Wirtgen cold milling manual

Technology and application

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For more than 50 years, milling technology has been one of Wirtgen GmbH's core areas of expertise. As a market leader in the field of cold milling, the company were, and are, largely responsible for many innovations and trail-blazing future-oriented technologies and today offer the most comprehensive product line in the industry.

We have published this manual to give both users and other interested persons an in-depth look into the world of cold milling. In addition to a short presentation of the general history of cold milling and Wirtgen's own product line, we will explain the core technologies, application possibilities and conditions of use (including increased requirements of the future) and supplement this with background information.

All the technical data presented here are values gained from experience and should not be viewed independently of the respective concrete application examples. They are thus subject to change and are generally only to be seen as guideline values which can be used for purposes of comparison.

If you require specific information on the use of Wirtgen cold milling machines, please contact a Wirtgen sales office or a dealer. Wirtgen assume no liability for damage, consequential damage or other claims resulting from the use of this manual.

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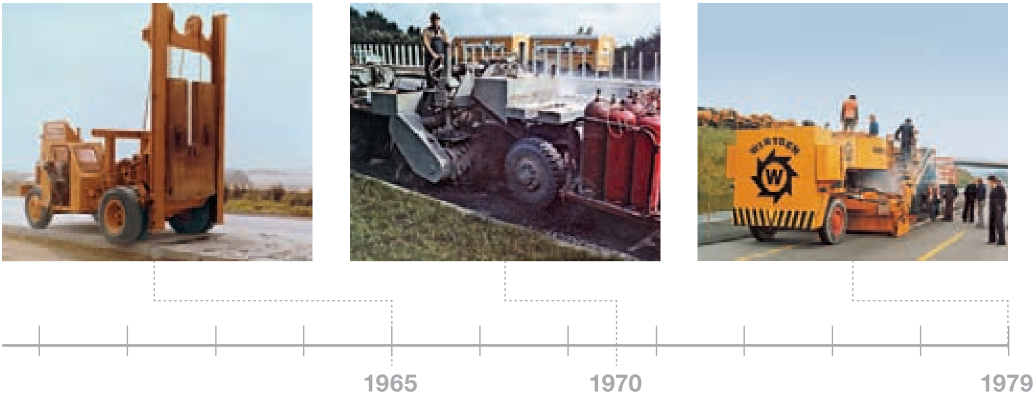
1 The basic concept of cold milling machines

1.1 The history of cold milling machines

1.1.1 Efficient milling technology: from hot milling to cold milling machines



Although the history of cold milling is still relatively young, milling has been a process well-known in street construction since the 1950s. The predecessors of today's modern milling machines were the rotary tillers, which milled the freshly sprayed bitumen into the subsurface and were either self-propelled or towed by tractors. Concrete breakers have been used to break up surfaces since the 1960s. The resulting material had to be bulldozed out with great effort, as targeted repair of individual damaged spots was not possible and made the process inefficient.

Due to the constant increase in traffic volume and the associated road wear, the problem had increasingly come to a head. New approaches had to be found:

1970 The birth of hot milling: Large-area gas burners attached to the milling machine (up to 20 metric tons in weight and 16 m long) heated the asphalt, which could then be removed by a rotating milling drum. For the first time, solid road surfaces could be repaired economically without renewing the entire asphalt layer and without damaging the material underneath.

In the mid 1970s, hot milling was recognised as the standard method for road construction, but due to the high energy costs involved, the great amount of smoke generated and the shallow depth of milling which could be achieved, the method was continually confronted with limits.

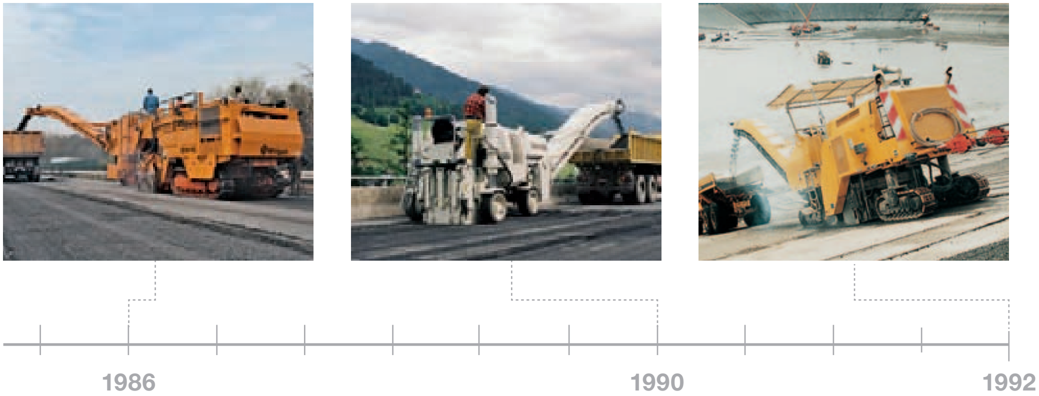
1975 The first “cold” road milling machines are developed in Europe. It was initiated by the idea of using carbide tools from the mining industry for milling road surfaces. This made heating of the asphalt unnecessary.

1979 Use of rotating picks begins. Carbide picks were ideal for removing the hardest layers, even at greater milling depths.

1981 The first front-loading cold milling machines appear on the market. The revolutionary loading logistics enable efficient loading of lorries with milled material.

1985 The use of tracked crawler units increases traction and use on surfaces not capable of bearing weight.

1987 The development of the mechanical milling drum drive enables high daily productivity and ensures even transmission of force.



1992 Exchangeable toolholder systems are introduced. Worn upper parts of a toolholder can be quickly exchanged via screw connections at the construction site.

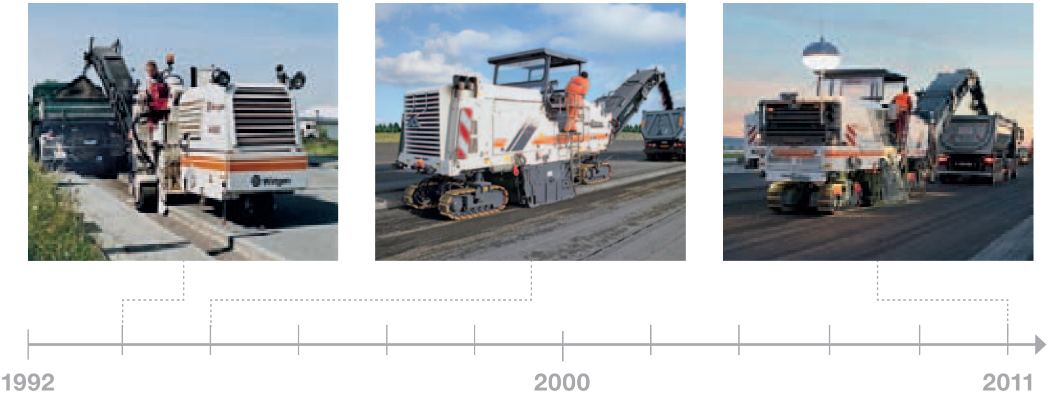
1993 High-precision levelling systems ensure exact milling depths and even milling surfaces.

2001 Milling drum systems such as the Flexible Cutter System (FCS) facilitate the exchanging of milling drums with different tool spacing or milling widths and increase machine performance.

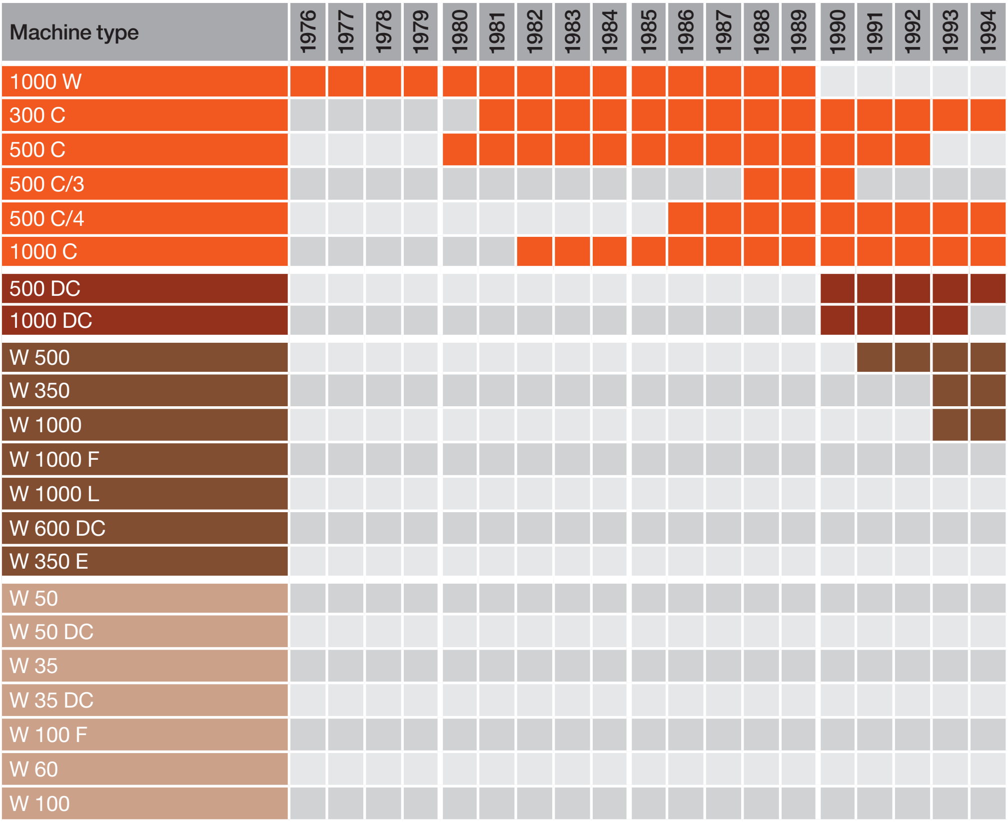
2005 Extraction systems such as the Vacuum Cutting System reduce the quantity of airborne particles and thus reduce environmental emissions.

2007 Thanks to innovative machine control systems such as WIDRIVE, the most important machine functions are linked to one another and controlled centrally.

2010 The latest generation of large milling machines set new standards in the area of performance and cost efficiency.


1992
2000
2011

Small milling machines



Machine type	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1000 W	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
300 C						■	■	■	■	■	■	■	■	■	■	■	■	■	■
500 C					■	■	■	■	■	■	■	■	■	■	■	■	■		
500 C/3													■	■	■				
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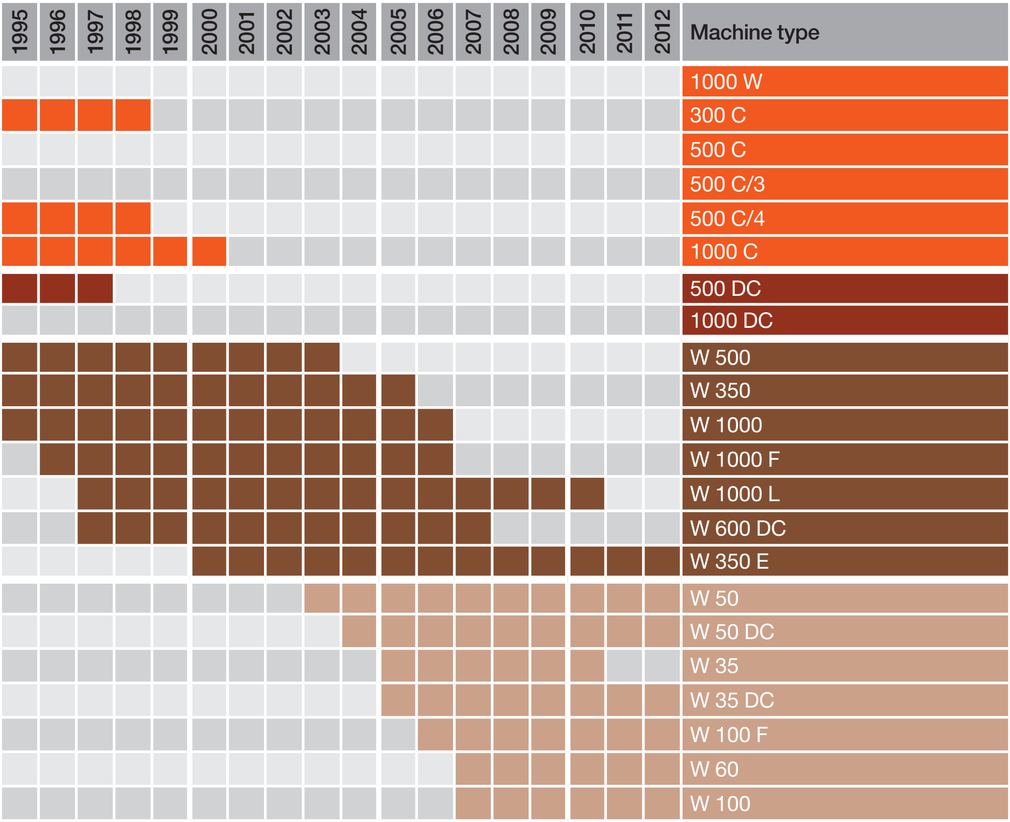

1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Machine type
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■	■	■	■															500 C/4
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■	■	■	■	■	■	■	■	■										W 500
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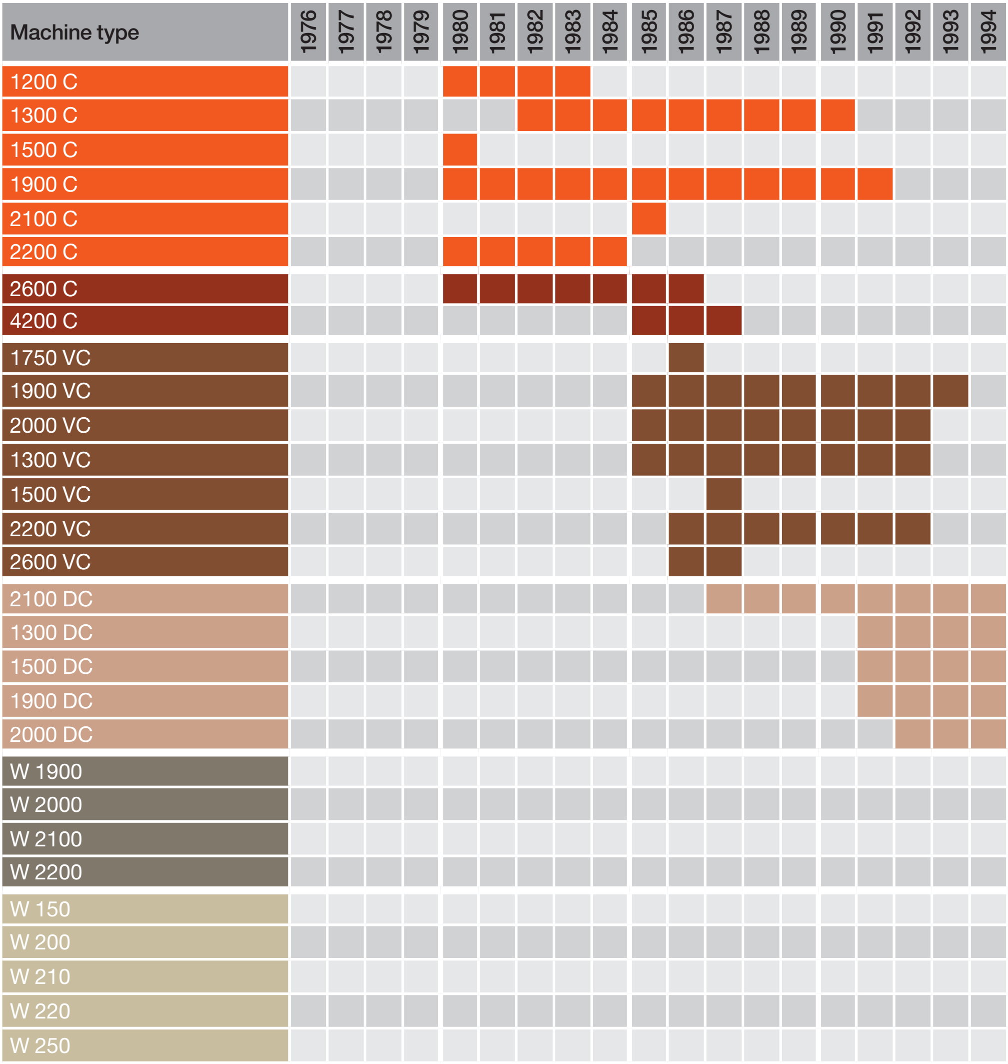
Large milling machines



Machine type	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1200 C					■	■	■	■											
1300 C							■	■	■	■	■	■	■	■	■				
1500 C					■														
1900 C					■	■	■	■	■	■	■	■	■	■	■	■			
2100 C										■									
2200 C					■	■	■	■	■										
2600 C					■	■	■	■	■	■	■								
4200 C										■	■	■							
1750 VC											■								
1900 VC										■	■	■	■	■	■	■	■	■	
2000 VC										■	■	■	■	■	■	■	■		
1300 VC										■	■	■	■	■	■	■	■		
1500 VC												■							
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2600 VC											■	■							
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1300 DC																■	■	■	■
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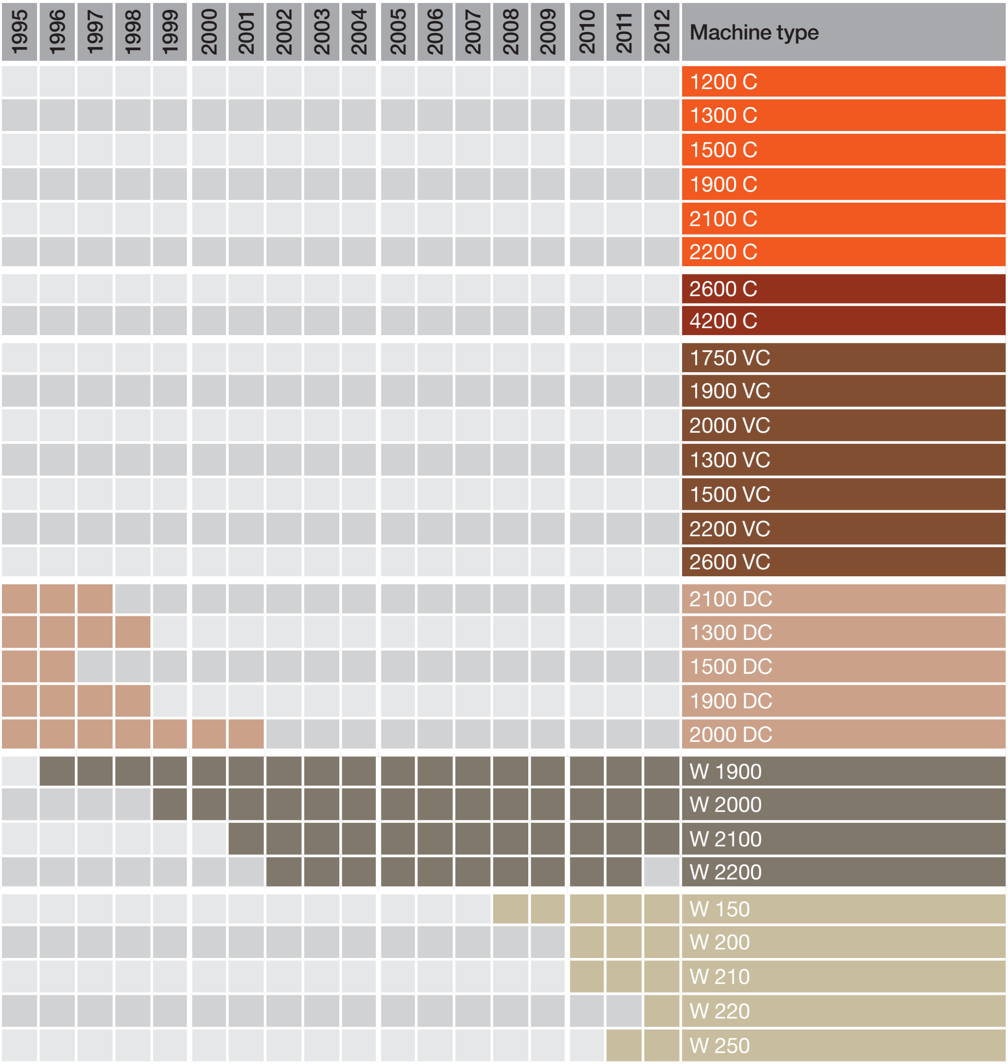
W 220																			
W 250																			



1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Machine type
																		1200 C
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■	■	■																2100 DC
■	■	■	■															1300 DC
■	■																	1500 DC
■	■	■	■															1900 DC
■	■	■	■	■	■	■												2000 DC
	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	W 1900
				■	■	■	■	■	■	■	■	■	■	■	■	■	■	W 2000
						■	■	■	■	■	■	■	■	■	■	■	■	W 2100
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													■	■	■	■	■	W 150
															■	■	■	W 200
															■	■	■	W 210
																	■	W 220
																■	■	W 250

1.2 Function and intended use

1.2.1 Motives and measures for structural upkeep

Cold milling was one of the first measures used in structural upkeep of road and traffic surfaces. A differentiation is made between maintenance (minor measures for structural preservation), repair (major measures for structural preservation and improvement of surface characteristics) and renewal (complete reconstruction). The condition of the milling surface affects the quality of the

Evenness

Condition parameter	**Appearance**	**Textured area**	**Possible cause**
Longitudinal evenness	Long-wave, large-area deformation	50 to 500 mm	Inconsistency of compaction
			Uneven layer thickness
			Insufficient load bearing capacity of foundation
			Standstill of paver during paving process
			Impact to paver while unloading material
			Unevenness in foundation structure
	Local, vertical deformation (load bearing capacity)	20 to 100 mm	Setting of the foundation
			Frost damage to the lower courses
Cross profile evenness	Shear deformation (with lateral bulges)	10 to 100 mm	High traffic load (with high shearing forces)
			Insufficient stiffness of the asphalt surface course
			Excessively soft binder
			Insufficient hollow space content and over-compaction
			High load on substantially heated surface

***For an explanation of terms, see Index of abbreviations, page 241.**

cf. ZTV BEA-StB Handbuch und Kommentar, page 51 and 169.

new surface courses, their performance characteristics and the economical and time-efficient execution of other construction work. For example, an even, true-to-profile milling result is an important criterion for paving surface courses of even thickness and for avoiding costly improvements, i. e. paving additional layers of asphalt for compensation.

	Suitable milling procedure				Suitable repair procedure				
	Micro-fine milling	Fine milling	Standard milling	Eco Cutter (complete removal)	OB*	DSK*	AC D*, SMA*, MA*, DSH-V*	RF*	EAD*
	○	●	● ●	○	○	○	○	● ●	● ●
	○	○	●	● ●	○	○	○	○	○
	●	● ●	● ●	○	○	● ●	● ●	● ●	● ●

● ● Suitable

● Suitable under certain conditions

○ Not suitable

Evenness

Condition parameter	Appearance	Textured area	Possible cause
Cross profile evenness	Vertical deformation	20 to 200 mm	Re-compaction of the asphalt surface course or lower courses
			Insufficient load-bearing capacity of lower courses
	Wear	5 to 50 mm	Excessively high mechanical load
			Minimal resistance of stone against wear

Roughness

Condition parameter	Appearance	Textured area	Possible cause
Surface grip	Polished grain surface	0.001 to 2 mm	High traffic load
			Insufficient polishing resistance of stone
	Binder / Mortar enrichment of the surface	0.001 to 5 mm	Unsuitable bitumen
			Structural separation of components during paving
			High binder content in asphalt
			High traffic load

*** For an explanation of terms, see Index of abbreviations, page 241.**

cf. ZTV BEA-StB Handbuch und Kommentar, page 51 and 169.

	Suitable milling procedure				Suitable repair procedure				
	Micro-fine milling	Fine milling	Standard milling	Eco Cutter (complete removal)	OB*	DSK*	AC D*, SMA*, MA*, DSH-V*	RF*	EAD*
	○	○	●●	●●	○	○	○	○	○
		●●	●●		○	○	○	○	○

	Suitable milling procedure				Suitable repair procedure				
	Micro-fine milling	Fine milling	Standard milling	Rough milling (complete removal)	OB*	DSK*	AC D*, SMA*, MA*, DSH-V*	RF*	EAD*
	●●	●	○	○	●●	●●	●●	●●	●●
	●●	●	○	○	○	●●	●●	●●	●●

●● Suitable ● Suitable under certain conditions ○ Not suitable

Material defects

Condition parameter	Appearance	Textured area	Possible cause
Alligator cracks	Alligator cracks		Absent layer bonding
			Insufficient load bearing capacity of the lower courses
			Compaction defect
			Low-temperature cracks
			Rolling cracks
			Cracks resulting from ageing and weather
Wear	Mortar loss		Insufficient adhesion between bitumen and stone
			Insufficient fine grain/filler grain
Grain eruptions	Grain eruptions/ Fretting (similar to wear)		Insufficient adhesion between bitumen and stone
			Heavy shear stressing of the surface
			Insufficient compaction
			Weather-sensitive stone
Individual cracks	Individual cracks		Reflection crack
			Fatigue crack
			Crack at open working seam
Mends	Mends		Maintenance measures (openings/potholes, open seams or connections)
			Road construction waste (within town)

***For an explanation of terms, see Index of abbreviations, page 241.**

cf. ZTV BEA-StB Handbuch und Kommentar, page 51 and 169.

	Suitable milling procedure				Suitable repair procedure				
	Micro-fine milling	Fine milling	Standard milling	Rough milling (complete removal)	OB*	DSK*	AC D*, SMA*, MA*, DSH-V*	RF*	EAD*
	●	●●	●●	○	●●	●●	●●	●●	●●
	●	●●	●●	○	●●	●●	●●	●●	●●
	●	●●	●●	○	●●	●●	●●	●●	●●
	○	●	●●	○	○	○	○	○	●
	○	○	●●	●●	●	●●	●●	●●	●●

●●	Suitable	●	Suitable under certain conditions	○	Not suitable

1.2.2 Layer-by-layer removal

The exact milling depth can be defined using the vertically adjustable crawler units of the cold milling machine so that individual layers, e. g. on motorways, major roads, airport runways etc., can be removed precisely. This creates a level, true-to-profile ground surface.

Careful removal of road markings, e. g. on car parks, airport runways and motorways, without damaging the layer underneath

Milling in tunnels for the purpose of lowering the tunnel and gallery floors

Partial road repairs

Milling of road connections to adjoining roads

Milling around road installations, such as manhole covers and water inlets

1.2.3 Reshaping

Reshaping is the targeted removal of individual layers for improvement of the surface structures.

- Restoration of road surface grip and evenness and thus traffic safety
- Fine milling of the surface before applying thin-layer surface coverings to ensure optimum interlocking with the road surface. This is why fine milling drums featuring a greater number of picks with a tool spacing of up to 4 mm are used.
- Repair of roads, as well as reshaping of parking areas, hall floors etc.

1.2.4 Special profiles

Special cross-section profiles can be created with special milling drums.

- Milling water channel profiles
- Milling grooves and slits
- Milling split cuts
- Milling supply shafts for cables, protective tubes, pipelines etc.

1.3 The components of modern cold milling machines

1.3.1 Milling machine types

Small milling machines

Small milling machines offer high manœuvrability and flexibility and are used for processing small areas and for precise milling in the tightest spaces. They are usually equipped with multiple wheeled crawler units. The milling drum is arranged at the rear of the machine.

Milling widths < 130 cm
Compact dimensions and light transport weights
Minimal milling radius, ideal for milling around
obstacles, tight curves, road installations

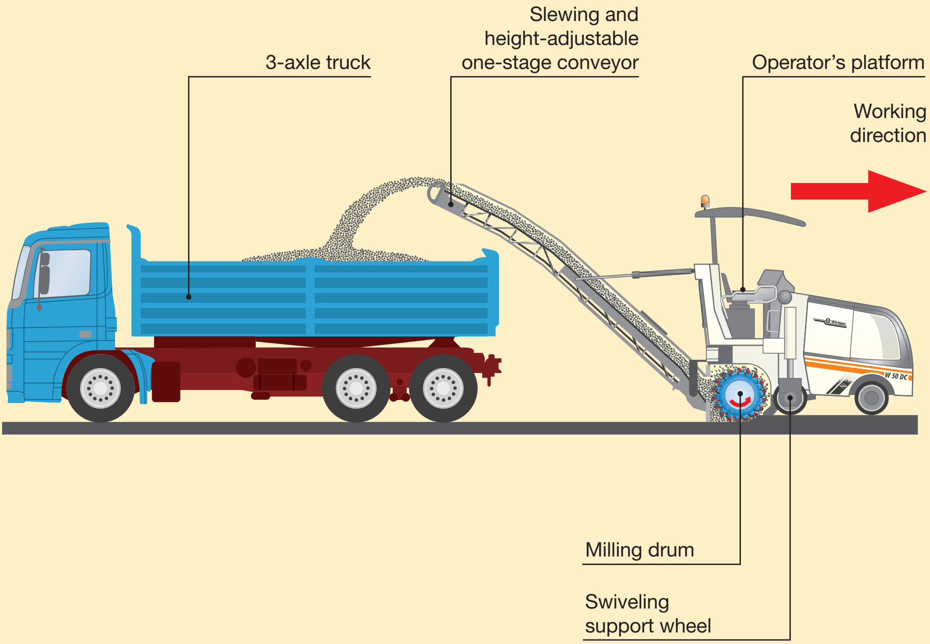
Large milling machines

Large milling machines offer high milling performance and are ideal for repair measures with high area performance. They are generally equipped with tracked crawler units. The milling drum is arranged between the crawler tracks.

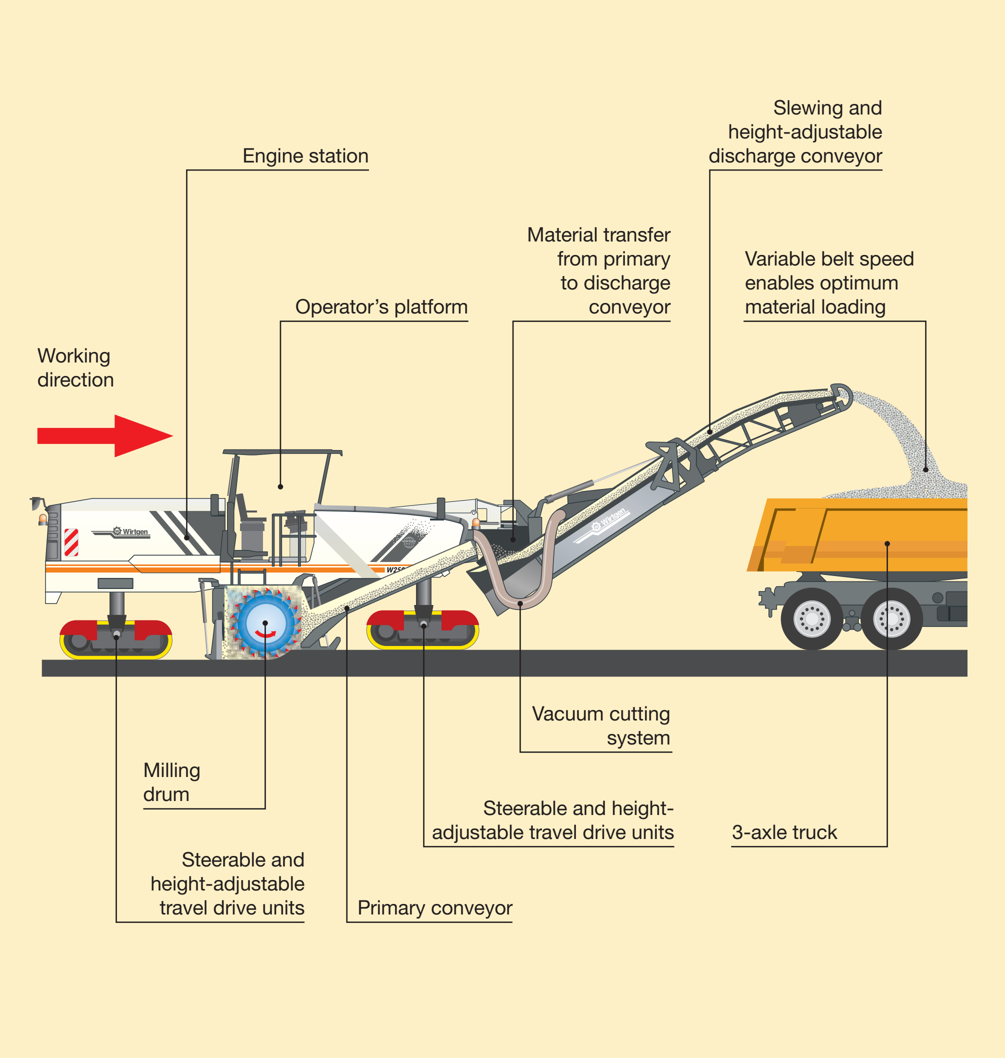
Milling widths > 130 cm
Strong motorisation > 250 kW
Thanks to the high volume performance, construction measures can be carried out faster, thus minimising traffic obstructions.

Front loading of the milled material enables optimum transport of material away and keeps the milling process flowing:
- Continuous filling of trucks thanks to “on-the-fly changes”,
- Smooth pulling in and out of trucks in the direction of the traffic passing by.

1.3.2 The components of a rear loader



1.3.3 The components of a front loader



1.4 The advantages of modern cold milling machines

1.4.1 Technical advantages

Cold milling establishes the basis for creating new road profiles. Layer-by-layer removal of damaged roads thus allows separation and selective reclamation by mixed material type.

The true-to-profile, even milling result enables quick and easy paving of new surface courses.
Vertical, clean milling edges ensure precise connections to existing layers.

1.4.2 Economic advantages

Cold milling is an especially quick and powerful construction method.

Construction costs can be reduced thanks to shortened construction site times.
"On-the-fly construction sites" cause fewer traffic obstructions: Repair is limited to the traffic surface affected by the damage, and traffic can simply flow past.
High economy through fine milling: After the surface work has been completed, the road can be opened to traffic again immediately.
Conservation of valuable raw materials: The reclaimed material is reused 100 %, usually recycled in hot or cold mixing plants.

2 Modern cold milling machines

2.1 Machine types and performance

2.1.1 Small milling machines with a milling width up to 600 mm

W 35 DC

- Mechanical milling drum drive for efficient power transmission
- Tight milling radii, e.g. for milling out manhole covers
- Continuous all-wheel drive for maximum traction
- Can be equipped with discharge conveyors with one of two different lengths as desired
- Extremely ergonomic operator’s platform with optimum visual conditions for the best possible operability

Technical Data

	W 35 DC
Milling width	350 mm (optional 500 mm)
Milling depth *	0-110 mm
Operating weight, CE	4,450 kg
Engine manufacturer and model	Deutz AG D 2011 L04W
Maximum engine power	42.8 kW/57.4 HP/58.2 PS at 2,300 min^{-1}
Full-load fuel consumption	12.6 l/h
Construction site (variety) fuel consumption	8.4 l/h
Exhaust level	EU Stage 3a/US Tier 3
Fuel tank	70 l
Water tank	275 l
Max. milling speed	0-25 m/min
Max. driving speed	0-6 km/h
Theoretical discharge conveyor capacity	33 m^3/h

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

W 50

- Economical all-round machine for all common small milling tasks
- Spacious operator’s platform, intuitively operated consoles, optimum view of the milled edge
- Most manœuvrable machine of its class, available in three- and four-wheel versions
- Mechanical milling drum drive for efficient power transmission
- Large variety of milling drums for every application

Technical Data

	W 50
Milling width	500 mm
Milling depth *	0-160 mm
Operating weight, CE	6,750 kg
Engine manufacturer and model	Deutz AG TD 2011 L04W
Maximum engine power	59.9 kW / 80.3 HP / 81.5 PS at 2,500 min^{-1}
Full-load fuel consumption	18.3 l / h
Construction site (variety) fuel consumption	8.3 l / h
Exhaust level	EU Stage 3a / US Tier 3
Fuel tank	165 l
Water tank	500 l
Max. milling speed	0-12.5 m / min
Max. driving speed	0-6 km / h
Theoretical discharge conveyor capacity	82 m^3 / h

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

W 50 DC

- Maximum efficiency has made it the best-selling cold milling machine in the 500 mm rear loader class
- Especially suitable for smaller milling tasks thanks to its amazing manœuvrability (three- and four-wheel versions)
- Short and long discharge conveyors available for different loading situations
- Efficient milling machine controller WIDRIVE and levelling controller LEVEL PRO for minimal operating costs
- Mechanical milling drum drive and electronic power control unit for maximum milling performance

Technical Data

	W 50 DC
Milling width	500 mm
Milling depth *	0-210 mm
Operating weight, CE	7,800 kg
Engine manufacturer and model	Deutz AG TCD2012 L04 2V AG3
Maximum engine power	92 kW / 123 HP / 125 PS at 2,100 min^{-1}
Full-load fuel consumption	23.7 l / h
Construction site (variety) fuel consumption	10.6 l / h
Exhaust level	EU Stage 3a / US Tier 3
Fuel tank	230 l
Water tank	600 l
Max. milling speed	0-27 m / min
Max. driving speed	0-5.3 km / h
Theoretical discharge conveyor capacity	82 m^3 / h

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

W 60i

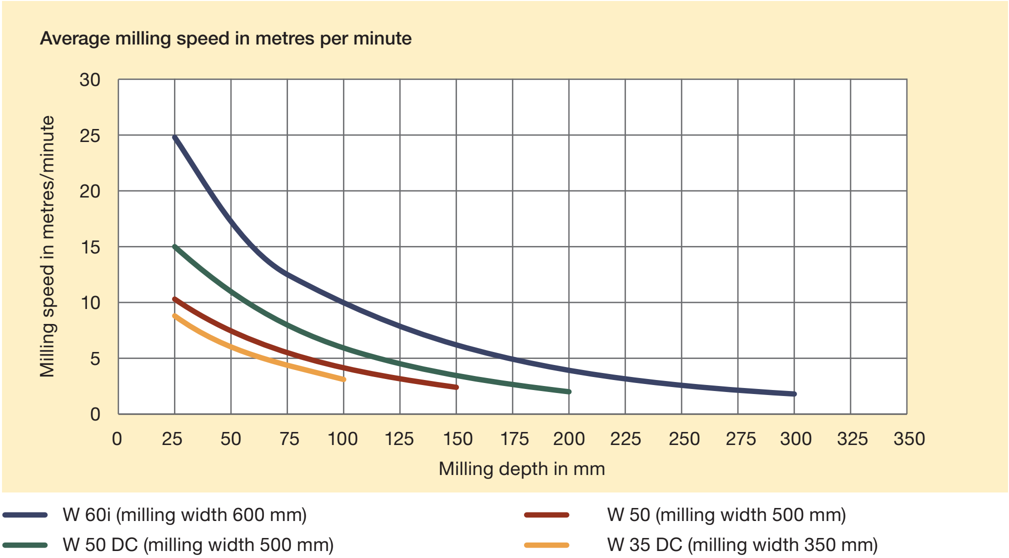
- Maximum milling performance up to a milling depth of 300 mm in the 600 mm rear loader class
- Efficient milling machine control WIDRIVE and levelling control LEVEL PRO for minimal operating costs
- Large and long discharge conveyor for loading three-axle trucks
- Especially suitable in milling mode in cramped construction site conditions
- Perfect ergonomics, well-laid-out consoles, optimum visual conditions

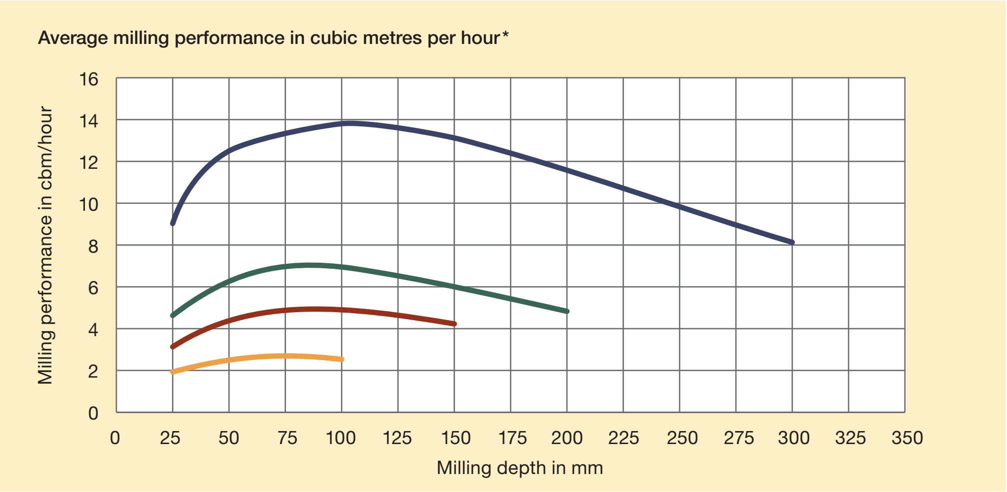
Technical Data

	W 60i
Milling width	600 mm
Milling depth *	300 mm
Operating weight, CE	13,800 kg
Engine manufacturer and model	Deutz AG TCD 6.1 L6
Maximum engine power	160 kW/215 HP/218 PS at 2,100 min^{-1}
Full-load fuel consumption	44 l/h
Construction site (variety) fuel consumption	18 l/h
Exhaust level	EU Stage 3b/US Tier 4i
Fuel tank	450 l
Water tank	900 l
Max. milling speed	0-30 m/min (1.8 km/h)
Max. driving speed	0-6 km/h
Theoretical discharge conveyor capacity	115 m^3/h

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

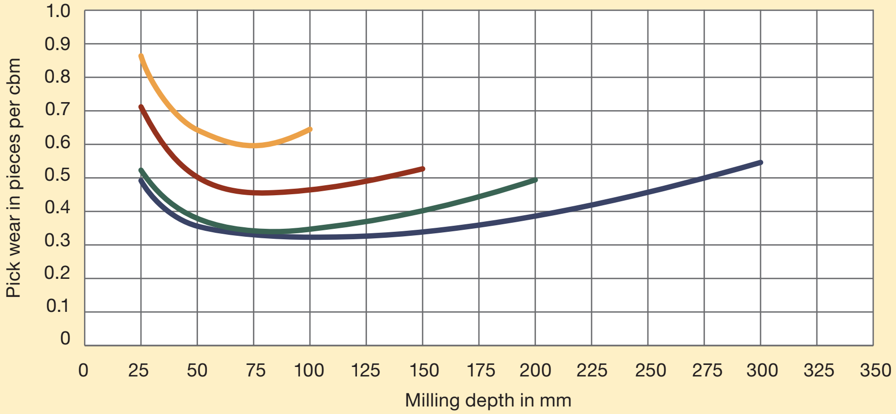
2.1.2 Comparison of machine performance (W 35 DC, W 50, W 50 DC, W 60i)


Average milling speed in metres per minute


Average milling performance in cubic metres per hour*

***including general machine downtime, such as truck changes, refuelling diesel, changing picks, general waiting times, etc.**

Pick wear in pieces per cubic metre



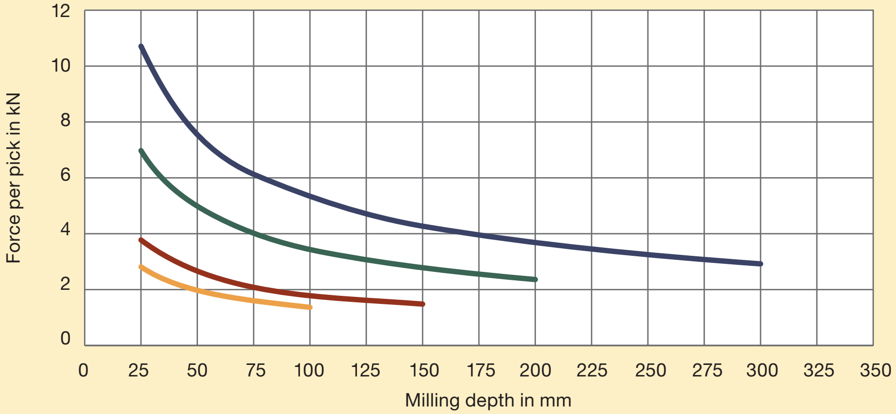
W 60i (milling width 600 mm)

W 50 (milling width 500 mm)

W 50 DC (milling width 500 mm)

W 35 DC (milling width 350 mm)

Average force per pick during milling in kilonewtons



Note: The charts shown here contain average guideline values. Depending on the milling task at hand, relatively great deviation from the average is possible.
All specifications in cubic metres pertain to compressed volume density (i. e. installed asphalt).

