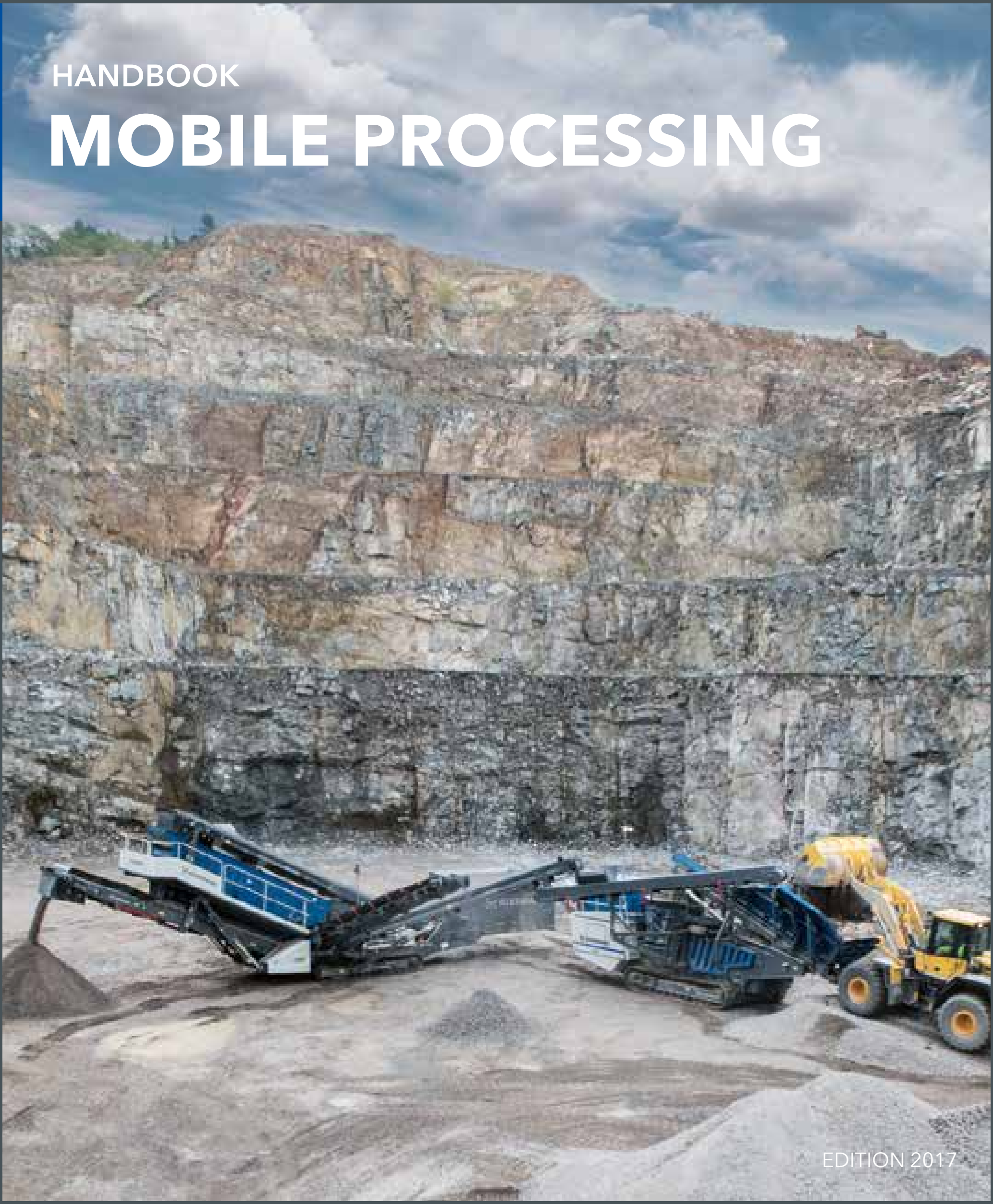
A WIRTGEN GROUP COMPANY

KLEEMANN

HANDBOOK

MOBILE PROCESSING



