a reduction of porosity in the asphalt layer is achieved. On this air voids

one must make sure that the demanded degree of compaction is reached and that the limit values for the void content are complied with.

This results in an enhanced stability of the layers and thus in a higher resistance against deformation. Good compaction also has a positive effect on the wear resistance of the wearing course.

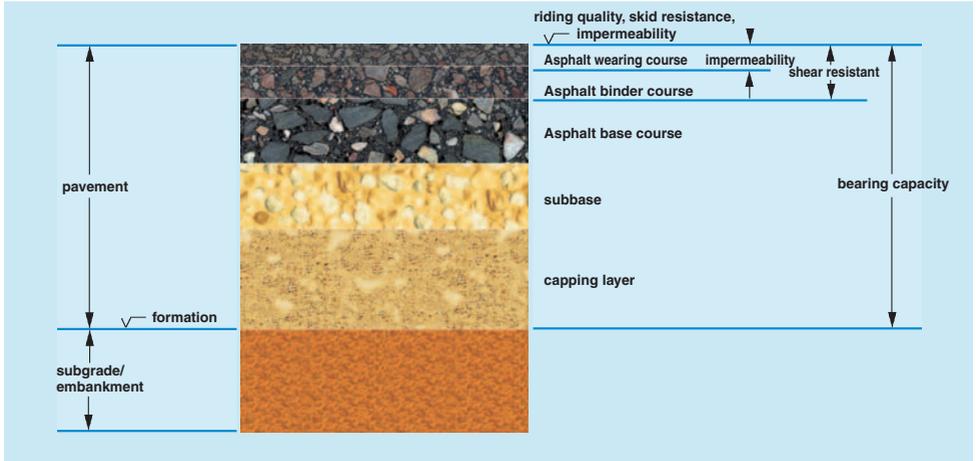


Fig. 1 Structure and properties of an asphalt road

At the same time the compaction machine should produce a level asphalt layer as desired for driving comfort, and a wearing course with closed and smooth surface structure, but with maximum grip.

Objectives of compaction	
Compaction performance	Quality characteristics
Higher density	Evenness
Defined air voids	Skid resistance
High stability and wear resistance	Closed surface

Fig. 2 Objectives of compaction

## 1.2 Influence of the mix composition

The composition of asphalt mixes varies widely in dependence on the expected loads caused by traffic and weather. They therefore also have quite different compaction properties. The compactibility of the

asphalt mix depends on the composition of minerals as well as the quality and viscosity of the bitumen and thus also on the temperature of the mix.

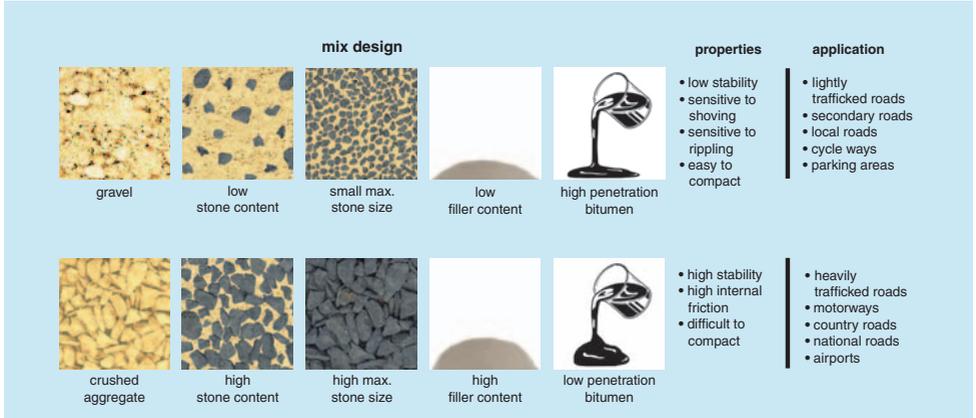


Fig. 3 Composition of asphalt mix

Asphalt mixes for roads with high traffic loads are designed for high deformation resistance. They are characterized by a bulky mineral skeleton structure, i.e. high stone contents, coarse grain, a high proportion of crushed grains in the sand range (crushed sand) and stiff bituminous mortar. These mixes are difficult to compact and require high compaction efforts.

Asphalt mixes for roads with low traffic volumes normally contain a lower proportion of stones, a considerably high amount of natural sand and soft bituminous mortar.

They are normally easy to compact, therefore do not require high compaction efforts, but, due to their lacking stability when hot after laying, may react very sensitively to the use of heavy compaction equipment or to a too early start of compaction work.

This may quickly result in material displacements and the formation of bow waves.

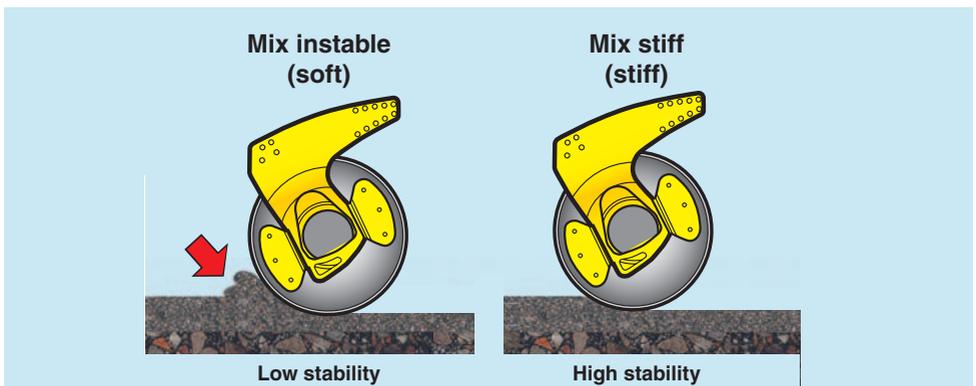


Fig. 4 Rolling behaviour with different asphalt mixes

### 1.3. Influence of the mix temperature

The temperature of the mix during compaction is of high significance for the compaction effort required. With too high mix temperatures the compaction by a roller is supported by the low viscosity of the bitumen. The bitumen acts as a lubricant and reduces the internal friction in the mineral mix. Due to the progressing stiffening of the bitumen caused by cooling, the compaction effort increases considerably under low temperatures.

Compaction therefore should, as a general rule, be started as soon as possible. Compaction temperatures between 100° and 140°C have been found most favourable for the conventional bitumen types. Compaction should be completed when the temperature has dropped to between 80° and 100°C.

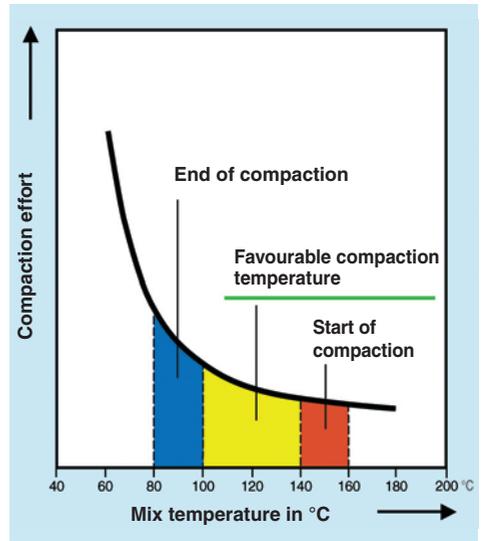


Fig. 5 Effect of the compaction temperature on the compaction effort

## 2. Compaction methods

### 2.1 Initial compaction with the finisher

With a low pre-compaction by the finisher the use of a light roller to initially press down the mix is a very sensible decision, because too heavy roller may adversely affect the evenness of the layer and, depending on the stability of the hot mix, may cause undesired displacements and misplacements in the material.

In such a case tandem vibratory rollers should drive the first two passes without vibration.

High initial compaction by the finisher has a favourable effect on the evenness of the layer and, at the same time, enables an early start of compaction, while the mix temperatures are still high. This favourably supports the compaction effect of the rollers, and final compaction can be achieved with only a few roller passes.



Fig. 6 Initial compaction by the finisher



Fig. 7 Laying and compacting with the BOMAG BF 600 P and the BOMAG BW 174 AD-AM

## 2.2 Static compaction

Static compaction is achieved by the deadweight of the roller. Tandem rollers and pneumatic tired rollers are used for this purpose. Compared with vibratory compaction the compaction effect is relatively low. With tandem rollers compaction is influenced by the static linear load (kg/cm) of the drum, with pneumatic tired rollers by the wheel load (t) and the tire inflation pressure (MPa).

Static compaction with tandem rollers makes sense if the initial compaction by the finisher was only low, if the asphalt mix is easy to compact, in case of porous asphalts and thin layers and when ironing wearing courses.

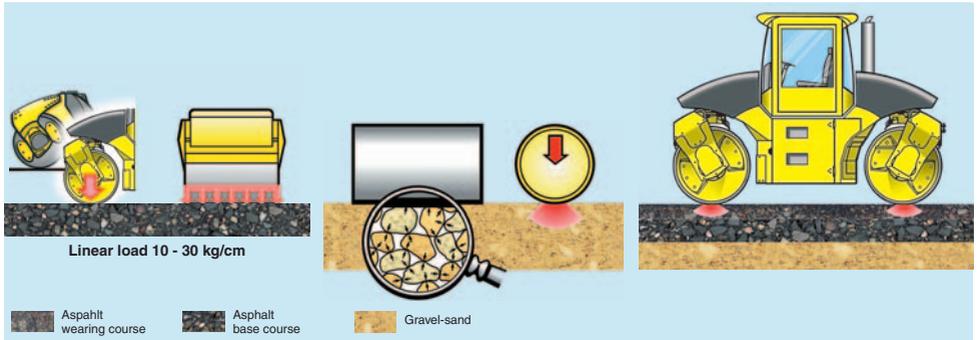


Fig. 8 Static compaction with tandem rollers

With the kneading and flexing effect of their wheels pneumatic tired rollers achieve a special quality in static compaction. It leads to a homogeneous distribution of the mix and closes the pores on the surface. The main areas of application are the pre-profiling and processing of easy to compact mixes

and the finish of the surfaces of wearing and base courses or of light traffic roads. Here the pneumatic tired roller is normally combined with a smooth drum roller.

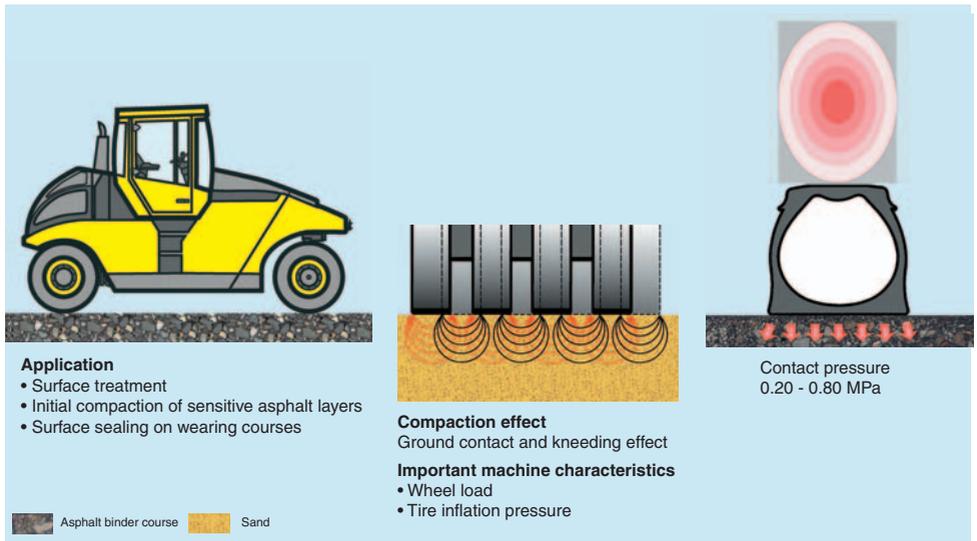


Fig. 9 Static compaction with pneumatic tired roller

## 2.3 Vibratory compaction

Vibratory rollers are very powerful, versatile and require considerably less passes than static rollers. The vibration reduces the internal friction in the mineral mix, so that the interaction between deadweight and dynamic load increases the density. Besides the static linear load, other factors like vibrating

mass, frequency and amplitude are therefore also decisive for the compaction effect.

For optimal compaction of different layer thicknesses bigger tandem vibratory rollers, in most cases with two amplitudes and two frequencies, are required.