2.1.3 Small milling machines with a milling width up to 1,300 mm

W100/W100i

- Very manœuvrable and powerful cold milling machine of the 1,000 mm rear loader class
- Especially suitable in milling mode in cramped construction site conditions
- Perfect ergonomics, well-laid-out consoles, optimum visual conditions
- Large and long discharge conveyor for loading three-axle trucks
- Efficient milling machine control WIDRIVE and levelling control LEVEL PRO for minimal operating costs

Technical Data

	W 100	W 100i
Milling width	1,000 mm	
Milling depth *	300 mm	
Operating weight, CE	14,250 kg	14,500 kg
Engine manufacturer and model	Deutz AG TCD 2012 L06 2V	Deutz AG TCD 6.1 L6
Maximum engine power	155 kW/208 HP/211 PS at 2,300 min^{-1}	160 kW/215 HP/218 PS at 2,300 min^{-1}
Full-load fuel consumption	42 l/h	44 l/h
Construction site (variety) fuel consumption	17 l/h	18 l/h
Exhaust level	EU Stage 3a/US Tier 3	EU Stage 3b/US Tier 4i
Fuel tank	450 l	480 l
Water tank	900 l	
Max. milling speed	0-30 m/min (1.8 km/h)	
Max. driving speed	0-6 km/h	
Theoretical discharge conveyor capacity	115 m^3/h	

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

W 100 F/W 100 Fi, W 120 F/W 120 Fi, W 130 F/W 130 Fi

- Available in the three basic milling widths of 1,000 mm, 1,200 mm and 1,300 mm
- Maximum productivity thanks to the highest engine power it its class
- Efficient milling machine control WIDRIVE and levelling control LEVEL PRO for minimal operating costs
- Available with either quiet-running wheels or rugged tracked crawler units
- Many additional milling widths starting at 300 mm are available when outfitted with the FCS system

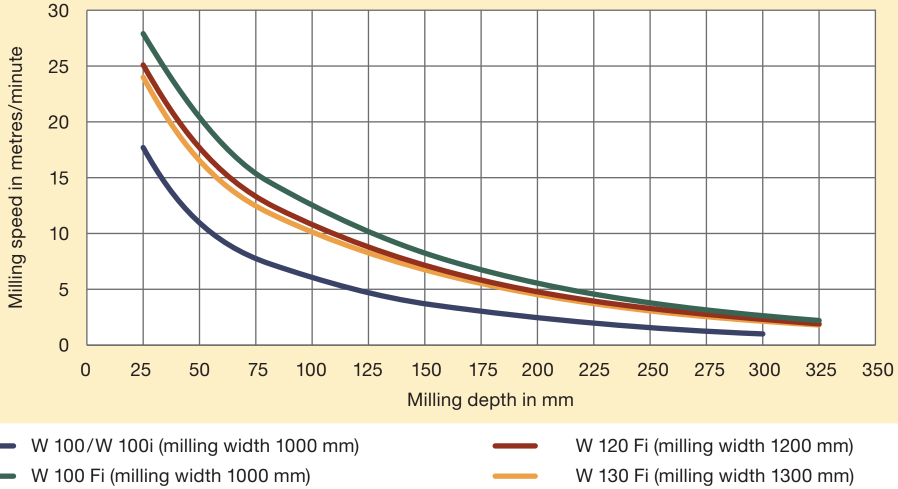
Technical Data

	W 100 F, W 120 F, W 130 F	**W 100 Fi, W 120 Fi, W 130 Fi**
Milling width	1,000 mm (W 100 F) 1,200 mm (W 120 F) 1,300 mm (W 130 F)	1,000 mm (W 100 Fi) 1,200 mm (W 120 Fi) 1,300 mm (W 130 Fi)
Milling depth *	0-320 mm	
Operating weight, CE	18,400 kg (W 100 F) 19,300 kg (W 120 F) 19,700 kg (W 130 F)	18,700 kg (W 100 Fi) 19,600 kg (W 120 Fi) 20,000 kg (W 130 Fi)
Engine manufacturer and model	Cummins QSC 8.3	Cummins QSL 9
Maximum engine power	227 kW/304 HP/308 PS at 1,900 min^{-1}	239 kW/320 HP/325 PS at 1,900 min^{-1}
Full-load fuel consumption	62 l/h	64 l/h
Construction site (variety) fuel consumption	25 l/h	26 l/h
Exhaust level	EU Stage 3a/US Tier 3	EU Stage 3b/US Tier 4i
Fuel tank	620 l	610 l
Water tank	1,400 l	1,340 l
Max. milling speed	0-32 m/min (1.9 km/h)	
Max. driving speed	0-125 m/min (7.5 km/h)	
Theoretical discharge conveyor capacity	176 m^3/h	

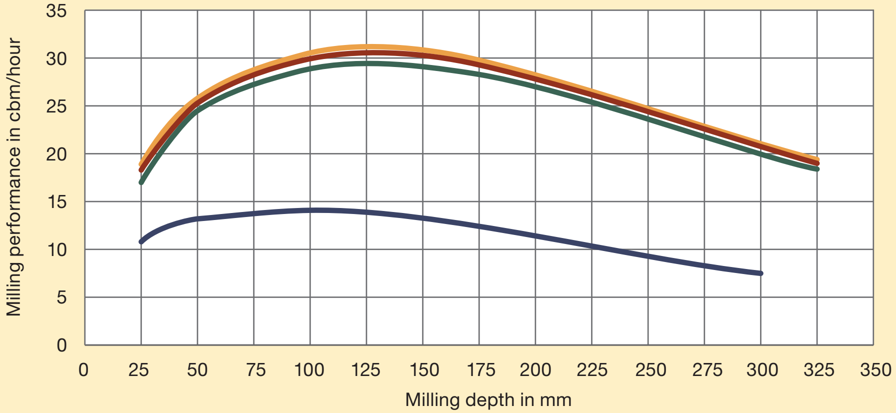
*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

2.1.4 Comparison of machine performance (W 100 / W 100i, W 100 F / W 100 Fi, W 120 F / W 120 Fi, W 130 F / W 130 Fi)

Average milling speed in metres per minute

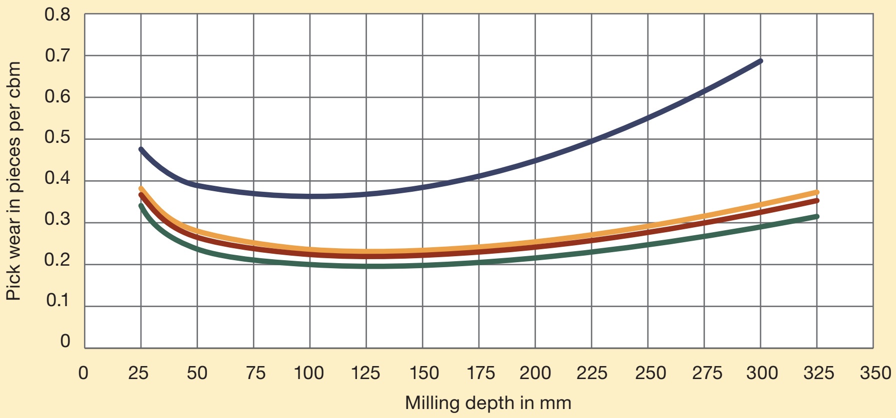


Average milling performance in cubic metres per hour*



***including general machine downtime, such as truck changes, refuelling diesel, changing picks, general waiting times, etc.**

Pick wear in pieces per cubic metre



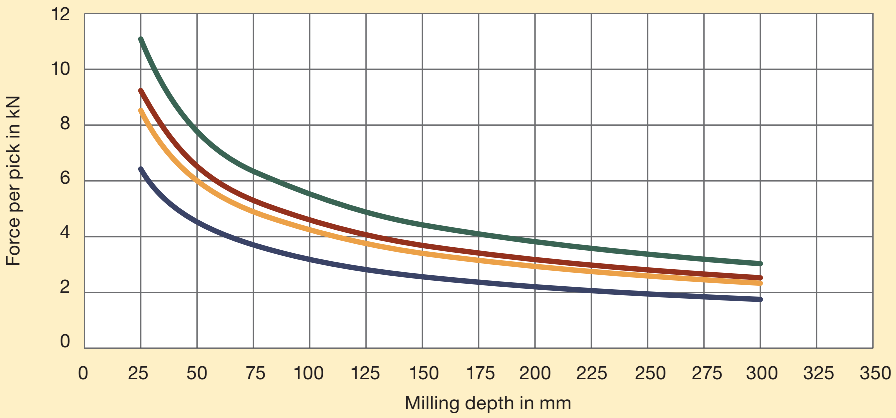
▬ W 100/W 100i (milling width 1000 mm)

▬ W 100 Fi (milling width 1000 mm)

▬ W 120 Fi (milling width 1200 mm)

▬ W 130 Fi (milling width 1300 mm)

Average force per pick during milling in kilonewtons



Note: The charts shown here contain average guideline values. Depending on the milling task at hand, relatively great deviation from the average is possible.
All specifications in cubic metres pertain to compressed volume density (i. e. installed asphalt).

2.1.5 Large milling machines with a milling width up to 3,800 mm

W 1900

- Very compact and easy to transport cold milling machine of the 2,000 mm milling-width class
- Economical 8-cylinder diesel engine with 350 kW maximum power for efficient working
- Compact dimensions and low transport weight for flexible order acceptance
- Optimum material loading conveyor system for optimum utilisation of the milling performance
- Mechanical milling drum drive and electronic power control unit for maximum milling performance

Technical Data

	W 1900
Milling width	2,000 mm (optional 2,200 mm)
Milling depth *	0-320 mm
Operating weight, CE	26,700 kg
Engine manufacturer and model	Daimler OM 502 LA
Maximum engine power	350 kW / 469 HP / 476 PS at 1,800 min^{-1}
Full-load fuel consumption	84 l / h
Construction site (variety) fuel consumption	38 l / h
Exhaust level	EU Stage 3a / US Tier 3
Fuel tank	850 l
Water tank	1,600 l (+ 1,000 l additional water tank)
Max. milling speed	0-29 m / min (1.8 km / h)
Max. driving speed	0-4.5 km / h
Theoretical discharge conveyor capacity	290 m^3 / h

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

W 2000

- World’s best-selling, extremely effective cold milling machine of the 2,000 mm milling-width class
- Powerful 6-cylinder diesel engine with 433 kW maximum power for efficient working
- Especially flexible thanks to FCS light for quick milling drum changes for fine milling or to the Eco Cutter
- PLC machine controller with WIDRIVE functionality
- Mechanical milling drum drive and electronic power control unit for maximum milling performance

Technical Data

	W 2000
Milling width	2,000 mm (optional 2,200 mm)
Milling depth *	0-320 mm
Operating weight, CE	30,000 kg
Engine manufacturer and model	Caterpillar C 15 ATAAC
Maximum engine power	433 kW/581 HP/589 PS at 2,100 min^{-1}
Full-load fuel consumption	124 l/h
Construction site (variety) fuel consumption	56 l/h
Exhaust level	EU Stage 3a/US Tier 3
Fuel tank	1,310 l
Water tank	3,430 l
Max. milling speed	0-84 m/min (0-5 km/h)
Max. driving speed	0-84 m/min (0-5 km/h)
Theoretical discharge conveyor capacity	330 m^3/h

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

W 2100

- Compact cold milling machine of the high-performance class with a 2,200 mm milling width
- Integrated LEVEL PRO levelling control for optimum results
- Rugged milling drum unit and discharge conveyor for maximum productivity
- Elastically suspended walk-through operator's platform with two operating consoles which can be pulled to the driver or pushed to the side
- Mechanical milling drum drive and electronic power control unit for maximum milling performance

Technical Data

	W 2100
Milling width	2,200 mm
Milling depth *	0-320 mm
Operating weight, CE	36,300 kg
Engine manufacturer and model	Caterpillar C 18 ATAAC
Maximum engine power	522 kW / 700 HP / 710 PS at 2,100 min^{-1}
Full-load fuel consumption	145 l / h
Construction site (variety) fuel consumption	65 l / h
Exhaust level	EU Stage 3a / US Tier 3
Fuel tank	1,300 l
Water tank	4,500 l
Max. milling speed	0-86 m / min (0-5.2 km / h)
Max. driving speed	0-86 m / min (0-5.2 km / h)
Theoretical discharge conveyor capacity	550 m^3 / h

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

W 2200

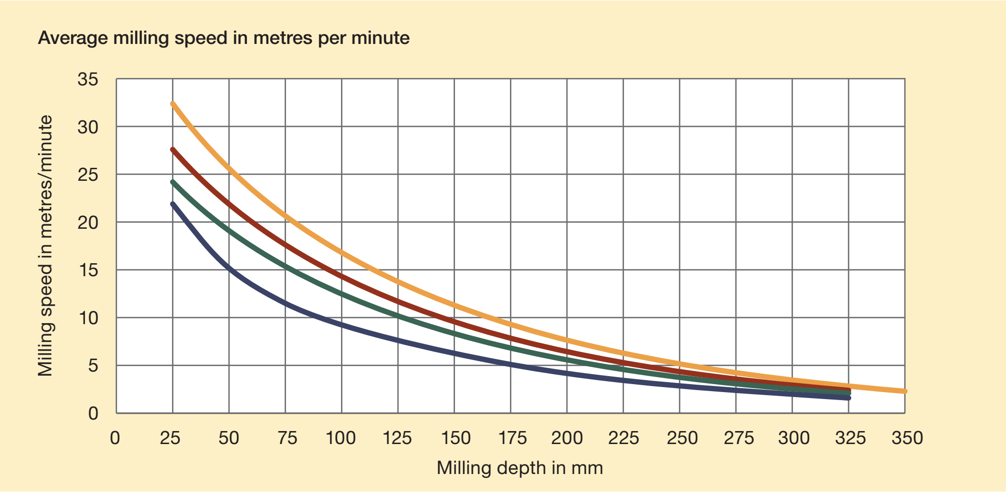
- Maximum milling performance with a milling width of 2,200, 2,500 or 3,800 mm
- Maximum engine performance with 708 kW for large milling tasks to be carried out efficiently
- Mechanical milling drum drive and electronic power control unit for maximum milling performance
- Integrated LEVEL PRO levelling control for optimum results
- Elastically suspended walk-through operator's platform with two operating consoles which can be pulled to the driver or pushed to the side

Technical Data

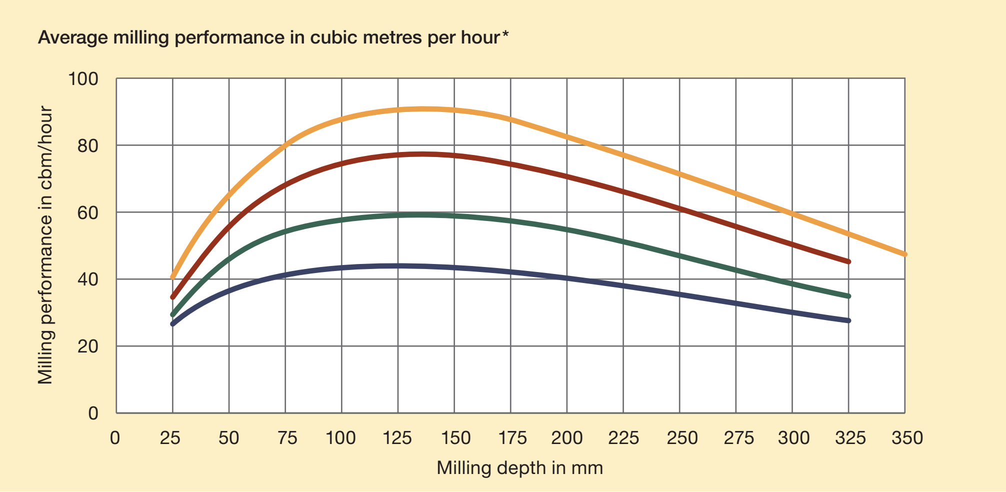
	W 2200
Milling width	2,200 mm (optional 2,500 mm or 3,800 mm)
Milling depth *	0-350 mm
Operating weight, CE	44,700 kg
Engine manufacturer and model	Caterpillar C 27 ATAAC
Maximum engine power	708 kW / 949 HP / 963 PS at 2,100 min^{-1}
Full-load fuel consumption	187 l/h
Construction site (variety) fuel consumption	84 l/h
Exhaust level	Not regulated in EU / US Tier 2
Fuel tank	1,500 l
Water tank	5,000 l
Max. milling speed	0-84 m / min (0-5 km / h)
Max. driving speed	0-84 m / min (0-5 km / h)
Theoretical discharge conveyor capacity	668 m^3 / h

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

2.1.6 Comparison of machine performance (W 1900, W 2000, W 2100, W 2200)

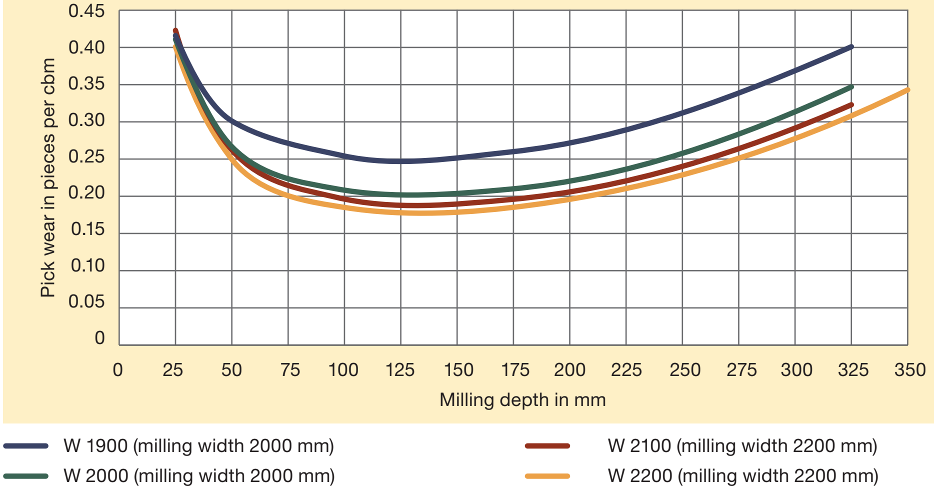


W 1900 (milling width 2000 mm)
W 2000 (milling width 2000 mm)
W 2100 (milling width 2200 mm)
W 2200 (milling width 2200 mm)

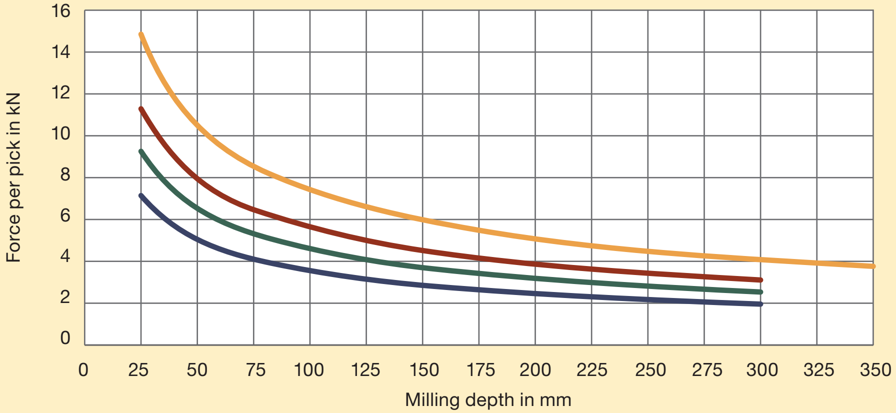


*including general machine downtime, such as truck changes, refuelling diesel, changing picks, general waiting times, etc.

Pick wear in pieces per cubic metre



Average force per pick during milling in kilonewtons



Note: The charts shown here contain average guideline values. Depending on the milling task at hand, relatively great deviation from the average is possible.
All specifications in cubic metres pertain to compressed volume density (i. e. installed asphalt).

2.1.7 Large milling machines with a milling width up to 2,200 mm

W 150 / W 150i

- One-person operation thanks to the user-friendly operating concept
- Wide range of FCS applications using milling drum units with 1.20 or 1.50 m working width
- Intelligent WIDRIVE machine control for maximum productivity
- Compact dimensions for machine transport without special permission
- Protects the environment to a large degree thanks to it’s quiet, low-emission engine and dust-reducing VCS

Technical Data

	W 150	**W 150i**
Milling width	1,200 mm (optional 1,500 mm)	
Milling depth *	0-320 mm	
Operating weight, CE	20,200 kg	20,600 kg
Engine manufacturer and model	Cummins QSL 8.9	Cummins QSL 9
Maximum engine power	276 kW / 370 HP / 375 PS at 1,900 min^{-1}	298 kW / 400 HP / 405 PS at 1,900 min^{-1}
Full-load fuel consumption	72 l / h	76 l / h
Construction site (variety) fuel consumption	29 l / h	30 l / h
Exhaust level	EU Stage 3a / US Tier 3	EU Stage 3b / US Tier 4i
Fuel tank	810 l	
Water tank	2,150 l	
Max. milling speed	0-32 m / min (1.9 km / h)	
Max. driving speed	0-5.3 km / h	
Theoretical discharge conveyor capacity	176 m^3 / h	

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

W200/W200i

- Solid machine concept with effective operation
- Efficient milling machine control WIDRIVE for minimal operating costs
- FCS light for flexible, broad spectrum of applications
- Three settable milling drum speeds for maximum milling performance
- PTS for automatic parallel machine alignment with road surface

Technical Data

	W 200	W 200i
Milling width	2,000 mm (optional 1,500 mm or 2,200 mm)	
Milling depth *	0-330 mm	
Operating weight, CE	27,180 kg	27,630 kg
Engine manufacturer and model	Cummins QSL 15	
Maximum engine power	410 kW/550 HP/558 PS at 1,900 min^{-1}	447 kW/600 HP/608 PS at 1,900 min^{-1}
Full-load fuel consumption	99 l/h	106 l/h
Construction site (variety) fuel consumption	40 l/h	42 l/h
Exhaust level	EU Stage 3a/US Tier 3	EU Stage 3b/US Tier 4i
Fuel tank	1,220 l	
Water tank	3,350 l	
Max. milling speed	0-85 m/min (5.1 km/h)	
Max. driving speed	0-85 m/min (5.1 km/h)	
Theoretical discharge conveyor capacity	375 m^3/h	

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

W 210 / W 210i

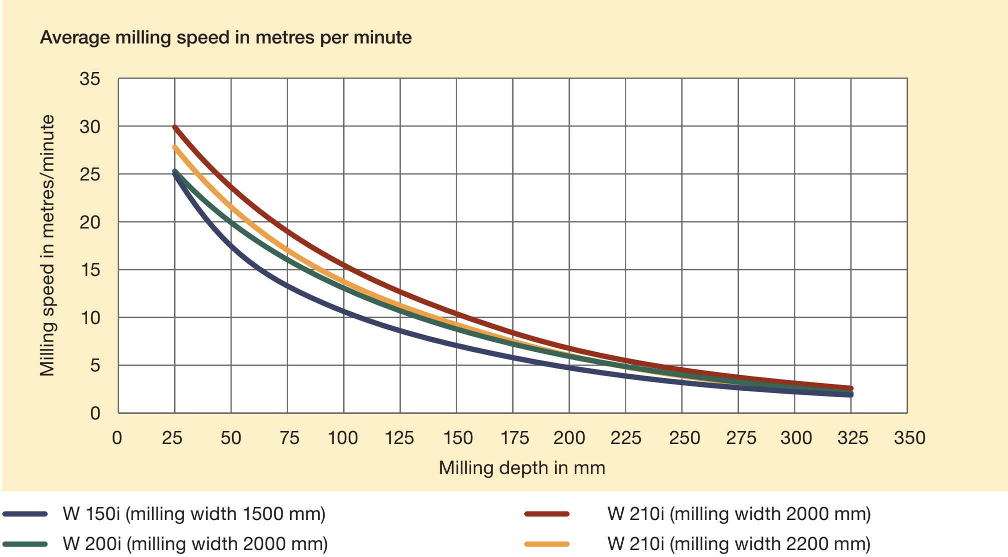
- "Dual engine concept" for demand-based output and lower fuel consumption, especially in partial-load range
- Three selectable cutting speeds for optimum adaptation to the milling application at hand
- Maximum stability and greatly simplified levelling via PTS (Parallel To Surface)
- FCS light for quick milling drum changes for fine milling or to the Eco Cutter
- State-of-the-art operator's platform with optimum ergonomics, intuitively operated consoles and practical new WIDRIVE functions which disburden the driver

Technical Data

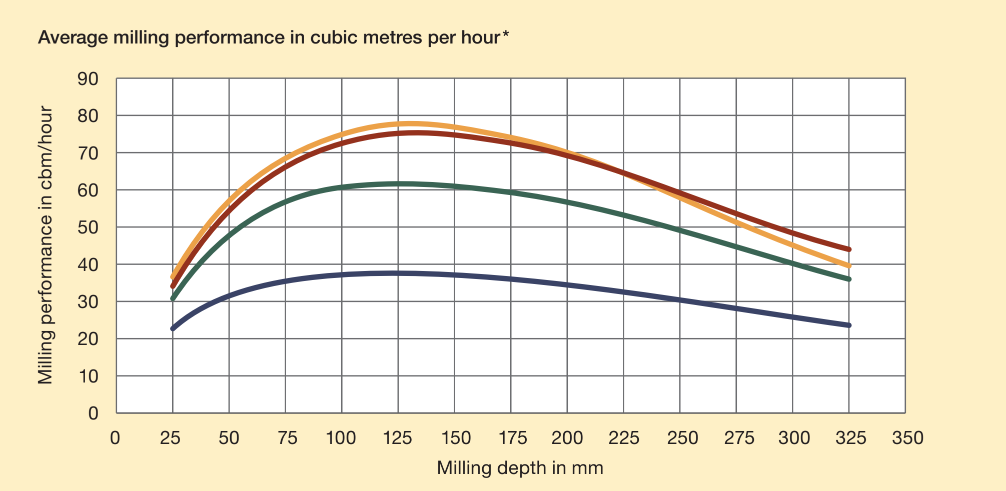
	W 210	**W 210i**
Milling width	2,000 mm (optional 1,500 mm or 2,200 mm)	
Milling depth *	0-330 mm	
Operating weight, CE	28,900 kg	
Engine manufacturer and model	Cummins QSL 8.9 + QSC 8.3	Cummins QSL 9 + QSL 9
Maximum engine power	500 kW / 671 HP / 680 PS at 1,900 min^{-1}	534 kW / 716 HP / 726 PS at 1,900 min^{-1}
Full-load fuel consumption	131 l / h	136 l / h
Construction site (variety) fuel consumption	52 l / h	54 l / h
Exhaust level	EU Stage 3a / US Tier 4	EU Stage 3b / US Tier 4
Fuel tank	1,220 l	
Water tank	3,350 l	
Max. milling speed	0-85 m / min (5.1 km / h)	
Max. driving speed	0-85 m / min (5.1 km / h)	
Theoretical discharge conveyor capacity	375 m^3 / h	

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

2.1.8 Comparison of machine performance W 150i (1500 mm), W 200i (2000 mm), W 210i (2000 mm), W 210i (2200 mm)



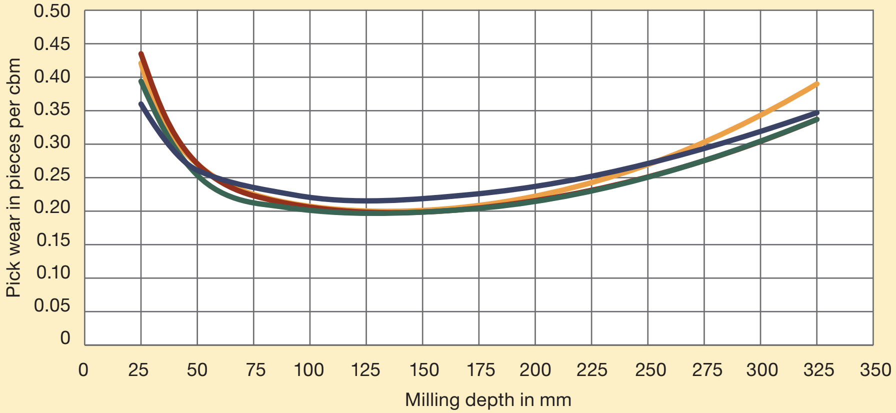
Average milling speed in metres per minute



Average milling performance in cubic metres per hour*

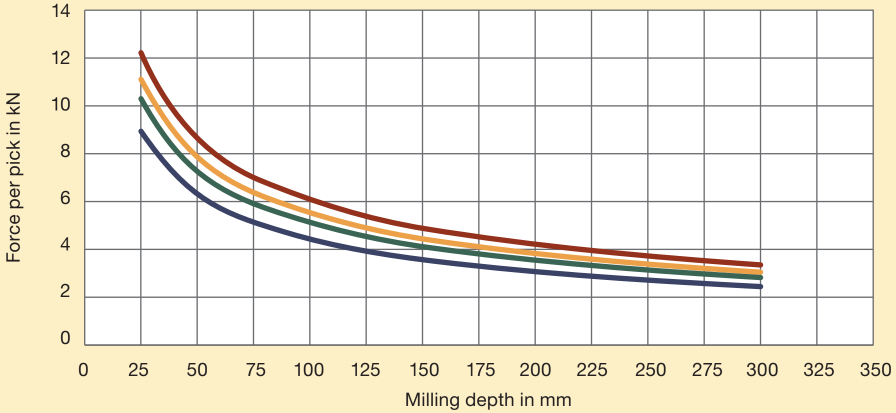
*including general machine downtime, such as truck changes, refuelling diesel, changing picks, general waiting times, etc.

Pick wear in pieces per cubic metre



- ▬ W 150i (milling width 1500 mm)
- ▬ W 200i (milling width 2000 mm)
- ▬ W 210i (milling width 2000 mm)
- ▬ W 210i (milling width 2200 mm)

Average force per pick during milling in kilonewtons



Note: The charts shown here contain average guideline values. Depending on the milling task at hand, relatively great deviation from the average is possible.
All specifications in cubic metres pertain to compressed volume density (i. e. installed asphalt).

2.1.9 Large milling machines with a milling width up to 3,800 mm

W 220 (2200 mm, 2500 mm)

- Maximum compromise between milling performance and compact machine weight
- Easy transport thanks to compact machine size and optimum weight
- Intelligent milling machine control WIDRIVE for low operating costs
- PTS for automatic parallel alignment with roadway surface
- FCS light for quick milling drum changes with working widths of 2.20 m and 2.50 m

Technical Data

	W 220
Milling width	2,200 mm (optional 2,500 mm)
Milling depth *	0-350 mm
Operating weight, CE	36,360 kg
Engine manufacturer and model	Caterpillar C 18 ATAAC
Maximum engine power	571 kW/766 HP/777 PS at 2,100 min^{-1}
Full-load fuel consumption	142 l/h
Construction site (variety) fuel consumption	57 l/h
Exhaust level	Not regulated in EU/US Tier 2
Fuel tank	1,460 l
Water tank	4,500 l
Max. milling speed	0-88 m/min (5.3 km/h)
Max. driving speed	0-88 m/min (5.3 km/h)
Theoretical discharge conveyor capacity	552 m^3/h

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

W 250 (2200 mm, 3800 mm)

- Amazing milling performance thanks to state-of-the-art machine control and maximum drive power
- “Dual engine concept” for milling with an engine up to 545 kW and milling with two engines up to 731 kW
- Six different milling widths from 2.20 m to 4.40 m
- Clever machine control WIDRIVE for low operating costs
- Intelligent propulsion drive controller ISC with anti-slip system, power regulation and precise driving along curves

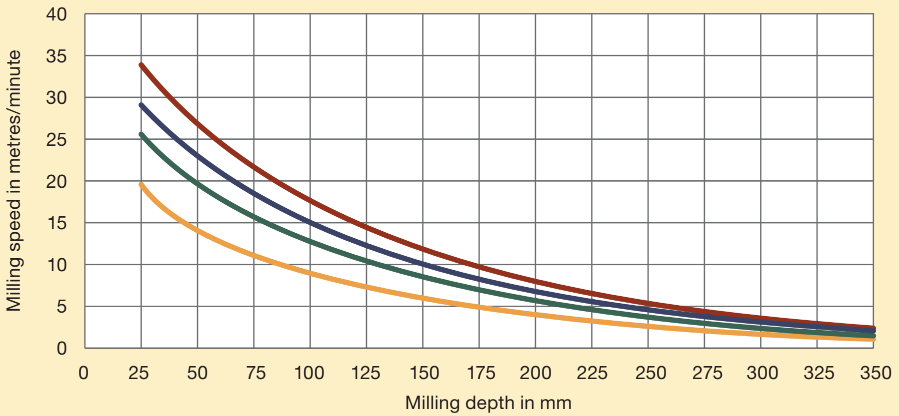
Technical Data

	W 250
Milling width	2,200 mm (optional 2,500 mm or 3,800 mm)
Milling depth *	0-350 mm
Operating weight, CE	43,800 kg
Engine manufacturer and model	Cummins QSX15 + QSL 8.9
Maximum engine power	731 kW/980 HP/994 PS at 1,900 min^{-1}
Full-load fuel consumption	197 l/h
Construction site (variety) fuel consumption	78 l/h
Exhaust level	EU Stage 3a/US Tier 3
Fuel tank	1,460 l
Water tank	4,850 l
Max. milling speed	0-88 m/min (5.3 km/h)
Max. driving speed	0-88 m/min (5.3 km/h)
Theoretical discharge conveyor capacity	668 m^3/h

*** = The maximum milling depth may deviate from the specified value due to tolerances and wear.**

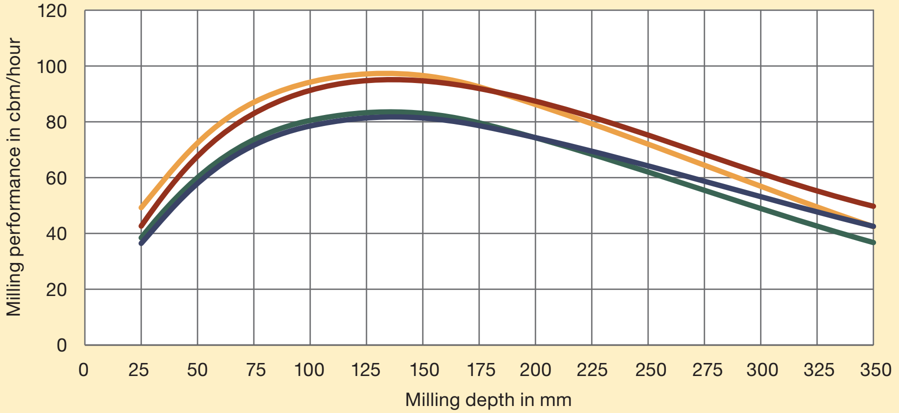
2.1.10 Comparison of machine performance W 220 (2200 mm and 2500 mm), W 250 (2200 mm and 3800 mm)

Average milling speed in metres per minute



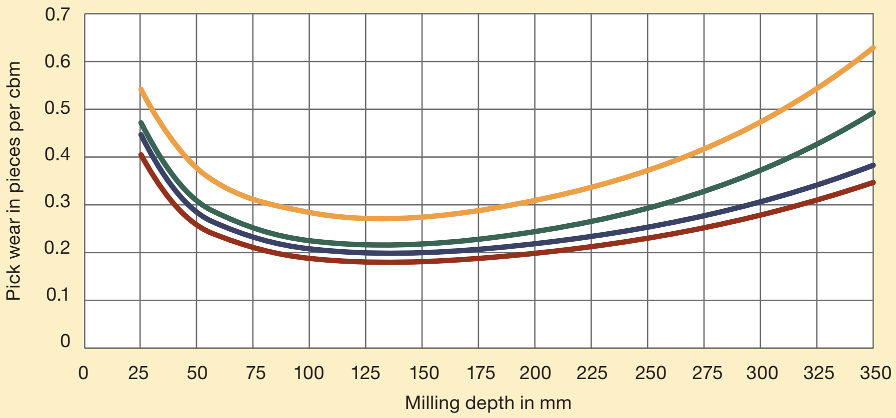
▬ W 220 (milling width 2200 mm)
▬ W 220 (milling width 2500 mm)
▬ W 250 (milling width 2200 mm)
▬ W 250 (milling width 3800 mm)

Average milling performance in cubic metres per hour*



*including general machine downtime, such as truck changes, refuelling diesel, changing picks, general waiting times, etc.

Pick wear in pieces per cubic metre



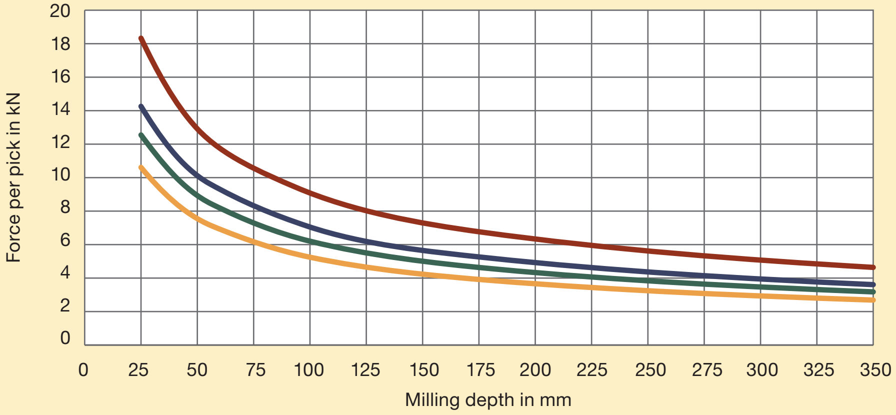
▬ W 220 (milling width 2200 mm)

▬ W 220 (milling width 2500 mm)

▬ W 250 (milling width 2200 mm)

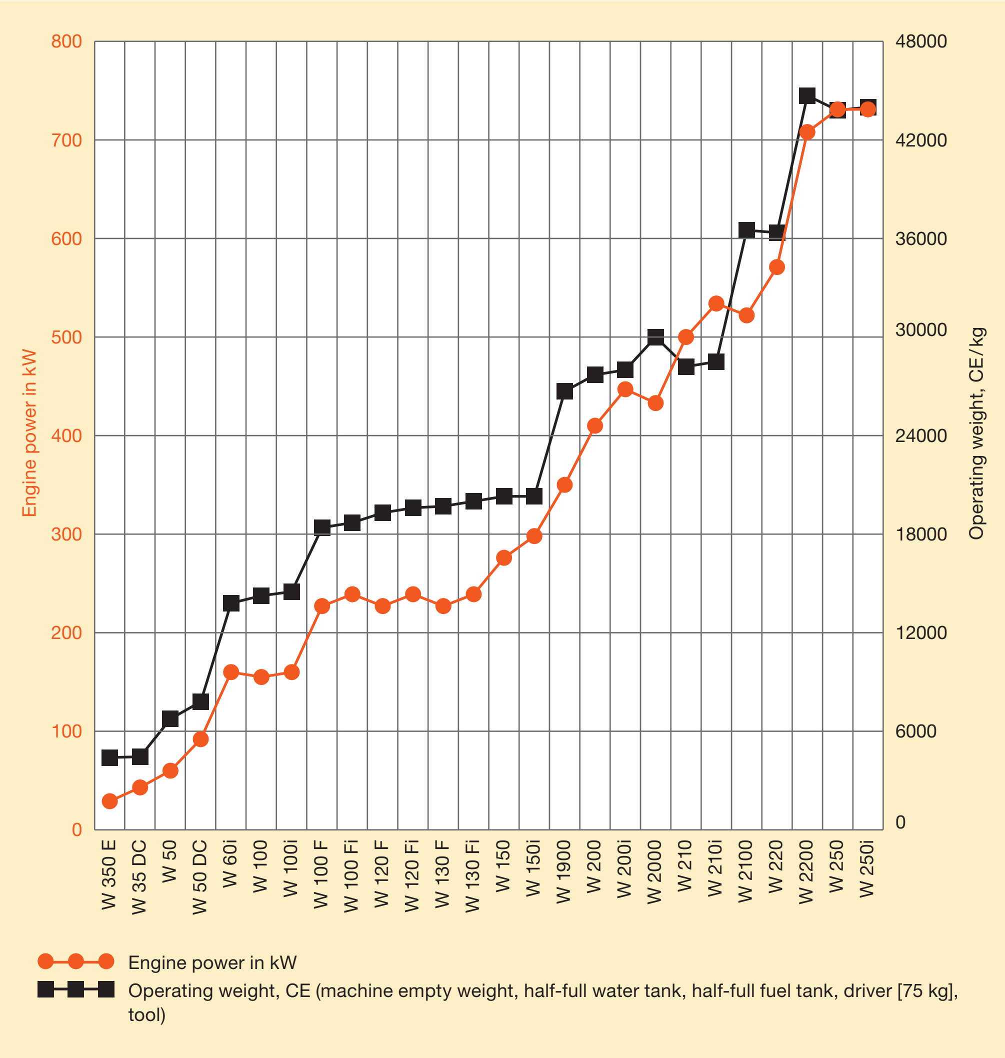
▬ W 250 (milling width 3800 mm)

Average force per pick during milling in kilonewtons



Note: The charts shown here contain average guideline values. Depending on the milling task at hand, relatively great deviation from the average is possible.
All specifications in cubic metres pertain to compressed volume density (i. e. installed asphalt).