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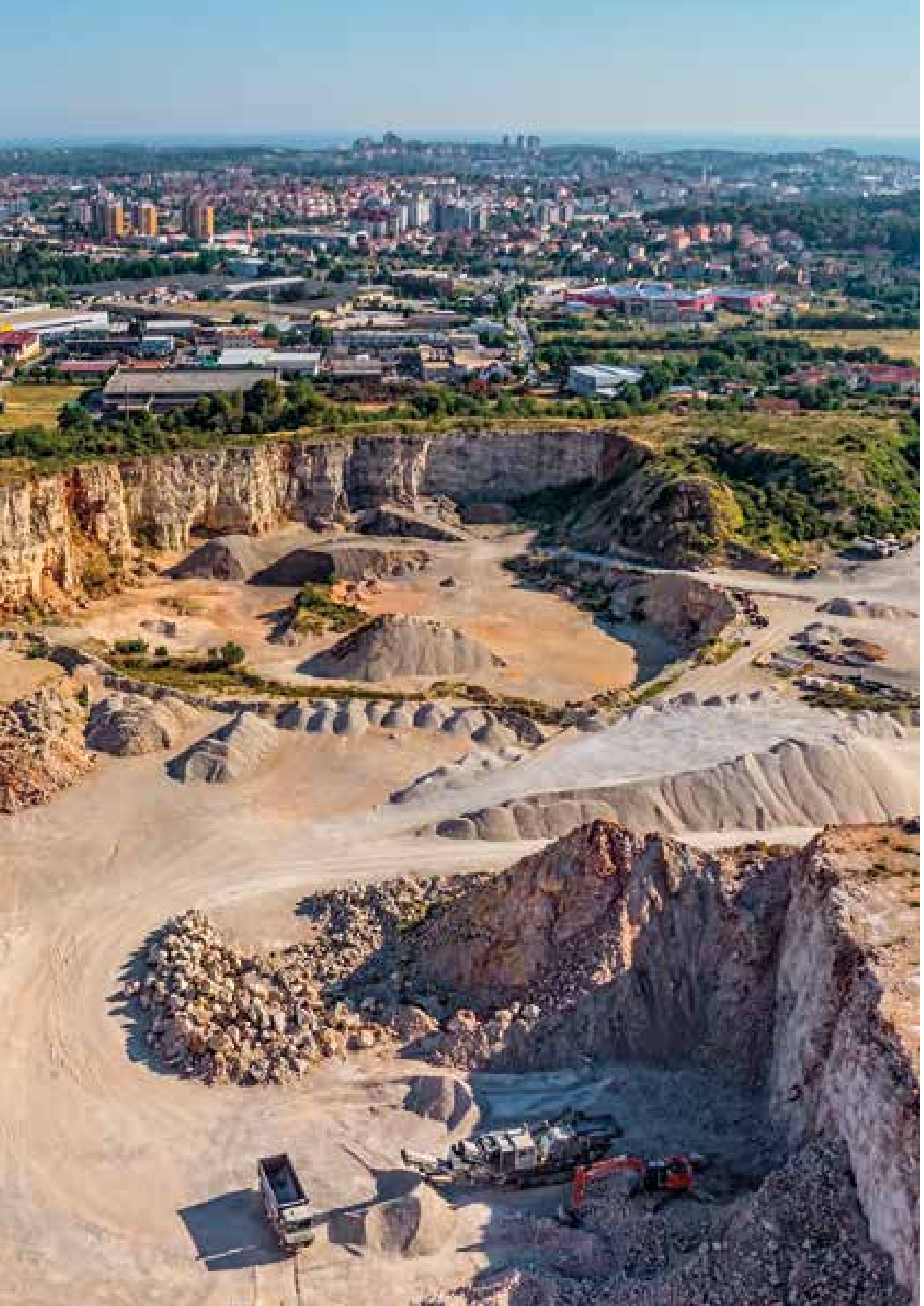
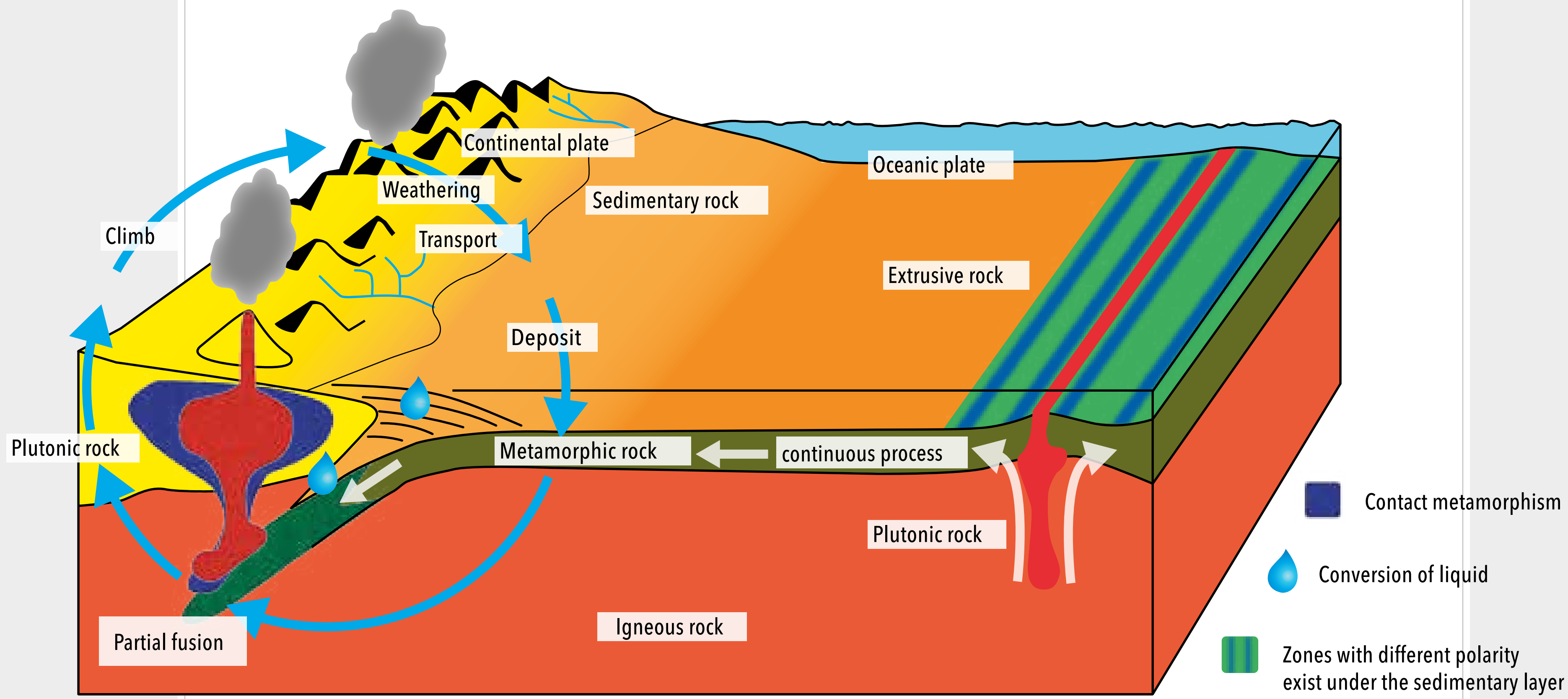