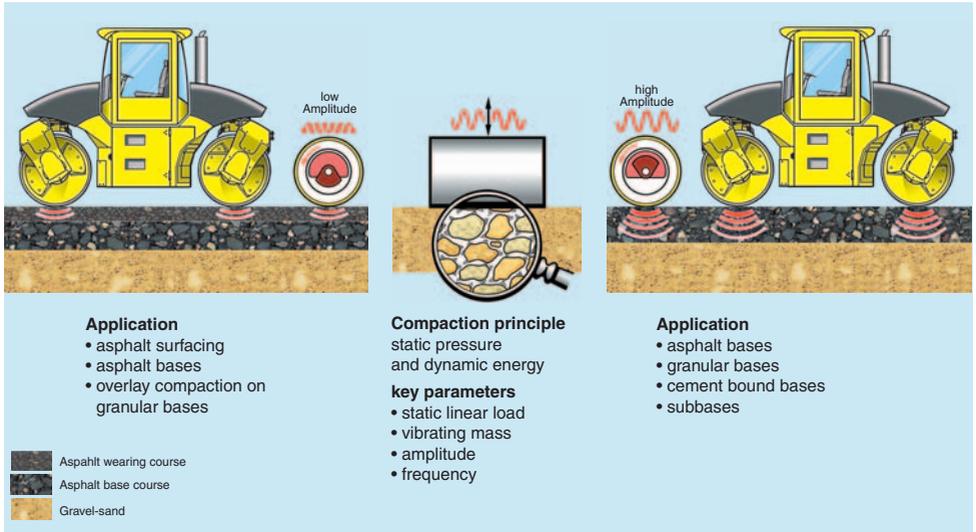


Fig. 10 Vibratory compaction using tandem rollers with circular exciter system

The rolling speed should be 3 to 6 km/h.

Too many passes with vibration can cause harmful loosening of material and disturbances in the structure.

Thickness of the asphalt layer d (cm)	Number of passes with vibration with various tandem vibratory rollers			K = low amplitude G = high amplitude Assumption: Compaction temperature > 100°C 4t = Machine with one amplitude only 1 pass = 1 pass in forward or in reverse direction
	4t	7t	10t	
2	2-4	1-2 (K)	1-2 (K)	
4	4-6	2-4 (K)	2-4 (K)	
6	4-8	4-6 (K)	2-4 (K)	
10	6-8	4-8 (K, G)	4-6 (K, G)	
14		6-8 (G)	4-6 (G)	
18		6-8 (G)	4-8 (G)	
Chip mastic d = 2		1-2 (K) + stat. pass	1-2 (K) + stat. pass	
d = 4		4-6 (K) + stat. pass	4-6 (K) + stat. pass	
porous asphalt d = 4			1-2 (K) + stat. pass	

Fig. 11 Typical values for the number of vibratory passes

## 2.4 Controlled compaction with ASPHALT MANAGER

With controlled compaction the required compaction energy is determined and automatically adjusted. In automatic mode no adjustments must be made by the driver. Rollers with ASPHALT MANAGER work with a directed exciter system; it is automatically regulated. During compaction the effective amplitude is optimally and continuously adapted to the actual conditions. Grain damages and disturbances in the structure of the asphalt are effectively prevented. Besides working in automatic mode, the roller driver is also able to pre-select a certain direction of vibration (manual mode).

There are six different directions available, ranging from vertical to horizontal (similar to oscillation). Due to their excellent adaptability, rollers with ASPHALT MANAGER are highly suitable for the complete spectrum of asphalt applications. Manual mode with horizontal vibrations is recommended for the compaction of layers on bridges, on/in multi-storey car parks or in the vicinity of structures which may be sensitive to vibrations.

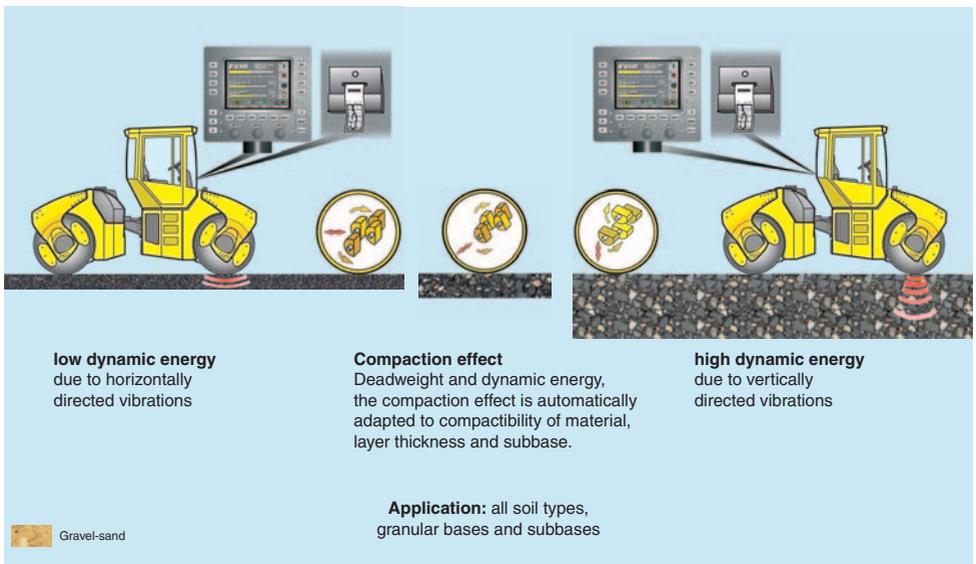


Fig. 12 Vibratory compaction ASPHALT MANAGER with directed exciter system

- Universal use
- Higher compaction performance without the risk of grain destruction
- Uniform compaction by continuous adaptation of the compaction energy
- Better evenness and more uniform surface structure on asphalt layers
- Unproblematic behaviour of the roller when compacting along edges and joints
- Optimally suited for layers on bridges and in the vicinity of constructions that may be sensitive to vibrations (similar to oscillation)
- Equipped with compaction and temperature measuring facilities

Fig. 13 Benefits of rollers with Asphalt Manager

## 3. Compaction equipment

### 3.1 Hand-guided compaction equipment

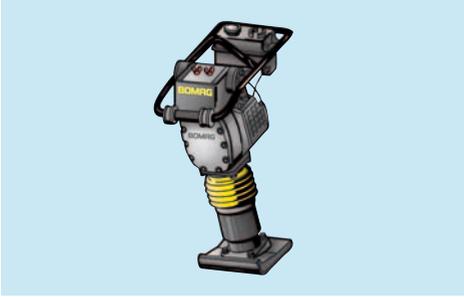


Fig. 14 Tampers

#### Tamper

Tampers belong to the smallest compaction machines used on construction sites. They are used under confined spatial conditions, where larger compaction machines cannot be used. They are available in the weight class from 60 - 80 kg. Tampers are powered by modern 4-stroke gasoline engines or, more rarely, by diesel engines. The engine driven eccentric (crank drive) causes the fast vertical movement of the tamper foot.



Fig. 15 Vibratory plate

#### Vibratory plates

Forward running and reversible vibratory plates are used for the compaction of small or confined asphalt surfaces. They are available in the weight range from 50 - 150 kg with working widths ranging from 45 to 60 cm. Vibratory plates are powered by gasoline or diesel engines. The exciter system (directed vibrator) is driven via V-belt and centrifugal clutch. The movement direction of reversible plates is achieved by adjusting the directed vibrator accordingly.

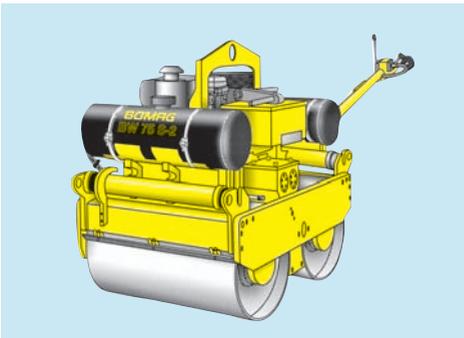


Fig. 16 Hand-guided rollers

#### Hand-guided tandem rollers

Hand-guided tandem rollers are available in the weight range from 600 - 1000 kg with working widths ranging from 60 cm - 75 cm. Both drums are either mechanically driven by a 2-stage mechanical gearbox, or by a hydrostatic drive. These rollers work with double vibration.

### 3.2 Light tandem rollers



Fig. 17 light, articulated tandem rollers

Light, articulated tandem rollers are ride-on rollers in the weight class from 1.3 to 4.2 t and working widths ranging from 80 cm to 138 cm. They are designed with hydrostatic travel and vibration systems for both drums.

### 3.3 Combination rollers



Fig. 18 Combination roller

Combination rollers are designed with a vibrating drum and a wheel set. They are particularly suitable for asphalt compaction on inclinations, for repairs and patchwork in the construction of footpaths, cycle paths and car parks. Combination rollers are available in the class ranging from 1.5 to 2.5 t and also from 7 to 10 t.

### 3.4 Pneumatic tired rollers



Fig. 19 Pneumatic tired roller

Pneumatic tired rollers are designed with a steering/oscillating axle at the front and a rigid drive axle at the rear. With an additional ballast of 10 t the deadweight of these rollers can be increased to 24 or 27 t respectively. The compaction effect is achieved with the deadweight of the machine and the kneading and flexing effect of the wheels. The tire inflation pressure affects the efficiency of compaction (e.g. the number of passes).

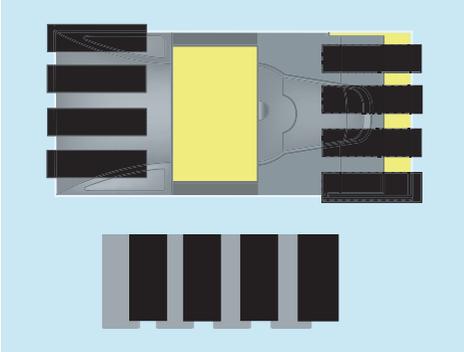


Fig. 20 Wheel position of the pneumatic tired roller

### 3.5 Articulated tandem rollers



Fig. 21 Articulated tandem rollers

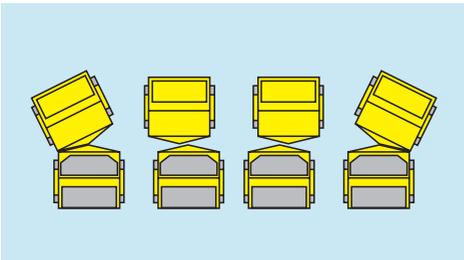


Fig. 22 Steering concept (articulated steered)

Both axles are equipped with 4 compactor wheels each; the wheels overlap (track offset) by approx. 40 mm).

Heavy tandem rollers in the weight range from 7 to 14 t with working widths of 1.50 m, 1.68 m, 2.00 m and 2.13 m are used for medium to large scale construction projects.

Vibration:

- only front
- or only rear
- or both drums

Drums:

- split or non-split

On rollers with central oscillating articulated joint both drums remain in track, even when cornering (left/right). The rollers have a standard crabwalk facility of 170 mm to either side. This facilitates among others the compaction along edges and the moving away from lateral limitations.

### 3.6 Pivot steered tandem rollers



Fig. 23 Pivot steered tandem rollers

Pivot steered tandem rollers are available in the 7 and 10 t weight range with working widths of 1.50 m and 1.68 m.

The travel and vibration drives are hydrostatic

Vibration: front and/or rear

Drums: front and rear: split or non-split

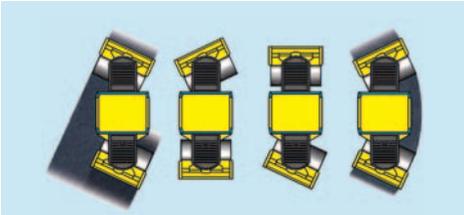


Fig. 24 Types of steering with pivot steering

The BOMAG pivot steering is a particularly convenient electric steering system. The driver can choose from the following settings:

- Diagonal (left/right)
- Only front
- Only rear
- Synchronous steering (both drums)
- Automatically front or rear depending on travel direction

### 3.7 Steering systems

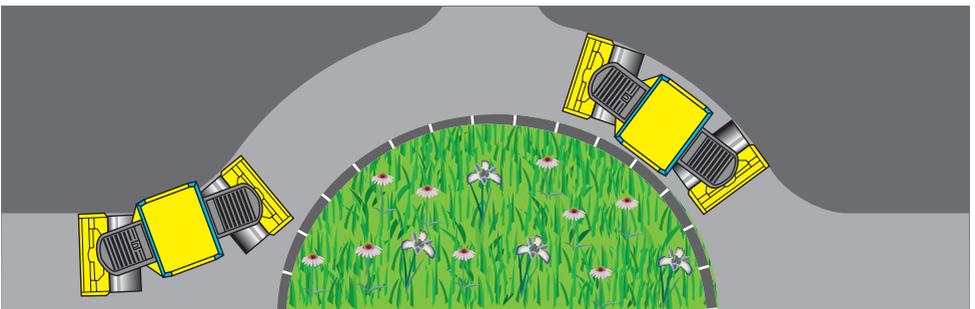


Fig. 25 Pivot steering

On pivot steered rollers both drums can either be steered together (synchronous steering) or individually at front or rear. Pivot steered rollers are additionally designed with a large adjustable crabwalk (up to 120 mm).