2.2 Overview of machine power-to-weight-ratio



Optimally determined ratio of engine power to operating weight

3 Core technology: Cutting

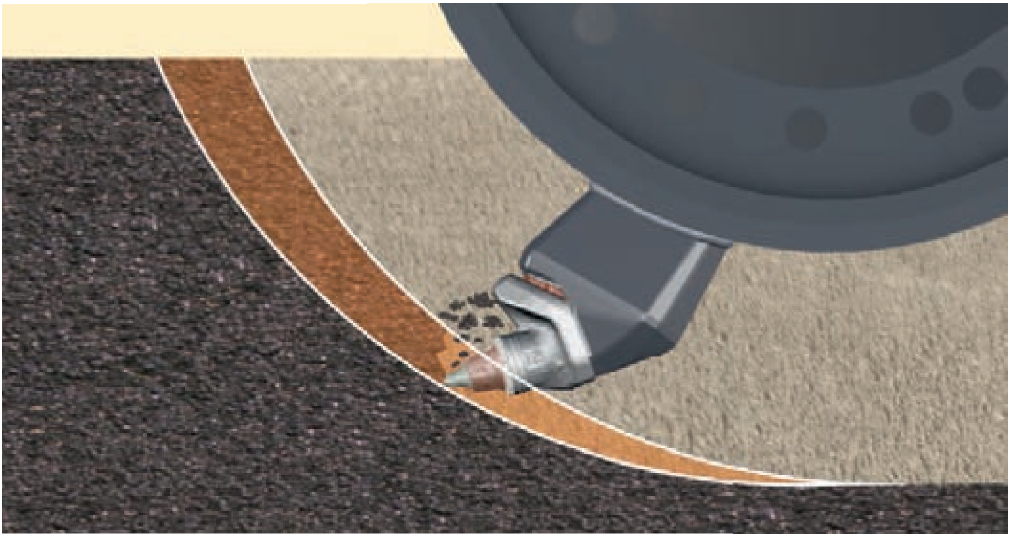
3.1 The cutting process

Cutting technology is one of Wirtgen's key competences in the development and production of cold milling machines. It has a major effect on the quality, cost and performance of the milling process.

3.1.1 The comma-shaped chip

During the cutting process, the rotating milling drum equipped with rotating picks works in up-milling mode, which means that the picks cut into the material in the upward direction. From when the pick enters to when it exits, a progressively thickening chip, the so-called comma-shaped chip, is formed. The size of the separated chip depends on the milling speed and the set milling depth.

During the actual cutting process, the forces at the pick increase as the chip thickness increases, i. e. the more material is separated, the greater the use of energy. When the pick enters the material, the amount of material is still minimal, and it reaches its maximum value shortly before separation of the comma-shaped chip. The amount of force applied is then reduced to zero directly afterwards.



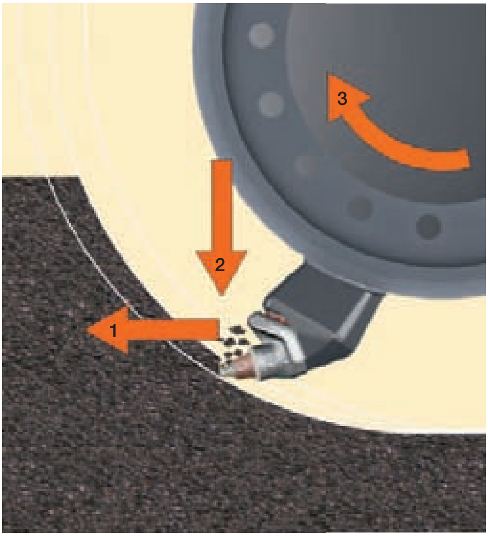
Cross-section of a comma-shaped chip in the cutting process

3.1.2 Forces in the cutting process

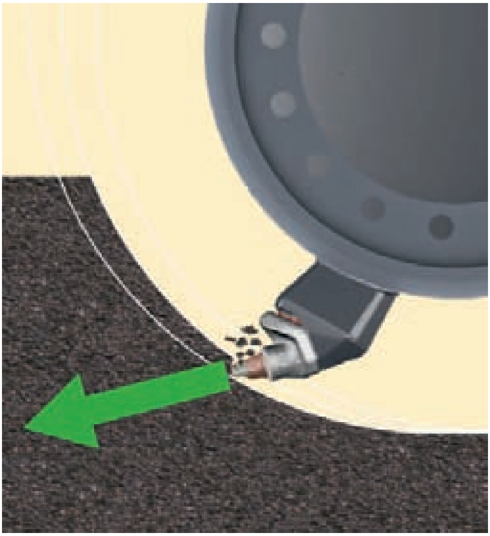
During the cutting process, enormous shearing and impact forces act on the pick.
They are dependent on the following factors.

Strength of the material to be cut
- Asphalt: bitumen quality and proportion
- Concrete: cement quality and proportion
- Mineral quality: Strength, wear-resistance, mineral proportion and mineral size
- Fine particles in the material
- Outside temperature
- Material thickness

Milling performance capacity of the machine
- Cutting speed at the pick
- Milling drum type (tool spacing)
- Force per pick (milling depth)
- Pick type used (pick shape)



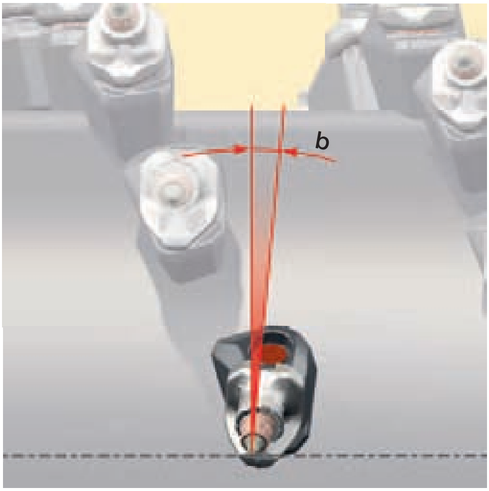
1 Travel drive force
2 Machine weight force
3 Milling drum rotational force



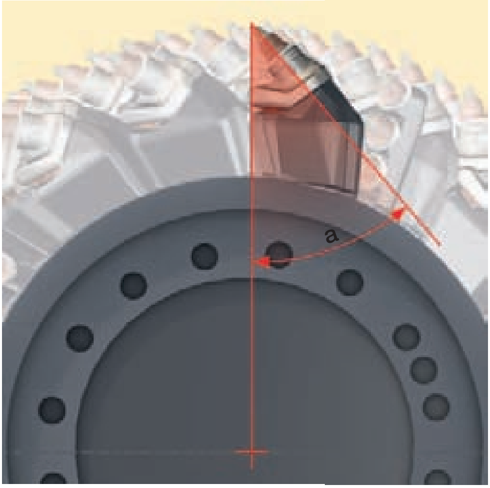
The cutting force is a result of the three forces shown to the left.

3.1.3 Position and cutting angle of the pick on the milling drum

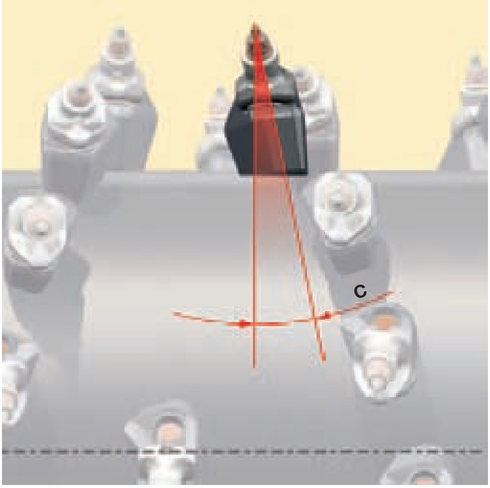
The position of the pick on the milling drum is defined by three co-ordinates and two spatial angles. They determine the cutting circle diameter, the tool spacing and the even distribution of all other picks on the milling drum in the compound. Optimum pick positioning ensures minimal pick wear and optimal cutting behaviour.



Rotation angle (b) at the coordinate cross



Contact angle (a) at the coordinate cross

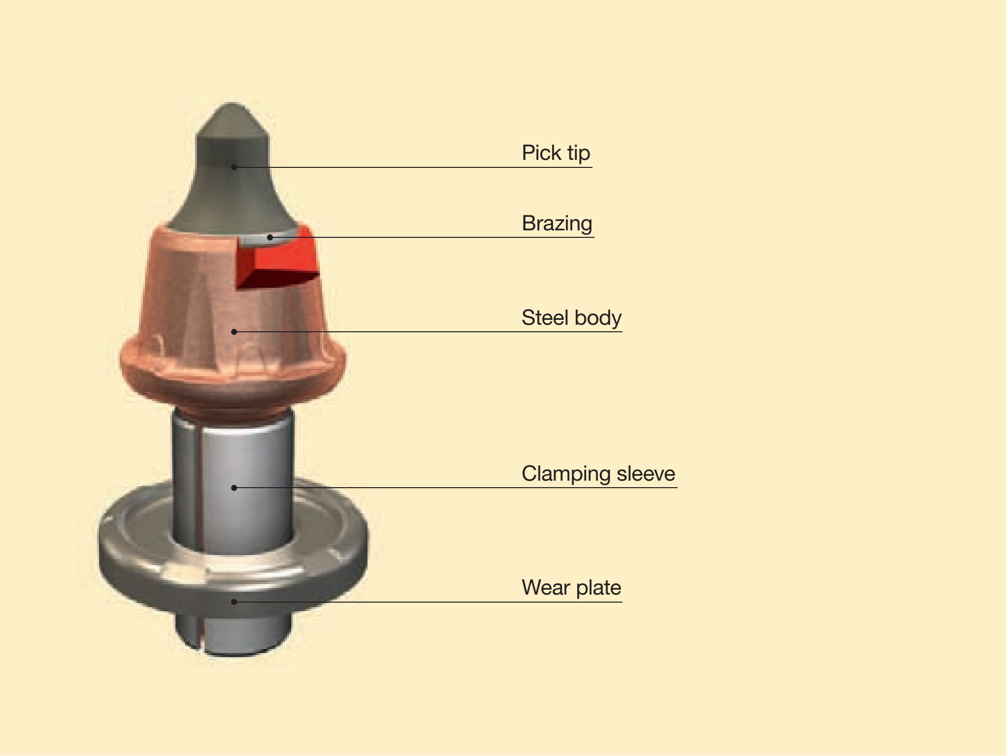


Tilt angle (c) at the coordinate cross

3.2 Function of the pick

3.2.1 Structure and features of the pick

The picks are the actual cutting tool of the cold milling machine. Their quality has a considerable influence on milling performance, milling results and milling costs. Since they are designed for a wide variety of applications, their design varies. Their structure is always the same, however, and generally consists of five components.

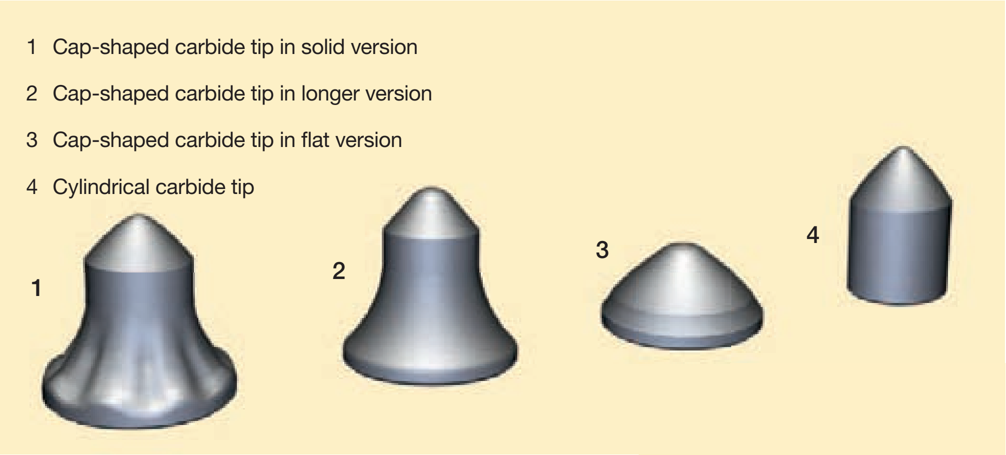


Components of a modern pick

3.2.1.1 The pick tip

The tips of the picks are subjected to extreme stresses and are made of especially wear-resistant carbide. They are comprised of a sintered tungsten-carbide-cobalt material (generally 94% tungsten and 6% cobalt). The most important characteristics of this material is its hardness, break- and wear-resistance and electrical and thermal conductivity.

The varying grain size of the tungsten carbide affects wear considerably. Whereas the coarse-grained portions ensure the required break resistance and temperature resistance, the fine-grained portions ensure great wear resistance. The finer the carbide grain, the more difficult it is for an external object to penetrate the surface. The cobalt is used as a binding agent to ensure the required break resistance even under high stress. During the sintering process, any spaces between the tungsten-carbide grains are filled up completely. The properties of the material can be changed in a targeted way by varying the mixture ratios and thus matched to the future area of application. Depending on the application, carbide metal tips in a wide variety of different diameters with a cap or cylindrical shape are used.



1 Cap-shaped carbide tip in solid version

2 Cap-shaped carbide tip in longer version

3 Cap-shaped carbide tip in flat version

4 Cylindrical carbide tip

Various carbide tip versions

3.2.1.2 The brazing

The carbide tip of the pick is solidly brazed to the steel body. The high-temperature braze used continually ensures proper functioning of the connection, even at the extremely high temperatures which arise during the cutting process.

3.2.1.3 The steel body

The steel body, comprised of a pick head and a pick shaft, is formed using the cold extrusion process with high dimensional precision and surface quality. Whereas the pick head must withstand enormous shearing and impact stresses and must be especially wear resistant, the pick shaft must be held securely and without breaking in the toolholder over its entire service life. Using a special process, different degrees of hardness are given to the pick head and shaft for this reason. The relationship between hardness and toughness largely determines the service life and usability of the pick.

Temperature-resistant braze connection

Wear-resistant steel body

3.2.1.4 The wear plate

The primary task of the wear plate is to ensure optimum pick rotation behaviour. It is made of 5 mm-thick hardened and tempered steel and is bevelled conically toward the shaft. The chamfer fits precisely into the holder guide, centres the pick in the toolholder and ensures the lowest possible degree of toolholder bore wear.
To easily attach the pick to the top part of the toolholder, the clamping sleeve is pre-clamped by the wear plate. This enables the pick to be mounted ready for operation in only a few steps.

3.2.1.5 The clamping sleeve

The cylindrical clamping sleeve ensures the precise positioning and secure seating of the pick in the toolholder. The shaft of the pick is held in the clamping sleeve so it can rotate. The sleeve diameter and length are subject to very tight tolerances during production which lead to considerably less wear on picks and toolholders and also enable optimum pick rotation behaviour.
In addition, so-called twin-stop clamping sleeves ensure precisely defined axial play.

Rugged wear plate

High-strength clamping sleeve

3.2.2 The principle of rotation

During the cutting process, the picks rotate with a precession motion around their longitudinal axis, whereby rotation occurs primarily in the free-wheeling phase under a pressure load and not in the cutting phase without a pressure load. This rotation does not run fully centred vertically, but rather causes slight “swaying movements” on the course of precession within the clamping sleeve as well and is also further strengthened by the vibrations on the toolholder. This is referred to as nutational movement.

Nutational movement causes the pick to rotate approx. 10 degrees per milling drum rotation. A complete rotation of the pick thus requires multiple milling drum rotations. This causes the contact surfaces of the picks to wear evenly and conically. This results not only in a very regular and optimal wear pattern, but also has the extremely important self-sharpening effect which ensures high milling performance.

Rotation of the pick around its longitudinal axis

3.2.3 Pick wear

The penetration and wear behaviour of the picks, and thus the productivity of the machine, depends on a variety of influential factors:

Machine type

- Engine power (milling performance or milling speed)
- Milling drum speed (cutting speed at the pick)
- Set milling depth

Milling drum type

- Milling drum width
- Cutting circle diameter
- Tool spacing of the picks
- Contact angle of the picks
- Wear condition of the toolholders

Picks

- Cutting tip shape of the picks
- Geometry of the pick body
- Wear condition of the pick

Covering characteristics

- Composition and type of the material to be cut
- Strength of the material to be cut
- Material temperature

3.2.3.1 Optimum wear pattern

Picks with cap-shaped carbide tip
Optimal wear: The carbide tip is worn evenly and conically.

Optimum wear pattern

3.2.3.2 Undesired wear patterns

Carbide breakage
Causes:

- Mechanical overloads caused by objects in the material to be cut, e. g. steel reinforcements or large rocks, which cannot be detected in the sub-surface before milling is begun.
- Thermal overloading due to high temperature in the cutting tip. Special materials to be cut can generate high temperatures which can be reduced by spraying in water. An insufficient flow of water can be traced back to soiled spray nozzles.

Erosion of steel body
Cause:

- Both soft and tough asphalt materials to be cut scrape past the pick shaft during the milling process. The result is heavier wear toward the pick bodies.

By using a larger cap-shaped tip, this wear can be reduced considerably.

Carbide breakage due to mechanical overload

High wear of steel body

Clamping sleeve wear
Cause:

- In soft materials to be cut, the wear on the picks can be well over the normal average. Due to the especially frequent stress, the clamping sleeve walls become thinner and deformed over time. This can reduce clamping force to such a degree that the pick could fall out by itself.

Insufficient or no pick rotation
Cause:

- If the rotational drive is insufficient (insufficient vibration at the toolholder), heavy, one-sided wear can appear on the carbide tip.
- In addition, the rotation can be hampered by soiling in the toolholder bore.

Deformed clamping sleeve

Wear due to insufficient pick rotation

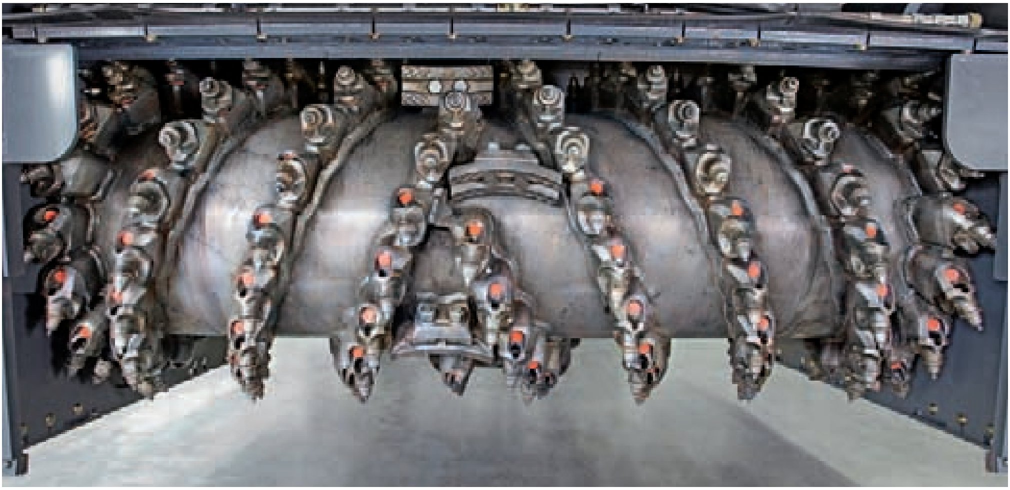
3.3 Toolholder systems

3.3.1 Function and structure

The toolholders are the interface between the pick and the milling drum. They hold the picks and ensure their optimum rotational capability. They are connected to the milling drum either completely or, in the case of modern systems, just with the bottom part of the holder via welding seams.

- Toolholders are made of highly hardened and tempered steel.
- They are forged at a temperature of approx. 1,150 °C.
- Thanks to special heat treatments, maximum wear resistance and toughness, as well as good welding characteristics, are achieved.
- The mounting bore for the pick in the toolholder for asphalt milling picks is standardised to 19.9 mm worldwide.
- The support surface for the pick is at a right angle to the bore and has an external diameter of 38 to 45 mm.

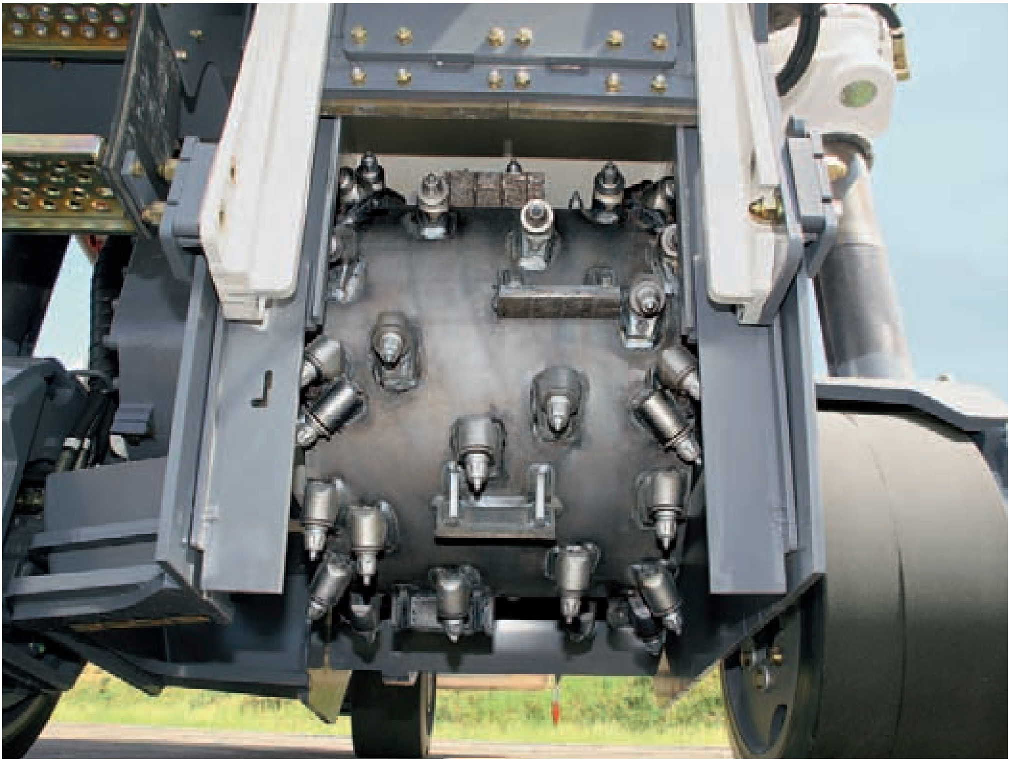
Nearly all of the engine power is transferred to cutting power via the toolholders. Low-wearing materials and optimally designed toolholder systems with improved pick rotation and easier pick changing guarantee a high pick service life and reduce operating costs.



Modern milling drum with exchangeable wearing components

3.3.1.1 Welded toolholder systems

With welded toolholder systems, the toolholders are permanently welded to the milling drum. Since they require less space, they are preferred on milling drums with small diameters and fine milling drums with minimal tool spacing. In both cases, these are milling drums which generate shallow milling cuts, which reduces the risk of wear and breakage of the toolholders and generally enables less-frequent replacement.



Compact milling drum of a small milling machine with welded toolholders

3.3.1.2 Quick-change toolholder systems

Toolholder quick-change systems enable easy and uncomplicated changing of worn or defective top sections of holders directly at the construction site. The bottom part of the quick-change toolholder system is permanently welded to the milling drum body here. On top of this is the top part, which is securely connected to the bottom part via a screw connection.

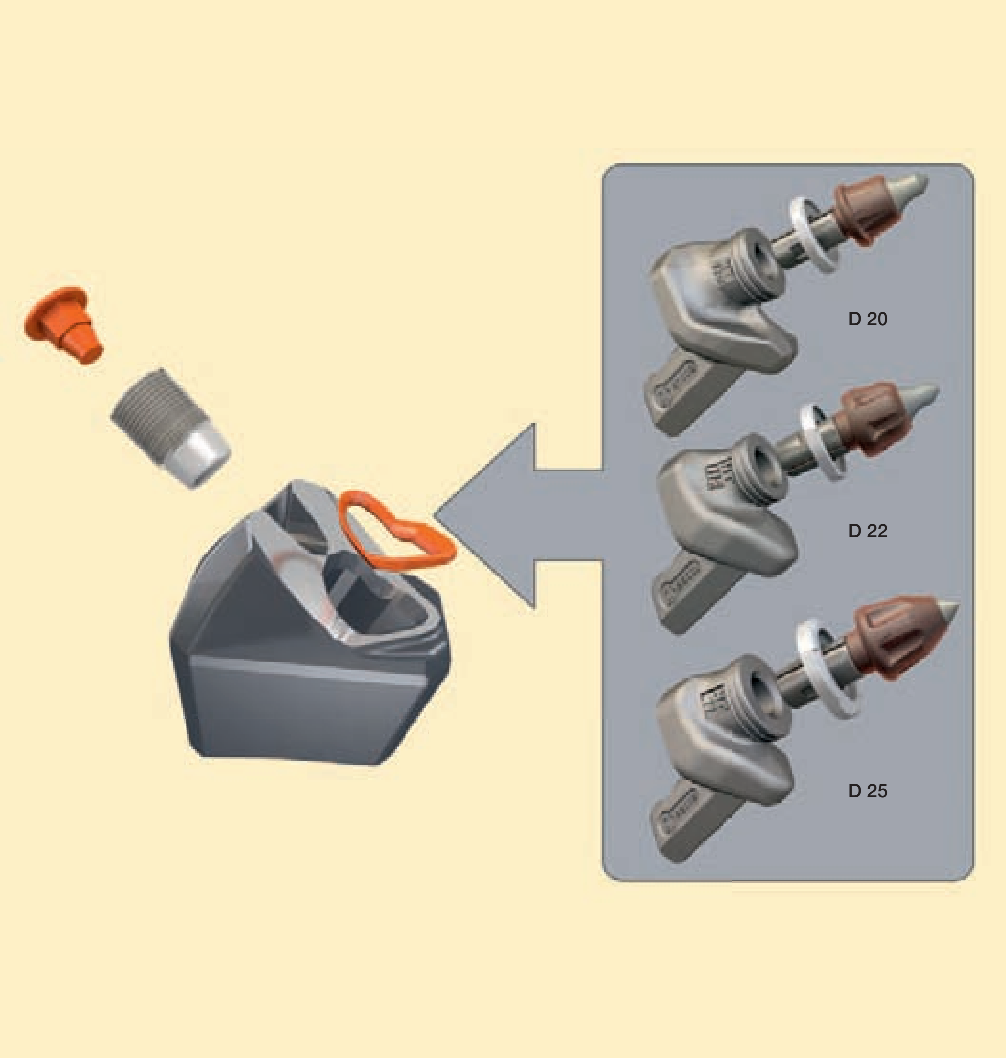
Standard milling drum of a large milling machine with exchangeable toolholders

3.3.1.3 Quick-change toolholder system HT11

The quick-change toolholder system HT11 features a combined system of low-wearing parts designed for resilient constructionsite use, easy operation and a long service life. The patented system is characterised by many advantages for the user:

- Quick replacement of individual toolholders in just a few minutes, even at the construction site.
- Maximum material hardness and thus wear resistance thanks to the use of high-quality wear-resistant steels.
- Rugged screw connection with continuous screw pre-tension.
- Special component geometry which enables exceptional repositioning of new toolholders for optimal milling.

HT11 for quick replacement of the upper part



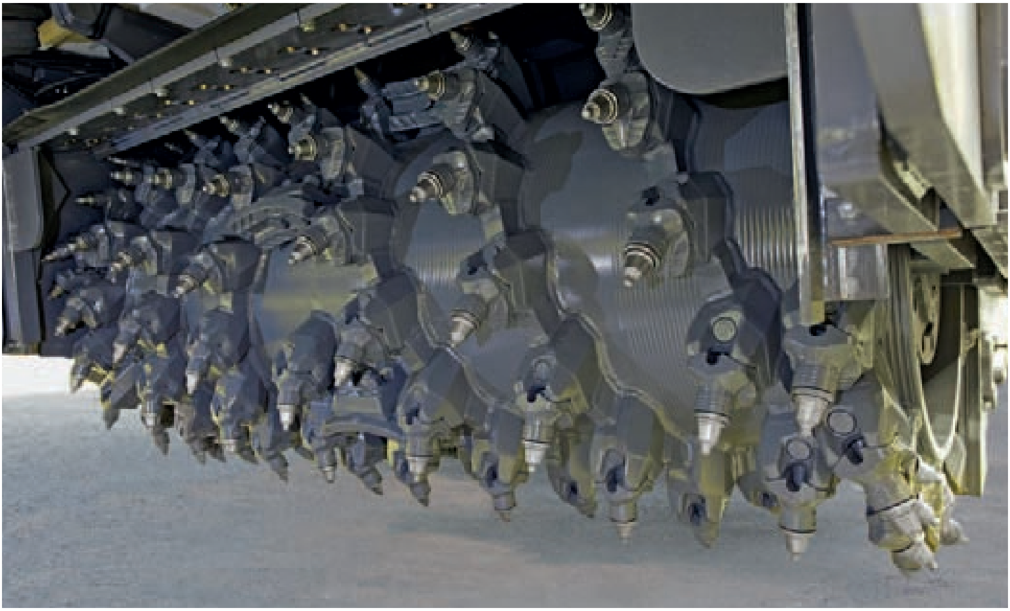
Components of the quick-change toolholder system HT11

3.3.1.4 Quick-change toolholder system HT22

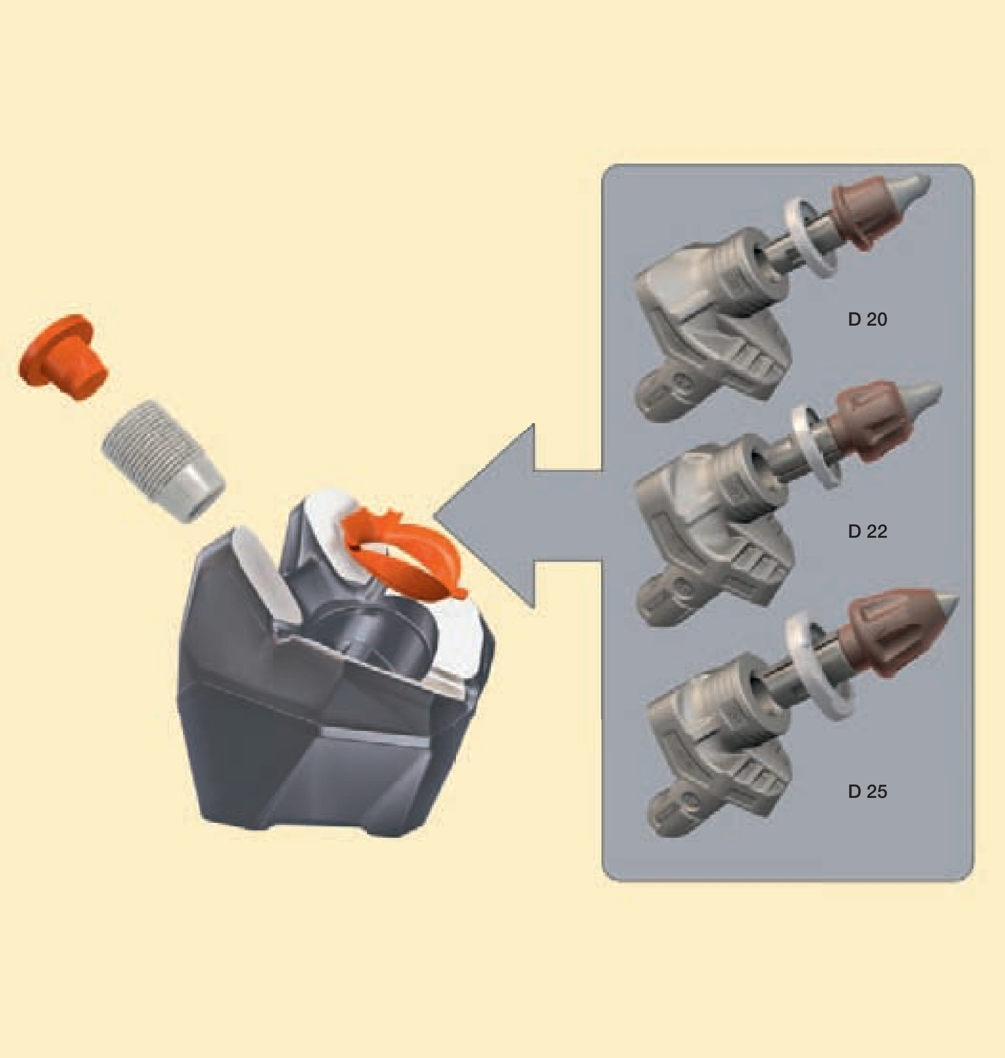
With the HT22, Wirtgen's new generation of toolholder systems, the features of the tried-and-tested HT11 have been further optimised. The system will be in use starting in 2013 and is characterised by even greater wear-resistance. The new toolholder system's especially long service life makes itself apparent at the construction site through considerable reduction in replacement intervals. Extended service intervals thanks to optimised attachment of the upper components are another advantage extending the overall service life of the milling drum.

Other advantages of the system:

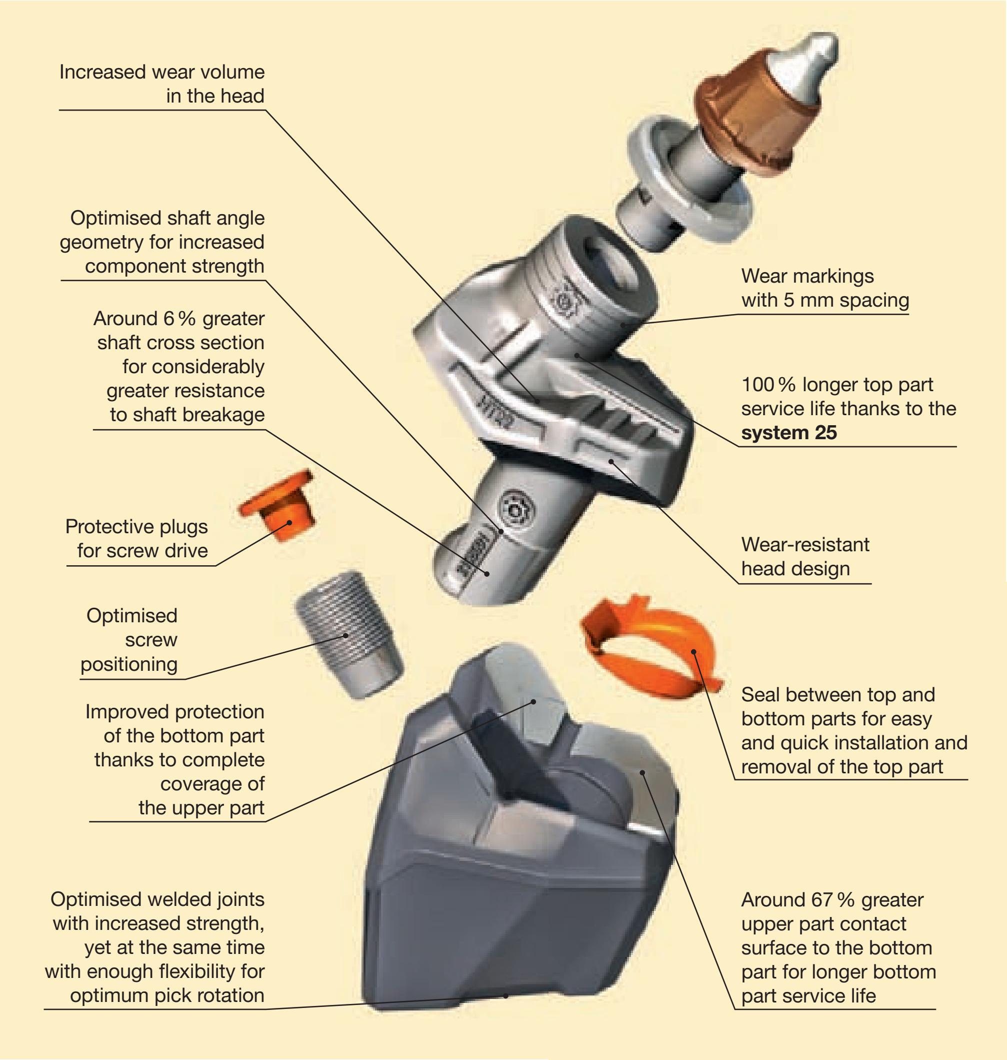
- Considerably greater wear volume
- Improved pick rotation behaviour
- Increased resistance to shaft breakage
- Longer service intervals
- Increased resistance to breakage
- Easy replacement option (tools remain the same as for the HT11)



Modern quick-change toolholder system HT22 with considerably greater wear volume



Components of the quick-change toolholder system HT22



Increased wear volume in the head

Optimised shaft angle geometry for increased component strength

Around 6 % greater shaft cross section for considerably greater resistance to shaft breakage

Protective plugs for screw drive

Optimised screw positioning

Improved protection of the bottom part thanks to complete coverage of the upper part

Optimised welded joints with increased strength, yet at the same time with enough flexibility for optimum pick rotation

Wear markings with 5 mm spacing

100 % longer top part service life thanks to the **system 25**

Wear-resistant head design

Seal between top and bottom parts for easy and quick installation and removal of the top part

Around 67 % greater upper part contact surface to the bottom part for longer bottom part service life

Considerably optimised functionality of the quick-change toolholder system HT22

3.3.2 Toolholder wear

The wear behaviour of the toolholder mainly depends on the following factors:

Machine type
- Engine power (milling performance or milling speed)
- Milling drum speed
- Set milling depth

Milling drum type
- Milling drum width
- Cutting circle diameter
- Tool spacing of the picks
- Contact angle of the picks

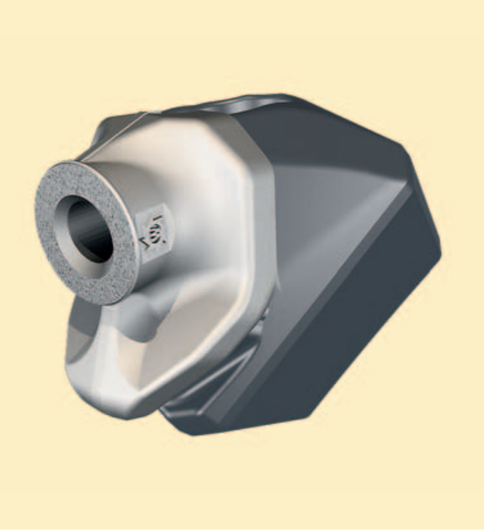
Picks used
- Geometry (pick shaft and clamping sleeve shape) of the pick body
- Wear condition of the pick

Covering characteristics
- Composition and type of the material to be cut
- Strength of the material to be cut
- Material temperature

3.3.2.1 Optimum wear pattern

Longitudinal wear parallel to the contact surface
Cause:

- During the milling process, smaller milled material particles are crushed and ground between the pick contact surface at the toolholder and the wear plate. Thanks to this abrasive effect, both the wear plate and the pick support surface on the toolholder wear parallel and evenly.



Optimum wear pattern

3.3.2.2 Undesired wear patterns

Non-parallel longitudinal wear
Heavier contact surface wear
toward the milling drum centre
Cause:

- As a result of minimal milling depths, e.g. with fine milling, the average resulting force is not directed in the direction of the pick axis. As a result of this and due to the greater contact pressure toward the milling drum centre, greater toolholder wear occurs.

As wear increases, the pick rotation deteriorates.

Non-parallel longitudinal wear
Heavier contact surface wear
away from the milling drum centre
Cause:

- As a result of large chip depths, e.g. when milling soft materials, the average resulting force is not transferred to the pick axis.

As wear increases, the pick rotation deteriorates.

Unfavourable contact surface wear
toward the milling drum centre

Unfavourable contact surface wear
away from the milling drum centre

Wear on the toolholder due to broken or abraded, and thus missing, pick

Cause:

- A typical wear bevel can be detected toward the outside of the milling drum. The toolholder is no longer protected by a pre-cutting pick. If picks and toolholders strike foreign bodies in the material to be cut, the pick and parts of the toolholder will be damaged from the resulting overload.

The risk of pick shaft breakage increases as a result of the reduced pick support.

Bore wear

Cause:

- If non-self-centring picks are used, the toolholder bore can become oval and wear increasingly in diameter. Increasing wear reduces the holding force of the clamping sleeve.

As wear increases, the pick rotation deteriorates.

Worn toolholder due to pick loss

Widening of the bore hole due to reduced pick self-centring

3.4 Milling drums

3.4.1 Function and structure

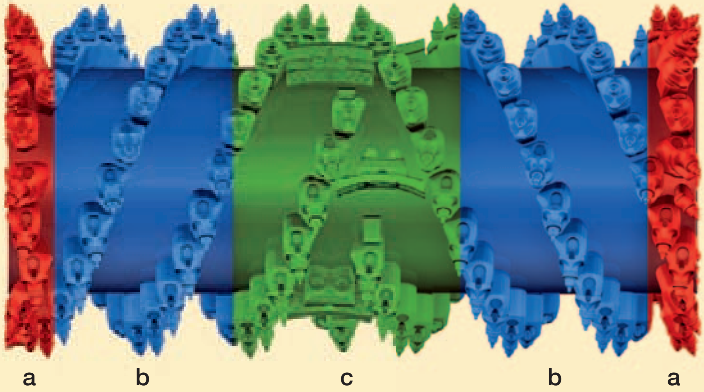
The upward-rotating milling drum outfitted with picks and toolholders is the heart of the cold milling machine. Milling drums are made according to a wide variety of criteria depending on the requirements of the application, from the standard milling drum to special versions such as Eco Cutters or fine and micro-fine milling drums. The efficient transport of milled material away to the loading conveyor is carried out by ejectors.

The milling drum must fulfil three main tasks:

- Cutting and breaking out of material particles from the compound.
- Conveying: Transport of the separated material particles to the area of the ejector.
- Ejection of the removed material particles onto the loading conveyor.

Spiral structure:
The spiral transports the separated milled material to the ejection area. In addition, the optimised spiral arrangement of the individual picks affect the milling pattern which arises (also called the herringbone pattern).

Outer ring area:
The outer ring area is tasked with generating a flat and right-angled milling edge. It forms the lateral end of the milling drum and the beginning of the feed spiral.