Pivot steered rollers are optimally suited for both small scale constructions (e.g. crossings, roundabouts, sharp bends) as well as large area projects (e.g. A-roads and motorways).

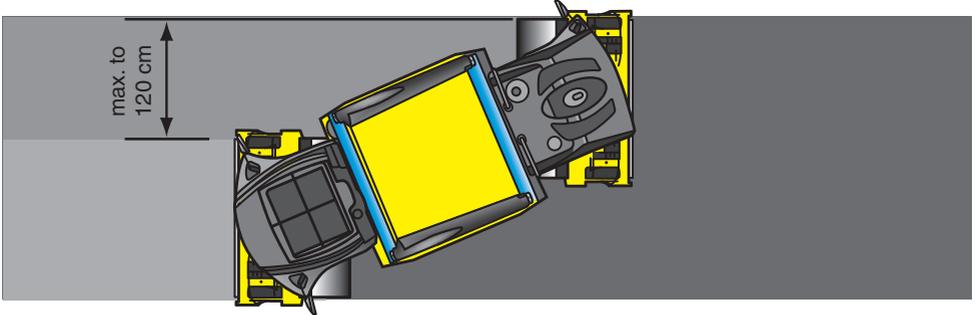


Fig. 26 Crabwalk

On pivot steered rollers full advantage can be made of the large "crabwalk" (up to 120 mm):

- The weight of the roller is distributed over a larger area; the roller does not sink in so deep.
- Unproblematic initial compaction of sensitive materials with high asphalt temperature
- Final "ironing" of large areas.
- The roller has a larger distance to the still instable edge of the asphalt layer.

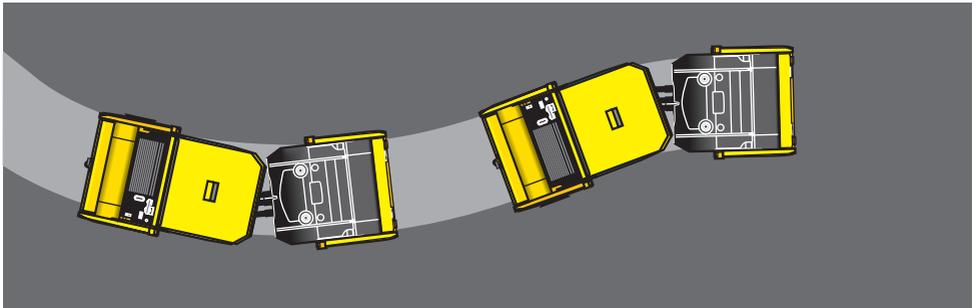


Fig. 27 Articulated steering

Tandem rollers with articulated steering have a central articulated oscillating joint between the drums.

This ensures that both drums run in track, even when cornering. When using the crabwalk the rear drum is offset either to the left or the right. Due to their design the tracks of tandem rollers can be offset by < 17 cm.

Practical benefits of the crabwalk facility:

- Unproblematic steering away from curb stones
- Rational working with the edge compressing cone
- Avoids sharp-edged track marks from the drum edges in the asphalt surface



## 4. Equipment characteristics of tandem and combination rollers

### 4.1 Split and non-split drums

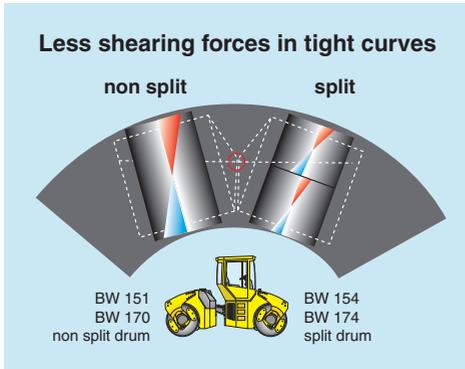


Fig. 28 Split and non-split drums

Tandem rollers with an operating weight of 7 t and higher are available with split or non-split drums. The benefit of the split drum are the reduced shearing forces when compacting highly sensitive asphalt layers in curves (urban applications). The risk of the asphalt cracking in the area of the drum edges is considerably reduced.

### 4.2 Sprinkling system

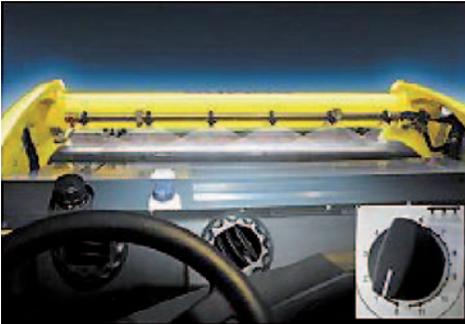


Fig. 29 The sprinkling system

Large tandem rollers are normally designed with two water pumps (1 spare pump).

Combination rollers are equipped with an additional pump to spray the rubber tires with emulsion. All rollers are equipped with interval switches to save water. With the switches the water quantity can be exactly metered for the application. The following applies in general: The drum surface should be moist but not wet. This requires an excellent view to the drum surface.

Switch for sprinkling system	Type of mix	Explanation:
Stage 3 – 5	Asphalt concrete	Asphalt ° C ( 100 – 140 )
Stage 5 – 8	Chip mastic asphalt	Asphalt ° C ( > 150)
Stage 12	-	Permanent sprinkling

Fig. 30 Reference values to preselect the sprinkler interval

Note:

Stage 12 of the sprinkler switch is used to check the function of the sprinkling system at standstill before

work is started. During work it is only used to wet the drum surface instantaneously and quickly.

### 4.3 Speed level

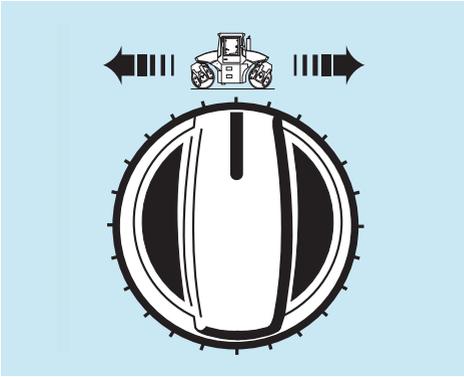


Fig. 31 Speed level selection BW 174 AD

On tandem rollers the rolling and transport speeds of the machine are controlled with the travel lever, on pneumatic tired rollers with the throttle pedal. Depending on the roller type, the desired final speed can be pre-set with a speed range switch, which particularly serves this purpose.

On pivot steered rollers the maximum travel speed can be pre-selected with a 24-stage switch. This speed is then reached when the travel lever is fully operated (in forward / reverse), which guarantees uniform compaction.



Fig. 32 Speed level selection BW 161 AD-4

On heavy articulated roller (BW 161 AD and higher) the speed can generally be adjusted in two steps from working speed to transport speed. This enables perfect adaptation of the travel hydraulics to the prevailing construction site conditions.

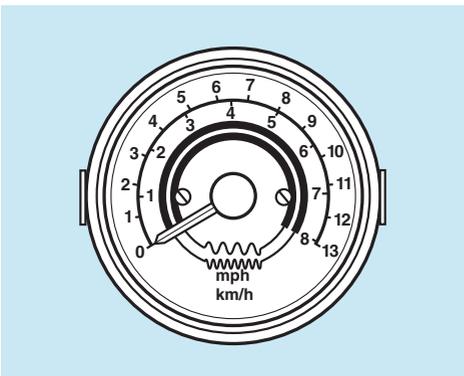


Fig. 33 Option: Speedometer

An analog speedometer is also available (optionally). On rollers with ASPHALT MANAGER the speed a digital display (BOP) shows the speed as standard.

## 4.4 Edge compressing and cutting equipment

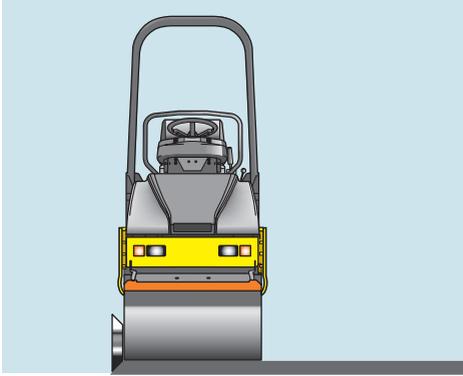


Fig. 34 Edge compressing unit

All small tandem rollers with edge cutting unit (weight range up to 4 t) are equipped with three tools ex factory:

- a) Compression roller with 45°-angle
- b) Cutting wheel
- c) Tapered roller

For large tandem rollers compression rollers (45° or 60° -angle) and a cutting wheel are optionally available.

The free edges of asphalt layers must be compressed with suitable tools, like e.g. edge compressing rollers.

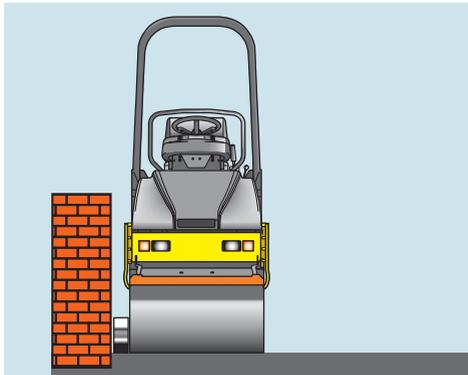


Fig. 35 Conical roll

The special shape of the tapered roller enables the roller driver to compact right against lateral limitations (e.g. walls of buildings). Since this usually only possible with light tandem rollers, the conical roll is only intended for tandem rollers with a weight of < 4 t.

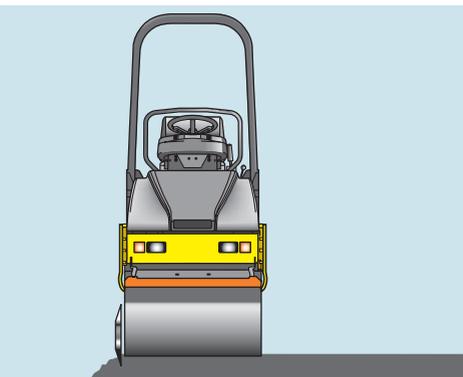
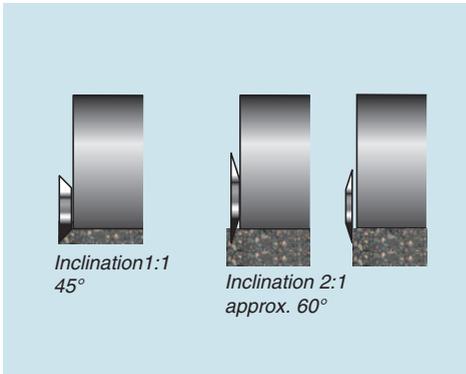


Fig. 36 Cutting wheel

The cutting wheel enables clean cutting of wearing courses along edges and middle joint, as well as along curb stones / edge of gutters.



*Fig. 37 Compressing rollers and cutting wheel*

Working with compressing roller or cutting wheel requires some experience. The attached tools can generally be conveniently operated from the operator's stand. For this purpose the machine is equipped with a hydraulic pressing system. Depending on the application it may be necessary to readjust the final stop for the swivel arm (roller position below drum). Tandem rollers can also be equipped with two compressing rollers (front right and rear left).



*Fig. 38 Compressing roller with inclination 1:1 (45°)*



*Fig. 39 The compressing roller produces a slanted and smooth layer edge*

## 4.5 Chip spreader



Fig. 40 BW 154 with BS 150 - Precision chip spreader

For accurate distribution of chips over the asphalt surface BOMAG offers attachment spreaders with various capacities for rollers in the weight class from 2.5 to 4 t as well as from 7 - 10 t. Precision spreaders (BS 150 and BS 160) with vibrating spreading screed are available for the large tandem rollers - hydraulically driven roller-type spreaders (BS 100 and BS 120) can be attached to the light tandem rollers. The objective of this measure is the application of grit to the asphalt surface to enhance the initial grip. Spreading widths from 1.00 m to 1.80 m are possible.

The spreading quantity can be adjusted by varying the hopper inclination angle at constant working speed. The hopper itself can be easily detached from the roller by simply disconnecting a hydraulic quick release coupling. The hopper can be conveniently filled on site by means of a wheel loader.



Fig. 41 BW 120 with attachment spreader BS 100 and foldable roll over protection structure

The attachment spreaders BS 100 or BS 120 are hydraulically driven roller-type spreaders for installation on small tandem rollers of the 2.5 - 4t class.

## 4.6 ROPS - Roll Over Protection Structure



Fig. 42 Articulated roller with ROPS/FOPS

All small tandem rollers can be optionally equipped with a roll over protection structure (rigid or foldable). All large rollers are either equipped with a ROPS\* - cab (standard in EU countries) or with ROPS-FOPS\*\* (with protection against falling down objects).

\*ROPS = Roll Over Protection Structure

\*\*FOPS = Falling Object Protection Structure

## 4.7 Working light



Fig. 43 Tandem roller with 230 V electrical connection

BOMAG rollers can be equipped with a 230 V power connection for large area illumination of over-night construction sites. A balloon with very bright halogen lamps (2 kW) enables uniform illumination of the construction site around the roller (approx. 500 m<sup>2</sup>).

## 5. Technical data of asphalt rollers

BOMAG offers optimally adapted tandem and combination rollers in the weight ranges from 1.5-4 t and from 7 - 14 t to suit the vast variety of applications in asphalt compaction.

The following tables give the user a complete overview of the most important roller data in a particular weight class.

		Small tandem rollers	
Weight class	t	1,5 - 2,5	3,2 - 4,2
Linear load	kg/cm	8-13	13-15
Working width	mm	800-1200	1300-1380
Engine power	kW	12-25	25-35
Amplitude	mm	0,4 - 0,5	0,4-0,5
Frequency	Hz	50-70	45-60
Centrifugal force	kN	20-45	25-50

Fig. 44 Characteristics of small tandem rollers

		Large tandem rollers*			
			AM		AM
Weight class	t	7-10	+	10-14	+
Linear load	kg/cm	25-30	+	27-32	+
Working width	mm	1500-1680	+	2000-2135	+
Engine power	kW	55-75	+	75-100	+
Amplitude	mm	0,3-0,7**	0 - 1,0**	0,35-0,85**	0 - 0,95**
Frequency	Hz	40-60	45	40-60	40-50
Centrifugal force	kN	70-90	160-170	85-130	150-250
* Operating weight with cabin		AM = ASPHALT MANAGER		**effective amplitude	

Fig. 45 Characteristics of large tandem rollers

Due to its highly sensitive kneading and flexing effect of the wheels the roller is particularly significant for purely static compaction.

Pneumatic tires rollers		
Weight class	t	8-27
Wheel load	kg	1000-3000
Ballast	t	5-12
Tire size		11.00-20 18 PR
Number of tires		4 front; 4 rear
Working width	mm	2050
Speed	km/h	20
Engine power	kW	75-100

Fig. 46 Characteristics of rubber tired rollers



## 6. Compaction performance

The area or volumetric output of the laying and compaction equipment is interdependent. These two outputs must therefore be exactly planned and calculated in mutual dependence.

The area output depends on the laying width, the working speed and the utilization factor of the finisher. The quantitative output results from the amount of mix and the area output of the finisher.

The area output or volumetric output of the compaction machines is influenced by the available rolling time as well as the number, operating mode, rolling speed and rolling width of the machines. The combination of compaction equipment to be used must follow the objectives of a number of influential factors and various quality criteria, such as e.g. adequate compaction, even surface with closed pores, internal bonding of layers, compaction of joints.



Fig. 47 Laying and compacting an asphalt layer using three finishers and five vibratory rollers (10t). Laying width > 10m; daily output > 3.000t.

The following formula is used to calculate the practical rolled area output F and the quantitative output M of a roller:

$$F = \frac{f \cdot b_{\text{eff}} \cdot v \cdot 1000}{n} \text{ (m}^2\text{/h)}$$

Meaning:

- F = Area output by rolling (m<sup>2</sup>/h)
- f = Reduction factor (0.75)
- b<sub>eff</sub> = Effective rolling width (m)  
(90% of drum width because of overlapping)
- v = Mean rolling speed (km/h)
- n = Number of passes

$$M = \frac{f \cdot b_{\text{eff}} \cdot v \cdot h \cdot \delta_A \cdot 1000}{n} \text{ (t/h)}$$

Meaning:

- M = Volumetric output (t/h)
- f = Reduction factor (0.75)
- b<sub>eff</sub> = Effective rolling width (m)  
(90% of drum width because of overlapping)
- v = Mean rolling speed (km/h)
- h = Layer thickness of material to be compacted (m)
- δ<sub>A</sub> = Density of mix to be compacted (t/m<sup>3</sup>)  
(δ<sub>A</sub> ~ 2,4 - 2,5 t / m<sup>3</sup>)
- n = Number of passes

The following average speeds are recommended:	
4 to 6 km/h for initial compression	(statically with tandem rollers)
3 to 5 km/h for main compaction	(statically with tandem rollers)
3 to 5 km/h for main compaction	(Vibration)
6 to 8 km/h for subsequent rolling (ironing)	(statically with tandem rollers)
4 to 8 km/h for main compaction	(Pneumatic tired roller)
10 to 12 km/h for subsequent rolling	(Pneumatic tired roller)

Fig. 48 Recommended rolling speeds

The number of necessary rolling passes can only be estimated in advance on the basis of experience or must be determined by compaction tests. In each individual case the number of passes depends on the compaction resistance and the temperature of the mix,

the thickness of the layer, the rolling speed, the roller type and the operating mode of the machine.

The following tables contain empirical values for the area output (m<sup>2</sup>/h) and the quantitative output (t/h) of compaction equipment from BOMAG.

Machine type	Operating weight	Area output (m <sup>2</sup> /h) with layer thickness		
		2-4 cm	6-8 cm	10-14 cm
	t	2-4 cm	6-8 cm	10-14 cm
	1,5-2,5	250-450	200-350	150-300
	3,0-4,5	400-800	250-600	250-450
	7-9	600-1500	500-900	400-700
	10-14	1000-2200	800-1200	600-900
	1,5-2,5*	250-450	200-300	150-250
	3,0-4,5*	400-800	250-500	250-400
	7-10*	600-1500	500-800	400-650

Fig. 49 Practical area output of compaction equipment in asphalt construction

\*Combination roller

Machine type	Operating weight	Volumetric output (t/h) with layer thickness		
		2-4 cm	6-8 cm	10-14 cm
	t	2-4 cm	6-8 cm	10-14 cm
	1,5-2,5	10-40	25-60	40-100
	3,0-4,5	20-60	40-90	70-160
	7-9	40-100	70-160	120-220
	10-14	70-120	100-200	180-280
	1,5-2,5*	10-35	20-55	35-90
	3,0-4,5*	20-55	35-80	65-140
	7-10*	35-100	60-170	90-200

Fig. 50 Practical volumetric output of compaction equipment in asphalt construction

\*Combination roller



Fig. 51 BW 203 AD on a 16cm asphalt bearing course with a compaction performance of 250 t/h



## 7. Preparing the compaction equipment

In order to be able to perform high quality compaction work, the "tools" required for this work must be optimally maintained or checked for functionality. This includes thorough inspection of the machine with respect to engine, hydraulic system and water sprinkling system,

before work is started. Possible faults, which could later cause major problems during compaction work, can thereby be detected at an early stage.

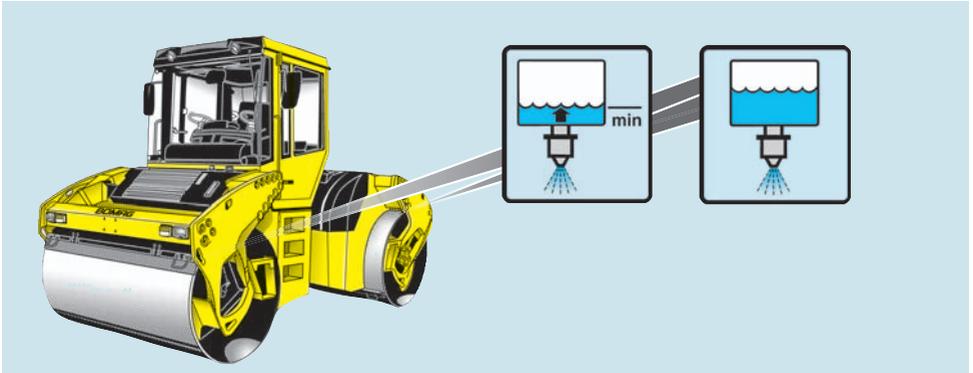


Fig. 52 Filling the water tanks, checking the water nozzles

Activities before starting work:

- Fill the water tanks
- Check the water filter (in case of frost unscrew the filter to drain the pump).
- Check the nozzles, clean or replace if necessary.
- In case of frost drain the complete water sprinkling system; unscrew all nozzles.

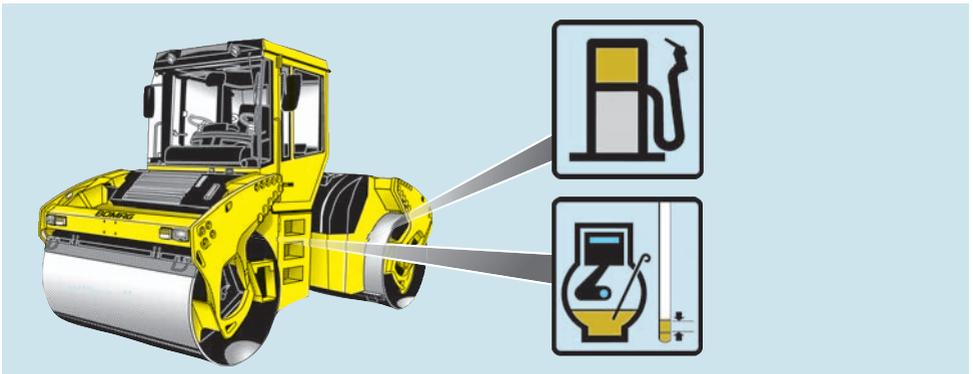


Fig. 53 Fuel level, engine oil check

- Check the engine oil level
- Check the fuel level
- General function test  
(Brake, light, warning horn, hazard light)

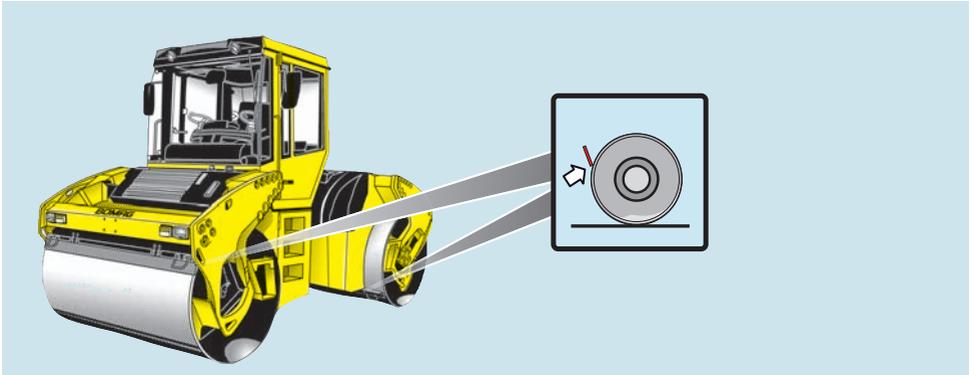


Fig. 54 The scrapers must be in contact

Scrapers should always touch the drum uniformly.

Function and characteristics of scrapers:

- Even distribution of sprinkling water
- Removal of large particles

- Foldable scrapers are maintenance free
- Fixed scrapers must be checked at regular intervals and readjusted when required.



Fig. 55 Recommended tire pressures

With pneumatic tired rollers the efficiency of compaction mainly depends on the tire pressure. In dependence on the corresponding wheel load the correct pressure must be adjusted so that the wheels have an even contact area.

The working speeds range from 4 to 8 km/h.

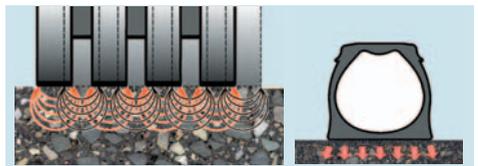


Fig. 56 Pressure distribution and optimal tire contact area

## 8. Rolling pattern

### 8.1 Compacting when paving with one finisher

Depending on the paving width of the finisher one or several rollers will be used side by side. The respective rolled tracks should overlap by at least 15 cm, to make sure that no uncompacted strips are left out. The same number of passes should be rolled on each track to ensure even compaction over the entire paving width.

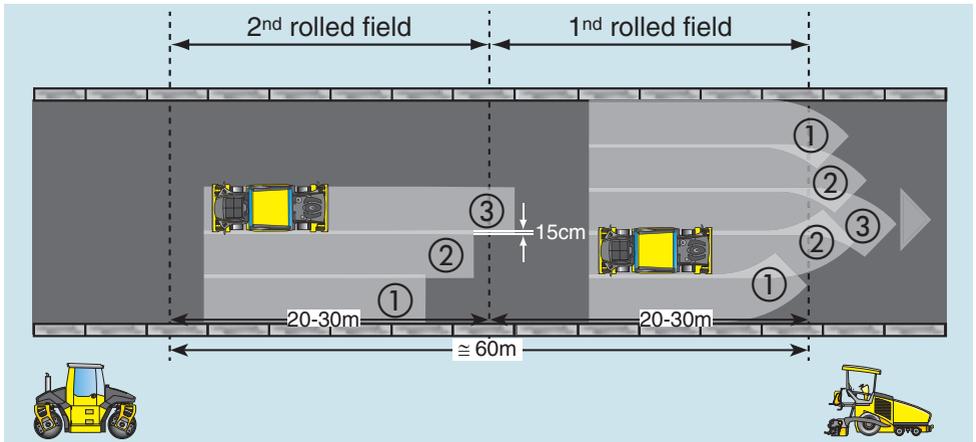


Fig. 57 Sequence of the compaction process (several fields)

The roller always follows the same rolled track back to the already cooled down, load-bearing area, where it is then reversed. If a curbstone, compaction will start right at the outer edge. Depending on mix, initial compaction and layer thickness it is recommended to finish the rolled track behind the finisher (field 1) with a slight radius to improve the transverse evenness of the surface.