Functional areas of the milling drum: a) Outer ring area, b) Conveyor spiral area, c) Ejection area

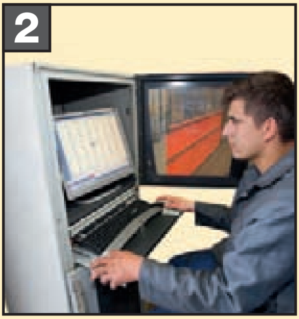
3.4.2 Milling drum production

Depending on the customer's wishes and the requirements of the respective region, milling drums with a wide variety of different toolholder positions are required. At Wirtgen's design and manufacturing department, this production process is carried out as follows:

1. First, data for milling drum production with optimum positioning of the individual toolholders is generated using Wirtgen's proprietary computer programs.
2. These data are then read into the computer-controlled toolholder setting devices.
3. The toolholder setting device positions the individual tools in the intended position.
4. Then, the positioning of the toolholder at the milling drum is checked completely.
5. The milling drum is welded entirely by welding robots.
6. Quality control is then carried out, and each milling drum has its own test log.
7. In the final assembly step, the picks are knocked into the toolholder.

Milling drum production

1


2


3


4


5

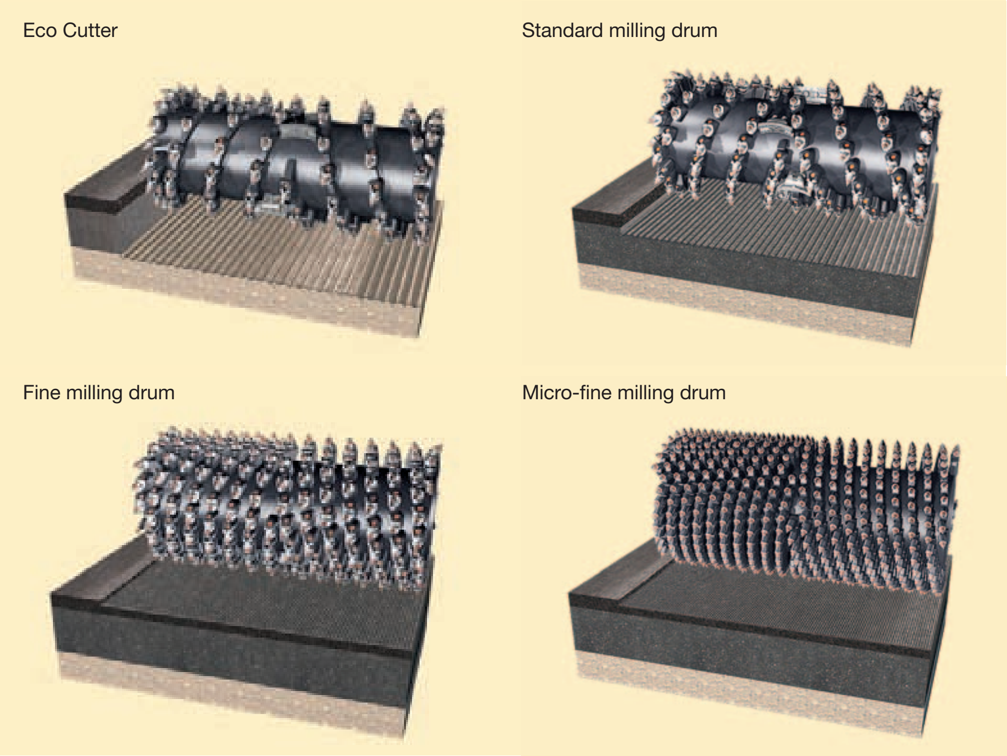

6


7


1 Construction
2 Computer positioning
3 Positioning of the toolholders
4 Measuring
5 Welding robot
6 Final inspection
7 Inserting picks

3.4.3 Milling drum types

The economic success of a construction site is determined by the high performance power of the machine and a simultaneous reduction in operating costs, among other things. To make optimum use of the machine's potential, Wirtgen offer a variety of different milling drum types which differ in their tool spacing and the maximum possible milling depth, which are determined by the application.



Eco Cutter

Standard milling drum

Fine milling drum

Micro-fine milling drum

Various milling drum types

Milling drum type	Tool spacing	Max. milling depth	Usage options	Texture depth area
Eco Cutter Rough milling drums	20 mm 25 mm	up to 35 cm	For greater demands on volume performance • Concrete milling work • Complete road removal	100 mm until 1,000 mm
Standard milling drums	12 mm 15 mm 18 mm	up to 35 cm	Universal milling drum for versatile use • Removal of surface or binder course • Complete road removal • Concrete milling work	25 mm until 100 mm
Fine milling drums	8 mm 10 mm	up to 8 cm	For high demands on macro- and microprofile • Removal of surface courses, incl. construction of a more even surface • Corrective milling work on road profiles	1 mm until 25 mm
Micro-fine milling drums	3 mm 5 mm 6 mm	up to 3 cm	For the highest demands on macro- and microprofile • Increase in surface grip by roughening road surfaces using the micro-fine milling process • Increasing the evenness of concrete roads • Preparation milling for surface treatment, cold paving of thin layers and other thin-layer paving • Removal of coatings from road surfaces or hall floors • Removal of road markings • Milling into road markings	0.05 mm until 1 mm

Classification of milling drum types

3.4.3.1 Standard milling drums

Standard milling drums are the most commonly used milling drum types used and offer a very broad range of applications. Thanks to their usual cutting tool spacing of 12-18 mm, they leave behind an exemplary milling pattern. They are ideal for removing entire road surfaces, as well as for removing one or more layers.

- High quality grooving enables optimum application of new layers to the surface.
- With standard milling drums, milling depths up to 35 cm and working widths between 30 cm and 4.30 m are possible.
- The picks and toolholders arranged in a spiral, combined with wear-resistant ejectors, ensure optimum material ejection and further transport.

Typical applications

- Removal of surface courses up to 6 cm
- Removal of road courses of different material thickness
- Very broad range of applications

Typical standard milling drum

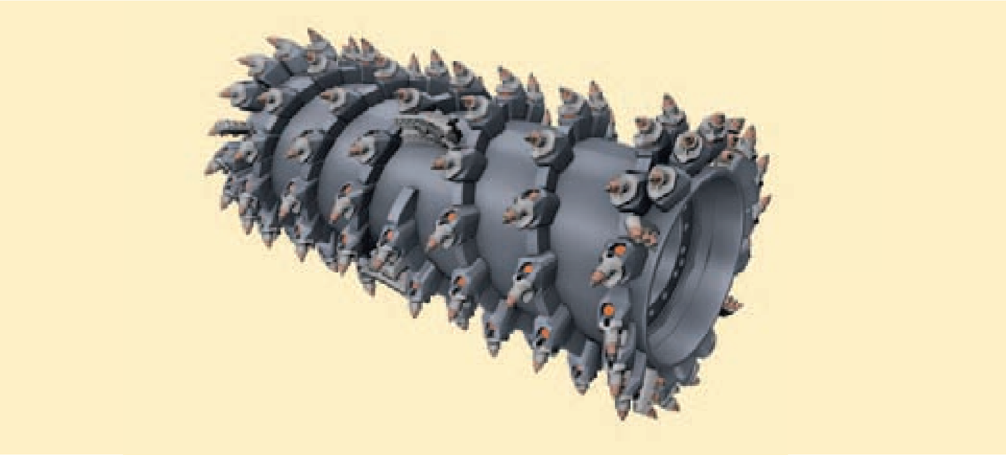
3.4.3.2 Eco Cutters

To achieve the best possible milling performance for removal, Eco Cutters are the ideal choice. The milling drum type developed by Wirtgen is optimally outfitted with a reduced number of picks with greater tool spacing.

- In comparison to a standard milling drum, up to 50 % fewer picks are found on Eco Cutters. This results in both considerably lower tool costs and greater milling performance.
- Less cutting resistance is generated due to the lower number of cutting tools. This results in an increased milling speed. Thus the removal performance of Eco Cutters can exceed that of standard milling drums by up to 50 %.
- The use of Eco Cutters achieves optimum economy when removing hard and wear-intensive road surfaces.
- The greater tool spacing results in a rougher surface texture.

Typical applications

- Complete road removal
- Milling of especially hard-to-cut materials
- Milling of road surfaces under increased time and cost pressure



Typical Eco Cutter milling drum

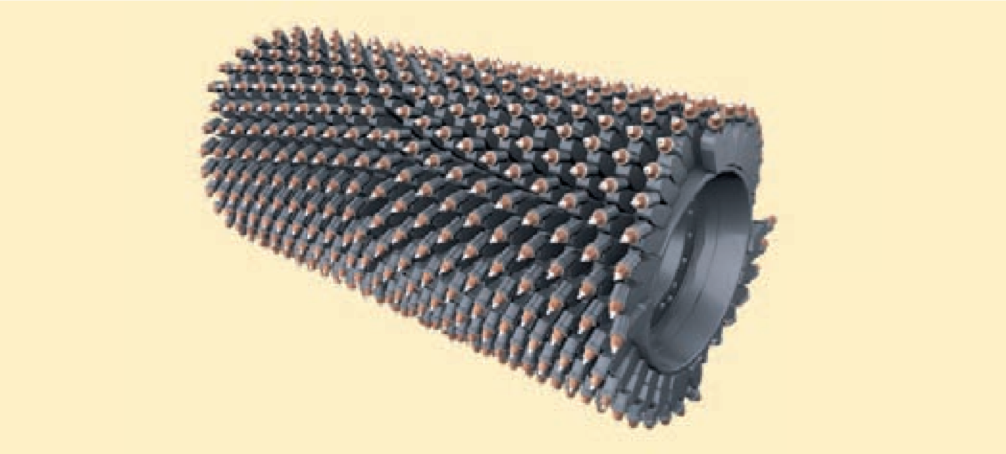
3.4.3.3 Fine milling drums and micro-fine milling drums

Fine milling drums feature a cutting tool spacing of just a few millimetres and generate a finely-textured road surface with a maximum milling depth of approx. 8 cm. Even finer surface structures can be achieved by using micro-fine milling drums with tool spacing under 6 mm. Here, the milling depth is reduced to max. 3 cm.
Fine milling is an especially economical and resource-conserving method.

- Complete removal of the road followed by subsequent repaving is not necessary.
- Traffic is only minimally affected, as the road can be driven on again right away.
- High daily productivity with precise milling.

Typical applications

- Restoration of road surface grip
- Removal of unevenness in road
- Preparation for the application of thin-layer coverings on roads
- Targeted changing of the transverse slope of roads
- Removal of coverings from surfaces
- Removal from contaminated surfaces

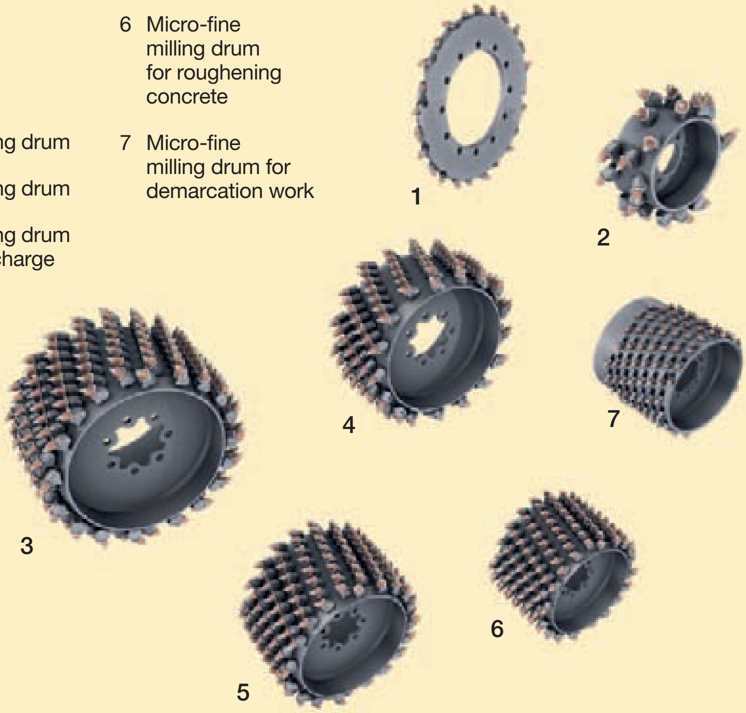


Typical micro-fine milling drum

3.4.3.4 Special milling drums

Special milling drums create special cross-section profiles.

- Milling drums of the barrel/V shape for creating water gutters
- Narrow cutting wheels for milling machines up to a 1 m working width
- Lateral milling wheels for large milling depths
- Cutting and lateral milling wheels for expansion joints and cable slots



1 Cutting wheel
2 Water channel milling drum
3 Micro-fine milling drum
4 Micro-fine milling drum
5 Micro-fine milling drum with lateral discharge
6 Micro-fine milling drum for roughening concrete
7 Micro-fine milling drum for demarcation work

Examples of various milling drums for small milling machines

3.4.4 Changing the performance characteristics of surfaces by using different milling drum types

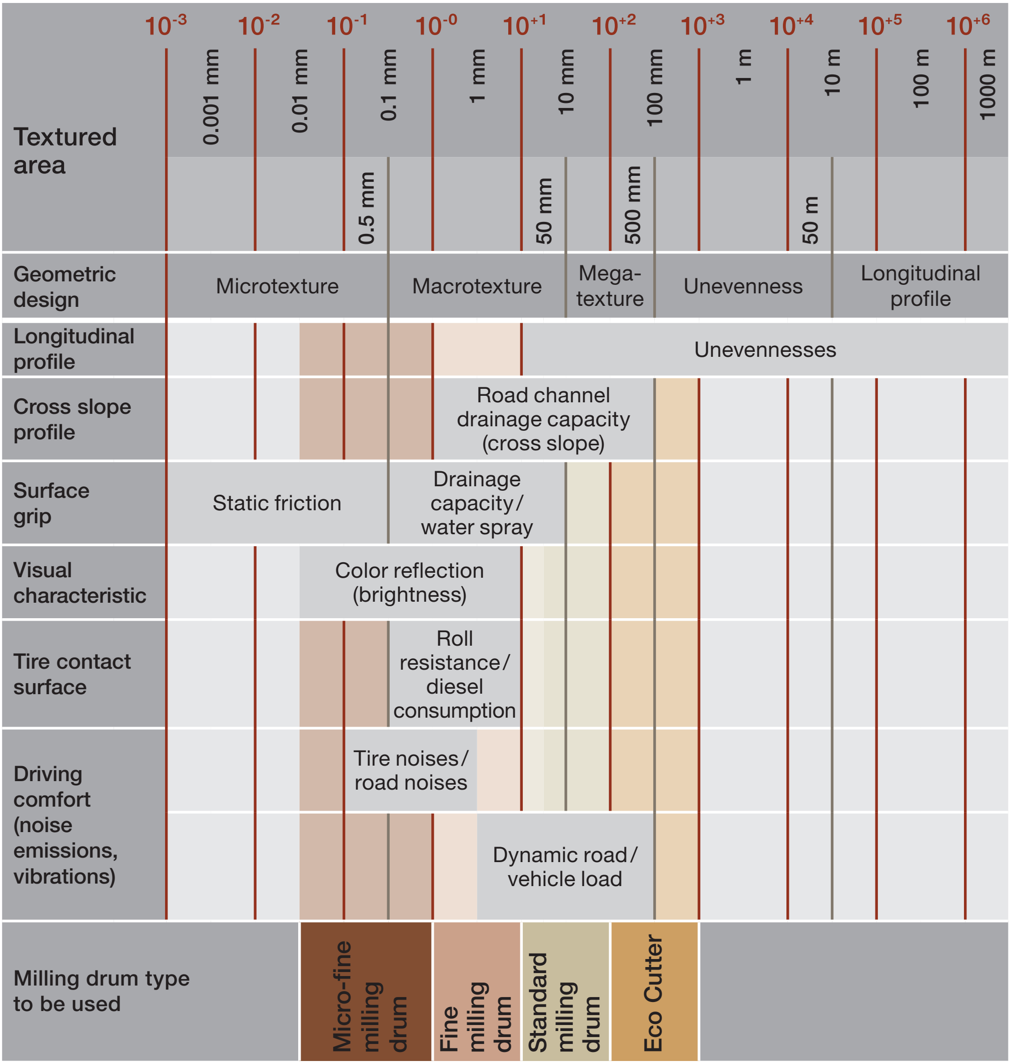
The texture (geometric shape) of the surface affects important performance characteristics such as roughness, surface grip, drainage capability, roll resistance and both acoustic and visual characteristics. It is classified as microtexture (< 0.001 mm to 0.5 mm), macrotexture (0.5 mm to 50 mm) or megatexture (50 mm to 500 mm), depending on the wavelength spectrum. Wavelengths over 0.5 m and up to 50 m are attributed to unevenness.

Milling enables the geometric shape conditions of surfaces, and thus their performance characteristics, to be changed in the wavelength ranges between 0.05 mm and 1 m. To achieve optimum results here, the selection of the milling drum to be used is decisive.

Texture ranges from 0.05-1 mm are processed with micro-fine milling drums to improve static friction/roughness of the surface, while drainage capability can be optimised through the use of fine milling drums in the texture range of 1 to 25 mm. In addition, the reflective characteristics, roll resistance and the acoustic characteristics of the surface can also be affected.

With standard milling drums, greater unevenness in the cross slope, such as road grooving, can be remedied. Improvement of the drainage capability is also the goal here. The same applies for the Eco Cutter equipped with even greater tool spacing.

Area micro- / macro- / megatexture, area unevenness, area longitudinal profile (left to right)



The use of different milling drum types can have a long-term effect on the performance characteristics of the surface.

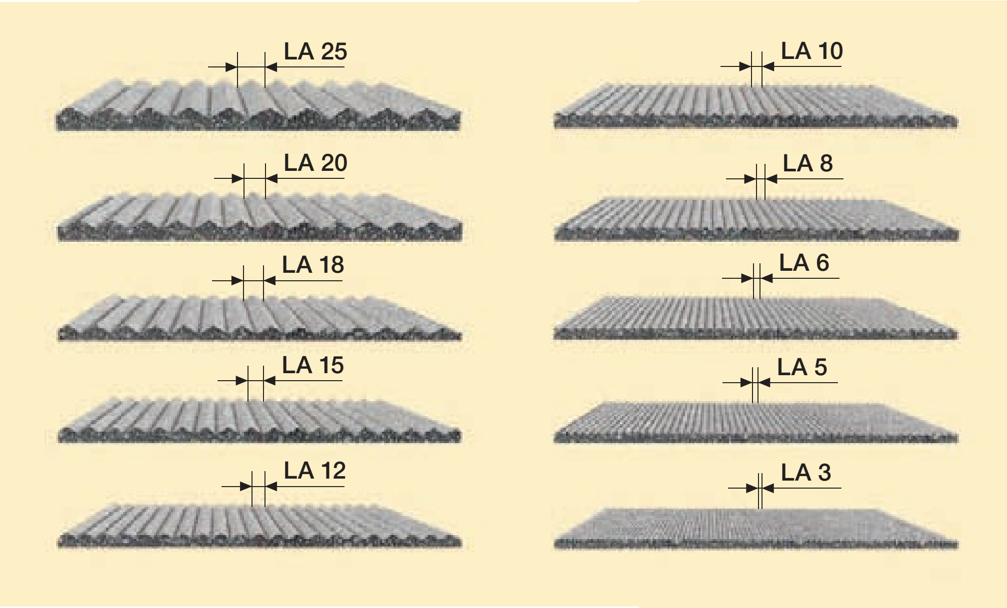
cf. Ludwig, S. Oberflächeneigenschaften und Straßenbautechnik. VSVI-Seminar Münster.

3.4.5 Tool spacing of milling drums

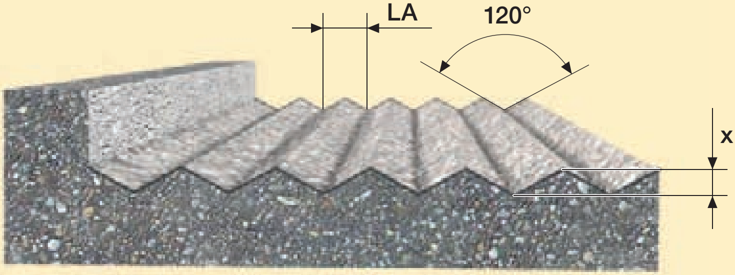
As a result of the penetration of picks into the road, a surface profile largely determined by the tool spacing, the milling drum speed and the machine milling speed arises.

Tool spacing is the distance from one cutting pick to the next closest cutting pick. The greater the tool spacing, the higher the milling performance and the lower the pick wear per m^3. Conversely, the smaller the tool spacing, the lower the milling performance and the greater the pick wear per m^3.

The milling drum speed is determined by the speed of the engine. It can be regulated so that the milling drum is always operated at the ideal cutting speed, depending on the required milling performance.



Surface profiles of the typical milling drum tool spacings



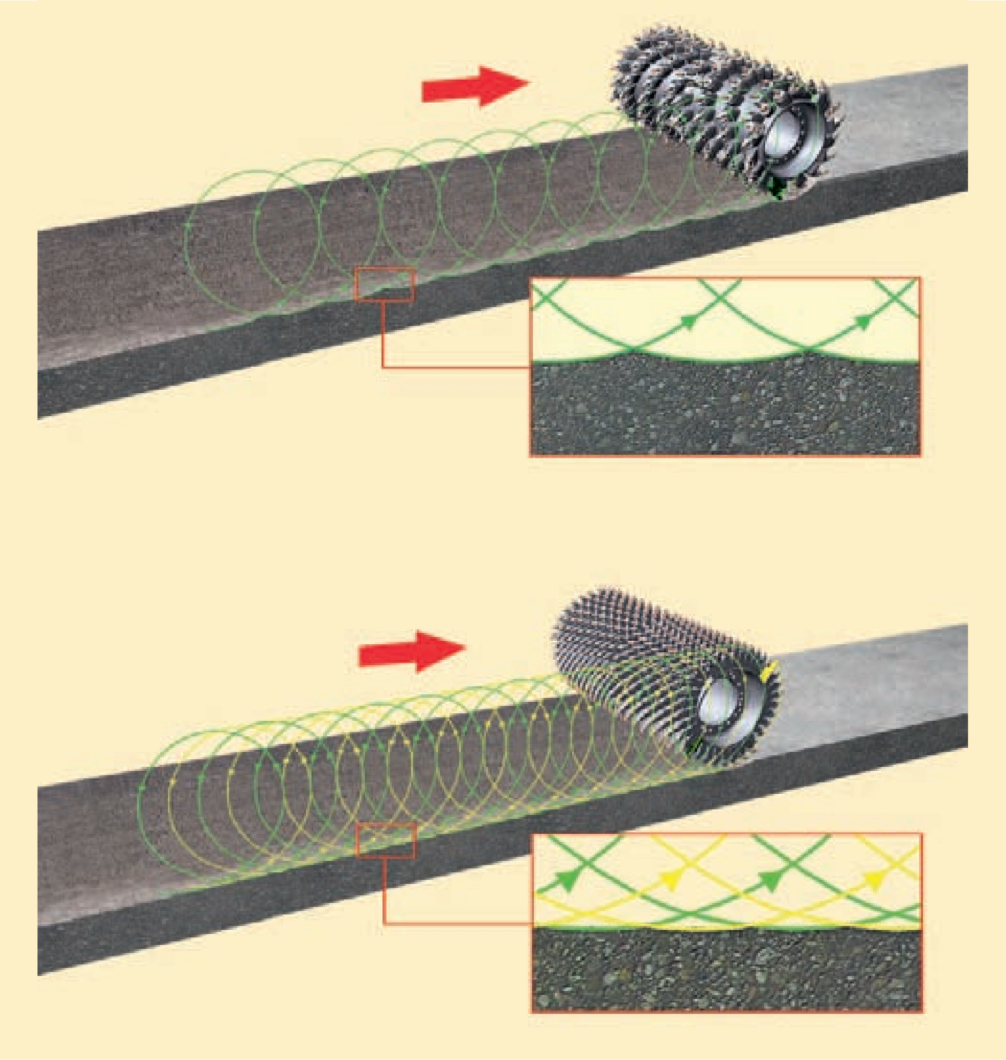
LA = Tool spacing in mm	x = Theoretical base height in mm	LA = Tool spacing in mm	x = Theoretical base height in mm
25	7.21	10	2.88
20	5.77	8	2.31
18	5.19	6	1.73
15	4.33	5	1.44
12	3.46	3	0.87

Theoretical base height of typical milling drum tool spacings

3.4.6 Effect of the milling speed on the milling pattern

In addition to the tool spacing and the milling drum speed, the milling speed determines the surface texture. The following applies here: The higher the milling speed, the rougher the milled surface. Thus, for example, one and the same milling drum can create a surface texture with different milling patterns by working at a constant milling drum speed, but at different milling speeds.

Optimum surface texture for surface course rehabilitation

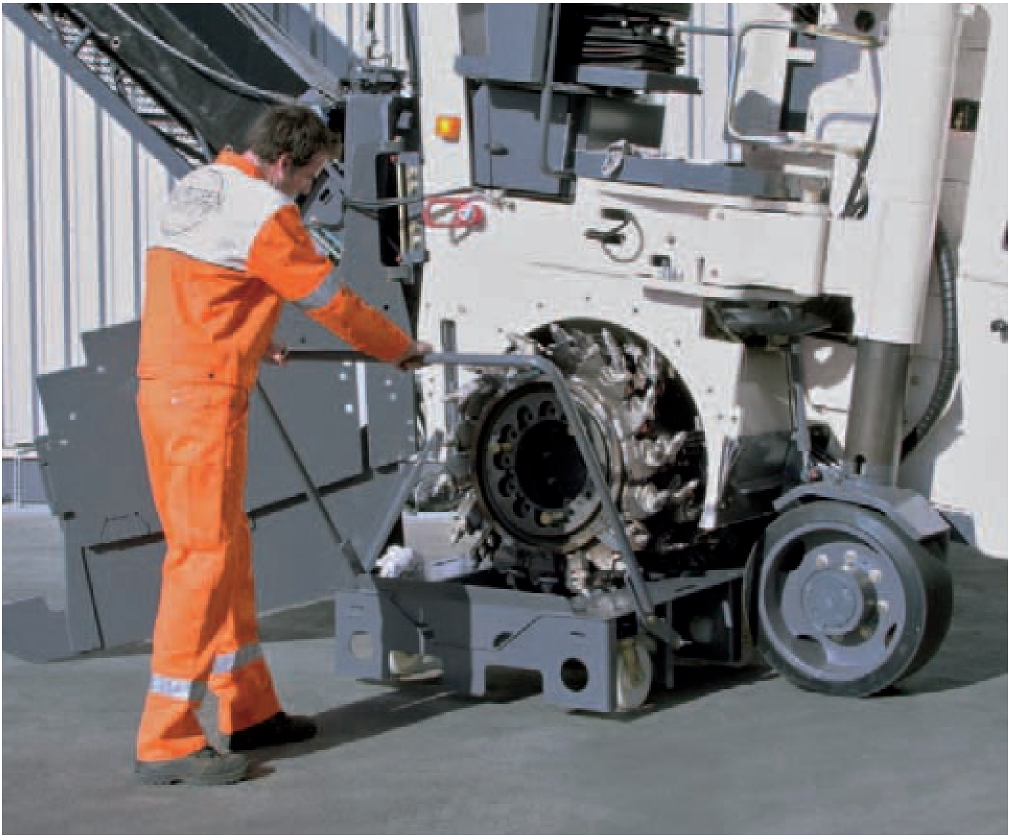


Effect of a double-occupied micro-fine milling drum on the surface texture

3.4.7 Modern milling drum quick-change systems

3.4.7.1 Function of the FCS milling drum quick-change system

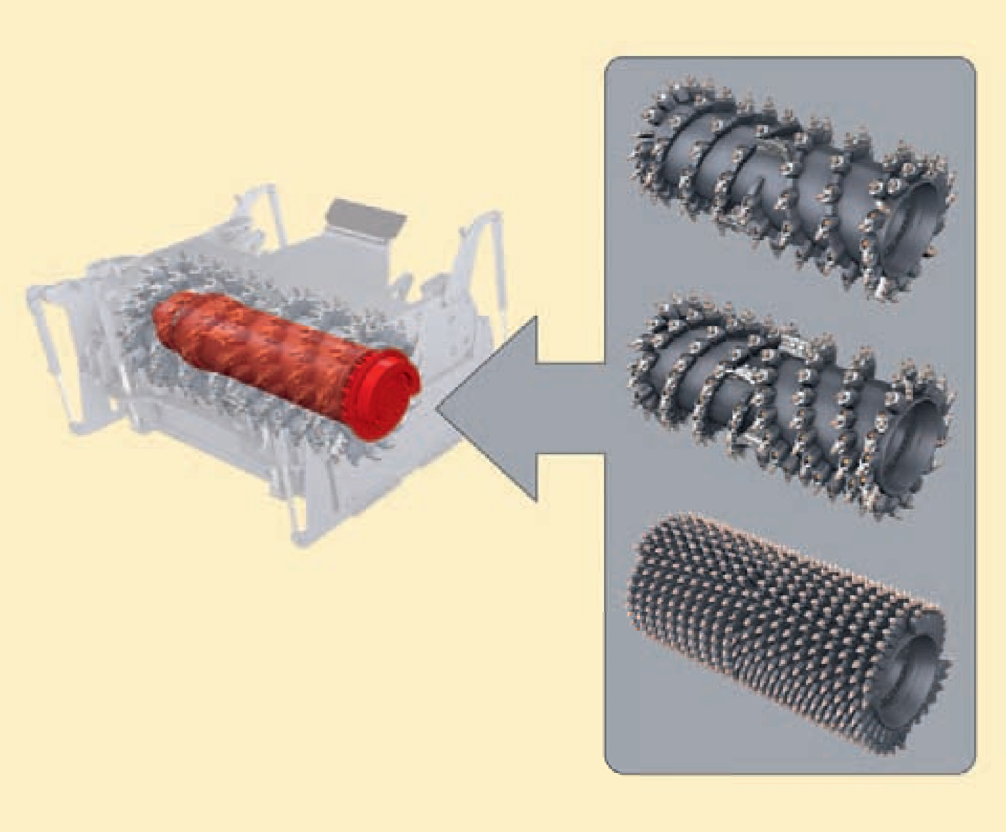
Thanks to the FCS (Flexible Cutter System) milling drum quick-change system from Wirtgen, the cold milling application spectrum is expanded considerably. The system enables the quick and easy conversion of milling drums of various different working widths, tool spacing or milling profiles so that the machine can be used in a very flexible way, is given a greater stress load and thus works in an especially economical way. Conversion is carried out in just a few steps.



Simple milling drum replacement with the FCS milling drum quick-change system

3.4.7.2 FCS Light

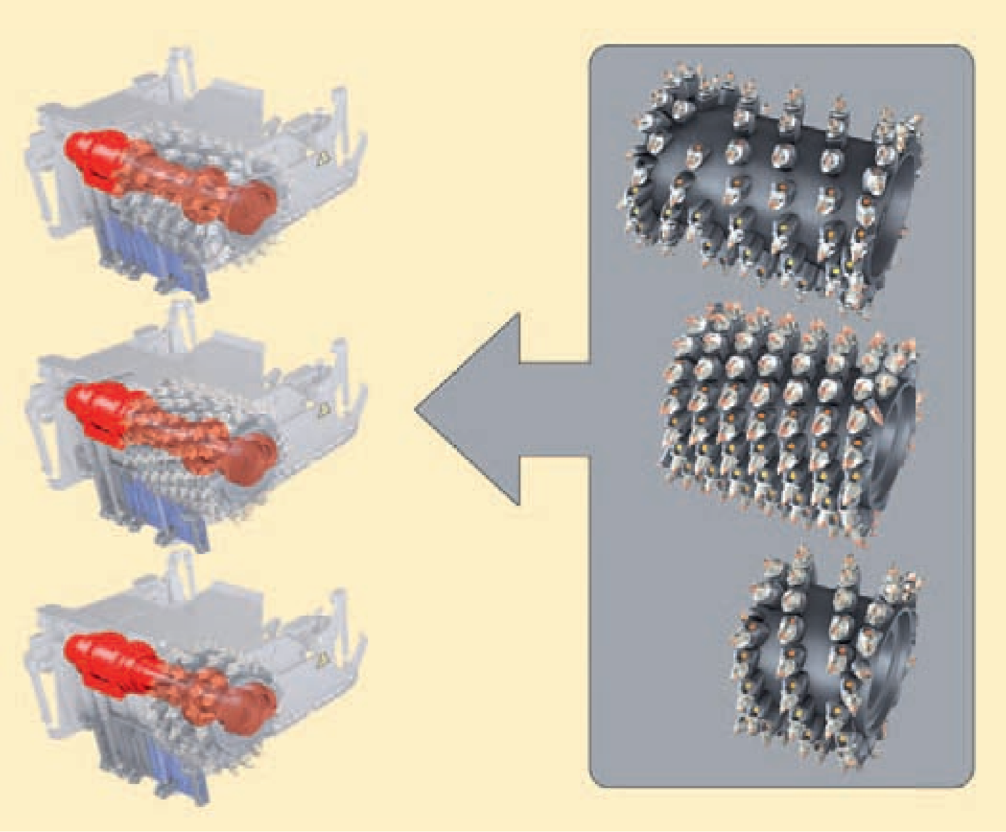
The simplified version of the Flexible Cutter System, the FCS light, enables the exchanging of milling drums of the same working width, but different tool spacing, in a very short period of time.



Typical milling drums for various milling applications with the FCS Light System

3.4.7.3 FCS full version

With the full version, the working width can also vary. With the accompanying scrapper systems, it is even possible to load the milled material.

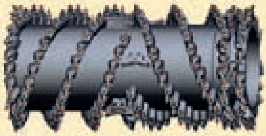


Typical milling drums for various milling widths with the FCS complete version

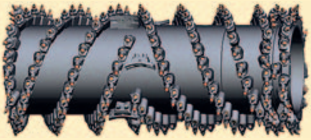
3.4.7.4 The FCS modular system

Using the extension elements from the FCS module for large milling machines (e.g. for the W 250), milling widths of 2.20 to 4.40 m are possible. These large “XXL formats” achieve enormous surface performance, so that even large construction sites can be processed in a short period of time.

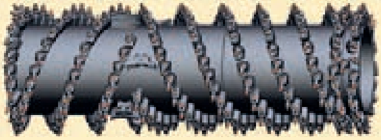
- Large increase in milling performance
- Reduced logistical expenditure thanks to lower machine and personnel usage
- Saves time thanks to fewer reversals



Standard milling drum with a milling width of 2.20 m

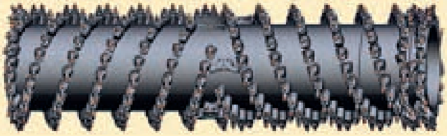


Standard milling drum with a milling width of 2.50 m

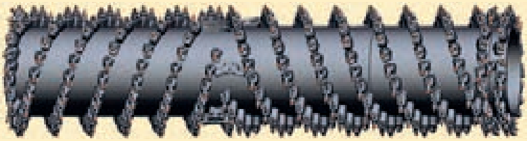


Standard milling drum with a milling width of 3.10 m

Standard milling drum with a milling width of 3.50 m



Standard milling drum with a milling width of 3.90 m



Standard milling drum with a milling width of 4.40 m

Possible milling widths with the FCS modular system of the W 250

4 Core technology: Levelling

4.1 The components of modern levelling

4.1.1 The job of levelling

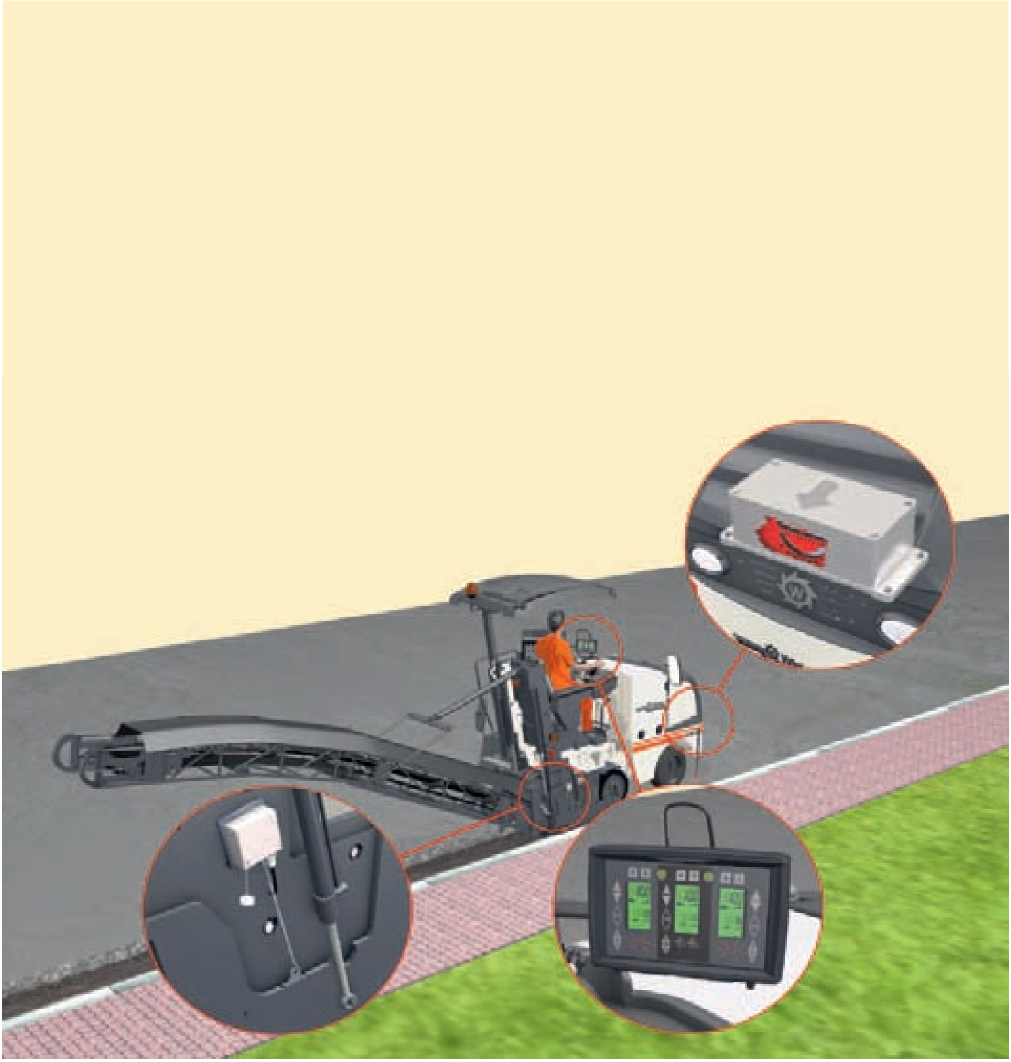
Levelling has the task of automatically controlling the milling depth or milling gradient based on a reference value as precisely as possible. To ensure the removal of a surface covering at the precisely specified height, the levelling system continuously matches the actual milling depth to the pre-set setpoint value and ensures it is complied with. One goal is to level or copy an existing surface. The other is the targeted removal of individual layers and the creation of defined surface profiles, e. g. cross slopes.
Depending on the construction measures and construction site conditions, different systems with different references are used.

4.1.2 Levelling with small milling machines

Due to their compact construction, small milling machines feature a very quickly responding levelling system. In contrast to large milling machines, the milling drum is not in the centre, but on the rear axle. The sensors of the levelling system are attached to the milling drum axle, where the height adjustment is carried out via repositioning of the lifting columns of the rear crawler units. During the milling process, the sensors register every change at the side plate and implement them at the lifting columns. If the stabiliser wheel of the small milling machine is folded away for milling flush with the edge, the response (and thus copying of the surface) occurs even more directly. The point of rotation of the vertical adjustment on the right-hand side now lies ahead of the milling drum, so a height adjustment of the lifting column thus results in a greater height change of the milling drum.

The milling depth can be controlled either manually or automatically using the levelling system. With the manual method, milling depth indicators provide information on the current milling depth. Scanning is carried out at the wheel brackets.

Automatic control keeps the pre-set milling depth or cross slope constant. The setpoint and actual values of up to three sensors are shown on the display at the operator's platform. Various different sensors applicable for the milling tasks can be tied in to the levelling system.



Typical components of a levelling control on small milling machines (cable sensors on both sides, levelling control display, cross slope sensor)

4.1.3 Levelling with large milling machines

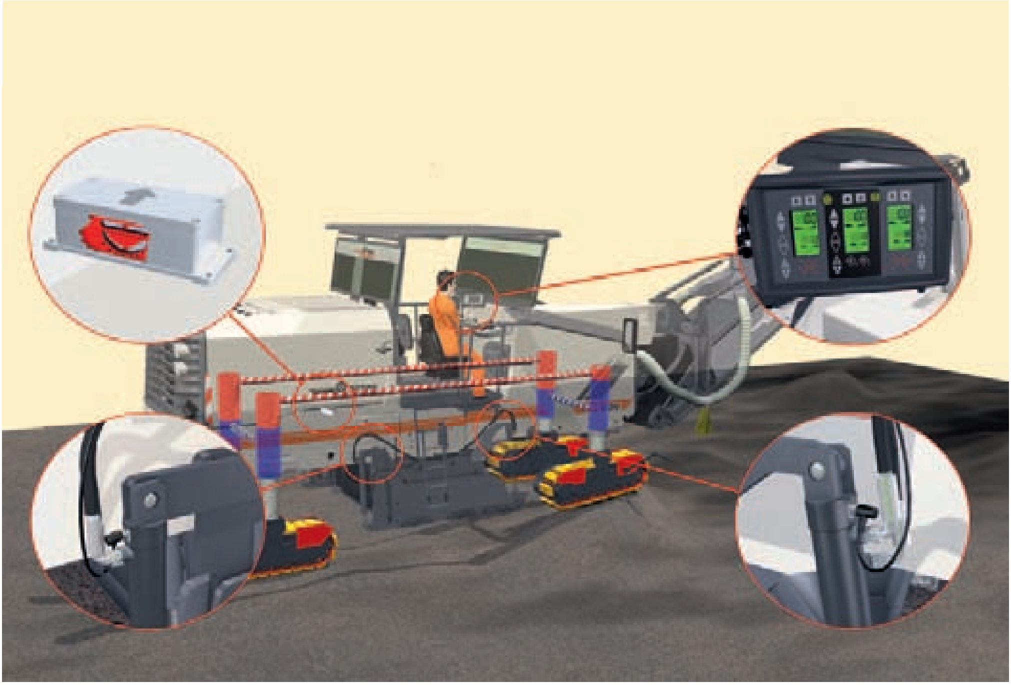
The greater the weight of the large milling machine, the more resistant it will be to external influences. The central milling drum concept enables the milling depth and cross slope to be set mechanically stable and kept constant. In this way, the measured levelling value is transferred absolutely precisely and optimal levelling results are achieved.