Fig. 58 BW 154 AP compacting a wearing course with a curbstone

## 8.2 Compacting when paving with two finishers

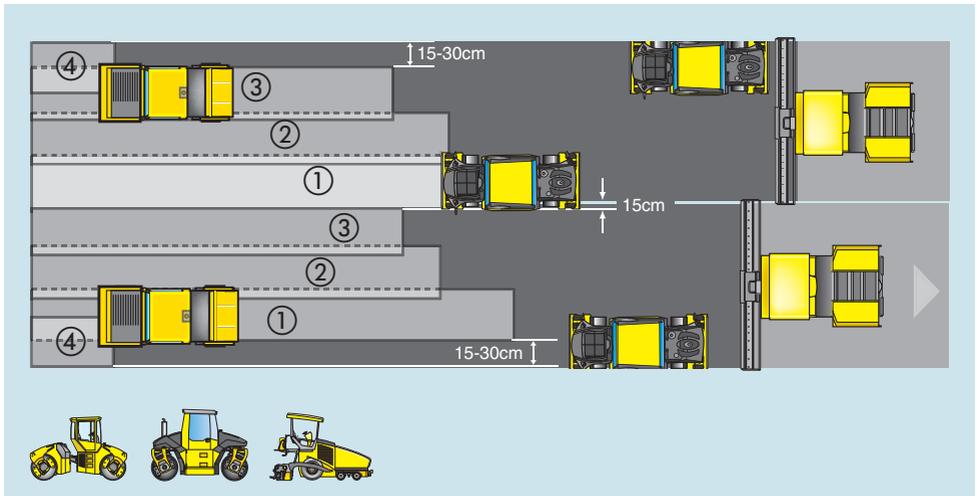


Fig. 59 Rolling concept with 2 pavers

When paving with staggered finishers (hot on hot), the joint should be compacted at the earliest possible time. For this purpose the rollers compact, e.g. in the right hand field, from the outer edges towards the middle. In the left hand field the joint is rolled immediately.

Here the rolled field overlaps the right field by 15 cm. This forces an intensive and dense connection between both tracks.

## 8.3 Asphalt compaction with tandem rollers only

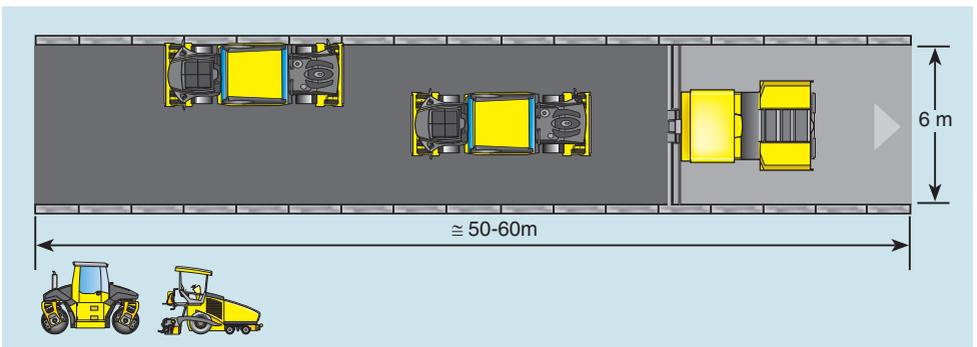


Fig. 60 Rolling concept with tandem roller

All types of mixes (base, binder and wearing courses) can generally be compacted with tandem vibratory rollers. The use of a pneumatic tired roller is not mandatory. Utilizing a high temperature level (approx. 140 - 160° C) has highest priority. The number of rolling passes with vibration depends on the layer thickness,

the linear load and the weather conditions. Depending on the stability and initial compaction of the mix it is most sensible to start with static initial compaction and subsequently continue the main compaction process with vibration.

## 8.4 Asphalt compaction with rubber tired and tandem rollers

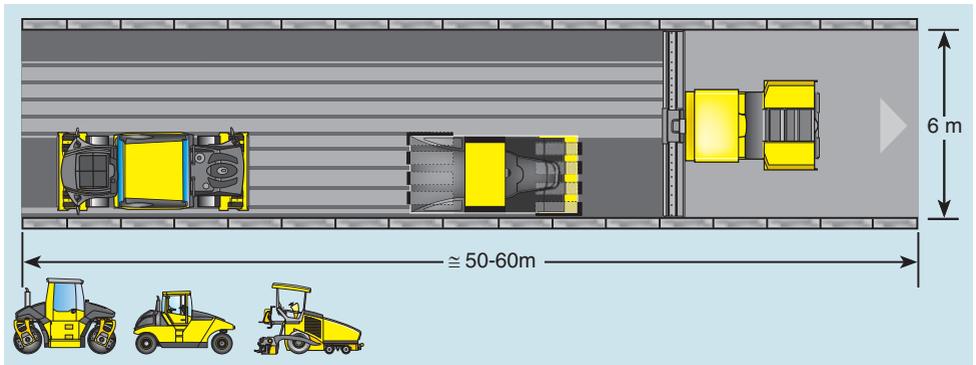


Fig. 61 Rolling concept with pneumatic tired and tandem rollers

Critical mixes, which are sensitive to scuffing, as may be used for binder and base courses or combined surface - base - course constructions, are initially compacted with pneumatic tired rollers. Here the wheels produce a highly beneficial kneading and flexing effect, without the danger of scuffing or tearing. Tandem rollers (7 - 10 t) are normally used for final compaction.



Fig. 62 Initial compaction, pneumatic tired roller BW 24 RH

## 8.5 Compacting asphalt layers with crown

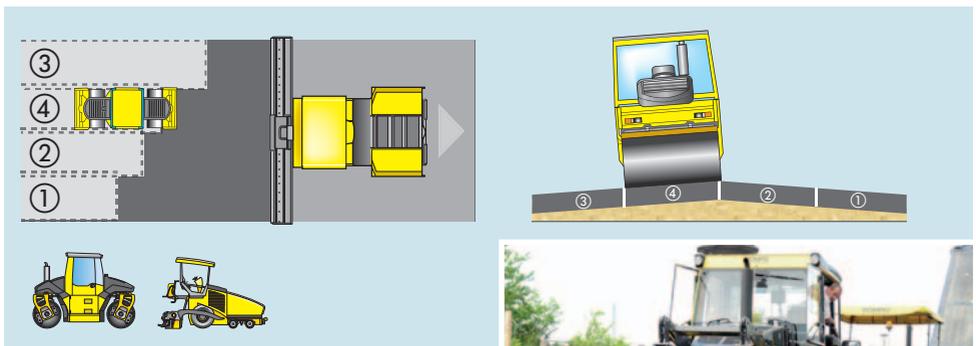


Fig. 63 Compacting a crown profile

On traffic areas with crown profile the longitudinal joint should be compacted in such a way, that a closed joint of identical height is produced. This requires a certain level of experience and diligence from the roller driver.



Fig. 64 Main compaction, BW 174 AD

## 8.6 Compacting curves

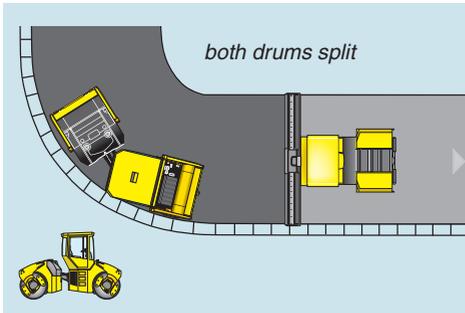


Fig. 65 Cornering with articulated rollers

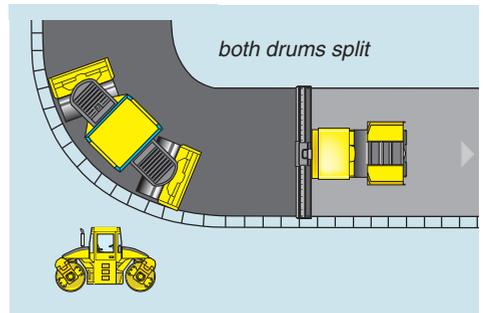
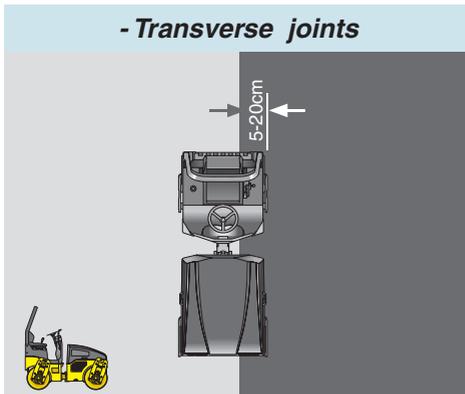


Fig. 66 Cornering with pivot steering

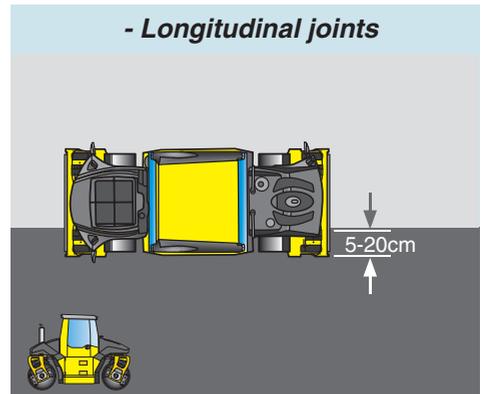
Articulated rollers should be used with crabwalk when compacting along the edge of the carriageway. This enables the roller driver to direct his attention to one drum when compacting the edge.

## 8.7 Compacting seams and joints



Transverse joint    ■ = hot asphalt    ■ = cold asphalt

Fig. 67 Transverse joint without traffic



Longitudinal joint    ■ = hot asphalt    ■ = cold asphalt

Fig. 68 Longitudinal joint without traffic

In order to compact transverse joints across the direction of paving the roller drives with only 5-20 cm of the drum on the hot, uncompacted layer and then moves bit by bit onto the hot layer. Since the manoeuvring space is in most case quite limited, a small and manoeuvrable compaction machine should be used for this purpose. If the available space is not big enough for manoeuvring, the transverse joint can

also be rolled or even paved diagonally to the paving direction.

When compacting a longitudinal joint (without oncoming traffic) approx. 20 cm of the hot mix is compacted. The major part of the drum rolls over the cold, stable material. This produces a closed joint with identical height without misplacements.

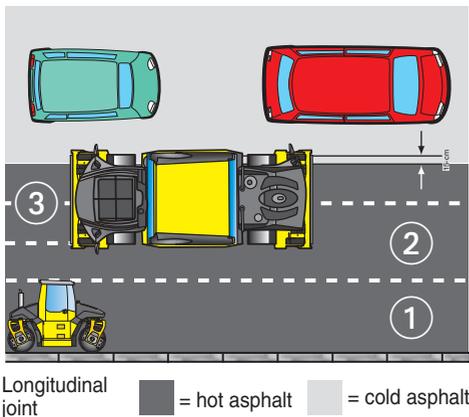


Fig. 69 Longitudinal joint with traffic

When rolling a longitudinal joint (with oncoming traffic) the rolling pattern 1-3 should be used. This produces a solid, stable basis, from which the roller can finally roll the longitudinal joint.



Fig. 70 Compacting a longitudinal joint

## 8.8 Application of chips to wearing courses

The grip of asphalt wearing courses is a very significant factor within the framework of general traffic safety. With the introduction of the ZTV Asphalt StB-01 the requirements concerning grip from the date of acceptance right to the end of the warranty period were determined in terms of figures and, since 01.01. 2002, are a fixed part of construction contracts in Germany. These requirements apply for roads or construction class SV and I to VI.

The right spreading technique is all what matters: Skid resistance is a characteristic of road surfaces, which is essentially determined by the concept of the mix and the paving technique. The initial grip is fundamentally influenced by paving - i.e. by correct rolling and chip distribution.

**Chip material:**  
Crushed sand or multiple crushed chipping (raw or binder coated) is normally used. The material should only be used dry and free of dust.