The height adjustment of large milling machines of the older generation features a permanently set rear point of rotation. Correction of the milling depth and the cross slope is controlled via the height adjustment at the lifting columns of the front crawler units.

Large milling machines of the latest generation have a point of rotation both in the front and rear. Height adjustment is carried out via the lifting columns of the front and rear crawler units, whereby all crawler units are hydraulically coupled. If one of the crawler units traverses

Typical components of a levelling control on large milling machines (cable sensors on both sides, levelling control display, cross slope sensor)

over a rise or through a recess, the arising height difference is automatically compensated for via the three different crawler units. Thanks to this principle of four-fold full oscillation, the machine always adjusts automatically to the ground and stability is noticeably improved. Closely tied to this is the PTS system (Parallel To Surface) which is integrated into the automatic levelling equipment, keeps the machine parallel to the surface during the milling process and supports the driver when positioning the machine in the milling track. Thanks to the integrated automatic positioning mechanism, all the crawler units can be lowered to the desired setpoint depth simultaneously with the push of a button. This causes the milling drum to penetrate into the material at a slower rate. Manual adjustment of the rear crawler units for precise compliance with the working depth is dispensed with. At the same time, machine operation is simplified considerably.

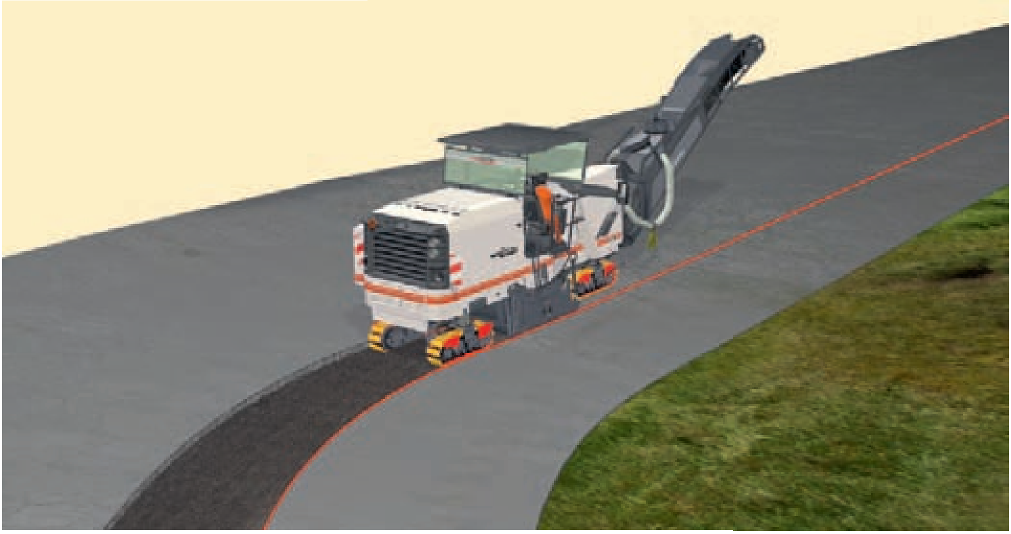


Typical components of a levelling control on large milling machines from the new generation with automated four-fold vertical control PTS (path sensors in hydraulic cylinder and Rapid Slope cross slope sensor)

4.1.4 Relative and absolute references

Relative line reference (e. g. surface of roads)

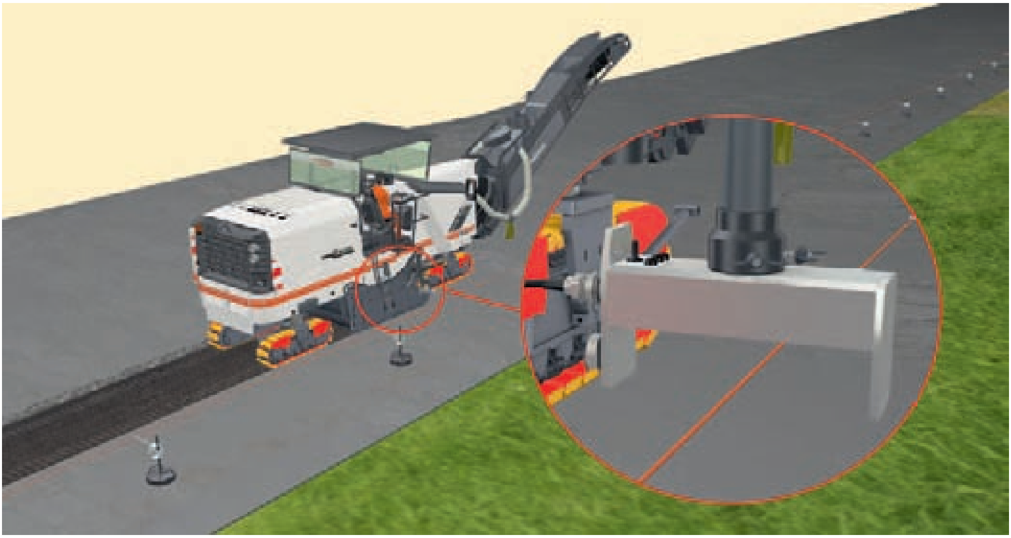
The reference used for the milling depth is the surface (e. g. the road), which is scanned in lines via the length of the lateral side plate. The side plate is linked to a sensor which measures the distance between the road profile and a fixed point on the machine frame. During the milling process, the up and down movements of the side plate, and thus the change in the distance, are transferred directly to the sensor. If deviations from the pre-set milling depth setpoint arise, correction is carried out automatically. Longitudinal waves which are smaller than the side plates are compensated for, but larger unevenness is not detected and copied to the new surface profile.



Typical reference line on the surface (red line) when scanning via the side plate.

Relative line reference (e.g. stringline or curb)

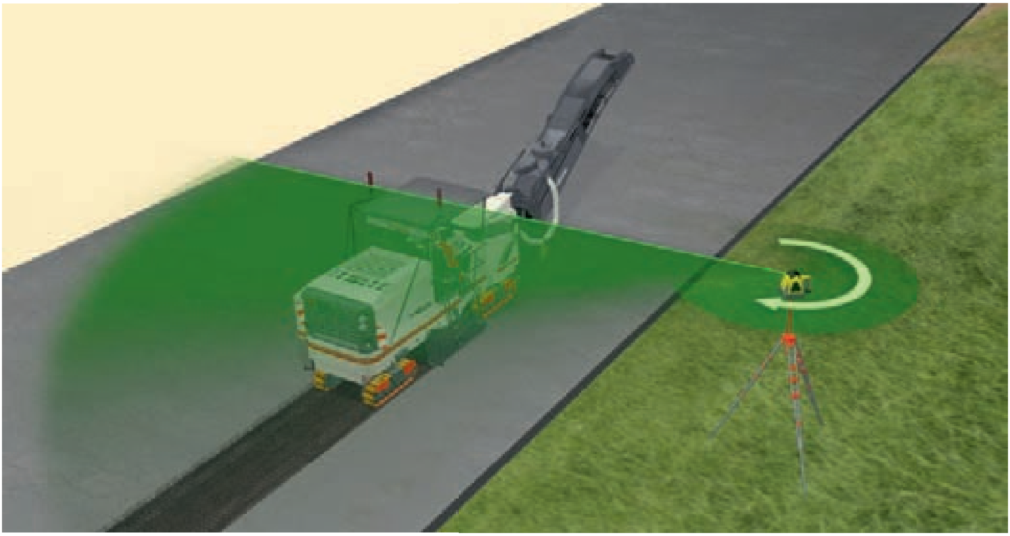
In this case, the reference is a specified contour, e.g. a stringline or a curb. If a stringline is put up, continuous scanning is carried out via a distance sensor permanently attached to the machine frame. The change in distance between the line and the machine frame is the dimension for the milling depth correction. Each deviation of the machine height is forwarded to the control, which converts this information into a corresponding curve. The result is a surface parallel to the height of the stringline.
Scanning via the height of the curb edge is carried out based on the same principle.



Typical reference line on a wire when scanning via the distance sensor (Sonic Ski sensor)

Relative reference (e. g. optical laser)

A stationary rotating laser generates an artificial level with its beam. This level serves one or, optionally, two laser sensors on the machine as a reference for realising the required milling depth. The laser sensors continuously measure the distance of the machine to the generated laser reference level. If the sensor measurement values deviation from the pre-set setpoint level, the corresponding signals are forwarded to the automatic levelling mechanism and the height is corrected. Depending on the rotating laser system, a range of up to 300 m is possible.

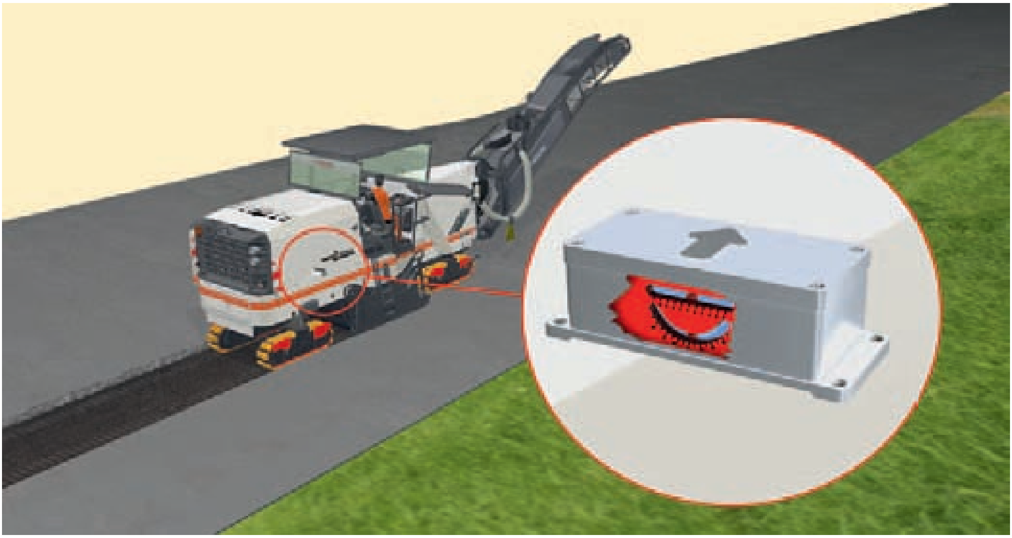


Laser reference level (green) for implementing a level milling depth

Absolute reference (e. g. gravitation)

The measurement corresponds to the principle of the electronic bubble level, i.e. the sensor measures the cross slope to the absolute horizon. The force of gravity is used as the reference.

Deviations from the gravitational force reference are detected by the sensor and immediately forwarded to the machine control. Using the specified setpoint machine inclination, the machine inclination is corrected automatically.

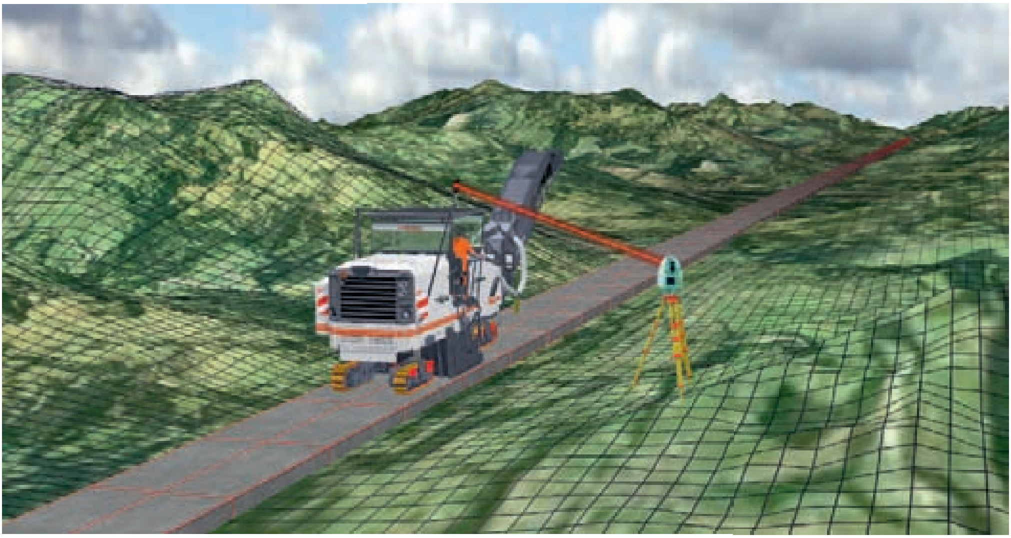


Absolute gravitation reference for determining the cross slope

Absolute reference (e.g. use of digital geodata)

A new surface model is created using 3D positioning data created by a surveying office. This enables the ideal milling depth to be transferred accurately to the 3D computer and then to the levelling system of the milling machine. The quality of the created data model has a decisive effect on the quality of the milling results.

After a one-time position determination, the current machine position and milling depth are determined using a high-precision angle and distance measuring unit (total station) and transmitted to the 3D computer on the cold milling machine for further processing.



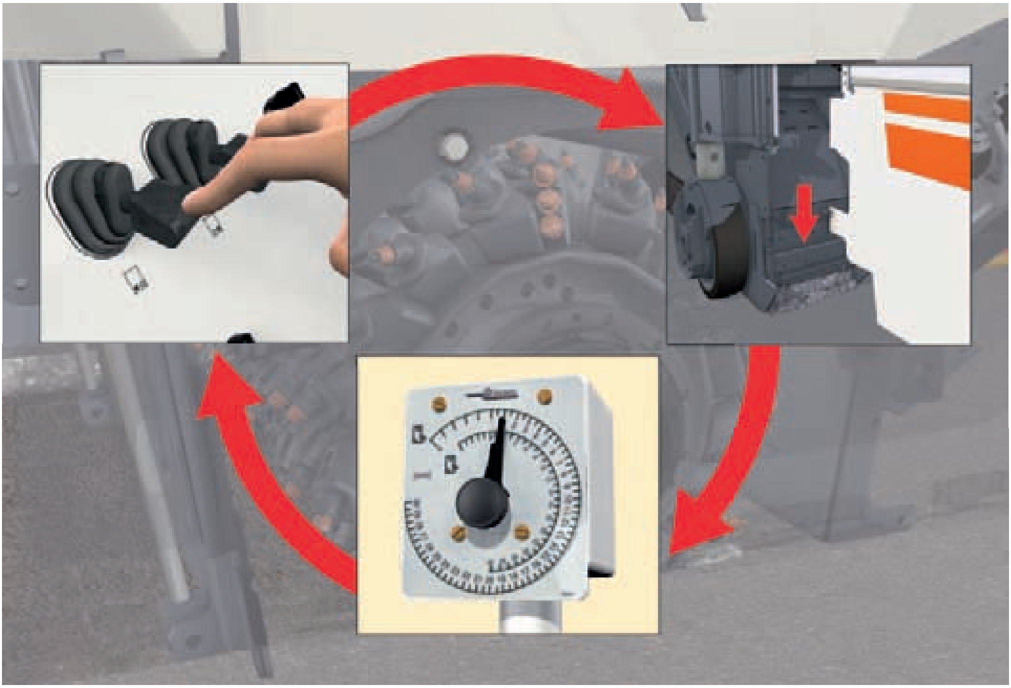
Absolute geodata reference for exact-position determination of milling depth

4.2 The levelling process

4.2.1 Manual levelling via mechanical milling depth indicators

Setting of the height adjustment on small milling machines is carried out manually by lowering the lifting column of the rear crawler units. Two indicators relay the required milling depth information to the operator, separately for the right and left sides. If the milling depth deviates from the setpoint value, the height is manually corrected by the operator via the rear lifting column.

In day-to-day construction site practice, the operator is always tied in to the milling and levelling process at the same time. Due to this “human factor”, the response to deviations in the milling depth are naturally slower and the correction is less precise, as it is not occurring automatically.



Visual reading of the milling depth position and manual readjustment

4.2.2 Automated levelling in the control loop (with relative and absolute references)

In the automated control process, the machine operator is relieved of such duties by the levelling system. The goal is to automatically control the milling depth or milling level based on a reference value as precisely as possible. This is a closed control loop which allows the use of a wide variety of sensors. Deviations in the setpoint milling depth are detected by the sensors and calculated by the levelling control, and a corresponding machine correction is initiated automatically. Depending on the reference, a variety of different sensors are used for different tasks.

Automated milling depth determination with relative references and corresponding regulation via the levelling control

Automated milling depth determination with relative references and corresponding regulation via the levelling control

4.3 Modern levelling controls from Wirtgen GmbH

4.3.1 An overview of system development

Until 2007

DLS1

The DLS1 milling depth regulator is both an operating panel and a control unit.

- It is comprised of a component which is used directly at the operator's platform and also as an external handset on each side of the machine for controlling the right and left milling depths. A regulator is required for each control loop (machine side).
- Interface for analog or CAN measurement data for side plate and cross slope sensors

2007

LEVEL PRO

The LEVEL PRO levelling system was developed especially for Wirtgen milling machines and is designed as a modular system. It enables simultaneous, automatic control of the milling depth on both sides of the machine from the operator's platform.

- User-friendly operating panels for use at the operator's platform or the machine sides
- Permanently installed digital controller for centralised control of the milling depth controller of both machine sides and evaluation of all sensors
- Simple and easy-to-learn operating concept (user-friendly graphical displays and function buttons)
- Simultaneous reading in of analog and CAN sensors is possible

2010

LEVEL PRO 2

To satisfy the expanded features of the new generation of Wirtgen large milling machines, the LEVEL PRO system was modified for complete function integration into the control system of the entire machine in 2010.

- Integration of four-fold oscillation
- Integration of the PTS system
- Introduction of analog cylinder sensors
- Preparation of control for multiplex as standard

A DLS1 milling depth controller is the operating and control unit for a sensor.

4.3.2 Wirtgen LEVEL PRO controllers (1 and 2)

The central station of the LEVEL PRO levelling system is a permanently installed digital controller which unifies all the control loops. It evaluates all sensors, communicates with the operating panel, controls vertical adjustment of the machine and ensures consistently good milling results. The operating panels can be attached both at the operator's platform and to the sides of the machine and are operated intuitively.

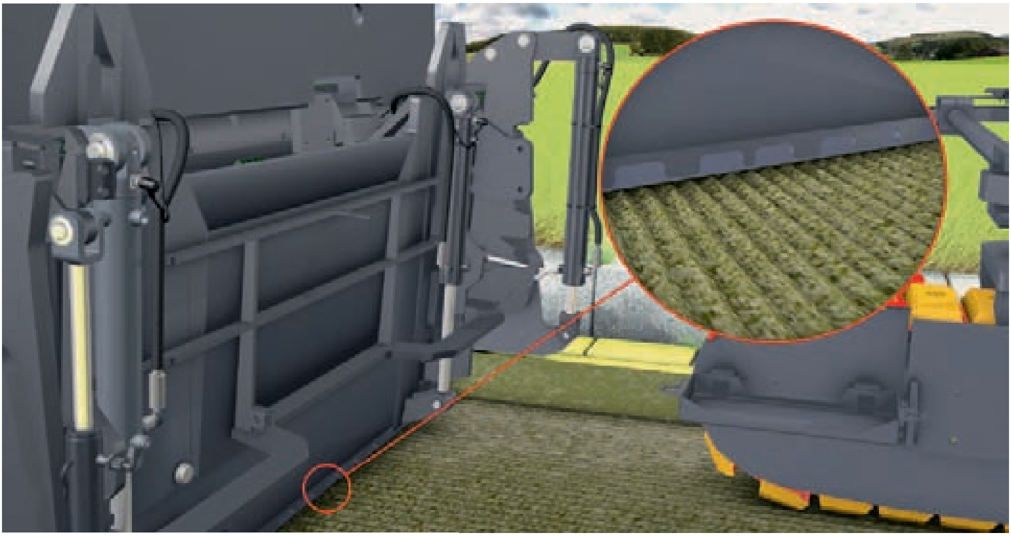
The LEVEL PRO operating display can display three sensors at the same time. The control unit is attached separately at a protected location on the machine.

4.3.2.1 The “MDI” milling depth indicator

The “MDI” milling depth indicator measures the actual distance between the side plate and scraper using the LEVEL PRO hydraulic cylinder sensors present on the machine. These values are shown in the LEVEL PRO display. The MDI is not linked to the automatic levelling mechanism, however, and does not access the control circuits of the machine.
Due to the high precision of the milling depth indicator, even the smallest deviations, e. g. those brought about by pick wear, between the pre-set and the actual values can be quickly detected and corrected.

Other advantages:

- Re-measuring of the actual milling depth after the machine is dispensed with.
- Possible subsequent work due to faulty milling depths is largely prevented.
- Easy monitoring by the machine operator using the actual milling result.



The differential value between the side plate and the scraper unit is determined and displayed via the levelling control display.

4.4 Modern sensors

4.4.1 Cable sensor

The cable sensor is a vertical sensor mounted at the side plate. While the side plate mechanically scans the reference surface, the sensor determines any unevenness or vertical differences. This direct measurement results in copying of the surface. Cable sensors are rugged and ensure reliable scanning, even in difficult weather conditions.

A mechanical cable sensor connected to the side plate with a wire determines the difference (milling depth) between the side plate and machine chassis.

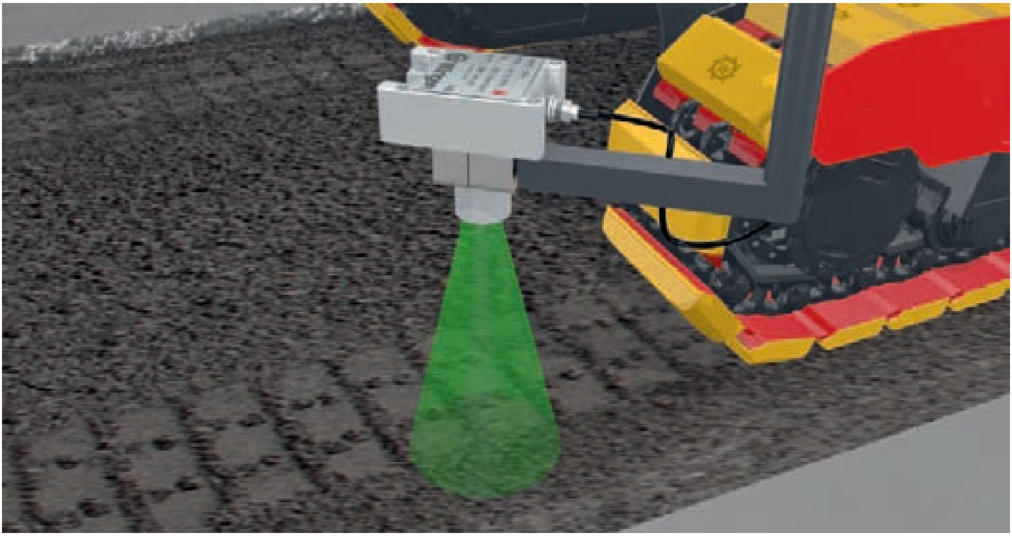
4.4.2 Hydraulic cylinder sensor

The cable and ultrasonic sensors used thus far are no longer required with the large milling machines of the latest generation, as both lifting cylinders at the side plate on each side contain displacement sensors. These sensors are non-wearing and are protected mechanically by the hydraulic cylinder housing. The surface is reliably copied by this resilient measurement method.

Path sensors in the hydraulic cylinder determine the difference (milling depth) between the side plate and machine chassis.

4.4.3 Ultrasonic sensor

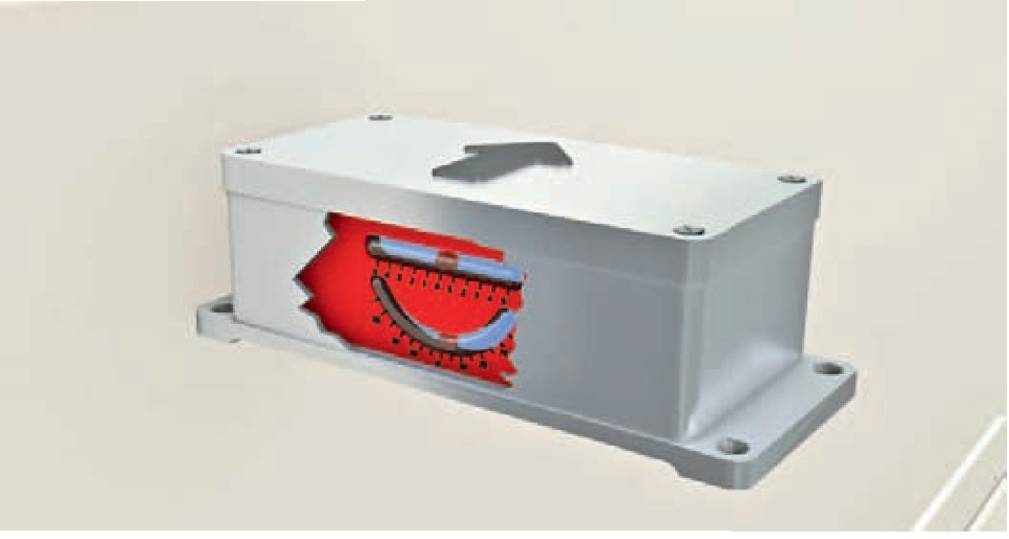
The ultrasonic sensor, which functions without making contact, can scan both the height of the side plate and the reference surface next to or in front of the milling drum. It emits high-frequency sound waves which bounce off the reference surface and are detected again by the sensor. The span of time between transmitting and receiving the signal serves as the measure for the distance to the surface. With this measurement process, the dependency of the speed of sound on the ambient temperature must be taken into account. Gusts or trails of wind from passing vehicles can briefly influence measurement, for example. Measurement errors caused by general temperature changes in the environment are largely compensated for by corresponding sensors in the device.



The non-contact ultrasonic sensor determines the distance of the machine to the reference surface.

4.4.4 Slope sensor

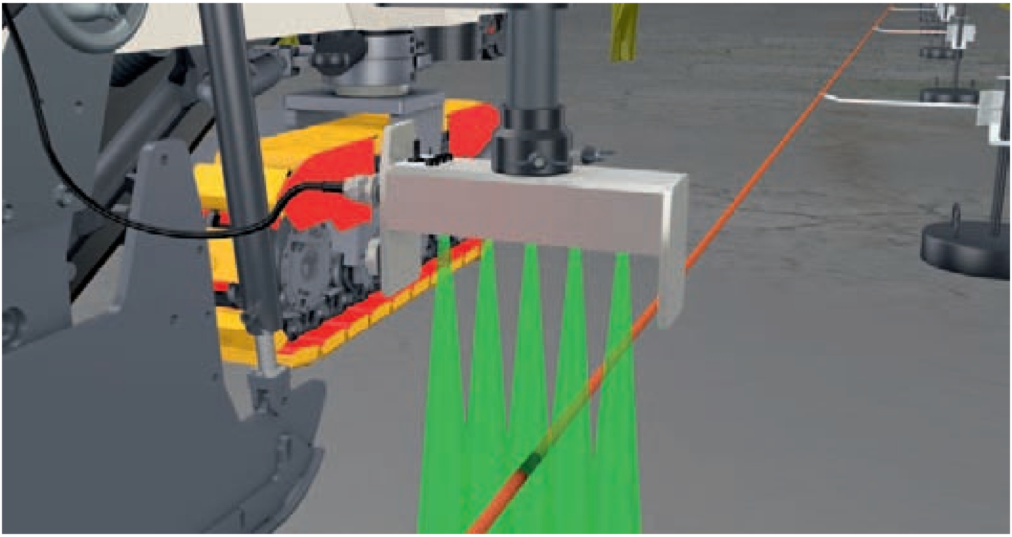
The slope sensor permanently mounted to the machine is used for the creation of surfaces where relative references cannot be used. The slope sensor uses an absolute and non-wearing measurement method. This enables surfaces to be created with any predefined cross slope.



The level sensor is used to determine the absolute difference to the gravitation force reference.

4.4.5 Sonic Ski sensor

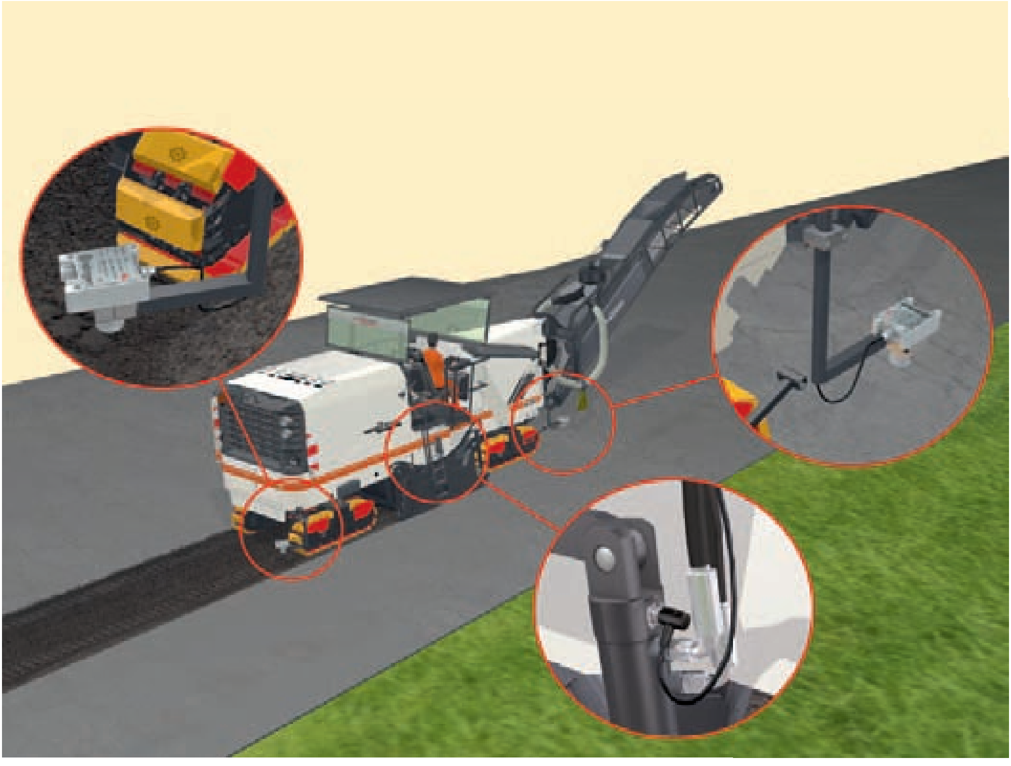
The Sonic Ski sensor contains five ultrasonic sensors which can be used for both contactless scanning of a line (alignment of the sensor perpendicular to the stringline) and for scanning a surface (alignment of the sensor in the direction of travel or parallel to the side plate). When a surface is scanned, the measurement value is formed by calculating the average of the individual ultrasonic measurements. Unevenness in the surface to be milled is quickly compensated for. Of these five ultrasonic measurements, only three are used for calculation of the average value. The highest and lowest values are discarded. In the case of cable scanning, the sensor must be switched over and repositioned accordingly. Here, only the smallest ultrasonic measurement value is evaluated. Measurement is vulnerable to temperature and wind, which is why the sensor enables quick temperature compensation via a separate reference measurement. The Sonic Ski sensor is arranged either longitudinally or crosswise on the machine.



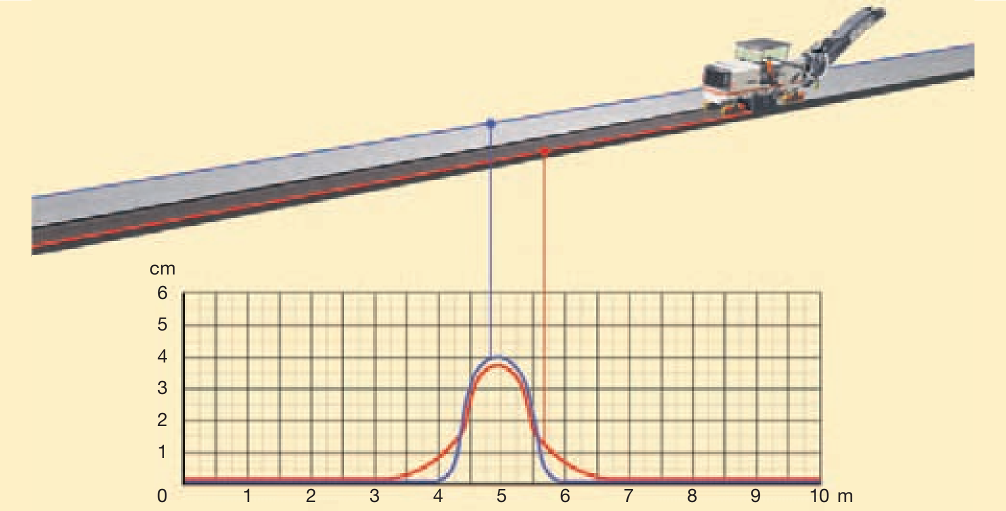
The non-contact Sonic Ski sensor determines the distance of the machine to the reference surface. This may also be a stringline.

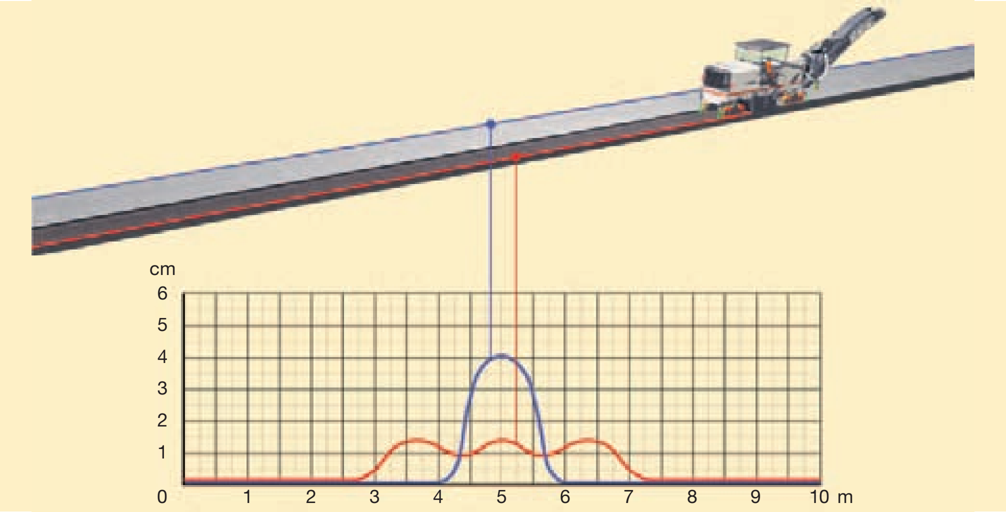
4.4.6 Multiplex systems

Multiplex systems are used to measure sustained, stretched-out unevenness and combine multiple sensors on one or both machine sides (e.g. cable, ultrasonic, cylinder sensor). Using the average value of the connected sensors, the current milling depth is calculated with high precision. Longitudinal waves can thus be highly compensated for. The system is especially suited towards fine milling work.



With the Multiplex levelling system, sensor signals are calculated to arrive at an average differential value. This enables unevenness to be smoothed out considerably.

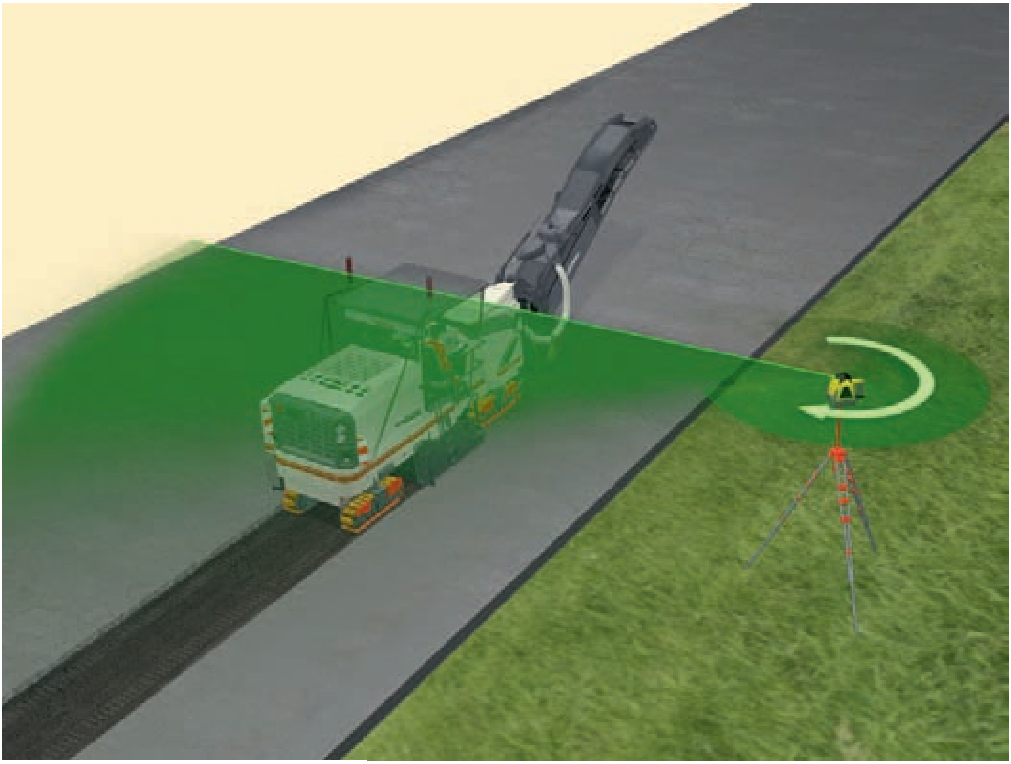




Milling depth smoothing using a simple sensor (image above) and Multiplex system (image below)

4.4.7 Laser sensor

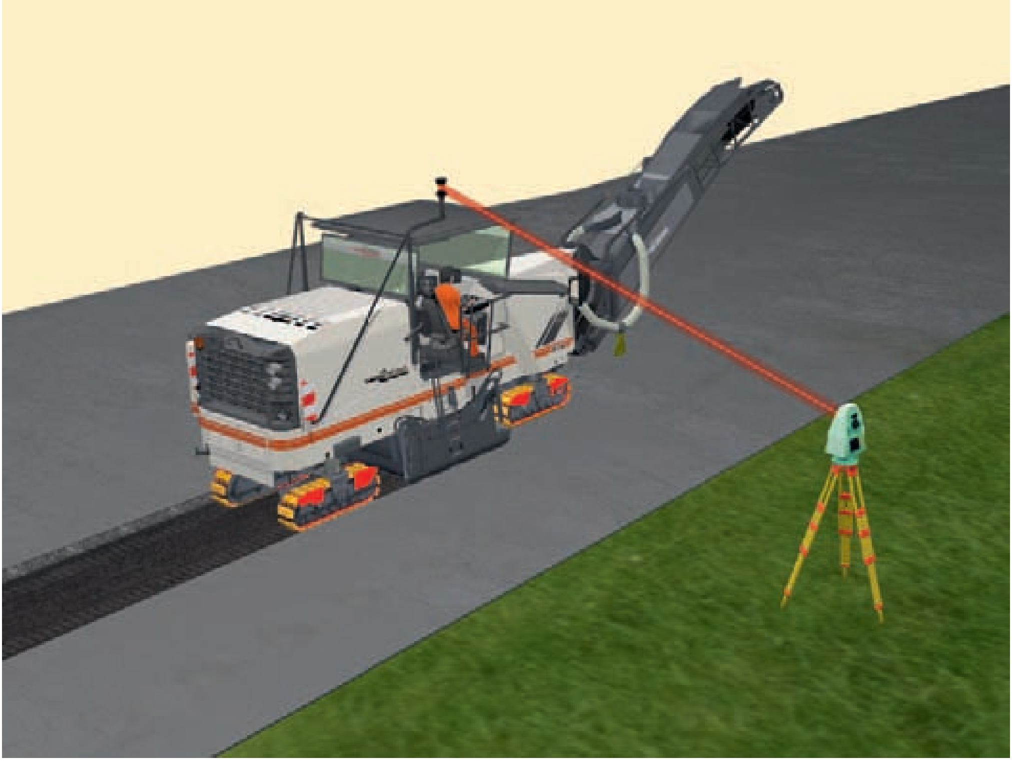
Laser sensors on the machine receive the signals of a rotating laser beam which creates a level reference surface in space through its rotation. The non-wearing and very precise vertical measurement is especially suitable for tunnel, airport, sport stadium and hall milling work.



With laser levelling methods, laser sensors on the machine receive signals from a rotating laser beam.

4.4.8 3D sensor

The current machine position is detected via a total station or GPS systems. These data are synchronised with a previously generated digital terrain model of the planned milling surface. During the milling process, the 3D computer continuously synchronises the setpoint and actual positions of the machine. The LEVEL PRO system compensates for the corresponding deviations. The LEVEL PRO and the 3D computer are linked to each other via the CAN bus. Due to the requirement for precision, the milling speed of the machine must be continually adjusted.



A total station focuses a receiver prism, from which it calculates the position and height of the cold milling machine. This data is transferred to the 3D computer for further processing.

4.5 Application recommendations for various levelling methods

4.5.1 An overview of usage recommendations

Possible applications	**Examples of deployment**
Removing a surface course	Milling off surface courses by 4 cm at a milling speed of 20 m/min.
Removing surface and binder courses	Milling off a 16 cm asphalt course at a milling speed of 8 m/min.
Complete removal of carriageways	Milling off a 24 cm asphalt course at a milling speed of 5 m/min.
Corrective milling work placing major demands on the evenness of the surface	Fine milling of a surface with longitudinal waves
Removing asphalt with a specified inclination	Fine milling of roads to optimise water drainage with a 2 % cross slope
Concrete milling	Milling off a 20 cm concrete course at a milling speed of 8 m/min.
Removing surfaces stipulated by stringwire	Milling off asphalt surface courses with reference to new edging
Making exactly even surfaces (renovation of the floors of indoor facilities, tunnelling, etc.)	Milling off hall floor surfaces to a depth of 2 cm
Establishing new surface contours according to digital models of the terrain	Milling airstrips to a milling depth of 4 cm

For the applications listed above, at least the main sensor should always be used. Each of the main sensors shown can also be used on both height controllers or be combined with the recommended secondary sensors in each case.