**Chip quantity:**  
The quantity is, among others, determined by the particle size of the wearing course and is generally in the range of 0.5 to 1.0 kg/m<sup>2</sup>, with particle size 1 / 3 mm (for wearing courses up to 0 / 8 mm) 1.0 to 2.0 kg/m<sup>2</sup>, with particle size 2 / 5 mm (for wearing courses > 0 / 8 mm)

**Timing:**  
The chips should be applied to the surface of the still hot wearing course at a time when it can still be pressed in by rolling. This should take place at the earliest after the 2nd rolling pass.



*Fig. 71 BW 174 AP with precision chip spreader BS 180*

Gritting asphalt surfaces requires a uniform and precise spreading technique. Since years BOMAG for this purpose delivers the approved and patented precision chip spreader BS 180 for installation on 7 to 10 t tandem rollers. The vibratory screed (under the hopper) distributes the chip evenly across the full rolling width. An excellent and reproducible spreading quality is reached with a constant rolling speed of approx. 4-6 km/h.

Additional advantage: With an even and accurate distribution of the chip a significantly lower chip quantity (600 - 800 g/m<sup>2</sup>) is very often required - in contrast to the reference values stated above. The hopper can be optionally moved sideways.



*Fig. 72 Chip hopper laterally displaceable*



*Fig. 73 Spreading quantity: Evenly, exact*

The material spread over a test section is weighed for the initial determination of the spreading quantity per m<sup>2</sup>. For this purpose the material spread over a reference area (1 m<sup>2</sup>) is swept up and weighed. The spreading quantity depends on the inclination of the hopper (see angle scale on hopper) and a constant speed of the roller (approx. 4-6 km/h).

With constant working speed the spreading quantity can be changed by tilting the hopper accordingly.



*Fig. 74 Spreading quantity regulation*

## 9. Compaction and paving faults

Frequently occurring problems in practice when rolling asphalt layers can be traced back to various causes.

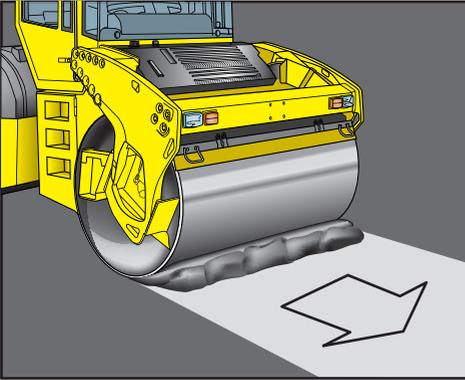


Fig. 75 Scuffing of mix in front of the drum

### Scuffing of asphalt mix in front of the roller

The roller pushes a bow wave in front

Possible causes are:

- Too heavy roller (high linear load) with to small drum diameter
- In stable mix is compacted too early at a too high temperature.

Recommendation:

- Use a lighter roller
- Initial compaction with pneumatic tired roller or combination roller
- Later start of compaction with reduced mix temperature

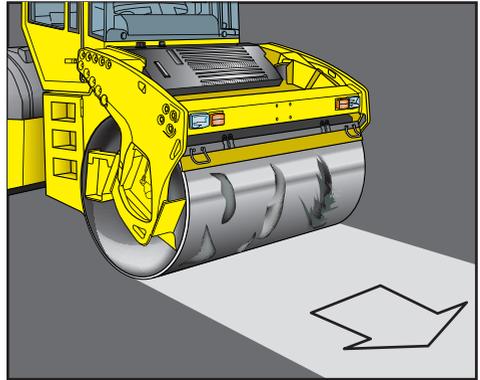


Fig. 76 Mix sticking to the drums

### Mix sticking to the drum

Possible causes are:

- The mix is compacted at a too high temperature
  - The drums are insufficiently sprayed with water.
- Recommendation:
- Before starting compaction work set to permanent sprinkling (stage 12) to wet the drums all around.

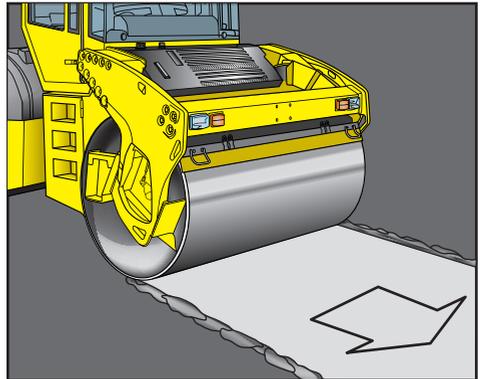


Fig. 77 Cambering along the side of the drum

### Cambering along the side of the drum

The following causes are possible:

- Insufficient initial compaction
- Mix too hot.
- Wrong composition of mix.

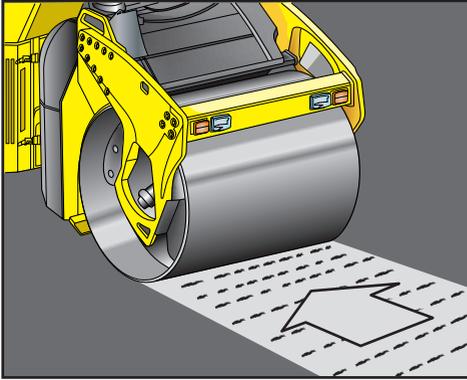


Fig. 78 Transverse cracks behind drum

### Transverse cracks

Transverse cracks normally do not reach very deep.

Possible causes are:

- Low initial compaction by finisher
- Too early use of too heavy rollers
- After paving the time until starting compaction is too long (the surface has cooled down, the core is still too hot, the roller penetrates the skin).
- The machine displaces the paved material on the subbase (the subbase is dirty or insufficiently sprayed).
- The asphalt surface is "quenched" (wind, too much sprinkling water).
- Compaction of too thick layers on inclinations (the thrust forces of the roller cannot + be absorbed).
- Use of so-called short mixes (high amount of and poorly graded natural sand, low amount of bitumen).
- Layer is over-compacted.
- Demixing phenomena as a result of poor mix distribution.

### Longitudinal cracks

Longitudinal cracks reach through the entire layer

The most frequent causes are:

- Faults in the subbase
- Shearing of the mix under a heavy roller (paving thick layers, a heavy roller has to wait a long time, the surface cools down and forms a skin with a hot core zone, the mix is sheared off during rolling).
- Insufficient initial compaction.
- Layer is over-compacted.

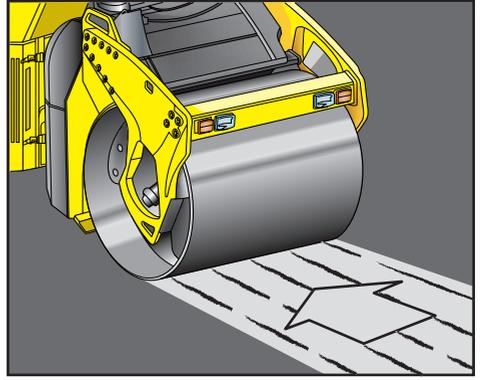


Fig. 79 Longitudinal cracks

- Poor stability of the mix due to its composition (especially the high contents of natural sands)
- Too high temperature of asphalt mix.
- Poor bonding of layers.
- Too high binder content in mix.
- Demixing phenomena as a result of poor mix distribution.



Fig. 80 Transverse and longitudinal cracks cause by the use of a too heavy roller

## 10. Basic rules for compaction work

Very high quality demands apply for the compaction of asphalt. They are intended to achieve a load bearing and wear resistant pavement, able to cope with the expected loads. Minimum values concerning evenness and durable grip of the surface must also be fulfilled.

The roller operator himself is also able to influence these quality characteristics by following some general rules.

1.	Start compaction work as early as possible. This also applies when using heavy rollers directly behind the finisher. However, the flatness produced by the finisher must not be disturbed.
2.	Start edge compression as early as possible, so that the mix is still deformable.
3.	Drum and tires must be sprayed with a sufficient amount of water to prevent mix from sticking to the drum. Drum and tires should be damp but not wet.  The sprinkling water is evaporated by the hot mix, which loses heat, and thereby reduces the available compaction time. Sprinkling with interval control reduces the required amount of water, similar to the addition of dispersant agent to the sprinkling water.
4.	Start smoothly and do not reverse jerkily.
5.	Do not vibrate at standstill to avoid the formation of ruts.
6.	Only switch on vibration when driving, when reversing switch off vibration before the actual reversing point is reached (or use the automatic vibration shut-down feature).
7.	On cross-sloped carriageways always start to compact from the lower edge towards the higher edge. This way the mix compacted by the roller acts as an abutment, which supports the roller.
8.	If possible displace and steer the roller only on compacted material, to avoid misplacements of material.
9.	Never stop the roller on still hot mix, since this could deform the layer.
10.	Always park the machine across the paving direction to be able to iron out any possible ruts.

*Fig. 81 Basic rules of asphalt compaction*



# 11. Compaction measurement and documentation systems

Rollers with ASPHALT MANAGER automatically regulate the required compaction energy by matching the effective amplitude to the prevailing conditions.

At the same time the stiffness modulus  $E_{ViB}$  (MN/m<sup>2</sup>) is continuously determined and the asphalt surface temperature is measured by an infrared sensor. The related information is displayed in the BOMAG Operation Panel (BOP). This enables easy tracking of the compaction progress.

With an assumed uniform stiffness of the layer subbase and a compaction temperature in the range of >100 °C, good correlations between density and  $E_{ViB}$  can be determined on site by comparative measurements.

Experience shows that the roller integrated measuring technique facilitates the compaction quality of asphalt layers.



Fig. 82 Asphalt Manager with compaction measuring system



Fig. 83 Compaction measurement for comparison with  $E_{ViB}$

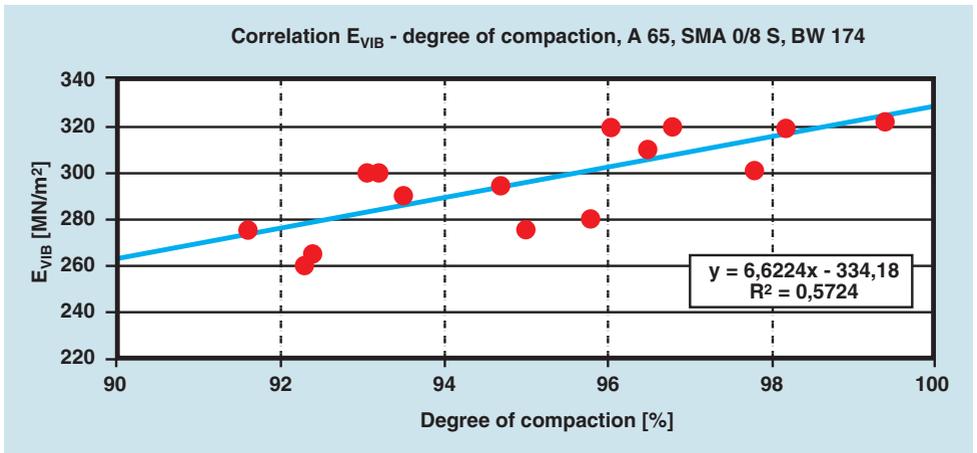


Fig. 84 Example of a correlation between degree of compaction and  $E_{ViB}$

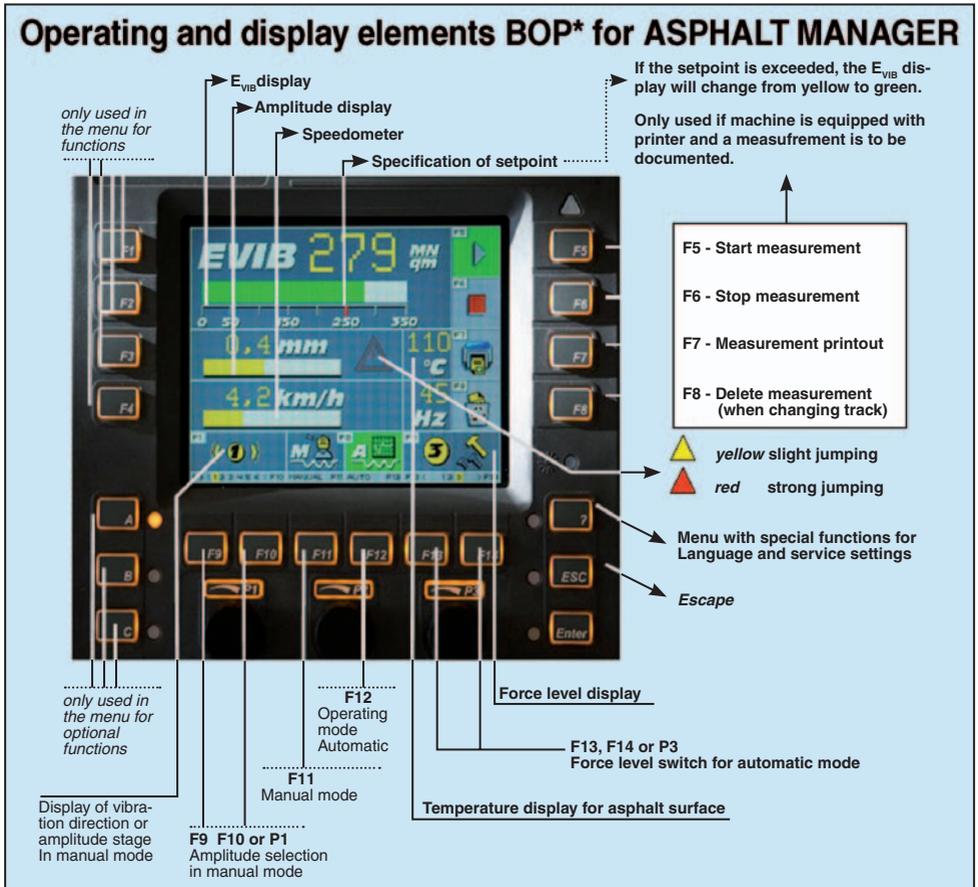


Fig. 85 BOMAG Operation Panel (BOP)

### Force level switch

In automatic mode both the maximum compaction power and the depth effect can be limited. 3 stages are available for this purpose. This limitation is very beneficial if the subbase under the layer to be compacted is not stable.

### Temperature display

The temperature is continuously recorded as asphalt surface temperature. Depending on layer thickness, ambient temperature and wind force, the mix temperature in the core of the layer may be up to 40 °C higher. Compaction should be completed when a surface temperature of 80 °C is reached.



Fig. 86 Asphalt Manager with BCM 05

Rollers with ASPHALT MANAGER can be equipped with the documentation system BCM 05 and a GPS-system to record all data.

This system enables complete and watertight documentation of all stiffness values  $E_{vib}$  (MN/m<sup>2</sup>), asphalt surface temperatures during compaction, roller application values (frequency, amplitude, speed), position of the compacting machine and number of passes for large-scale construction projects.



Fig. 87 Continuous compaction control on asphalt CCCA

The application of a continuous compaction control on asphalt (CCCA) requires the use of the following modules:

- BCM 05 display with BCM 05 mobile software
- BCM05 office software
- BCM 05 Positioning software
- GPS-system

USB memory sticks are used to transfer data from BCM 05 to the construction site office. Here the data are evaluated and managed with the BCM 05 Office program module.



Fig. 88 BW 174 AM with BCM 05 and GPS

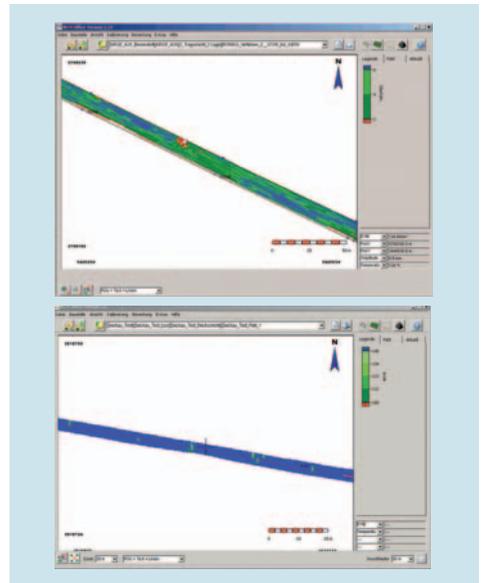


Fig. 89 CCCA documentation of measuring values and passes



# 12. Appendix

## A1 Road construction classes

The total thickness of the road pavement and the gradation of the individual layers with respect to type and thickness are divided into construction classes, according to the traffic load. In Germany the most suitable road design is taken acc. to certain criteria

from tables with standardized traffic area pavements. These tables can be found in the "Richtlinien für die Standardisierung des Oberbaues von Verkehrsflächen" (currently RStO-01\*) (Guidelines for the standardization of traffic area pavements).

Construction class	SV				I				II				III				IV				V				VI			
Equival. 10-t axle passes in Mio	> 32				> 10 - 32				> 3 - 10				> 0.8 - 3				> 0.3 - 0.8				> 0.1 - 0.3				≤ 0,1			
Thickn. of frost prot. pavement	55	65	75	85	55	65	75	85	55	65	75	85	45	55	65	75	45	55	65	75	35	45	55	65	35	45	55	65
Asphalt bearing course on frost blanket layer																												
Wearing course																												
Binder course	22				18				14				14				18				14							
Asphalt base course	34				30				26				22				18				14							
Frost blanket layer	45				45				45				45				45				45							
Thickness of frost blanket layer	-	31	41	51	25	35	45	55	29	39	49	59	-	33	43	53	27	37	47	57	21	31	41	51	25	35	45	55

Fig. 90 Examples for road construction with asphalt pavement acc. to RStO

## A2 Mix types and layer thicknesses

When designing asphalt layers one must consider the ratio of layer thickness and biggest grain. By experience the layer thickness should here by 3-4 as big as the biggest grain used in the asphalt layer. Otherwise negative properties with respect to compactibility and

deformation resistance can be expected. In general the layer thickness follows the regulations ZTV Asphalt StB\* and RStO\*.

\*German regulations

Layer	Types of mixes	Layer thickn. acc. to ZTV Asphalt-StB* or ZTVT-StB [cm]	Recommended layer thickness for specifications [cm]
Asphalt wearing courses	Asphalt concrete 0/5	2,0 to 3,0	2,0
	Asphalt concrete 0/8	3,0 to 4,0	3,0
	Asphalt concrete 0/11	3,5 to 4,5	4,0
	Asphalt concrete 0/11S	4,0 to 5,0	4,0
	Asphalt concrete 0/16S	5,0 to 6,0	5,0
	Stone mastic asphalt 0/5	2,0 to 3,0	2,0
	Stone mastic asphalt 0/8	2,0 to 4,0	3,0
	Stone mastic asphalt 0/8S	3,0 to 4,0	3,5
	Stone mastic asphalt 0/11S	3,5 to 4,0	4,0
	Mastic asphalt 0/5	2,0 to 3,0	2,0
	Mastic asphalt 0/5	2,5 to 3,5	2,5
	Mastic asphalt 0/11	3,5 to 4,0	3,5
	Mastic asphalt 0/11S	3,5 to 4,0	3,5
Asphalt binder courses	Asphalt binder 0/11	only for profile compens.	-
	Asphalt binder 0/16	4,0 to 8,5	5,0
	Asphalt binder 0/16S	5,0 to 8,5	6,0
	Asphalt binder 0/22S	7,0 to 10,0	8,0
Asphalt base layers	Mix types 0/22	≥8,0	≥8,0
	Mix types 0/32	≥8,0	≥8,0

Fig. 91 Asphalt mix types and the corresponding layer thicknesses

### A3 Asphalt base course

For new road constructions the asphalt base course (single or multi layer) is laid on the unbonded frost blanket layer (gravel or crushed rock layer) of the pavement. It mostly consists of a mixture of coarse particle materials (0/32 mm or 0/22 mm) with additives and bitumen.

Base courses have the function of distributing loads; they should therefore be particularly stable and must be paved true to profile. Moreover, they should protect the substructure against moisture (rain).

Type of mix	Particle size	Particle size > 2 mm	Particle size < 0.09 mm	Over-size max.	Minimum binder content*	Marshall stability at 60°C min. **	Marshall flow**	Air void content
	mm	Weight-%	Weight-%	Weight-%	Weight-%	kN	mm	Vol.-%
1	2	3	4	6	7	8	9	10
AO	0/2 to 0/32	0 to 80	2 to 20	20	3,3	2,0	1,5 to 4,0	4,0 to 20,0
A	0/2 to 0/32	0 to 35	4 to 20	10	4,3	3,0	1,5 to 4,0	4,0 to 14,0
B	0/22; 0/32	over 35 to 60	3 to 12	10	3,9	4,0	1,5 to 4,0	4,0 to 12,0
C	0/22; 0/32	over 60 to 80	3 to 10	10	3,6	5,0	1,5 to 4,0	4,0 to 10,0
CS	0/22; 0/32	over 60 to 80	3 to 10	10	3,6	8,0	1,5 to 5,0	5,0 to 10,0

#### Explanations

- 1) Mix types AO only for full depth asphalt pavements
- 2) Mix type A only for lower layer of base course
- 3) Mix type CS for construction class SV and subject to special loads traffic areas: minimum 60% crushed grain > 2 mm, ratio of crushed sand to natural sand min. 1:1
- 4) Mix types B, C, CS possible for all other pavements or construction classes (B limited)
- 5) \*for the use of paving bitumen
- 6) \*\*Determination on marshall samples

Fig. 92 Composition and properties of asphalt base courses

### A4 Asphalt binder course

On roads with higher traffic loads (construction class III and higher) the binder course is applied to the tack-coated base course as a single layer. As already indicated by its name, this layer bonds the wearing course to the base course; it thereby has the function of a compensating layer to optimize the evenness. Apart from this, the binder course also absorbs a significant part of the shearing strain caused by traffic. The particle size of the mix is in the region of 0/11 to 0 / 22 mm).

Typical applications are highly stressed traffic areas. Mix types used for asphalt binder courses must have very high and durable deformation resistance properties. Multiple crushed stones with durable edges are used for this purpose. The mix has a high proportion of coarse particles and crushed sand and therefore shows a tendency of demixing during haulage to the construction site and paving with a finisher. Asphalt binders generally require a high compaction level.

		0,22 S	0/16 S	0/16	0/11
<b>Minerals</b>		High-grade chip, high grade sand, stone dust		High-grade chip, high-grade crushed sand, natural sand, stone dust	
Particle size fraction	mm	0/22	0/16	0/16	0/11
Grain fraction < 0,09	mm wgt-%	4 to 8	4 to 8	3 to 9	3 to 9
Grain fraction > 2	mm wgt-%	70 to 80	70 to 75	60 to 75	50 to 70
Grain fraction > 8	mm wgt-%	-	-	-	≥ 20
Grain fraction > 11,2	mm wgt-%	-	≥ 25	≥ 20	≤ 10
Grain fraction > 16	mm wgt-%	≥ 25	≤ 10	≤ 10	-
Grain fraction > 22,4	mm wgt-%	≤ 10	-	-	-
Crushed sand-natural sand ratio		1:0 <sup>1)</sup>	1:0 <sup>1)</sup>	≥ 1:1	≥ 1:1
<b>Binder</b>					
Binder type/Grade		(50/70) <sup>2)</sup> , 30/45 PmB 45	(50/70) <sup>2)</sup> , 30/45 PmB 45	50/70, 70/100 (30/45) <sup>2)</sup>	50/70, 70/100
Binder content	Wgt-%	4,0 to 5,0	4,2 to 5,5	4,0 to 6,0	4,5 to 6,5
<b>Mix</b>					
Air void content of the Marshall specimen	Vol.-%	5,0 to 7,0	4,0 to 7,0	3,0 to 7,0	3,0 to 7,0
Compaction temperature	°C	135 + 5	135 + 5	135 + 5	135 + 5
<b>Layer</b>					
Paving thickness	cm	7,0 to 10,0	5,0 to 8,5	4,0 to 8,5	only for profile compensation, not for classes SV. I to III and traffic areas with special loads
Course weight	kg/m <sup>2</sup>	170 to 250	125 to 210	95 to 210	
Degree of compaction	% > 97	> 97	> 97	> 96	thickness up to > 3 cm
1) When adding asphalt granulate in the form of milling asphalt from surface layers, the natural sand content in the resultant mix must not exceed 5 M. %.					
2) Only in exceptional cases					

Fig. 93 Composition and properties of asphalt binder courses

## A5 Asphalt wearing courses

The wearing course is the top part of the asphalt road pavement. It therefore needs to be properly sealed and deformation resistant. The surface must keep its grip also when subjected to traffic. It should also be wear resistant and weather proof. Furthermore, the wearing course must be flexible, fairly silent but still with maximum grip. It consists of a well graded mineral mix (the particle size of the mix ranges from 0 / 5 to 0 / 16 mm ) and bitumen acting as binder.

Typical applications are roads and motorways, airports, layers on bridges, agricultural roads and cycle paths. Depending on the category of road and the expected traffic loads, different wearing course concepts can be realized. As an example, coarse mix with a higher chipping content and a higher layer thickness is used for roads with higher traffic loads. Fine-particle mixes with low air void content and lower layer thickness are particularly suitable for roads with low traffic loads.

## - Asphalt concrete

Asphalt concrete is, as indicated by the name, a mineral mix based on the concrete principle. It contains all types of particle sizes from zero up to the respective larger particle size in an appropriately adjusted ratio. The mean crushed aggregate content is approx. 50 weight-%.