	Side plate sensors (cable sensor or hydraulic cylinder sensor)	Multiplex systems	Scanning in front of the milling drum	Slope sensor	Ultrasonic sensor	Sonic ski sensor	Laser sensor	3D sensor
	●●●	●	●●	●	●	●	○	○
	●●●	●	●●	●	●	●	○	○
	●●●	●	●●	●	●	●	○	○
	●●	●●●	●	●	●	●	○	○
	●●	●	●	●●●	●	●	○	○
	●●●	●	●●	●	●	●	○	○
	●	●	●	●●	●	●●●	○	○
	●	●	●	●	●	●	●●●	○
	●●	○	○	●	○	○	○	●●●

●●●	Main sensor	●●	Recommended second sensor
●	Alternative second sensor	○	Not suitable

4.5.2 Application examples of common levelling methods

4.5.2.1 Levelling with side plate – side plate

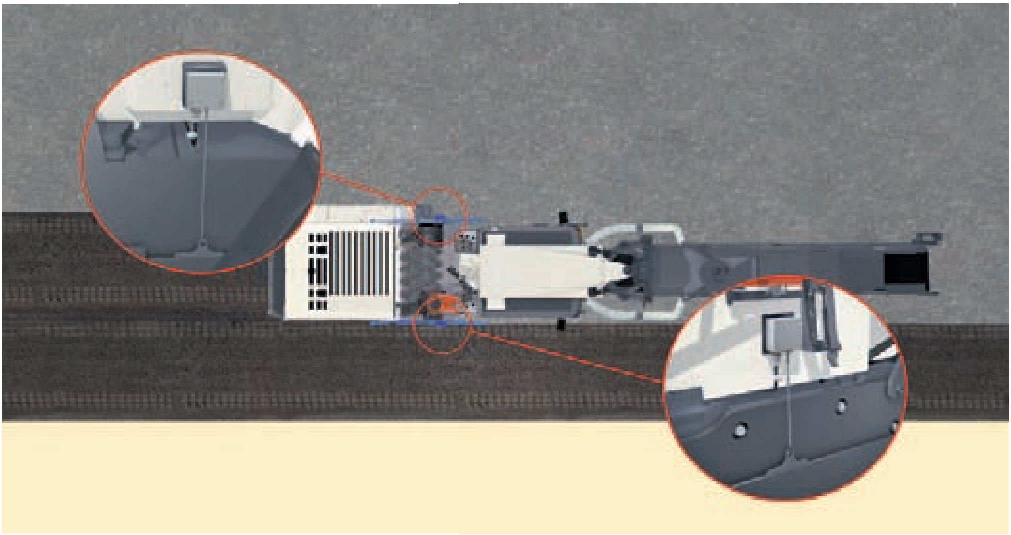
Scanning on the left and right machine sides with cable sensors at the side plate.

Advantages

- Very precise levelling method
- Very fast measured value implementation
- Very resilient and versatile levelling method

Note:

- Surface unevenness is copied or smoothed out less
- The reference line must be sustainable with side plate

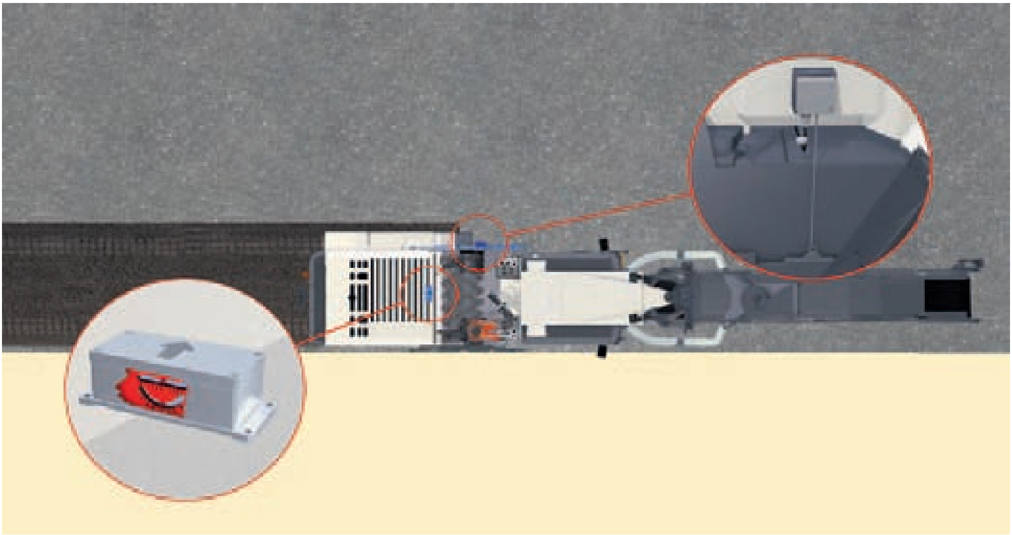


4.5.2.2 Levelling with side plate – slope sensor

Scanning on the left machine side with a cable sensor on the side plate and a slope sensor on the right side of the machine. The measured height on the one machine side in combination with the cross slope yields a constant and event milling profile.

Advantages

- Very precise levelling method
- Optimum and easy to implement combination of measurement sensors, e. g. for paving crowns



4.5.2.3 Levelling with side plate/ scanning ahead of the milling drum with hydraulic cylinder

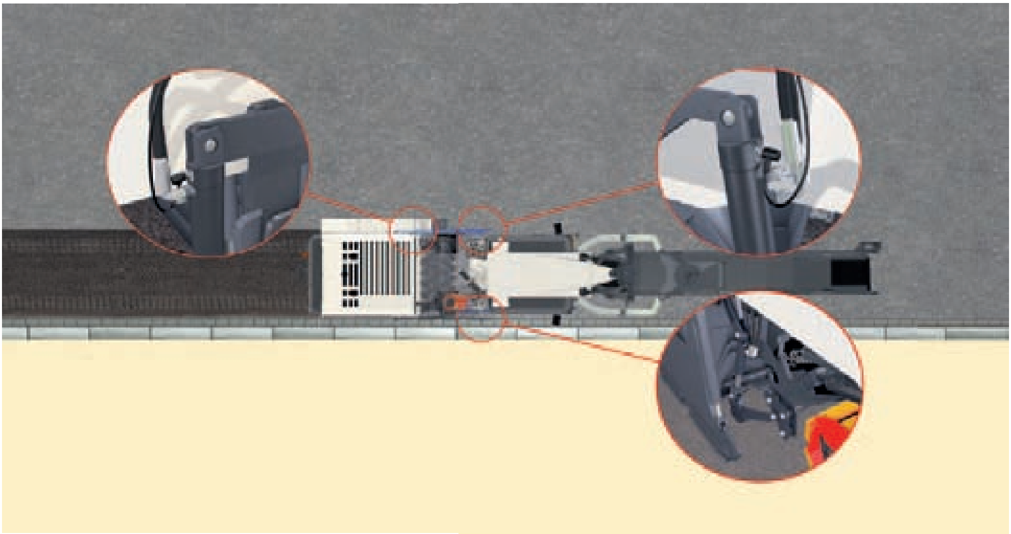
If a suitable reference is not available next to the lane to be milled, vertical scanning relative to the non-milled surface is carried out directly in front of the milling drum. A skid which can be moved vertically via a hydraulic cylinder is pressed onto the road surface. The vertical position can now be read via sensors in the hydraulic cylinder.

Advantages

- Very precise levelling method
- Very fast measured value implementation
- Very resilient and versatile levelling method
- Hydraulic cylinder sensors are very wear-resistant
- Scanning on solid surfaces in front of the milling drum due to a lack of scanning options next to the machine

Note:

- The short skid when scanning in front of the milling drum cannot smooth longitudinal waves.

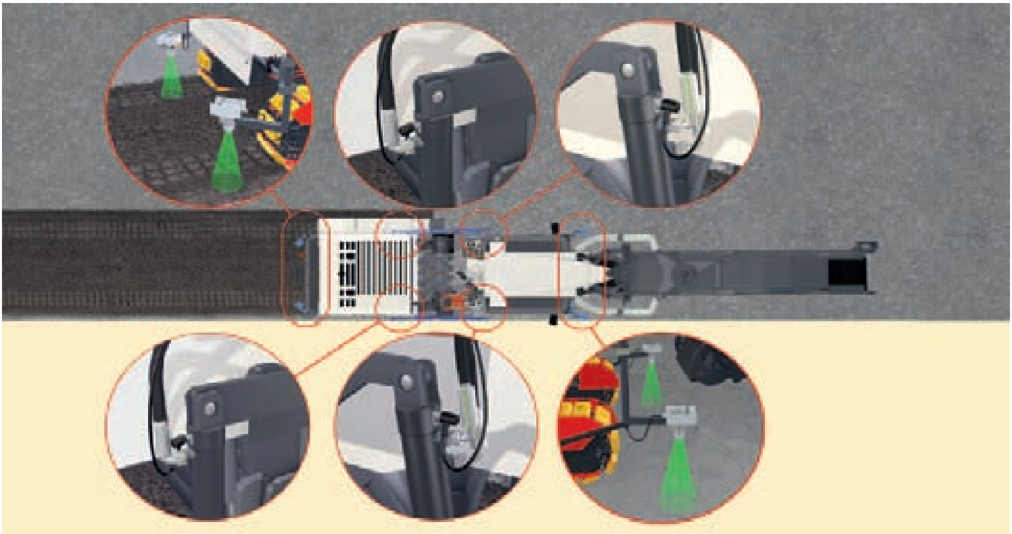


4.5.2.4 Multiplex levelling method

The controller calculates the average value from the measured values of the various sensors. Moving arms enable favourable positioning of the sensors. Longitudinal waves, in particular, can be very effectively compensated for using this method.

Advantages

- Many different sensor combinations are possible
- Road surfaces are smoothed to a high degree
- Application-dependent positioning of the sensors
- Less and faster installation expenditure



4.5.2.5 Levelling with laser signals

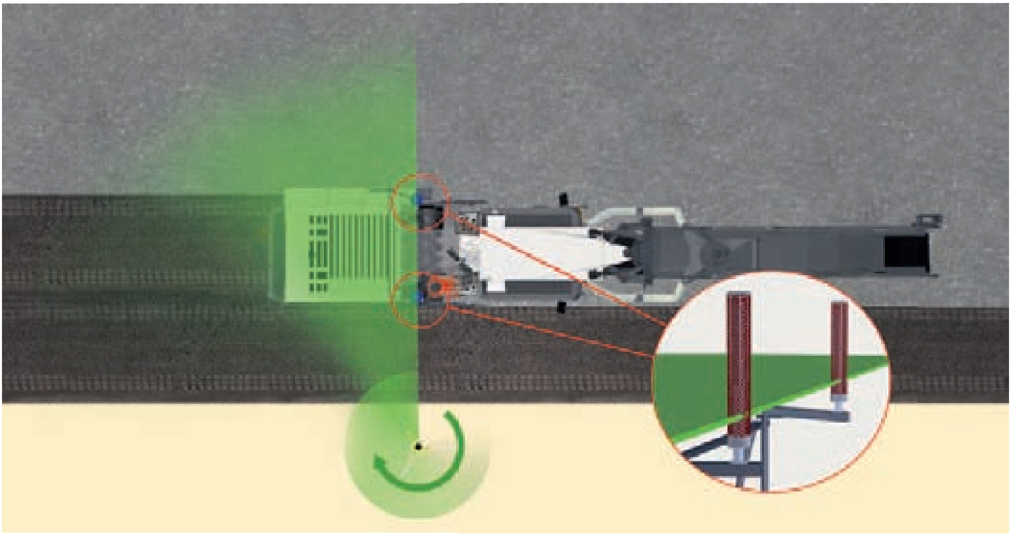
Two laser sensors on the machine continuously measure the changes in distance to the artificially created level of the stationary rotating laser.
If they leave this level, the automatic levelling mechanism receives a signal and the height is corrected.

Advantages

- Creation of large flat areas without mechanical reference points
- Resilient measurement method, as the laser is located above the operator's workspace

Note:

- Adaptation of the milling speed to the sensor measurement principle
- Range is limited by the rotating laser



4.5.2.6 Levelling with 3D positioning

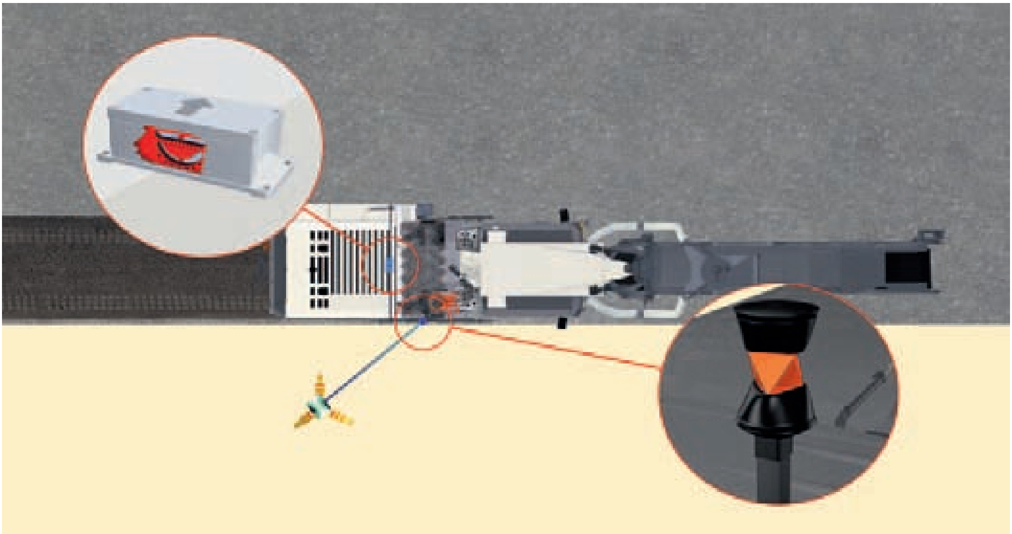
Thanks to the continuous synchronisation between the setpoint and actual machine position within a 3D model, the targeted removal of predefined surfaces is possible. The milling speed must be adjusted according to the precision requirements.

Advantages

- Independent vertical references via digital terrain model
- Optimal preparation of the milling surface contour for subsequent construction processes

Note:

- Construction site conditions must permit the use of total stations
- Digital terrain models must be created and edited before the milling process
- Milled surfaces must be checked using a 3D measurement method



4.5.2.7 Levelling with side plate / scanning with ultrasonic sensor

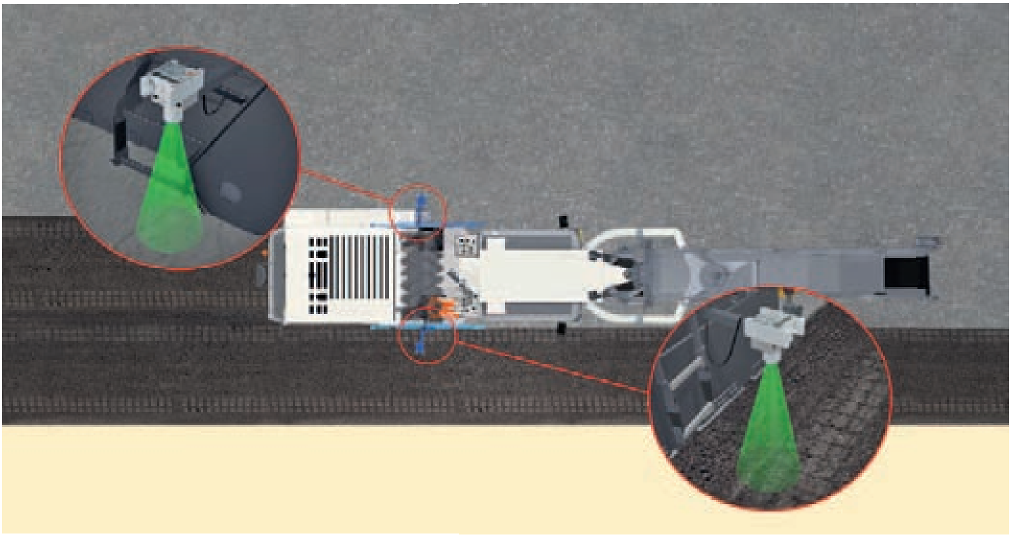
An alternative to scanning of the left and right machine sides with cable sensors at the side plate is scanning with an ultrasonic sensor. The sensor, which functions without making contact, can scan both the height of the side plate and the reference surface next to or in front of the milling drum.

Advantages

- Contact-less measurement method for scanning on loose and solid ground
- Very fast measured value implementation
- Very versatile levelling method

Note:

- Surface unevenness is copied
- Sensitive sound wave measurement

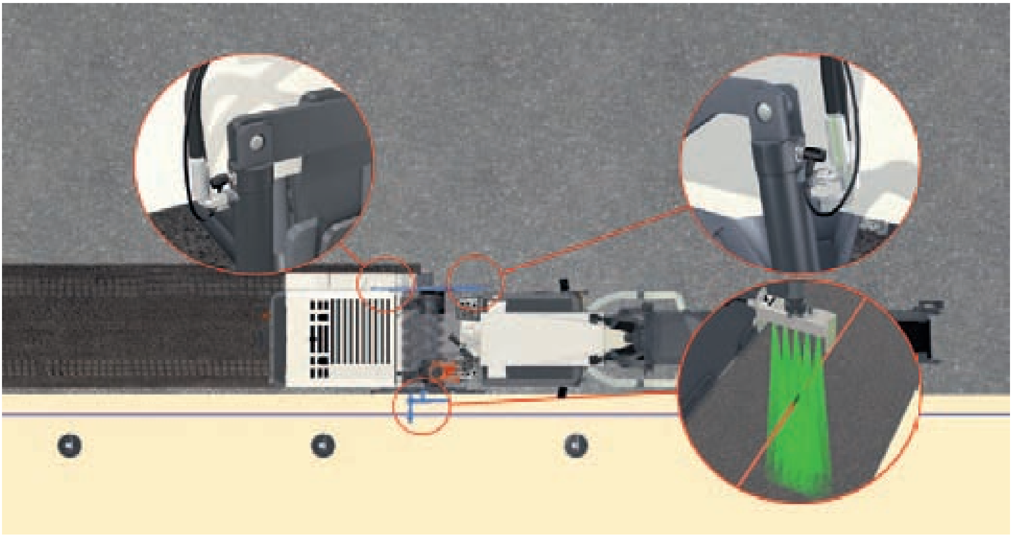


4.5.2.8 Levelling with side plate / scanning with Sonic Ski sensor on wire

The contact-less scanning of a reference, e. g. a stringline, is possible thanks to the perpendicular arrangement of the Sonic Ski sensor. The measurement values to be determined here are highly reliable thanks to effective temperature correction measurement.

Advantages

- Contact-less scanning of the stringline or fiberglass rod and very uneven surfaces
- Very fast measured value implementation
- Very versatile levelling method



4.6 Levelling quality

4.6.1 Optimum levelling results using modern machine technology

A host of technical developments to modern machine technology ensures consistently good levelling results and considerable unburdening of the machine operator. The progressive automation of technical processes, in particular, contributes considerably to levelling optimisation.

Depending on the model, the configuration and the environmental parameters, each machine levels in a different way. To achieve optimum results, the levelling parameters are stored for the respective machine, linked to the LEVEL PRO automatic levelling mechanism and called up during the working process. The levelling system automatically detects the machine series and sets the correct parameters without the machine operator having to adjust the parameters manually.

The advantages of modern machine technology:

- **PTS (Parallel To Surface)**
  With PTS, the milling machine is always automatically aligned parallel to the road surface in the longitudinal direction during the milling process, when simultaneously lowering the front and rear crawler units, when lowering the rear crawler units into the milling track or when changing the milling depth. This automatic function represents considerable unburdening of the machine operator. Manual movement of the rear crawler units to achieve the optimum milling depth is dispensed with.

- **Four-fold oscillation**
  PTS is based on the concept of four-fold oscillation. Here, all four lifting columns are coupled to one another hydraulically. If one of the crawler units strikes unevenness in the

ground, the other three crawler units compensate for the vertical difference. Through the principle of four-fold oscillation, not only is vertical compensation implemented more rapidly, but driving stability of the machine is increased considerably as well.

Automatic positioning mechanism
The automatic positioning mechanism supports the driver when positioning the equipment in the milling track up to the maximum positioning depth. When the LEVEL PRO automatic mechanism is activated (applies only for the new generation of large milling machines), the crawler units are simultaneously lowered with the milling drum rotating at high speed. When the machine reaches the surface, continuous reduction of the lowering speed occurs until the milling drum has penetrated to the entered setpoint milling depth. This automatically controlled, careful positioning is not only positive in terms of wear on the pick, but also considerably reduces the risk of breakage when milling work is begun.

Adjustment of control speed for each individual sensor type
The LEVEL PRO controller evaluates the data of the sensors and adjusts the height of the machine. To achieve consistently good milling results and high quality, each sensor can be configured individually and optimally during the milling process.
Setting and configuration work can be carried out during the process. They increase both efficiency and convenience.

4.6.2 The effect of milling speed and the environmental parameters on the levelling process

The levelling process is influenced by a number of factors:

- Machine model and series
- Type and number of sensors
- Environmental parameters
- Construction site situation

Irrespective of this, it must be possible for the machine operator to respond appropriately to each situation and to work at an even milling speed for optimal milling results. Time and again, limitations which result in the reduction of the milling speed are encountered, from the general condition of the machine and the cutting tools used to the processing speed of the data (human/ controller) to the traversal speed (hydraulics) of the machine. The time constant of measurement value acquisition also plays an important role, which is especially determined by the selected sensor and its measurement principle. Thus the acquisition of the measurement value of the cross slope, for example, is considerably slower than that of the height measurement using a cable sensor.

In principle, there is an ideal combination of sensor and milling speed for every usage condition.

W 250

5 Core technology: Machine control

5.1 The control process for cold milling machines

Today, cold milling machines are extremely effective construction machines. High milling performance is the most important factor of their success. This involves an increase in the complexity of machine operation. In addition to entirely manual machine control by the machine operator, an increasing number of computer-supported machine controls are currently in use. Machine operators are supported by such computer controls (e. g. WIDRIVE), especially when operating modern high-performance cold milling machines.

Modern operating and information displays on large milling machines

5.1.1 Manual control

During manual control, individual functions are initiated by the machine operator and all machine functions are operated via manual switches or control valves. Thus, the procedures are monitored solely by the machine operator and his/her practical experience.

Typical manual machine control on small milling machines

5.1.2 WIDRIVE control

Modern cold milling machines feature intelligent machine controls especially effective at automating work processes. A variety of different sensor signals are processed as input values by the control and translated to mechanical movements or physical values via actuators (e.g. hydraulic control valves or electric switches).
In the process, the actual values are continually compared to the set point values, and deviations are corrected. The correction occurs automatically via the WIDRIVE control system but can also be overridden manually.

Control tasks:

- Logical linking and evaluation of input signals in order to create output signals
- Registration and storage of data for evaluation and further processing
- Control/regulation of machine functions
  - Time-dependent sequence of control actions in the proper order
  - Diagnosis and evaluation of malfunctions

The development of machine-integrated control concepts such as WIDRIVE opens up new possibilities for increasing productivity.

WIDRIVE, the intelligent control system of Wirtgen cold milling machines, functions as the brain of the machine. The most important functions – such as the diesel engine, travel and milling drum drives, the conveyor drive, the water-spraying system, vertical adjustment, steering, levelling and the milling unit – are linked to one another centrally and controlled automatically. At the same time, the great potential of the cold milling machine is optimally utilised under consideration of environmental aspects relevant, greater cutting performance and lower operating costs.

An overview of today’s automated control functions:

Automated engine speed for travel and milling modes

- Automated speed adjustment in milling mode
  - While the engine automatically sets the working speed once the milling process is started, it automatically enters idle mode when the milling process is complete. This not only reduces fuel consumption, but also considerably reduces the amount of noise generated.
- Automated speed adjustment in transport mode
  - The engine only accelerates to the fastest possible speed once the maximum transport speed is reached. Otherwise the speed is kept as slow as possible depending on the speed travelled.
    The reduced amount of noise generated and reduced fuel consumption are two significant advantages here as well.

Automatic machine control options by linking different machine functions in the WIDRIVE system.

Four-fold full floating and vertical adjustment system

- Automated alignment ensures that the machine always works parallel to the surface of the road and automatically detects when a vertical adjustment should be made. This increases machine stability and relieves the driver so that he/she can fully concentrate on the milling process. For this purpose, multiple sensor signals work together, whereby the machine controller evaluates and corrects the current machine height position and machine state.

Automatic water management

- Water consumption can be reduced considerably thanks to automated connection of the water system when starting the milling drum or when switch-off occurs after milling work stops.
- Water pump pressure is increased or decreased depending on the engine load and milling speed.

Automated conveyor speed regulation

- Consistent output is ensured thanks to a consistently maintained conveyor speed, even when the diesel engine speed is reduced. At the same time, the conveyor automatically switches over to transport mode when the machine is driven in reverse so that no milled material is lost.

WIDRIVE offers significant advantages:

Technology for people: The workload is not only made easier for the machine operator, but he or she is also given greater motivation thanks to the cold milling machine’s convenient operation and practice-oriented modern features. He or she can thus fully concentrate on the milling process.

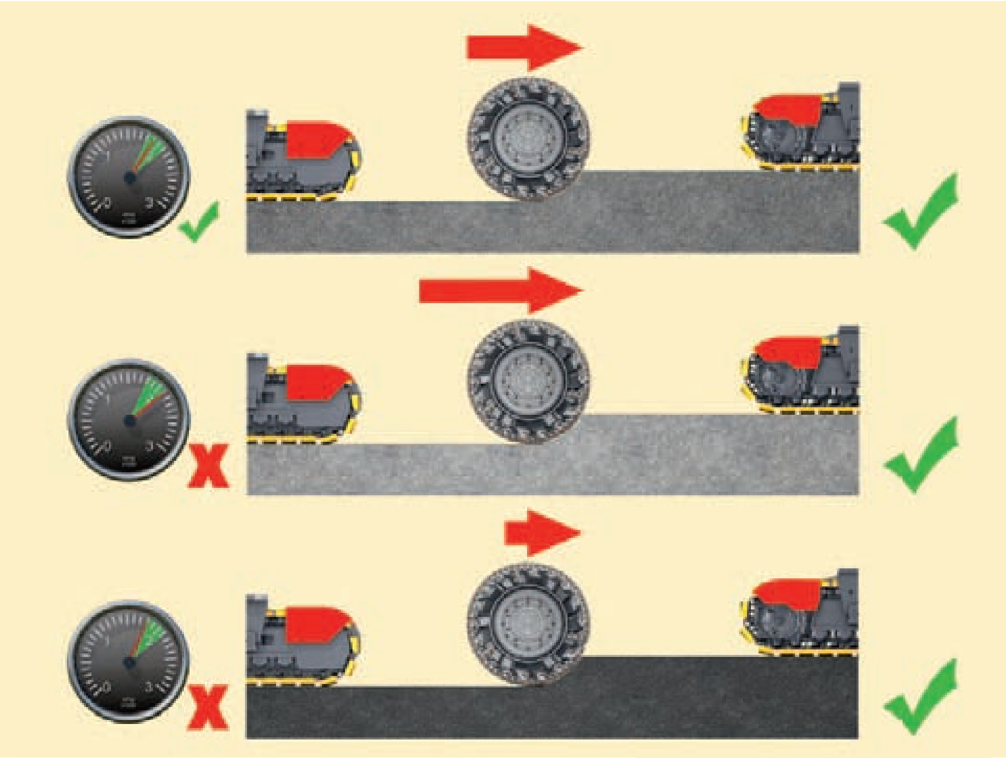
Favourable overall environmental balance: Optimised engine control reduces the burden on the environment from exhaust emissions. At the same time, noise emissions are reduced considerably.

Reduction in operating costs: In addition to increasing milling performance through faster operating procedures, this results in a reduction in diesel fuel consumption (thanks to situation-dependent speed control) and water consumption (thanks to automatic connection and disconnection).

5.1.3 Automated milling performance regulation

Automated milling performance regulation optimises milling speed based on the engine load. If a pre-set engine speed is fallen below, the milling speed is reduced automatically.

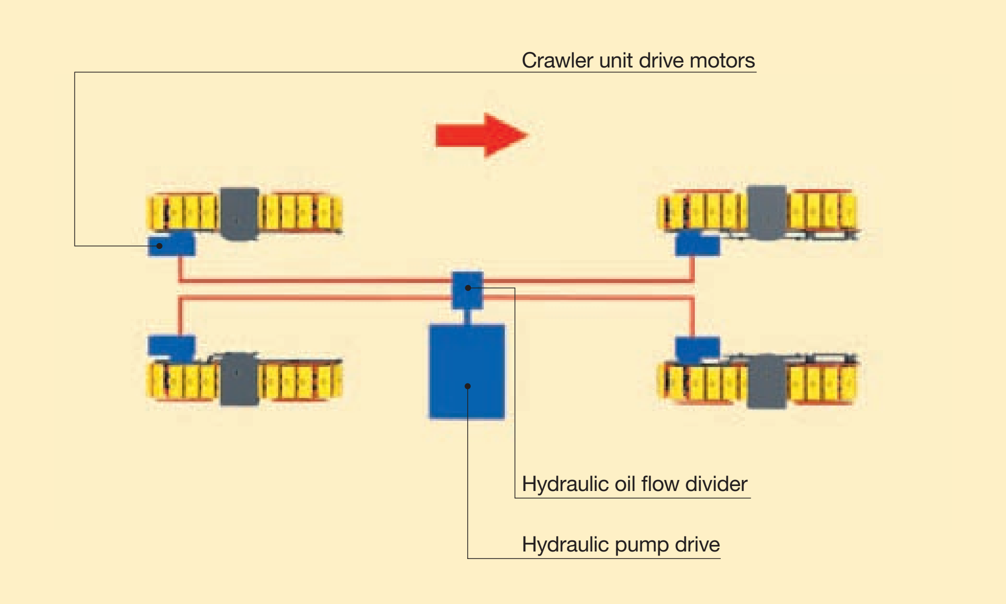
This results in automatic setting of the optimum milling speed with maximum milling performance in the control circuit by the machine control.



Automatic control of the maximum milling speed via engine load

5.1.4 Hydraulic and electronic differential lock

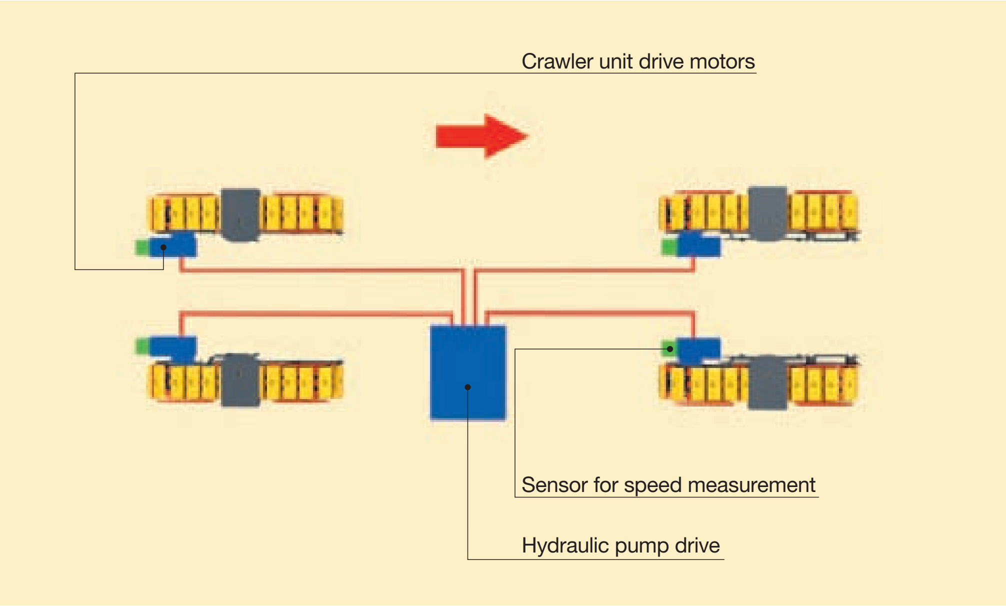
The hydraulic differential lock distributes propulsion evenly to the drive crawler units. At the same time, hydraulic volume flow (oil quantity) is distributed from the drive pump in four equal volume flow rates and fed to the drive motors of the crawler unit chain by the so-called flow dividers. This ensures that the individual crawler unit chains run at a synchronised speed, which reduces the slippage of individual crawler chains.



Entirely hydraulic differential lock via central flow divider

The electronic differential lock (ISC) directly and individually regulates the speed of the crawler unit chains via the respective crawler unit chains' individual drive motors. At the same time, the speed of each crawler unit chain is detected via sensors and compared to a set point value. The ISC corrects deviations automatically.

In addition, the ISC takes into account the different speeds of the inner and outer crawler units when taking curves. This special attribute of the electronic differential lock ensures optimum traction at all times, allows for the smallest curve radii possible and reduces wear. When the machine is under way on a load-free transport journey, the ISC switches off automatically.



Modern automatically regulated differential lock with situation-dependent crawler unit drive motor control

5.1.5 Diagnostics systems on cold milling machines

Thanks to the Wirtgen information and diagnostics system, the user is able to monitor the current operating data quickly and comprehensively. Automated self-diagnosis of the machine automatically monitors the diesel engine and the hydraulic and electrical components.

These include, for example:

- Current engine status (speed, temperatures, filter states)
- Current hydraulic system status (valve position, pressures, filter states, temperatures)
- Current electrical system status (switching conditions, cable and sensor functions)
- Maintenance intervals

Malfunctions are displayed and, at the same time, interactive troubleshooting is initiated immediately.

Operating display for travel drive diagnosis on modern large milling machines

5.1.6 Job data collection on cold milling machines

A variety of different performance data can be displayed on modern cold milling machines thanks to intelligent linking of the machine control and the levelling system. Job data collection makes it possible, for example, to calculate and display daily performance (in m^3 or t) via the machine control.

The most important job data in detail:

- Display of the truck's load quantity for the purpose of optimum truck loading
- Display of the number of loaded trucks over the course of a day of production
- Display of the total weight of the milling quantity over the course of a day of production or the entire machine lifetime
- Display of the milled surface over the course of a day of production or the entire machine lifetime

Operating display for job data collection on modern large milling machines

6 Using cold milling machines

6.1 Layer-by-layer removal of asphalt roads

6.1.1 W 50 DC – Rehabilitation milling with small milling machines

Milling task:

The ailing road surface of a quiet residential area had to be renewed. For this purpose, the surface course of the 970 m^2 area was milled down 4 cm and the milling granulate was then loaded onto trucks.

Items of note:

For logistical reasons, it was not possible to use the compact W 100 F with front loading. Due to the narrowness of the street, a machine capable of effective milling in tight spaces and high manœuvrability, in addition to high performance, was needed. The W 50 DC fulfils these requirements.

Construction site information	
Total area in m^2	970
Milling depth in m	0.04
Removal amount in m^3	38.8
Machine values	
Machine type	W 50 DC
Milling width in m	0.5
Theoretical milling speed in m/min.	8.3
Practical milling performance in m^3/h	5.0
Performance time in h	7.8

6.1.2 W 100 F – Complete removal of asphalt courses

Milling task:

A road on the edge of a town was fully milled off over a length of 800 m and a width of 2.5 m. The W 100 F, which was specially designed for surface rehabilitation and the complete removal of asphalt courses, was used. The milled material was loaded onto the truck via the cold milling machine's large front loading conveyor.

Items of note:

In this section of the road, there was a large number of installations, including manholes, valve covers, water channels, etc., which had to be milled around.

Construction site information	
Total area in m^2	2,000
Milling depth in m	0.24
Removal amount in m^3	480
Machine values	
Machine type	W 100 F
Milling width in m	1.0
Theoretical milling speed in m/min.	4.0
Practical milling performance in m^3/h	25.9
Performance time in h	18.5

6.1.3 W 210 – Layer-by-layer removal of surface and binder courses

Milling task:

Both the surface and binder courses of a country road with an area of 6,000 m^2 had to be removed layer by layer. While the surface course was being removed down to a depth of 4 cm, the binder course beneath it was milled down by 8 cm. The milling work was carried out with the compact W 210 large milling machine, characterised by a broad performance range and a diesel fuel-saving drive design (dual engine concept).

Items of note:

To minimise traffic obstructions, only one half of the heavily trafficked road was blocked off. Traffic was directed past the construction site on the other side of the road.

Construction site information	
Total area in m^2	2 x 6,000 = 12,000
Milling depth in m	0.04 / 0.08
Removal amount in m^3	240 + 480 = 720
Machine values	
Machine type	W 210
Milling width in m	2.0
Theoretical milling speed in m/min.	26.0 / 18.0
Practical milling performance in m^3/h	66.0 / 95.0
Performance time in h	3.6 + 5.1 = 8.7

6.1.4 W 250 – Surface course renewal

Milling task:

The entire surface course of a heavily trafficked arterial city road was fully renewed over an area of 30,000 m². The high-performance W 250 cold milling machine characterised by strong motorisation and a high conveyance capacity was used. The surface course was milled down by 4 cm. For optimum removal efficiency, a milling drum with a 3,800 mm working width for a removal width of 7.6 m was selected.

Items of note:

Due to the high traffic load, there was a great amount of pressure to complete the construction work within a short period of time. Thanks to the high area performance of the W 250, the milling work could be finished in an especially short amount of time.

Construction site information	
Total area in m²	30,000
Milling depth in m	0.04
Removal amount in m³	1,200
Machine values	
Machine type	W 250
Milling width in m	3.8
Theoretical milling speed in m/min.	23.3
Practical milling performance in m³/h	127.0
Performance time in h	9.4

6.2 Milling concrete roads

6.2.1 W 150 – Milling out concrete

Milling task:

The 8,700 m² heavily damaged concrete surface on a company's premises had to be milled out 10 cm deep. The compact W 150 large milling machine is characterised by excellent removal performance, even on concrete, and enables quick working.

Items of note:

For especially high milling performance, an Eco Cutter with a tool spacing of 25 was used.

Construction site information	
Total area in m²	8,700
Milling depth in m	0.10
Removal amount in m³	870
Machine values	
Machine type	W 150
Milling width in m	1.5
Theoretical milling speed in m/min.	4.9
Practical milling performance in m³/h	19.0
Performance time in h	46

6.2.2 W 250 – Complete removal of concrete roads

Milling task:

For the purpose of full rehabilitation of a concrete road on the A 5, a total area of 25,000 m² in two layers (10 cm and 20 cm) had to be fully removed. An Eco Cutter outfitted with W1/17 picks was used for milling off the concrete.

Items of note:

During the first milling pass, the steel pins were exposed. In the second milling pass, the remaining concrete was milled out and the steel pins broken out.

Construction site information	
Total area in m^2	2 x 25,000 = 50,000
Milling depth in m	0.10 + 0.20
Removal amount in m^3	2,500 + 5,000
Machine values	
Machine type	W 250
Milling width in m	2.2
Theoretical milling speed in m/min.	7.6 + 4.0
Practical milling performance in m^3/h	47.0 + 55.0
Performance time in h	53 + 91

6.3 Layer-by-layer removal of other materials

6.3.1 W 350 E – Removal of screed surfaces

Milling task:

During rehabilitation work in a church, the screed course of a 46 m^2 area was to be removed down to a milling depth of 6 cm. The compact, electrically driven W 350 E enables milling without emitting harmful exhaust.

Items of note:

To minimise soiling the church's interior to the greatest degree possible, the resulting dust had to be extracted immediately. The W 350 E features a separate extraction connection for the attachment of an extraction system.

Construction site information	
Total area in m^2	46
Milling depth in m	0.06
Removal amount in m^3	2.8
Machine values	
Machine type	W 350 E
Milling width in m	0.35
Theoretical milling speed in m/min.	2.2
Practical milling performance in m^3/h	1.0
Performance time in h	2.7

6.3.2 W 210 – Milling off a sport area

Milling task:

The entire surface of a cinder pitch at a sport club (7,200 m²) was milled off down to a depth of 8 cm. The powerful W 210 large milling machine, which offers optimum milling performance across a broad spectrum of use thanks to its economical drive concept, was used. The use of one engine was entirely sufficient for milling the surface.

Items of note:

Thanks to the innovative Operator Comfort System, the W 210 sets standards in driving comfort and convenience. The hydraulically traversing and swivelling cab quickly brings the machine operator to the optimum viewing position and features a high-quality interior.

Construction site information	
Total area in m^2	7,200
Milling depth in m	0.08
Removal amount in m^3	576
Machine values	
Machine type	W 210
Milling width in m	2.0
Theoretical milling speed in m/min.	40.0
Practical milling performance in m^3/h	115.2
Performance time in h	5

6.4 Road reshaping

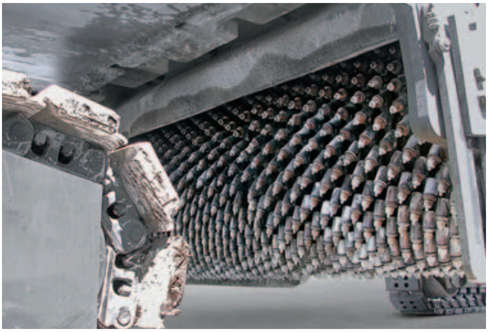
6.4.1 W 2000 – Fine milling of concrete surfaces

Milling task:

The levelness of a 5,000 m² concrete surface was to be restored via fine milling. A W 2000 cold milling machine equipped with a fine milling drum with tool spacing of 6x2 was used.

Items of note:

Fine milling eliminates road surface deformations and creates even, level surfaces.



Construction site information	
Total area in m^2	5,000
Milling depth in m	0.008
Removal amount in m^3	40
Machine values	
Machine type	W 2000
Milling width in m	2.0
Theoretical milling speed in m/min.	12.0
Practical milling performance in m^3/h	5.2
Performance time in h	7.7

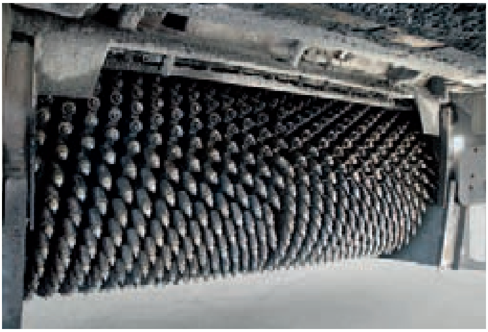
6.4.2 W 2000 – Preparation for surface work

Milling task:

In preparation for the installation of a thin-layer surface covering, a 45,000 m² asphalt surface had to be milled off with a fine milling drum with a tool spacing of 6x2 down to an average depth of 1.5 cm.

Items of note:

In addition to the preparatory measures for thin-layer paving, milling was necessary to improve levelness. By using the W 2000 cold milling machine with its Multiplex levelling system, the degree of levelness required was far exceeded. The very level surface, which was given the optimum degree of roughness, is excellently suited for paving of new thin layers.



Construction site information	
Total area in m^2	45,000
Milling depth in m	0.015
Removal amount in m^3	675
Machine values	
Machine type	W 2000
Milling width in m	2.0
Theoretical milling speed in m/min.	18.0
Practical milling performance in m^3/h	17.5
Performance time in h	38.6

6.5 Special milling contours

6.5.1 W 50 DC – Milling rumble strips

Milling task:

Rumble strips at the edge of the road are intended to alert tired drivers and startle them when they are leaving the road. Indentations were milled into the asphalt with the W 50 DC along a 48 km stretch of road.