	0/16 S	0/11 S	0/11	0/8	0/5
<b>Minerals</b>	High grade chipping, high grade crushed sand, natural sand, stone dust				
Particle size mm	0/16	0/11	0/11	0/8	0/5
Grain fraction < 0.09 mm weight-%	6 to 10	6 to 10	7 to 13	7 to 13	8 to 15
Grain fraction > 2 mm weight-%	55 to 65	50 to 60	40 to 60	35 to 60	30 to 50
Grain fraction > 5 mm weight-%	-	-	-	≥ 15	≤ 10
Grain fraction > 8 mm weight-%	25 to 40	15 to 30	≥ 15	≤ 10	-
Grain fraction > 11.2 mm weight-%	≥ 15	≤ 10	≤ 10	-	-
Grain fraction > 16 mm weight-%	≤ 10	-	-	-	-
Crushed sand-natural sand ratio	≥ 1:1	≥ 1:1	≥ 1:1 <sup>3)</sup>	≥ 1:1 <sup>3)</sup>	-
<b>Binder</b>					
Grade	50/70 (70/100) <sup>1)</sup>	50/70 (70/100) <sup>1)</sup>	70/100 (50/70) <sup>1)</sup>	70/100 (50/70) <sup>1)</sup>	70/100 (160/220) <sup>1)</sup>
Binder content weight-%	5,2 - 6,5	6,9 - 7,2	6,2 - 7,5	6,4 - 7,7	6,8 - 8,0
<b>Mix</b>					
Marshall specimen: Compaction temperature °C Air void content <sup>2)</sup> Vol.-%			135 ± 5		
a: Class I, II, III <sup>4)</sup> , a. St SLW	3,0 to 5,0	3,0 to 5,0			
b: Class II a. IV			2,0 to 4,0	2,0 to 4,0	
c: Class V, VI, St SLW a. rural roads			1,0 to 3,0	1,0 to 3,0	1,0 to 3,0
<b>Layer</b>					
Paving thickness cm	5,0 - 6,0	4,0 - 5,0	3,5 - 4,5	3,0 - 4,0	2,0 - 3,0
or paving weight kg/m <sup>2</sup>	120 - 150	95 - 125	85 - 115	75 - 100	45 - 75
Degree of compaction %	≥ 97	≥ 97	≥ 97	≥ 97	≥ 96
Air void content Vol.-%	≤ 7,0	≤ 7,0	≤ 6,0	≤ 6,0	≤ 6,0

### Explanations

- 1) Only in exceptional cases
- 2) With a content of > 20 M.-% blast-furnace or steel mill slag the water absorption must be determined instead of the porosity calculation. The same limit values apply.
- 3) Only for construction class III.
- 4) Only for construction class III for traffic areas subjected to exceptional loads.

Fig. 94 Composition and properties of asphalt concrete

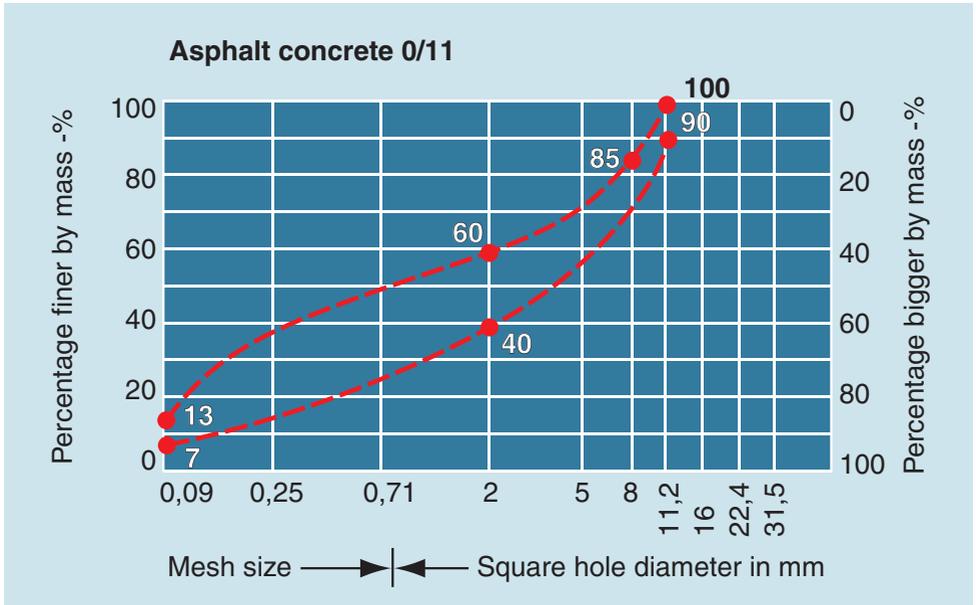


Fig. 95 grain-size distribution curve of asphalt concrete (0/11)

## - Stone mastic asphalt (SMA)

Stone mastic asphalt is a special type of asphalt for wearing courses. It is a mineral mix with a higher bitumen and stone content. It has a high content of the coarsest particles of each fraction. The binders used normally are road construction bitumen types or, for exceptionally heavy traffic loads, polymer modified bitumen types with stabilizing additives. They primarily work as binder carriers. The mineral composition follows the principle of gap-grading. This results in a self-supporting chipping skeleton the cavities of which are to a large extent filled with mastic like mortar.

Due to its special composition this mix is highly wear resistant, deformation and fatigue proof. However, for the same reason it is also difficult to compact and should therefore preferably be compacted with heavy rollers (8 - 10 t) at high temperatures.

As a measure to enhance the initial grip after paving crushed sand or multiple crushed chipping should be spread on the still hot surface, at the earliest after the second roller pass.

		0.11 S	0/8 S	0/8	0/5
<b>Minerals</b>		High-grade chip, high grade crushed sand, stone dust		Multiple crushed chipping, crushed sand, Natural sand, rock flour	
<b>Particle size</b>	mm	0/11	0/8	0/8	0/5
Grain fraction < 0,09 mm	wgt-%	9 to 13	10 to 13	8 to 13	8 to 13
Grain fraction > 2 mm	wgt-%	73 to 80	73 to 80	70 to 80	60 to 70
Grain fraction > 5 mm	wgt-%	60 to 70	55 to 70	45 to 70	< 10
Grain fraction > 8 mm	wgt-%	> 40	< 10	< 10	-
Grain fraction > 11,2 mm	wgt-%	< 10	-	-	-
Crushed sand-natural sand ratio		1:0	1:0	> 1:1	> 1:1
<b>Binder</b>					
Binder type		50/70 (PmB 45) <sup>1</sup>	50/70 (PmB 45) <sup>1</sup>	70/100	70/100 (169/220) <sup>1</sup>
Binder content	wgt-%	> 6,5	> 7,0	> 7,0	> 7,2
<b>Stabilizing additives</b>					
Content in mix	wgt-%	0,3 to 1,5			
<b>Mix</b>					
Marshall specimen:					
Compaction temperature	°C	135 + 5	135 + 5	135 + 5	135 + 5
Air void	Vol.-%	3,0 to 4,0	3,0 to 4,0	2,0 to 4,0	2,0 to 4,0
<b>Layer</b>					
Paving thickness	cm	3,5 to 4,0	3,0 to 4,0	2,0 to 4,0	2,0 to 4,0
Paving weight	kg/m <sup>2</sup>	85 to 100	70 to 100	45 to 100	45 to 75
Paving thickness	cm	2.5 to 5.0	2,0 to 4,0	-	-
Paving weight	kg/m <sup>2</sup>	60 to 125	45 to 100	-	-
Degree of compaction	%	≥ 97			
Air void	Vol.-%	≤ 6,0			
1) Only in exceptional cases					

Fig. 96 Composition and properties of stone mastic asphalt

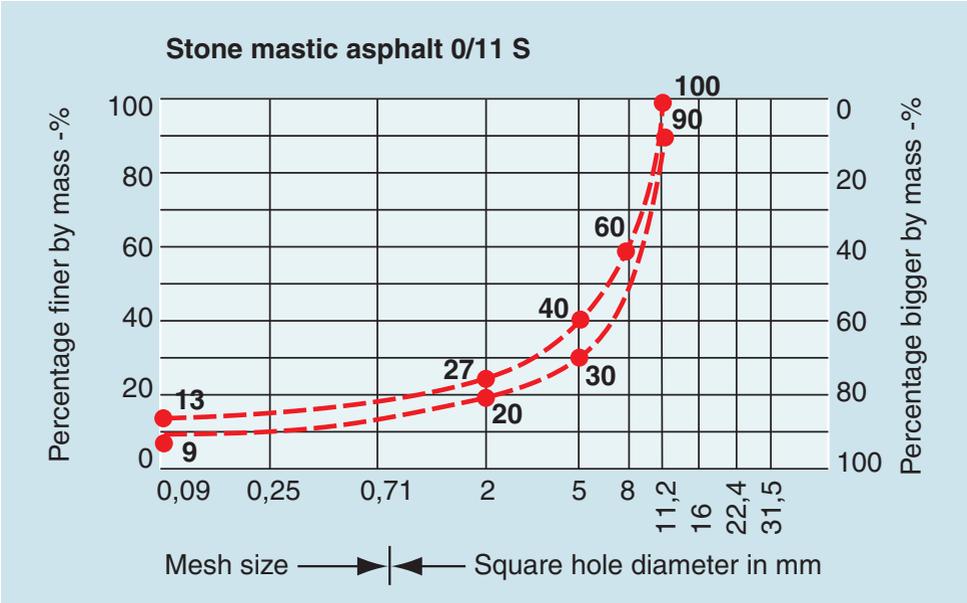


Fig. 97 Grain-size distribution curve of stone mastic asphalt (0/11S)

## A6 Combined surface-base-course construction

This course is a single-layer bituminous paving, which fulfils the function of both base and wearing course. It is normally used for less heavily trafficked roads (construction class VI) and asphalt pavements with small total thickness as well as low demands on the deformation resistance.

The usually used particle size is 0/16 consisting of a particle graded mineral mix and road construction bitumen 70 /100. Since round grain material (natural sand, gravel) is frequently used, the material can also be highly sensitive to scuffing during compaction work. Combination rollers are therefore frequently used to compact single-course constructions. Layer thicknesses from 6 to 10 cm are quite common.

		0/16
Minerals		Chipping a./o. gravel, crushed sand a./o. natural sand, rock flour
Particle size	mm	0/16
Grain fraction < 0,09 mm	wgt-%	7 to 12
Grain fraction > 2 mm	wgt-%	50 to 70
Grain fraction > 11.2 mm	wgt-%	10 to 20
Grain fraction > 16 mm	wgt-%	≤ 10
<b>Binder</b>		
Binder type		70/100, 160/220
Binder content	wgt-%	≥ 5,2
<b>Mix</b>		
Marshall specimen:		
Mix ratio	Vol.-%	1,0 to 3,0
Compaction temperature	°c	135 ± 5
Marshall stability	kN	≥ 4,0
Marshall flow	mm	2,0 to 5,0
<b>Layer</b>		
Paving thickness	cm	5,0 to 10,0
or paving weight	kg/m <sup>2</sup>	120 to 250
Degree of compaction	%	≥ 96
Air void	Vol.-%	≤ 7,0

Fig. 98 Composition and properties of the combined surface-base-course construction

## A7 Bitumen types

Road construction bitumen is a distillation product from treatment of mineral oil. The specific requirements are stipulated in the European standard DIN / EN 12591. This standard replaces the old German standard DIN 1995.

Polymer modified bitumen (PmB) is an industrially manufactured mix of bitumen and polymer materials. The polymer materials thereby change the viscoelastic behaviour of the bitumen. As a result the bitumen sticks better to the minerals, it has a larger plasticity span (larger range between breaking point and softening point) and a high elasticity. It is therefore particularly suitable for areas subjected to high traffic loads, chip mastic asphalts and porous asphalt layers.

The designation of the individual bitumen types follows the penetration limits. The selection of a bitumen type depends on the expected traffic loads under due consideration of the workability; it is stipulated in the ZTV Asphalt - StB.

DIN 1995			DIN EN 12591		
Type	EP RuK	Penetration	Type	EP RuK	Penetration
B 200	37-44	160-210	160/220	35-43	160-220
B 80	44-49	70-100	70/100	43-51	70-100
B65	49-54	50-70	50/70	46-54	50-70
B45	54-59	35-50	30/45	52-60	30-45
B 25	59-97	20-30	20/30	55-63	20-30

Fig. 99 Old and new classification of bitumen types



## ***List of rules and literature***

ZTV Asphalt – StB 01: Zusätzliche Technische Vertragsbedingungen und Richtlinien für den Bau von Fahrbahndecken aus Asphalt, Ausgabe 2001

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Floss, R. (2001): Compaction Technology in Earthwork, Highway and Transportation Engineering. BOMAG Fachbuch, Boppard

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