Items of note:

This milling task was carried out via easy conversion of the W 50 DC machine with a rumble strip attachment package.

Construction site information	
Total length / km	48
Machine values	
Machine type	W 50 DC
Theoretical milling speed in m/min.	22.0
Performance time in h	49

6.5.2 W 50 DC – Milling grooves

Milling task:

Grooves with a width of 8 cm had to be milled down to a depth of 30 cm so that the cables of a traffic guidance system could be installed. The powerful W 50 DC small milling machine can be outfitted with narrow cutting rings or side milling wheels to mill slits.

Items of note:

Even narrow radii can be milled with precision and low wear.

Construction site information	
Total length / m	1,230
Milling depth in m	0.30
Removal amount in m^3	29.5
Machine values	
Machine type	W 50 DC
Milling width in m	0.08
Theoretical milling speed in m/min.	3.3
Practical milling performance in m^3/h	2.4
Performance time in h	12.4

6.5.3 W 35 DC – Demarcation of road markings

Milling task:

A road marking had to be removed over a distance of 5.6 km. Paint markings or thermoplastic markings can be fully removed by the versatile W 35 DC small milling machine.

Items of note:

Special milling drums with narrow tool spacing and tapered edges on both sides were used to ensure a soft transition from the unworked surface to the milled-out strips.

Construction site information	
Total length / km	5.6
Machine values	
Machine type	W 35 DC
Milling width in m	0.15
Theoretical milling speed in m/min.	12.0
Performance time in h	10

6.5.4 W 350 – Milling around tram tracks

Milling task:

An expansion joint had to be milled along a tram line over a distance of 520 m. For this purpose, the versatile W 350 small milling machine was outfitted with a specially designed rail milling kit, which allowed the surface to the right and left of the rail to be milled in a single pass to a depth which could be set and locked.

Construction site information	
Total length / m	520
Machine values	
Machine type	W 350
Theoretical milling speed in m/min.	4.1
Performance time in h	5

7 Calculating milling performance

7.1 Parameters which affect milling performance

The milling performance of a machine can be determined as a current snapshot via the milling speed at the construction site. To determine the actual daily milling performance, many other factors must be taken into account. In addition to the actual milling task, they include such various machine parameters as the milling drum type, pick wear/replacement times, material parameters, such as the asphalt composition, and the construction site conditions, including the milling granulate logistics involved. The resulting allowance factor of the maximum possible to the actual daily milling performance can vary from 25 to 70 %. A simplified assumption would be an allowance factor of 70 % with a small milling machine and 50 % with a large milling machine.

Influence parameter	Variable example parameter	Change in overall milling performance
Milling drum type	Tool spacing 25 mm Eco Cutter	20%
	Tool spacing 15 mm standard milling drum	**0%**
	Tool spacing 8 mm	-35%
	Tool spacing 6 mm x 2 picks	-60%
Milling drum speed	High speed	-20%
	Medium speed	**0%**
	Low speed	10%
Pick type	W4 pick	-5%
	W5 pick	**0%**
	W6 pick	5%
	W7 pick	3%
	W8 pick	-3%

Note: The values shown here are for orientation purposes only.

Influence parameter	Variable example parameter	Change in overall milling performance
Properties of the layer to be milled	Soft asphalt	25%
	Medium asphalt	**0%**
	Hard asphalt	-30%
	Soft concrete	-10%
	Medium concrete	-35%
	Hard concrete	-60%
Layer temperature (mainly influences asphalt)	-10 to 0 degrees Celsius	-25%
	0 to 15 degrees Celsius	-10%
	15 to 30 degrees Celsius	**0%**
	Over 30 degrees Celsius	20%
Construction site situation	Blocked road, full removal	20%
	Tight construction site conditions with limited access options for trucks, full removal	10%
	Unrestricted access options for trucks, surface course milling work	**0%**
	Partial small milling surfaces with many obstacles	-25%
	Milling surfaces with many obstacles	-60%
Transport logistics	No material loading	15%
	Sufficient trucks without waiting time for cold milling machine	**0%**
	Too few trucks, 25% waiting time	-30%
	Too few trucks, 50% waiting time	-60%
Operating personnel	High level of experience and motivation	15%
	Average experience	**0%**
	Little experience	-15%

cf. Ludwig, S. Oberflächeneigenschaften und Straßenbautechnik. VSVI-Seminar Münster.

7.2 Milling performance calculation examples

7.2.1 Basic guidelines for determining performance values

Legend

Abbreviation	Unit (abbreviation)	Description
FB	Metres (m)	Machine milling width
FT	Metres (m)	Milling depth
Fg	Metres / minute (m / min)	Milling speed
A	Square metres (m^2)	Milling surface area
Ap	Square metres / hour (m^2/h)	Practical area performance per hour
Factor a	Percent (%)	Allowance factor
V	Cubic metres (m^3)	Milled material volume
G	Tonnes (t)	Weight of the milled material volume
P	Tonnes / metre^3 (t/m^3)	Material thickness
Z	Hours (h)	Total work time
M	Units	Total practical pick consumption

Formulae for determining performance values

Practical area performance Ap per hour
Ap in m^2/h = milling speed Fg in m / min x 60 min / h x machine milling width FB in m x (1-Factor a)

Practical milled material volume V in m^3
V in m^3 = milling surface area A in m^2 x milling depth FT in m

Practical milled material weight G in t
G in t = milled material volume V in m^3 x material density in t/m^3

Required work time Z in practice, in hours
Z in h = milling surface area A in m^2 / milling surface area performance Ap in m^2/h

Required number of picks M in practice for the construction site, in pieces
M in pieces = pick consumption in pieces / m^3 x practical milled material volume V in m^3

Material thickness

Material group	Material	Volume density (compacted)	Bulk density of milled granulate (un-compacted)
Asphalt	Asphalt base course 0/32 mm	2.45 t/m³	1.9 t/m³
	Asphalt binder 0/22 mm	2.47 t/m³	1.95 t/m³
	Asphalt concrete 0/16 mm	2.45 t/m³	2.05 t/m³
Concrete	Concrete B25	2.45 t/m³	2.2 t/m³
Construction materials	Gravel sand 0 to 32 mm	2.05 t/m³	1.72 t/m³
	Mineral base course 0 to 56 mm	2.15 t/m³	1.80 t/m³
	Crushed limestone 32 to 45 mm	1.75 t/m³	1.52 t/m³
	Rhine River sand 0 to 2 mm	1.85 t/m³	1.56 t/m³
	Main River sand 0 to 2 mm	1.90 t/m³	1.60 t/m³
	Sieve rubble	2.15 t/m³	1.80 t/m³
Sediment Rocks	Sandstone	2 - 2.7 t/m³	1.2 - 1.6 t/m³
	Iron ore	3.8 - 5.3 t/m³	3.2 - 4.5 t/m³
	Bauxite	2.3 - 3.5 t/m³	1.7 - 2.6 t/m³
	Limestone/Marl	1.7 - 2.9 t/m³	1.0 - 1.8 t/m³
	Gypsum	2.0 - 2.3 t/m³	1.3 - 1.5 t/m³
	Salt rock	1.6 - 3.0 t/m³	1.2 - 2.4 t/m³
	Hard coal	1.2 - 2.5 t/m³	0.9 - 2.1 t/m³
	Brown coal	1.0 - 1.2 t/m³	0.8 - 1.0 t/m³

cf. MFA. 2000 edition, page 14-15.

7.2.2 W 35 DC calculation example

Construction site data:

Task: Milling out a damaged car park surface course in Germany and loading of the milled granulate into wheel loader buckets

Machine milling width: FB = 0.35 m
Milling depth: FT = 0.03 m
Total milling surface area:
A = 7 m x 45 m = 315 m^2
Surface: Soft mastic asphalt

Specifications from tables:

- Milling speed: Fg = 8 m/min (see table on page 36)
- Allowance factor: Factor a = 65% (see table on page 174/175)
- Asphalt material thickness: P = 2.4 t/m^3 (see table on page 177)
- Pick consumption: 0.7 pieces/cbm (see table on page 37)

Performance calculation:

Practical area performance Ap per hour
8 m/min x 60 min/h x 0.35 m x (1 - 65%) =
58.8 m^2/h

Practical milled material volume V in m^3
315 m^2 x 0.03 m =
9.45 m^3

Practical milled material weight G in t
9.45 m^3 x 2.4 t/m^3 =
22.7 t

Required work time Z in practice, in hours
315 m^2/58.8 m^2/h =
5.4 h

Required number of picks M in practice for the construction site, in pieces
0.7 pieces/m^3 x 9.45 m^3 =
7 pieces

7.2.3 W 50 DC calculation example

Construction site data:

Task: Complete milling out of an asphalt course of an inner-city side street in Germany, loading the material onto a 3-axle truck

Machine milling width: FB = 0.5 m
Milling depth: FT = 0.10 m
Total milling surface area:
A = 80 m x 3.8 m = 304 m^2
Surface: Medium asphalt

Specifications from tables:

- Milling speed: Fg = 6 m/min
  (see table on page 36)
- Allowance factor: Factor a = 60%
  (see table on page 174/175)
- Asphalt material thickness: P = 2.35 t/m^3
  (see table on page 177)
- Pick consumption: 0.35 pieces/cbm
  (see table on page 37)

Performance calculation:

Practical area performance Ap per hour
6 m/min x 60 min/h x 0.5 m x (1 - 60%) =
72 m^2/h

Practical milled material volume V in m^3
304 m^2 x 0.10 m =
30.4 m^3

Practical milled material weight G in t
30.4 m^3 x 2.35 t/m^3 =
71.5 t

Required work time Z in practice, in hours
304 m^2/72 m^2/h =
4.2 h

Required number of picks M in practice for the construction site, in pieces
0.35 pieces/m^3 x 42.6 m^3 =
15 pieces

7.2.4 W 130 F calculation example

Construction site data:

Task: Milling out an asphalt surface course of a blocked off city street in Belgium, loading the material onto a 4-axle truck

Machine milling width: FB = 1.3 m
Milling depth: FT = 0.03 m
Total milling surface area:
A = 760 m x 6 m = 4,560 m²
Surface: Medium asphalt

Specifications from tables:

- Milling speed: Fg = 18 m/min (see table on page 40)
- Allowance factor: Factor a = 50% (see table on page 174/175)
- Asphalt material thickness: P = 2.4 t/m³ (see table on page 177)
- Pick consumption: 0.36 pieces/cbm (see table on page 41)

Performance calculation:

Practical area performance Ap per hour
18 m/min x 60 min/h x 1.3 m x (1 - 50%) =
1,404 m²/h

Practical milled material volume V in m³
4,560 m² x 0.03 m =
136.8 m³

Practical milled material weight G in t
136.8 m³ x 2.4 t/m³ =
328.3 t

Required work time Z in practice, in hours
4,560 m² / 1,404 m²/h =
3.3 h

Required number of picks M in practice for the construction site, in pieces
0.36 pieces/m³ x 136.8 m³ =
50 pieces

7.2.5 W 210 calculation example

Construction site data:

Task: Complete milling off of an asphalt surface course of a blocked-off bypass road in the USA and loading of the material onto a semitrailer

Machine milling width: FB = 2.2 m
Milling depth: FT = 0.06 m
Total milling surface area:
A = 450 m x 15.2 m = 6,840 m^2
Surface: Soft asphalt

Specifications from tables:

- Milling speed: Fg = 21 m/min (see table on page 52)
- Allowance factor: Factor a = 55% (see table on page 174/175)
- Asphalt material thickness: P = 2.35 t/m^3 (see table on page 177)
- Pick consumption: 0.25 pieces/cbm (see table on page 53)

Performance calculation:

Practical area performance Ap per hour
21 m/min x 60 min/h x 2.2 m x (1 - 55%) =
1,247.4 m^2/h

Practical milled material volume V in m^3
6,840 m^2 x 0.06 m =
410.4 m^3

Practical milled material weight G in t
410.4 m^3 x 2.35 t/m^3 =
964.5 t

Required work time Z in practice, in hours
6,840 m^2 / 1,247.4 m^2/h =
5.5 h

Required number of picks M in practice for the construction site, in pieces
0.25 pieces/m^3 x 410.4 m^3 =
103 pieces

7.2.6 W 250 calculation example

Construction site data:

Task: Complete removal of a blocked-off motorway lane with separate removal of the surface course, binder course and base course and loading of the material onto a semitrailer

Machine milling width: FB = 2.2 m
Milling depth:
Surface course FT = 0.04 m,
Binder course FT = 0.10 m,
Base course FT = 0.12 m
Total milling surface area:
A = 3,600 m x 7.9 m = 28,440 m^2
Surface: Medium asphalt

Specifications from tables:

- Milling speed:
  Surface course Fg = 26 m/min
  Binder course Fg = 17.6 m/min
  Base course Fg = 15 m/min
  (see table on page 56)
- Allowance factor:
  Factor a = 48%
  (see table on page 174/175)
- Asphalt material thickness:
  P = 2.45 t/m^3
  (see table on page 177)
- Pick consumption:
  Surface course = 0.25 pieces/cbm
  Binder course = 0.2 pieces/cbm
  Base course = 0.19 pieces/cbm
  (see table on page 57)

Performance calculation:

Practical area performance Ap per hour
Surface course:
26 m/min x 60 min/h x 2.2 m x (1 - 48%) =
1,785 m^2/h
Binder course:
17.6 m/min x 60 min/h x 2.2 m x (1 - 48%) =
1,208 m^2/h
Base course:
15 m/min x 60 min/h x 2.2 m x (1 - 48%) =
1,030 m^2/h

Practical milled material volume V in m^3
Surface course:
28,440 m^2 x 0.04 m = **1,138 m^3**
Binder course:
28,440 m^2 x 0.10 m = **2,844 m^3**
Base course:
28,440 m^2 x 0.12 m = **3,413 m^3**
Total V = 7,395 m^3

Practical milled material weight G in t
7,395 m^3 x 2.45 t/m^3 = **18,118 t**

Required work time Z in practice, in hours
Surface course:
28,440 m^2 / 1,785 m^2/h = **15.9 h**
Binder course:
28,440 m^2 / 1,208 m^2/h = **23.5 h**
Base course:
28,440 m^2 / 1,030 m^2/h = **27.6 h**
Total Z = 67 h

Required number of picks M in practice for the construction site, in pieces
Surface course:
0.32 pieces/m^3 x 1,138 m^3 = **364 pieces**
Binder course:
0.2 pieces/m^3 x 2,844 m^3 = **569 pieces**
Base course:
0.19 pieces/m^3 x 3,413 m^3 = **645 pieces**
Total M = 1,578 pieces

8 Milling quality

8.1 Classification of surface characteristics

As the only point of contact between the tires and road, the road surface is specified by physical and functional characteristics. High traffic loads, the effects of weather and structural defects in the material all lead to wear and thus to a drop in the quality of the surface over time. As a consequence, traffic safety and driving comfort are compromised. Milling allows the physical and functional surface characteristics to be changed.

Physical surface characteristics	
Texture / Roughness	Geometric shape of the surface in the wavelength range from a few micrometres to several decimetres (micro-/macro-/megatexture)
Evenness	Surface course resistance to deformation • Longitudinal evenness • Cross evenness (lane channels)
Technical properties regarding lighting	Reflection capacity of the surface, dependent upon • Surface texture stone grain • Weather (humid, wet, dry)

cf. Ludwig, S. Oberflächeneigenschaften und Straßenbautechnik. VSVI-Seminar Münster.

Functional surface characteristics

Surface grip	Amount of force transmission between vehicle tires and road depending on the traffic load and weather Influenced by: • Texture • Material composition of the road
Brightness	Light density of the road depending on the surface texture stone grain, soiling and weather Advantages of light roads: • Increase in traffic safety • Improvement in deformation resistance (less heating due to sunlight) • Minimising of lighting costs
Noise development	The formation of road traffic noise depending on the material composition of the road surface Influenced by: • Drive noise • Tire / road noises • Air-flow noise
Water drainage	Drainage capacity Influenced by: • Road geometry • Evenness • Texture • Weather

cf. Ludwig, S. Oberflächeneigenschaften und Straßenbautechnik. VSVI-Seminar Münster.

8.2 Evaluation of milling quality

The quality of the milling surface has a decisive influence on the progress of further construction measures on site. The more precise the milling result, the greater the time and cost efficiency of subsequent construction stages, and the better the performance characteristics of the newly paved road surface.

The milling quality can be measured directly at the construction site. Testing of the levelness in the longitudinal and cross directions and of the nominal height is carried out with both contact and non-contact measuring procedures. The texture of the surface, which is the main variable for surface grip and noise emissions, can be determined using a variety of measurement procedures.

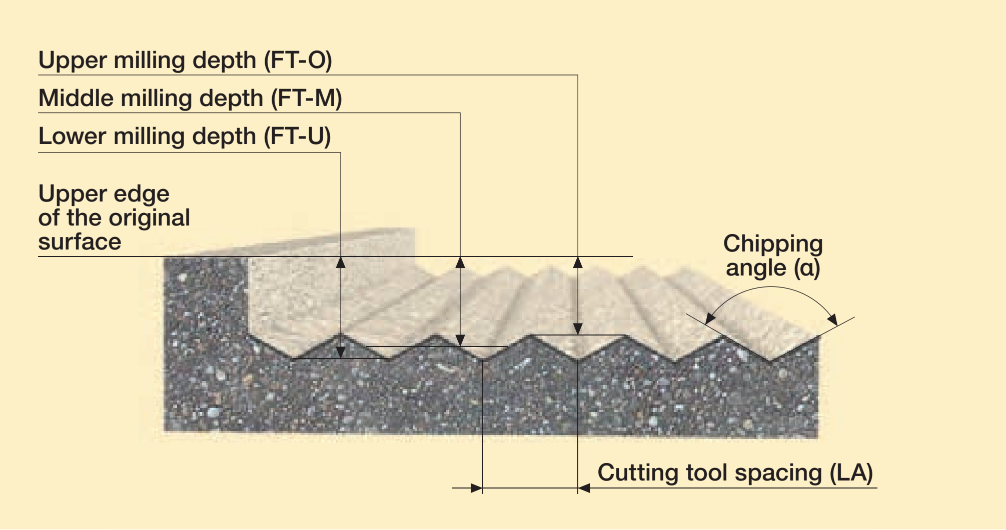
Guidelines for profile-compliant positioning of the milling surface	
Deviation from the cross slope	± 0.4 %
Guidelines for evenness measurement	
Limit values in longitudinal and cross directions within a 4 m measurement section	
Standard milling of unobstructed sections at a specific level	Milling of asphalt surface courses: ≤ 6 mm Milling of asphalt base, binder and surface courses: ≤ 10 mm
Standard milling for sections with restrictive structural points of constraint or other installations	Milling of asphalt surface courses: ≤ 10 mm
Fine milling of unobstructed sections at a specific level	For construction classes SV to III: ≤ 4 mm, For construction classes IV to VI: ≤ 6 mm.

cf. MFA. 2000 edition, page 14-15.


Wirtgen

8.2.1 Measuring the milling depth

When milling solid materials, a so-called tool spacing profile is created in the direction of milling. This profile is determined among other things by the cutting tool spacing (LA), the chipping angle (α) and the milling speed. Three different milling depths can be calculated from this. The upper and lower milling depths can be measured, the middle milling depth follows from the average of these two values.



8.2.2 Measuring the milling width

The milling width depends on the milling drum's working width. The distance between the two level, right-angled milling edges that occur during the work process is measured. In doing so, it must be taken into consideration that the theoretical milling drum width does not necessarily match the actual, practical milling width. The milling width may vary on the one hand due to various wear conditions of the picks and toolholders; on the other hand, if the milling drum was not positioned at a right angle, the milling width may increase in the direction of milling.

8.2.3 Checking the tool spacing

The tool spacing ruler is used to verify correct tool spacing. This is a tool spacing pattern fan which shows all tool spacings (from 3 to 25 mm) using individual metal templates. To carry out measurement, the template of the notified tool spacing is held in the tool spacing of the actual milling profile which arose. Deviations from the pattern can be identified immediately and rectified if necessary.

8.2.4 Measuring the milling speed

The milling speed has a considerable influence on the texture and quality of the surface. The higher the milling speed, the rougher the milled surface. It can be measured either during or after milling.

During milling, a machine position is defined and a corresponding marking made on the roadway. After one minute of milling, the next roadway marking is made. By measuring the distance between the two markings, the milling speed value in metres per minute can be determined.

Measurement after completion of milling takes place by measuring the distance between pick penetrations in a cutting line. This value is multiplied by the milling drum rotation speed. The result is the milling speed in metres per minute.

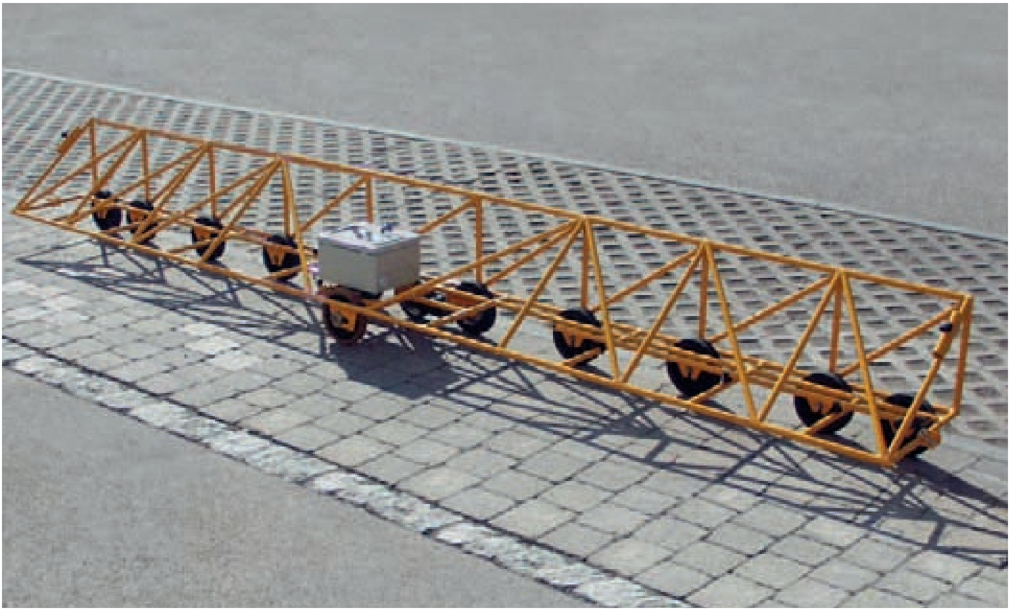
8.2.5 Measuring levelness with the 4-metre-long levelling staff

The levelness of the milled area is checked using a 4-metre-long aluminium levelling staff. The staff is placed over the street and a measuring wedge outfitted with a grid is slid underneath it.

The levelness is determined by the gap measured between the surface and the levelling staff. The further the measuring wedge can be slid under the staff, the greater the deviation from level.

8.2.6 Measuring levelness with the profilograph / planograph

Among the world's most widely used systems for measuring the longitudinal and transverse levelness of surfaces are the profilograph (measurement of cross levelness) and the planograph (measurement of longitudinal levelness). Similar to the levelling staff, they involve a long bar featuring several fixed wheels and another wheel in the centre which can move up and down. The outer wheels are spaced four metres apart. Both systems are moved across the surface in the direction of measurement. If the measuring wheel in the centre traverses recesses or rises in the longitudinal direction of the road, vertical movement occurs. This is recorded and transmitted either graphically or, as per the current standard, electronically.



8.2.7 Measuring levelness using the laser scanning procedure

Laser scanners provide a high-resolution, digital model of the scanned surface and enable far-reaching analyses of their condition. The laser scanning of roads is carried out using measurement vehicles which scan the surface profile using laser sensors at high speed over a width of four metres. During movement, the respective spacing of sensors to the road surface is measured, from which 3D coordinates are calculated. This creation of a grid and the movement of the vehicle generates a three-dimensional map (point cloud) of the road surface from individual point measurements. This technology simultaneously enables high measurement precision at high measuring speed.

8.2.8 Measuring roughness using the sand patch method

The sand patch method as per EN 1766 is one of the volumetric procedures used for determining the macrotexture. A specific quantity of sand (generally 14 g of standard sand I as per DIN 1164) is poured onto the dry, cleaned test surface and spread out by a hardwood or hard rubber stamp moved without pressure in a circular motion until a circular sand patch which can be spread out no further is created. The diameter is then determined from four equidistant points. The quotient of the volume (sand quantity) and the area of the circle yield the average surface texture depth, which in turn allows conclusions to be drawn regarding the roughness of the surface. This procedure is quick and easy to perform.

8.2.9 Measuring surface grip using the SCRIM (SKM) test

The SCRIM (Sideways-Force Coefficient Routine Investigation Machine) measuring system, also known as the sideways-force procedure (SKM), is used to determine the surface grip of larger areas. The apparatus is generally attached to a truck so that long sections of road can be measured in a short period of time.

A measuring wheel angled opposite the direction of travel is attached approx. 1.5 m in front of the rear axle of the truck. This wheel determines the sideways-force coefficient. This value characterises the road surface grip and describes the ratio of the sideways force on the measuring wheel to the normal force of the measuring wheel with a wheel load of 200 kg.
The non-profiled measuring wheel moves vertically and is moved over the road surface in the direction of travel at a constant angle of 20°. The vehicles are outfitted with a channel flow device for wetting the measuring track with an even film of water (0.5 mm).

The measuring speed is based on the maximum permissible speed on the section of road and lies between 40 and 80 km/h. Every 20 m, a measured value is recorded, and the average value for each 100-metre-long section is determined using the respective five values.

The sideways frictional force F_Y arising as a result of the angled position is measured. Its ratio with the normal force F_Z yields the sideways force coefficient $\mu_Y = \mu_{SCRIM}$ ($\mu_{SCRIM} = F_Y : F_Z$).

Evaluation of surface grip via ZEB (condition recording and evaluation)				
ZEB values		**Condition variables**		
Condition value	**Significance**	**40 km/h**	**60 km/h**	**80 km/h**
		µSCRIM	**µSCRIM**	**µSCRIM**
1		0.66	0.61	0.56
1.5	Target value	0.63	0.58	0.53
2		0.59	0.54	0.49
3		0.52	0.47	0.42
3.5	Warning value	0.49	0.44	0.39
4		0.45	0.4	0.35
4.5	Threshold value	0.42	0.37	0.32
5		0.38	0.33	0.28

cf. M BGriff. 2003 edition, page 15

8.2.10 Measuring surface grip using the SRT pendulum and the water outflow procedure

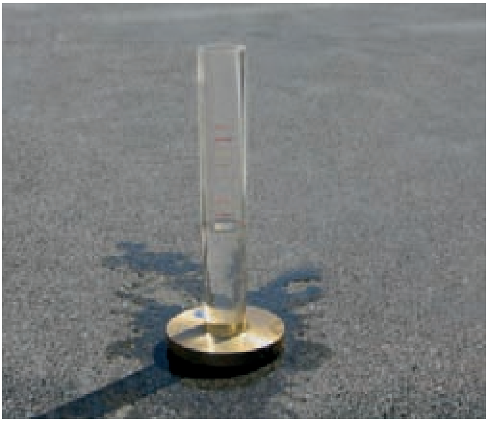
The SRT pendulum device (Skid Resistance Tester) determines the surface grip of surfaces and measures their microroughness. To determine the macroroughness of a surface and at the same time to carry out a surface grip and roughness measurement, the procedure is preferably performed in combination with the outflow measurement.

The **SRT pendulum** is comprised of a three-armed base frame supporting a column with a scale plate and a bearing head in addition to the pendulum arm and drag indicator. A rubber sliding shoe is located at the end of the pendulum. After releasing from its horizontal position, the pendulum with the sliding shoe swings over a defined contact area and is braked according to the effect the texture has. The pendulum energy remaining after the braking procedure is recorded via the drag indicator. The following general rule applies: The lower the swing of the pendulum, the greater the SRT value and therefore the greater the grip of the surface.

To measure the road, five measuring points are set up for each measuring field with a spacing of 300-500 metres. Five measurements are carried out at each measuring point, from which the average value is then calculated. An average value for each measuring field is calculated from this average value calculated from the five measuring points of the measuring field. This method is time-consuming and is suited mainly for measurements of smaller areas.

The Moore **outflow meter** is used to check the macrotexture (roughness) of surfaces. The device is comprised of an acrylic glass cylinder with a measurement scale, a brass weight ring and a rubber seal at the outlet opening.

For measurement, the cylinder is filled with a defined quantity of water and placed on the road. As soon as the water level passes the top red mark, a stopwatch is started. The time which passes until the bottom red marking is reached is decisive, as this provides both the measurement value and the result of the test point. If the surface features considerable macroroughness, i.e. good drainage capability, the interval until the cylinder empties is short.



SRT pendulum		
Limit values for condition recording and evaluation		
Target value	**Warning value**	**Threshold value**
≥60 SRT units (e.g. after measures to improve surface grip have been taken)	55 SRT units	50 SRT units

Outflow meter		
Limit values for condition recording and evaluation		
Target value	**Warning value**	**Threshold value**
≤30 s (e.g. after measures to improve surface grip have been taken)	60 s	120 s

cf. ZTV Asphalt-StB 07, page 46

9 Cold milling and the environment

9.1 Reusing asphalt granulate

In Germany, recovered asphalt has been recognised as an important source of raw material thanks to its thermoplastic properties and has been systematically supplied for recycling since the end of the 1970s. Cold milling machines play a decisive key role here. They enable the controlled removal of asphalt of different qualities and substances, particularly through the selective removal of individual layers. Asphalt granulate reclaimed in this way is either processed in asphalt mixing systems especially equipped for this purpose or on site. Depending on its suitability for construction and its quality characteristics, the material is supplied for reuse in asphalt base courses, surface courses or binder courses.

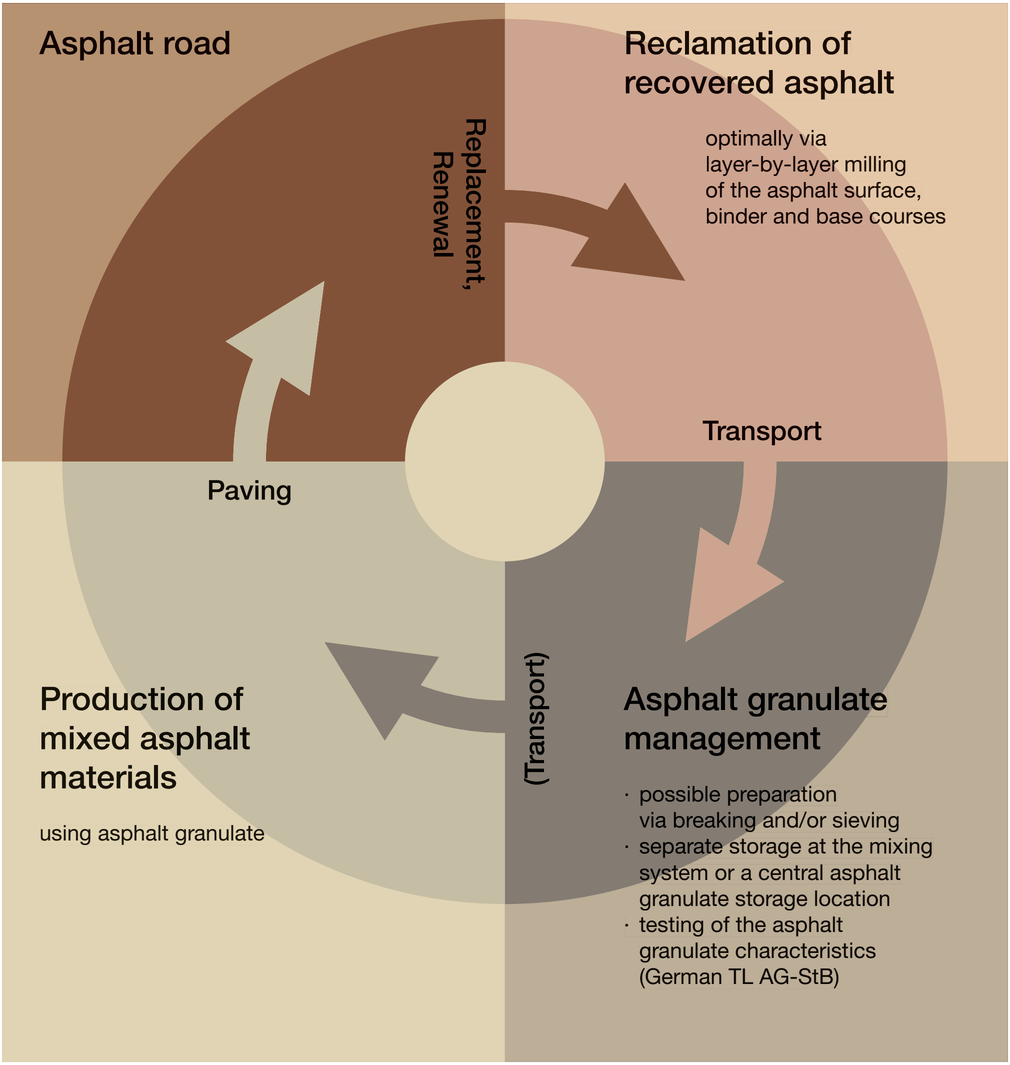
The methods and legal regulations on reusing asphalt granulate described here are based on the procedure practiced in Germany.

9.1.1 Terms

Recycling / Reuse
The inconsistent use of the terms “recycling” and “reuse” has prompted the German Asphalt Association to define a clear distinction between the two.

Recycling:
Recovered asphalt is supplied back into the material circuit as new material. As a result, a new product arises (e. g. the addition of asphalt granulate when producing material mixtures for base courses with hydraulic binders).

Reuse:
Recovered asphalt is defined as the repeated use of a material for the same purpose. Processing asphalt into asphalt thus mirrors the highest level of recycling and guarantees technical and qualitative equivalence of the product created in this manner.



optimally via layer-by-layer milling of the asphalt surface, binder and base courses

- possible preparation via breaking and/or sieving
- separate storage at the mixing system or a central asphalt granulate storage location
- testing of the asphalt granulate characteristics (German TL AG-StB)

using asphalt granulate

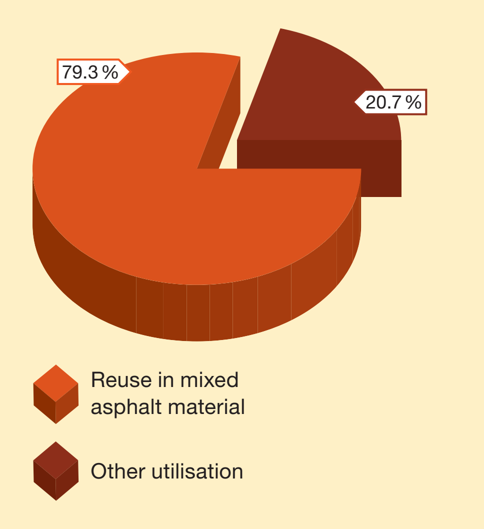
Optimum asphalt granulate circuit

9.1.2 Historical overview and the current state of research

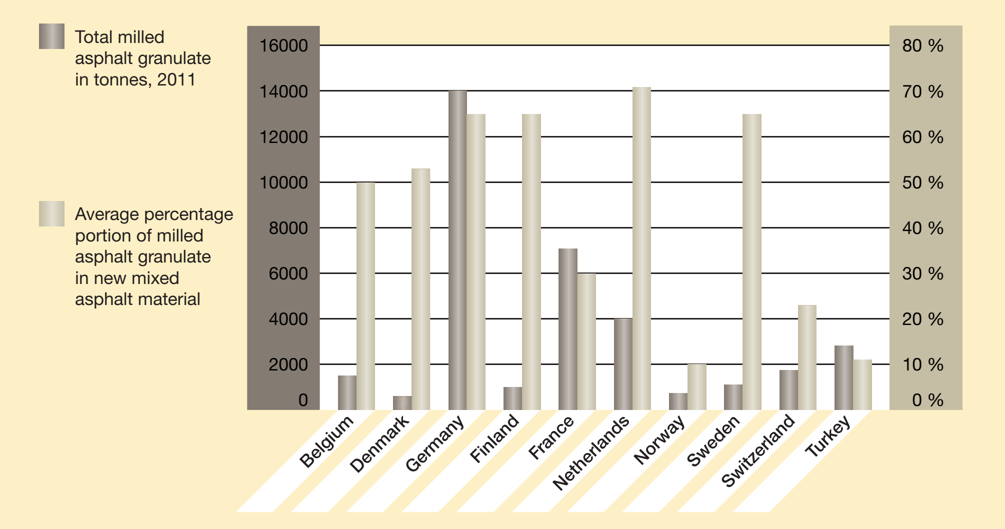
In the 1980s and 1990s, the mixed material types produced with recovered asphalt granulate were at first only used in the construction of asphalt base courses. With the shift of road construction activities from new construction to maintenance measures, reuse in asphalt binder and surface courses became increasingly important. These growing requirements resulted in the specification of more stringent quality criteria for the asphalt granulate which could be met due to technical improvements:

Selective milling through innovative machine technology
Separate and dry storage of the asphalt granulate
Sieving of asphalt granulate and selective addition after examination
Improved technologies for increasing the quantities added
Increased use of parallel drums in asphalt mixing systems

The portion of reused asphalt granulate increased considerably over the past few years. In Germany today, around 80 % (11.4 million metric tons) of the over 14 million metric tons of recovered asphalt are supplied for reuse without compromising quality. Thus, the proportion has nearly doubled over the past 25 years. The remaining 2.5 million metric tons are supplied for recycling, e.g. as filler material in noise barriers.



Total amount of asphalt granulate in Germany in 2011, as well as the average percentage addition of asphalt granulate in new mixed asphalt material



Amount and average quantity added of asphalt granulate (2011)
cf. EAPA. Asphalt in figures, 2011.

This development is not least the result of associated research work. In laboratory tests and practical test series carried out since 1988, the quality of mixed material types produced with recovered asphalt has been tested with regard to reuse in asphalt base, binder and surface courses and compared to mixed material types comprised solely of new materials.
The following, among other things, are evaluated:
The evenness of the new mixed material with regard to the composition of its characteristics
The cold and fatigue behaviour of recovered asphalt and its effect on the mechanical characteristics of asphalt surface courses
The effect of adding cold and heated asphalt granulate on the evenness and mechanical composition (tensile strength) of the resulting mixed material
Compressibility and resistance to deformation

The result of long-term studies confirms that, when quality criteria are paid careful attention, a mixed material with added asphalt granulate is absolutely equivalent to a mixed material comprised solely of new materials and can be used in all courses. The addition of hard asphalt granulate also affects both the deformation behaviour and the cold and fatigue behaviour positively.

9.1.3 Legal regulations in Germany

With the new version of the German Life-Cycle Resource Management Act, which took effect on June 1st 2012 and which is based on the German Life-Cycle Resource and Waste Management Act of 1996, legislators pursued the basic idea of conserving natural resources and reintroducing waste material into the material circuit and recycling them.

This means that asphalt produced by reusing asphalt granulate is preferred for use as long as the aggregates fulfil the quality demands and the binder mixture in the asphalt is suitable.

The German Life-Cycle Resource Management Act of 1996 implements the EU Waste Framework Directive as German law. The implementation of the European set of standards for the asphalt sector into a corresponding national body of rules took place in 2008 and includes:

Technical supply conditions for mixed asphalt material for the construction of paved areas for use by vehicular traffic (German TL Asphalt-StB 07)
Technical supply conditions for asphalt granulate (German TL AG-StB 09)
Additional technical contractual conditions and guidelines for constructing with asphalt paved areas for use by vehicular traffic (German ZTV Asphalt-StB 07)

The technical body of rules is supplemented by a leaflet on the reuse of asphalt, 2009 edition (German M WA).

Although the German road construction industry already enjoys a leading position in the fulfilment of the German Life-Cycle Resource Management Act, road administration is still required. It must meet the contractual and technical requirements to ensure the reuse of recovered asphalt at a high standard. At the same time, the qualitative and economical requirements of the client, the contractor and the mixed material producer must be taken into account.

9.1.4 Recovered asphalt

Asphalt is a technically manufactured mixture of valuable raw materials such as bitumen, binders containing bitumen, aggregates and/or other ingredients. Recovered asphalt is reclaimed via milling or breaking up asphalt; asphalt granulate is broken-up recovered asphalt reclaimed from the milling process.

Due to its thermoplastic characteristics, bitumen is the most valuable component. Thanks to this aspect of its make-up, recovered asphalt can be replasticised and reused for the production of new mixed asphalt materials.

9.1.4.1 Reclamation and storage

In order to be supplied for the highest level of material reuse, i.e. for creating new mixed asphalt material, recovered asphalt must meet high quality demands. These include, for example, the homogeneous nature of the material, which can only be met if proper care was taken and monitoring was carried out while reclaiming the recovered asphalt.
Layer-by-layer milling of the old asphalt layer enables separate reclamation of the material (base, binder and surface courses) and separate, sorted storage. After further processing, the material can be supplied for its intended purpose in a manner that meets the demands of both economy and quality. This includes:

Production of mixed asphalt mixtures
Production of construction material mixtures
  for base courses without a binder
Production of construction material
  mixtures with hydraulic binders

Outdoor storage under an open sky is possible, but sheltered storage is much more economical, as it helps minimise the water content of the broken material. The following general rule applies: The more moist the milling granulate, the more energy required when producing the asphalt mixture. At the same time, sheltered storage prevents the washing out of contaminated substances, thus preventing the risk of ground water contamination.

9.1.4.2 Suitability and classification of the milled granulate

Asphalt granulate is suited for addition to asphalt binder mixtures if the requirements for construction materials specified in the technical body of rules (German TL Asphalt-StB 07 and TL AG-StB 09) are met. This must be verified in preliminary investigations via suitability testing. The higher the value of the course in which use is intended, the greater the testing and investigation expenditure.

The test result is decisive for the maximum possible quantity of asphalt granulate which can be added when producing asphalt binder mixtures. The evenness of the material is of central importance here. In addition to the corresponding calculation formulae, nomograms are used to help determine the maximum possible asphalt granulate amount to be added to asphalt base, binder and surface course mixtures.
Water vapour exiting the material limits the amount of material which can be added.

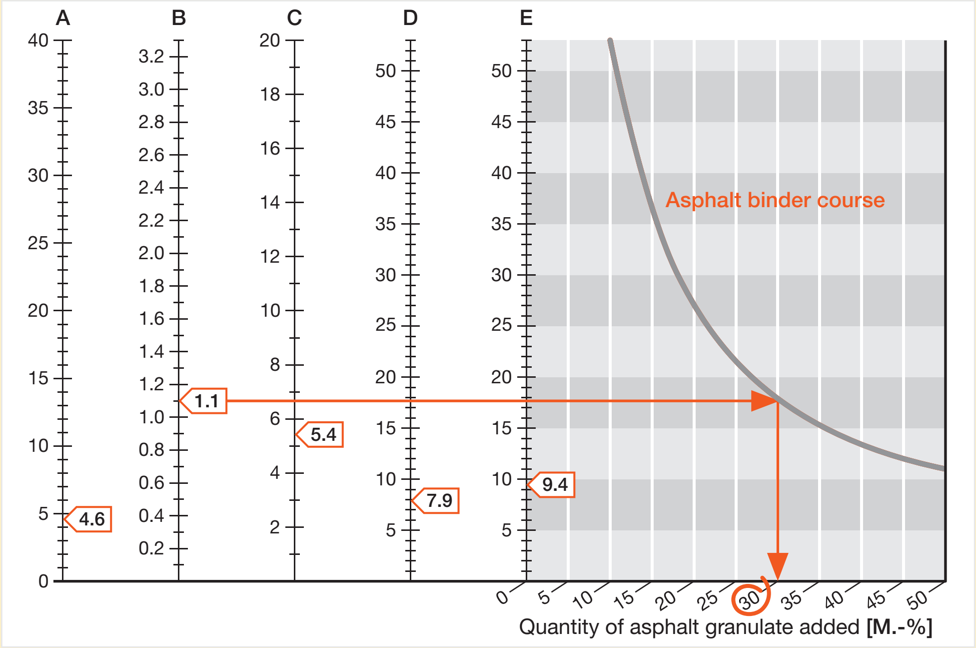
The following is tested:
Environmental compatibility
  – Testing for components typical of tar/pitch
Maximum piece size
Evenness, determined by
  – Binder content
  – Softening point (ring and ball) of the binder contained in the asphalt granulate
  – Portion of grain size classes in the extracted aggregate mixture
    • < 0.063 mm
    • 0.063 to 2 mm
    • > 2 mm
Raw density
Foreign material content

9.1.4.3 Example and calculation for the addition of mixed asphalt material in asphalt binder courses

The evenness of the asphalt granulate is determined using the range of parameters, mentioned on the right, on at least five samples per heap. The range describes the difference between the greatest and smallest value of the measurement series.

The ranges of the individual parameters are entered into the ordinates of the nomogram. A parameter’s maximum range on the ordinates is decisive for determining the maximum possible asphalt granulate quantity added. In the example on the right it is the binder content. This results in a limitation value of 30 M.-% for the maximum amount which can be added of the mixture.

	A	B	C	D	E
Parameter	Softening point (ring and ball) [°C]	Binder content [M.-%]	Grain portion < 0.063 mm [M.-%]	Grain portion 0.063 mm to 2 mm [M.-%]	Grain portion > 2 mm [M.-%]
Sample 1	68.6	5.8	9.8	27.7	62.4
Sample 2	64.0	5.8	11.3	25.2	63.5
Sample 3	64.8	5.2	9.2	19.8	70.9
Sample 4	68.0	4.7	6.7	21.5	71.8
Sample 5	66.4	5.1	12.1	23.8	64.1
Range	4.6	1.1	5.4	7.9	9.4

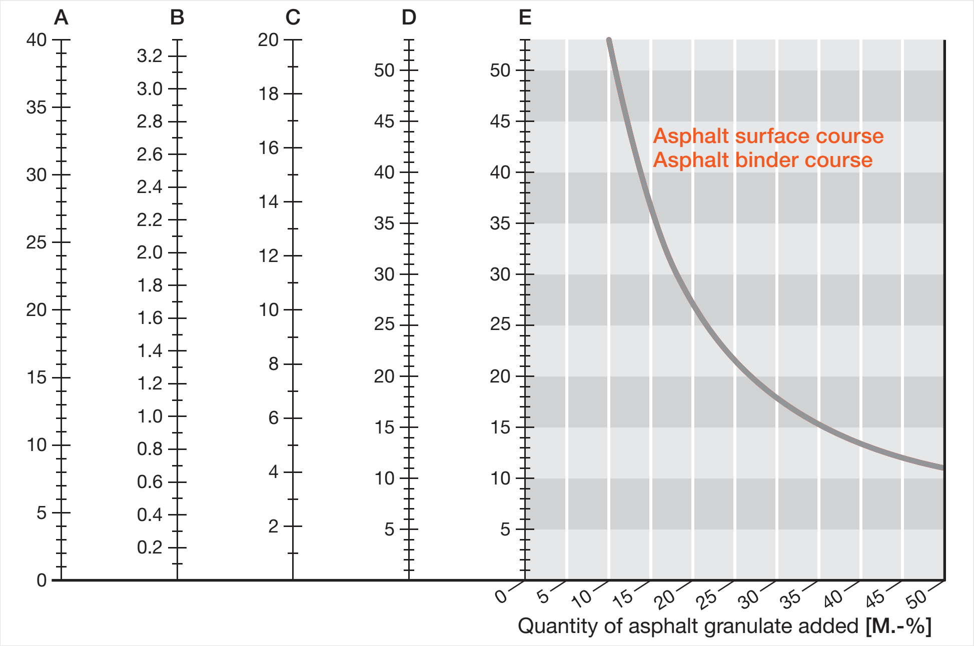


Example for calculating the maximum possible quantity added of asphalt granulate in mixed asphalt binder material via nomogram "Asphalt binder course"

Table and diagram cf. Deutscher Asphaltverband e. V. (eds.). Wiederverwenden von Asphalt. Page 23.

9.1.4.4 Asphalt surface courses and asphalt binder courses

Using the nomogram, the maximum possible quantity to be added can be determined graphically based on the range of features. In the nomogram below, the additional feature (grain portion from 0.063 to 2 mm) is taken into account with its own abscissa.

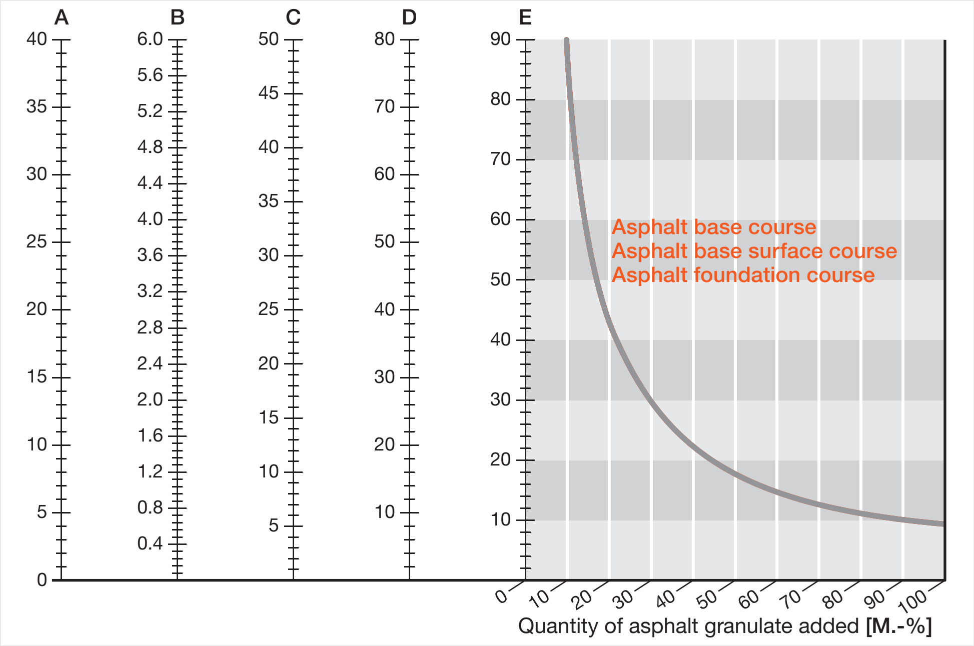


Nomogram for calculating the maximum possible quantity added of asphalt granulate in mixed asphalt material for asphalt surface courses and asphalt binder courses

9.1.4.5 Asphalt base courses, asphalt base surface courses and asphalt foundation courses

Using the nomogram shown below, the maximum possible quantity to be added can again be determined graphically based on the range of the five features.

The maximum quantity to be added based on the evenness of the asphalt granulate is also the smallest of the values determined for the five parameters here.



Nomogram for calculating the maximum possible quantity added of asphalt granulate in mixed asphalt material for asphalt base courses, asphalt base surface courses and asphalt foundation courses

9.1.5 Utilising asphalt granulate in stationary hot mixing systems

A variety of stationary system technologies are available for reusing asphalt granulate when producing new mixed asphalt materials. Suitable mixing systems include batch and drum mixing systems and continuous mixing systems. In principle, the addition of the asphalt granulate can be either hot or cold, depending on the system.

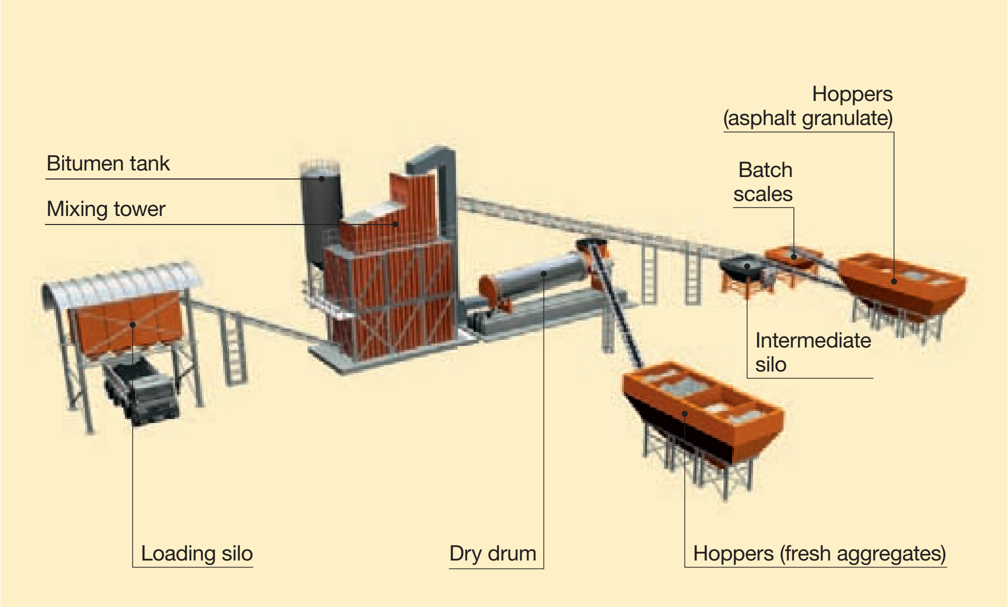
9.1.5.1 Batch and drum mixing systems

Mixed asphalt materials in Germany are produced primarily in batch mixing systems. The components of the mixed asphalt material, which are determined in advance, are mixed in an asphalt mixer in batches. This flexible procedure enables the mixture formula to be changed quickly and also enables adjusted mixing times. The procedures for adding material to heat cold asphalt granulate vary.

Heating via hot aggregates

Aggregates, binders and additives are weighed in according to the mixture variable, and the cold asphalt granulate is added to the mixer either via an intermediate silo or batch scales. The asphalt granulate is heated there by the new or unused aggregates, which are in turn heated in the dry drum. Suddenly arising water vapour can be diverted via a variety of different devices. Only then is the new binder added to counter any hardening. The maximum additive quantity for asphalt granulate is 30 M.-% of the mixture.

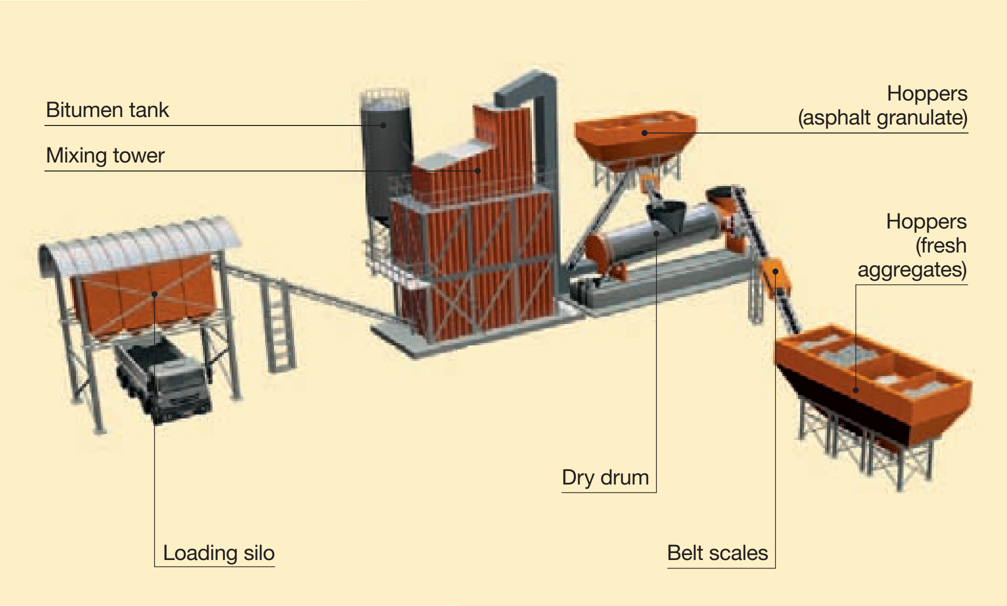
Alternatively, the mixing process under non-stop addition of the asphalt granulate takes place in the dry drum discharge, hot elevator or sieve bypass pocket. The hot aggregates heat the cold asphalt granulate here as well. The maximum additive quantity is 40 M.-% of the mixture.



The addition of cold asphalt granulate to the mixer takes place via either an intermediate silo and aggregate scales or separate batch scales.

Joint heating with the aggregates

The addition of the asphalt granulate to the centre of the dry drum or to the dry drum via the burner-side end wall takes place continuously, where both it and the aggregates are heated. The maximum recommended additive quantity is 40 M.-% of the mixture.

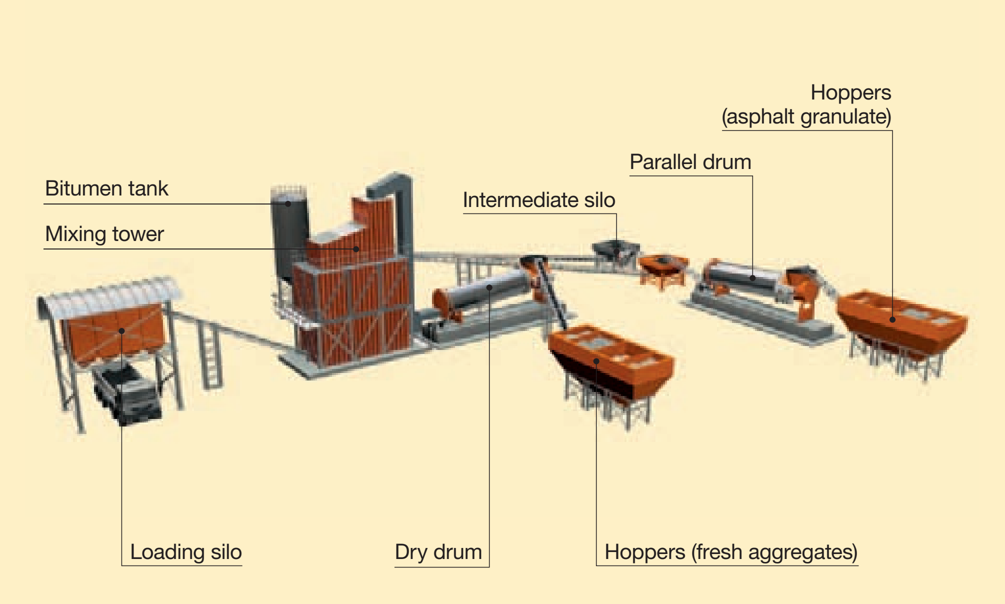


The cold asphalt granulate is added to the dry drum centrally or on the burner side.

Heating in separate equipment

The asphalt granulate is carefully heated to max. 130 °C in so-called parallel drums and added to the mixer in batches. This procedure requires considerably less energy, enables additive quantities up to 50 M.-% of the mixture as per the body of rules (theoretically, additive quantities up to 80 M.-% of the mixture should be possible due to the machine's technology) and is especially oriented toward high throughput. The joint mixture of asphalt granulate and new aggregates takes place in the dry drum.

In Germany, only 20 % of asphalt mixing systems are equipped with parallel drums. The reason for this are the high investment costs which have quickly amortised thanks to the high throughput and heavily reduced energy costs. In comparison, 98 % of Dutch systems are equipped with parallel drums.

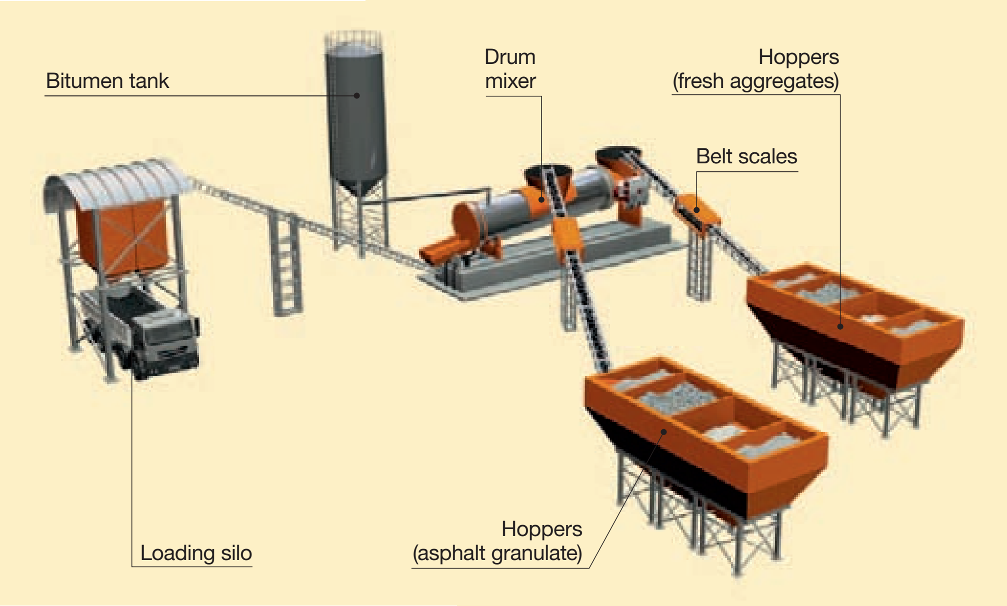


The addition of asphalt granulate heated in the parallel drum takes place either via an intermediate silo and aggregate scales or an intermediate silo and separate batch scales.

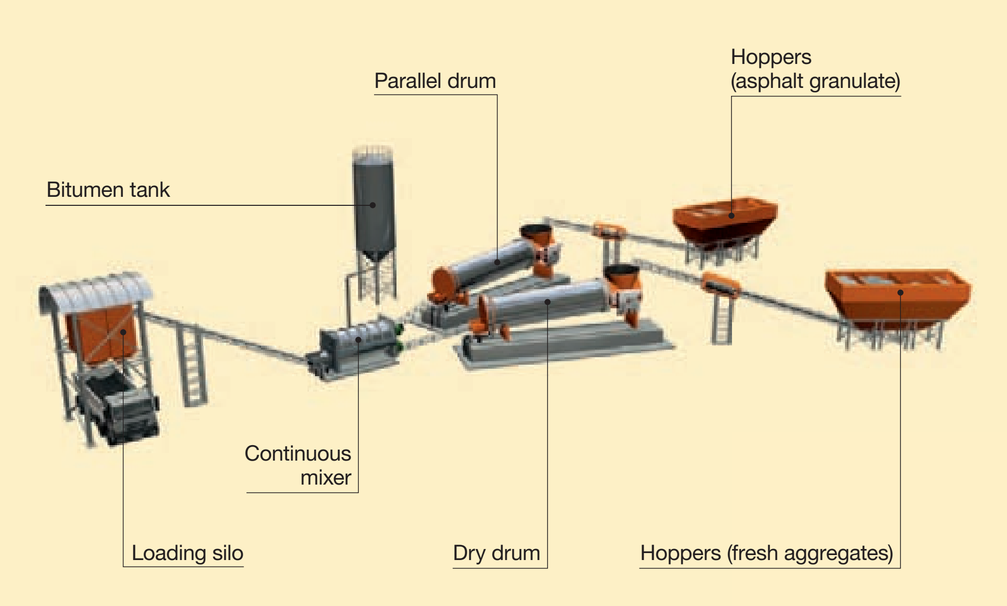
9.1.5.2 Continuous mixing systems

The mixing procedure takes place continuously in a drum or in a downstream continuous mixer. Dosing of the asphalt granulate is also carried out continuously. The asphalt granulate and the unused aggregates are weighed separately on belt scales, heated together in the drum and mixed with the binder in a single step.

In addition, separate heating in a parallel drum is also possible. Subsequent addition takes place in a downstream continuous mixer.



The addition of cold asphalt granulate to the drum mixer takes place either at the same time as the cold aggregates or separately in the centre of the drum. Both the asphalt granulate and the aggregates are weighed separately.



The addition of asphalt granulate heated in a parallel drum occurs in a downstream continuous mixer.

9.1.6 Cold recycling as an economical alternative

Cold recycling is a fast and economical method of producing high-quality base courses. Damaged surfaces are renovated on site using the available milled materials without process energy. By adding binders, a homogeneous bound layer can be created. Thanks to the use of available construction materials and the elimination of disposal costs, cold recycling is especially economical, protects the environment and conserves resources.

For structural repairs in particular (e. g. deformations, fatigue cracks, etc.), it is often determined that the structure of the road structure is damaged, seldom the material within. Using the cold recycling procedure, a new, homogeneous layer is created via the addition of binders. In this case, one speaks of structural repair of the road structure.

Cold recycling is also especially appropriate if the asphalt granulate can no longer be supplied for hot processing due to its specific characteristics. This is the case, for example, if the recovered asphalt is full of components containing tar or pitch. Pitch/tar was used for ground stabilisation and surface processing, as well as in base, surface and binder courses, until 1990. If unavoidable, the removal of these layers is to be carried out individually via selective milling and provided for reuse – and for reuse only. For more detailed information regarding this topic, please refer to the “Leaflet on the utilisation of road construction materials containing pitch and of asphalt granulate in bitumen-bound base courses via cold processing in mixing systems”, 2007 edition (Merkblatt für die Verwertung von pechhaltigen Straßenausbaustoffen und von Asphaltgranulat in bitumengebundenen Tragschichten durch Kaltaufbereitung in Mischanlagen M VB-K, Ausgabe 2007).

Cold recycling enables up to 100 % of recovered asphalt to be reused. Substances containing the additional components are first bound to bitumen and/or a cement base by mixing the milled material with binder before being reused in the foundation; the edges of the courses are also sealed with bitumen so that they pose no risk for the environment. The disposal costs for layers containing pitch are eliminated, and the lack of heating prevents a health risk.

Cold recycling technology is being increasingly used not only in Europe but also worldwide and is valued as an economical and ecological method of rehabilitation. The advantages of the procedure are made apparent particularly when difficult conditions are involved.

Advantages of cold recycling:
100 % reuse of the material
Conservation of resources, reduction of the portion of new materials
Encapsulation of material containing tar using binders is possible
Shortened construction times, minimal obstruction of traffic
Highly economical
Considerable reduction in the amount of emitted CO_2
Low energy expenditure
Shortening of transport routes

9.1.6.1 In-plant cold recycling

The damaged road surface is removed with a cold milling machine and transported to a mobile cold mixing system in the immediate vicinity of the construction site. Wirtgen cold recycling mixing systems are mounted to a semi-trailer and have their own engine station, which guarantees quick implementation. Here, the milled material is transferred to the hopper. Milled soil and pieces over 45 mm are removed by the sieve, the material is weighed and then mixed with cement and bitumen in a twin-shaft compulsory mixer. The cold mixed material can then be applied using an asphalt paver or, if necessary, stored over a longer period of time.

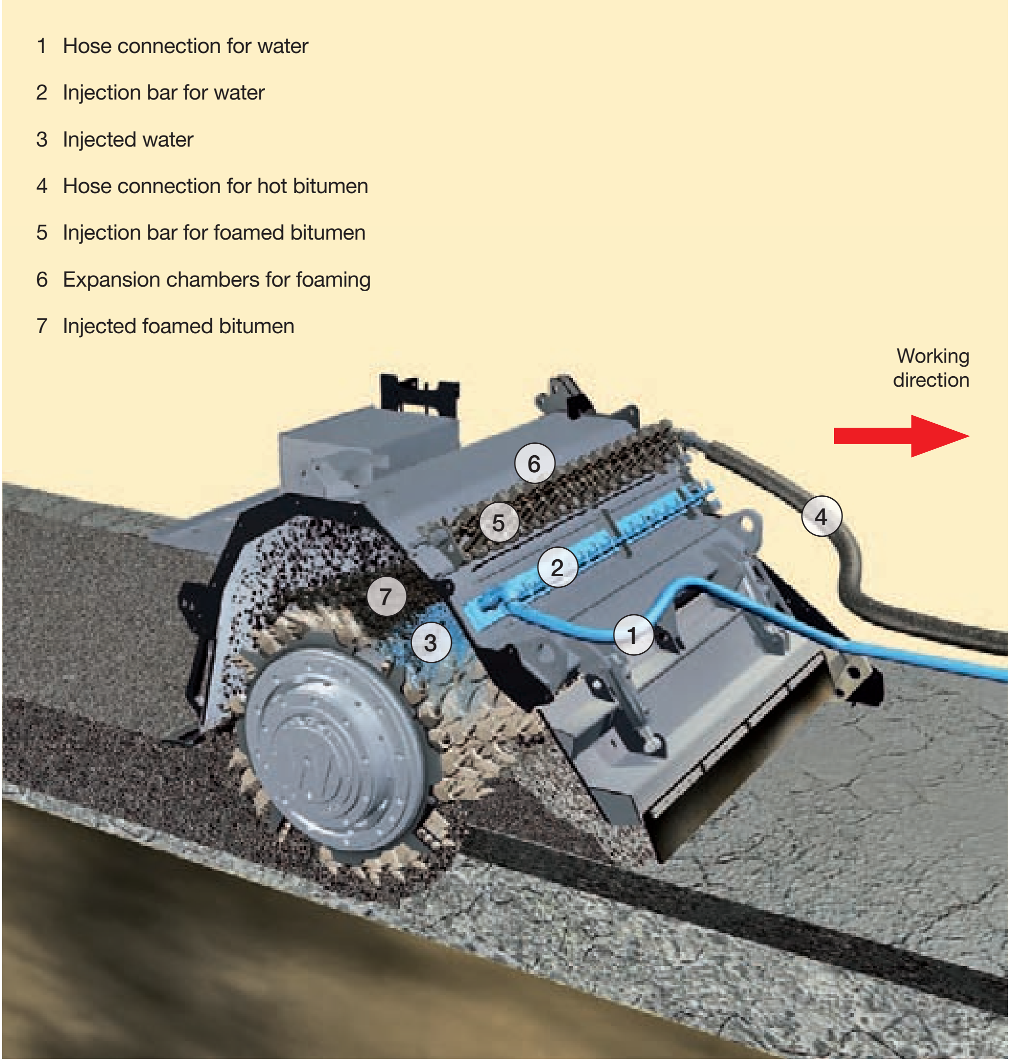
Mobile Wirtgen cold recycler mixing unit KMA 220

9.1.6.2 On-site cold recycling

Modern cold recyclers, equipped with a milling and mixing motor, loosen the covering layers in need of rehabilitation, granulate the recovered asphalt, prepare it with binders and reapply it via an accompanying paving screed. The entire process occurs in a single machine pass. Up to 100% of both the bound layers and parts of the unbound layers are reused. During the milling and mixing procedure, water is added via an injection pump to achieve the moisture content required for subsequent compaction. At the same time, liquid binder (cement suspension, bitumen emulsion, foam bitumen, etc.) is added. The properties of the base course which is created depend considerably on the binders used.

Hydraulic binder (e.g. cement)
Bitumen emulsion (mixture of road construction bitumen and water)
Foam bitumen (addition of water and air to a hot bitumen jet)

Modern Wirtgen cold recycler WR 240i being used for recycling



Cold recycling via milling with the addition of sprayed-in bitumen foam

9.1.7 Use of asphalt granulate as an economical vision for the future

The framework for reusing recovered asphalt was drafted and solidified to the highest degree with the entry into force of the German Life-Cycle Resource Management Act and the technical body of rules based on it. As increasing raw material shortages and price increases, especially in the case of bitumen, necessarily lead to an explosion in the cost of the mixed asphalt material, it makes economic sense to increase the rate of reuse.

Quality assurance through layer-by-layer milling
Mixed material with recovered asphalt granulate can be reused in all layers and is of absolute equal value, as long as it fulfils the defined quality criteria. In addition, it must be given preference over a product produced solely of new raw materials as per the German Life-Cycle Resource Management Act. Quality is only assured, however, if reclamation of the recovered asphalt is handled in a careful and monitored way. This requirement can only be fulfilled via layer-by-layer milling.
Thanks to the targeted tendering of layer-by-layer milling on the part of the client, high-quality reuse can be supported while the requirements of legislators can simultaneously be taken into account. There is neither a qualitative nor a legal basis for limitations (e.g. the exclusion of asphalt granulate in surface courses) as they are still practiced in some German states.

Energy savings through resource-conserving production of asphalt mixtures
The competitiveness of the asphalt industry also depends to a large degree on energy costs. They can be reduced greatly by using modern technologies and storage methods:
Increased use of parallel drums
Dry storage of asphalt granulate

Increased use of alternative processes such as cold recycling
Reduction of energy expenditure
Transport cost savings
Material savings

Additional detailed information on the topic of cold recycling technology is available in the "Wirtgen Cold Recycling Technology" manual at www.wirtgen.de/en/.

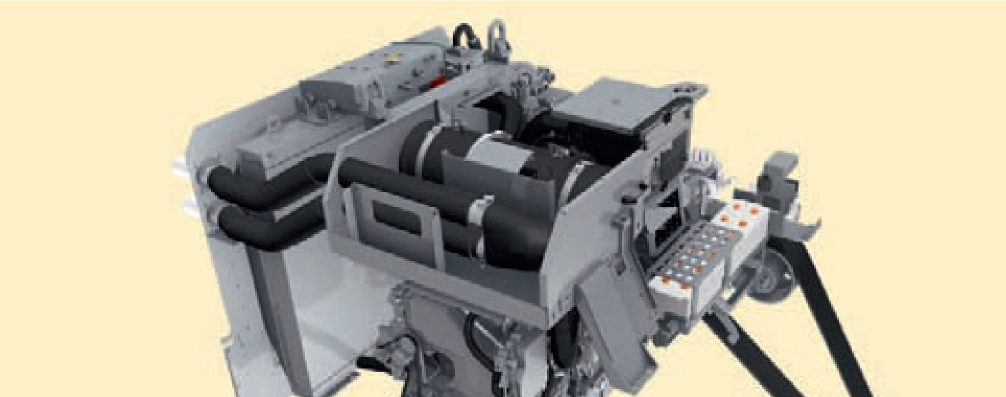
9.2 Environmental emissions due to cold milling

9.2.1 Exhaust emission levels

Since 1996, there have been legally binding limit values for the emission of harmful substances from the diesel engines of mobile construction machines. This applies in particular to reducing harmful fine dust (PM) and nitrogen oxide (NO_x). These limit values for harmful substances have been met using technical measures on and in the engine and are fulfilled without exception by all Wirtgen cold milling machines as per the country-specific specifications.

Since 2011, new exhaust levels (Exhaust gas level IIIB, Tier 4i) have taken effect in Europe and the USA. They apply for engines of performance class 130 – 560 kW (174 – 751 HP) and greater and include the greatest limit value reduction thus far.

The latest generation of Wirtgen cold milling machines are equipped with state-of-the-art engine technology for extremely low environmental emissions. Easy to recognise and assign thanks to the type designation "i" (intelligent emission control), they comply with the new stringent exhaust levels and run on nearly sulphur-free diesel fuel. A DPF (diesel particle filter) system drastically reducing particle emissions is used for exhaust processing.



Modern engine technology: linked with high efficiency to the machine control

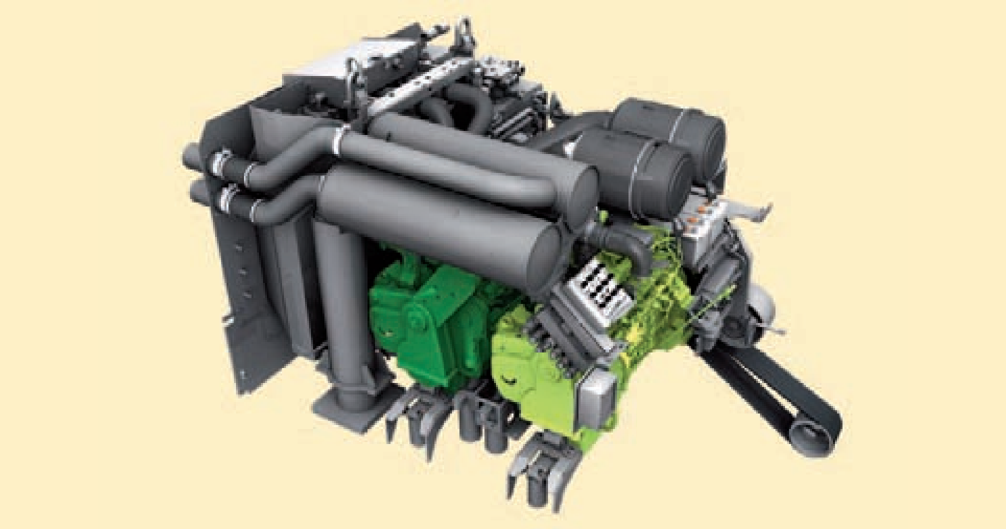
9.2.2 Noise emissions of cold milling machines

The new generation of cold milling machines feature modern technology to help to reduce noise emissions:

- Engine compartment sound insulation
- Automatic speed reduction when milling is complete
- Low-noise engines
- Engine speed dependent on travelling speed:
  - Automated adjustment of the advance rate to the respective load of the diesel engine
  - A selection of different engine working speeds

- The new generation of large milling machines' environmentally friendly dual engine concept:
  - The second engine can be shut down to save diesel fuel and reduce noise, depending on the task

Engine compartment sound insulation

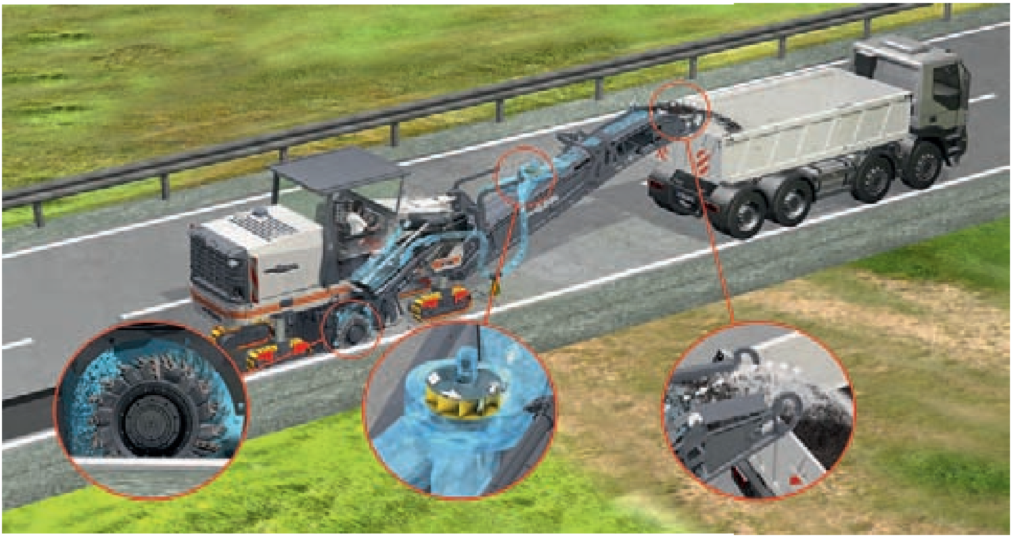


As minimal as possible diesel consumption thanks to the innovative Dual Engine Concept

9.2.3 Reduced dust emissions

During the milling process, fine material particles and water vapour arise in the milling unit. Wirtgen offers an extraction system for road milling machines with a front-loader system which considerably reduces the quantity of airborne particles. Using the VCS (vacuum cutting system), the air/water vapour mixture is extracted from the milling drum housing and then fed to the milling material flow on the loading conveyor via a hose system. Finally, the condensed particles are loaded onto a truck and removed together with the milled material.

Unobstructed view of the milled edge for the machine operator
Considerably improved visual conditions for night work
Measurably lower engine soiling (diesel filter and oil filter)
Overall lower soiling of the machines (crawler unit pillar guide, etc.)
Increase in working comfort and thus increased performance



Effective dust reduction in the working area thanks to the innovative vacuum cutting system (VCS)

9.2.4 Vibration emissions

Mechanical vibrations arise during the milling process. One of Wirtgen's top priorities when designing milling machines are damping components:

Engine mounted in silent blocks with elastic suspension

Vibration-decoupled operator's platform

The elastically mounted footboard in the operator's platform and the rubber buffer on the access ladder footboard reduce vibrations

Optimum cutting power distribution at the milling drum

Pleasant working conditions for the highest performance

10 The future of cold milling

10.1 Roads and their importance to industry

A well-established and high-quality road network is of fundamental importance for infrastructure and makes an indispensable contribution in ensuring a country's mobility and growth. However, high traffic load, age-related wear and weather influences lead to deterioration of the road condition over time, which results in an increasing number of accidents and traffic obstructions due to speed limits or road blockages. Transport requires more time and delivery dates are more difficult to calculate. These are economically decisive factors, especially for the goods industry, which relies on smooth, reliable and punctual logistics.

There's no detour around rehabilitation. Cold milling machines, situated at the beginning of the construction process, play a significant role in high-quality, efficient and quick work. They have a decisive influence on the quality of the road, driving comfort and the optimisation of the flow of traffic, which is crucial for goods traffic. A level and correctly positioned milling surface enables the paving of asphalt layers of even thickness, which enables vehicle loads to be optimally distributed over the road.

The condition of the road directly affects the everyday life of the truck driver: The higher the road quality, the fewer the impediments caused by backups and load restrictions. This enables the driver and his or her client to quickly process transport orders. The flow of traffic becomes safer and more consistent. In addition, level and anti-skidding road surfaces reduce the number of accidents and vehicle wear and also lower repair costs.

Cold milling machine being used for the rehabilitation of an inner-city asphalt surface course

10.2 The use of cold milling in day-to-day traffic

Time and cost pressure at the construction site demands ever more powerful and economical machines. Cold milling machines are not an exception to this development. On the contrary, since they are increasingly being used during low-traffic periods, i.e. at night and on Sundays and holidays, speed and noise reduction, with no reduction in quality, are important criteria. Over the past few years, cold milling machines have experienced an enormous increase in efficiency thanks to the development of new processes and technologies. Their spectrum of use has expanded considerably for the same reason. As a market leader, Wirtgen has been responsible for a large portion of this development:

- Fuel-saving drive designs for low operating costs and low environmental emissions (e. g. noise and dust reduction)
- Modern machine control systems for optimum quality results
- Compact and lighter machines for flexible machine transport
- Highly efficient construction with minimal obstruction of traffic
- Good service accessibility at the construction site

Cold milling machine being used for the rehabilitation of a main road at night

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www.kalibrierstelle-sachsen-anhalt.de

www.zehntner.com

www.strassenbaudigital.de

www.men.niedersachsen.de

Glossary/Abbreviations

Alligator cracks:	Fine to gaping breaks in the surface.
Asphalt base course:	This lowermost course of the road structure provides upper courses with an even and stable base. They are comprised of single or multiple layers of paved mixed asphalt materials.
Asphalt binder courses:	Positioned between the asphalt base course and the asphalt surface course with the objective of enabling good load transfer and to ensure good interlocking of the layers. It also serves to reduce any unevenness of the asphalt base course, thus enabling the asphalt surface course to be created with an even thickness and the required levelness.
Asphalt surface course:	The uppermost, especially highly stressed courses of asphalt pavement. They are subjected to the immediate effects of traffic and the weather and serve to bear loads and transfer and distribute them to the asphalt base course via the asphalt binder course. It is responsible for the surface characteristics, such as surface grip, noise reduction etc.
Break-outs:	Areas where the surface course has been removed. Also referred to as potholes in advanced stages.
Break-up asphalt:	Recovered asphalt reclaimed via breaking up/incorporating a layer package in soil.
Evenness:	Has a significant impact on traffic safety. A differentiation between two types is made: **Crosswise evenness:** Important for sufficient drainage of the road. Lane channels can impede the drainage of water and thus lead to aquaplaning. **Longitudinal evenness:** Impacts driving comfort, road body stress, noise emissions and driving safety.
Grain size class:	The grain size class of stone grains in asphalt granulate is characterised by lower and upper sieve sizes.
Individual cracks:	Reflection cracks or low-temperature cracks crosswise to the road.
Mends:	Arise as a result of patching road surface damage and covering crack damage over a limited area, for example.

Milled asphalt:	Small pieces of recovered asphalt reclaimed via milling.
Recovered asphalt:	Milled asphalt or break-up asphalt.
Roughness:	Determined by the surface texture and the characteristics of the surface course. Altered by traffic load, weather and the environment.
Structural upkeep:	Measures for structural upkeep of paved areas for vehicular traffic.
Maintenance:	Minor structural measure for structural preservation of paved areas for vehicular traffic which can be carried out with minimal expenditure. (The filling of potholes or individual cracks, the milling off of deformations in smaller areas, the grouting of open joints and surface processing of individual damaged areas).
Repair:	Structural measure for structural preservation or improvement of surface characteristics carried out on contiguous areas, generally the width of a traffic lane and a thickness of up to 4 cm. (Surface processing, application of thin asphalt surface courses, re-paving, replacement of an asphalt surface course).
Renewal:	Complete renewal of a paved area for vehicular traffic or parts of it.
Surface grip:	Characterises the effect of the roughness (surface texture) and the material composition on the friction resistance (tractive capability) between the tyres and the road. Influenced by the composition of the mixed material, the minerals and dulling. A differentiation is made between: ◤ Fine roughness (sharpness) ◤ Coarse roughness (decisive for the surface grip of the road if wet)
Wear:	Loss of mortar or bituminous binders from the road surface leading to the liberation of stone grains near the surface due to the missing binder.

Abbreviations

OB:	Surface processing
DSK:	Cold-paved thin layers
EAD:	Replacement of an asphalt surface course
RF:	Re-paving
DSH-V:	Hot-paved thin asphalt layers on seal
AC D:	Asphalt concrete
SMA:	Splittmastixasphalt (Stone Mastic Asphalt)
MA:	Mastic Asphalt

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