1 Primary and secondary raw materials

The stone of the extinct volcanoes weathers and is carried to the plate underneath by erosion, is deposited here and forms sedimentary rock. If the plates shift any further, the sedimentary rock at the plate interface changes into metamorphic rock when exposed to heat and pressure, which is melted into magma with increasing movement and starts its cycle when it flows from a volcanic vent.



Igneous rocks

Igneous rock (Magmatite) develops from the solidification of molten rock (magma) beneath the earth's surface. If the molten rock breaks through the earth's surface and cools very quickly, this is called extrusive rock (vulcanite), which has a fine crystalline structure. If the magma solidifies beneath the earth's surface so-called plutonic rocks (plutonites) are formed, which have a medium- to coarse-grained structure, as cooling is only effected slowly.

Sedimentary rock

Sediments are deposits of materials which result from the weathering of rocks, the remains of dead fauna or flora and chemical processes. If these partly coated deposits are exposed to pressure and heat, sedimentary rocks are formed.

Metamorphic rocks

Igneous, sedimentary and also existing metamorphic rocks are turned into metamorphites in the event of pressure and temperature changes as a result of geodynamic processes. During these processes the crystalline structure is transformed, but not necessarily the chemical composition. A new formation of minerals within the rock is also possible. Metamorphic rocks take their name from “Meta” (change) and “Morph” (shape).

Igneous rock – Gabbro

Gabbro quarry, Germany

Deposits
Worldwide ▷ Well-known large deposits in Karelia, Emirates, South Africa, in India in the state of Andhra Pradesh and on Greenland in the Skaergaard Intrusion (complex) ▷ Most common rock in the deep oceanic crust

Formation and structure
Deep-seated magma-like rock (plutonites) ▷ Through the slow cooling beneath the earth's surface and solidification into coarse-grained texture ▷ Dark to black colour, sometimes reflective green and blue ▷ Mainly consisting of iron and magnesium silicates ▷ Volcanic equivalent to basalt

Use
Unlimited as aggregate for constructing transport routes such as roads, rail tracks and water ▷ Concrete and asphalt ▷ Natural stone for indoor and outdoor area

Properties and workability

Crushability
good — poor

Hardness
soft — hard

Wear
abrasive — less abrasive

Grain shape production
easy — difficult

Sand content
low — high

Energy requirement
low — high

Extraction

Recommended machine
*

* Shaping with horizontal/vertical impact crusher

Special features

- High specific consumption of explosives
- Generally chunky pieces of blasted rock with high tendency towards boulders
- Many deposits pose the risk of causing dust diseases due to the high content of free silica

Igneous rock – Diabase

Diabase quarry, Germany

Deposits
Worldwide, including in India and Turkey ▷ Besides Germany, also found in south England ▷ Other European deposits in Czech Republic and Finland

Formation and structure
Igneous rock ▷ Solidified near the earth's surface in an ocean environment in fine- to medium-grained structure and brought to the surface through formation of mountain ranges ▷ Dark to black colour, sometimes greenish

Use
Unlimited as aggregate for constructing transport routes such as roads, rail tracks and water ▷ Concrete and asphalt ▷ Secondary as natural stone in indoor and outdoor area ▷ Rock dust for improving soil

Properties and workability

Crushability
good — poor

Hardness
soft — hard

Wear
abrasive — less abrasive

Grain shape production
easy — difficult

Sand content
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Extraction

Recommended machine
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* Shaping with horizontal/vertical impact crusher

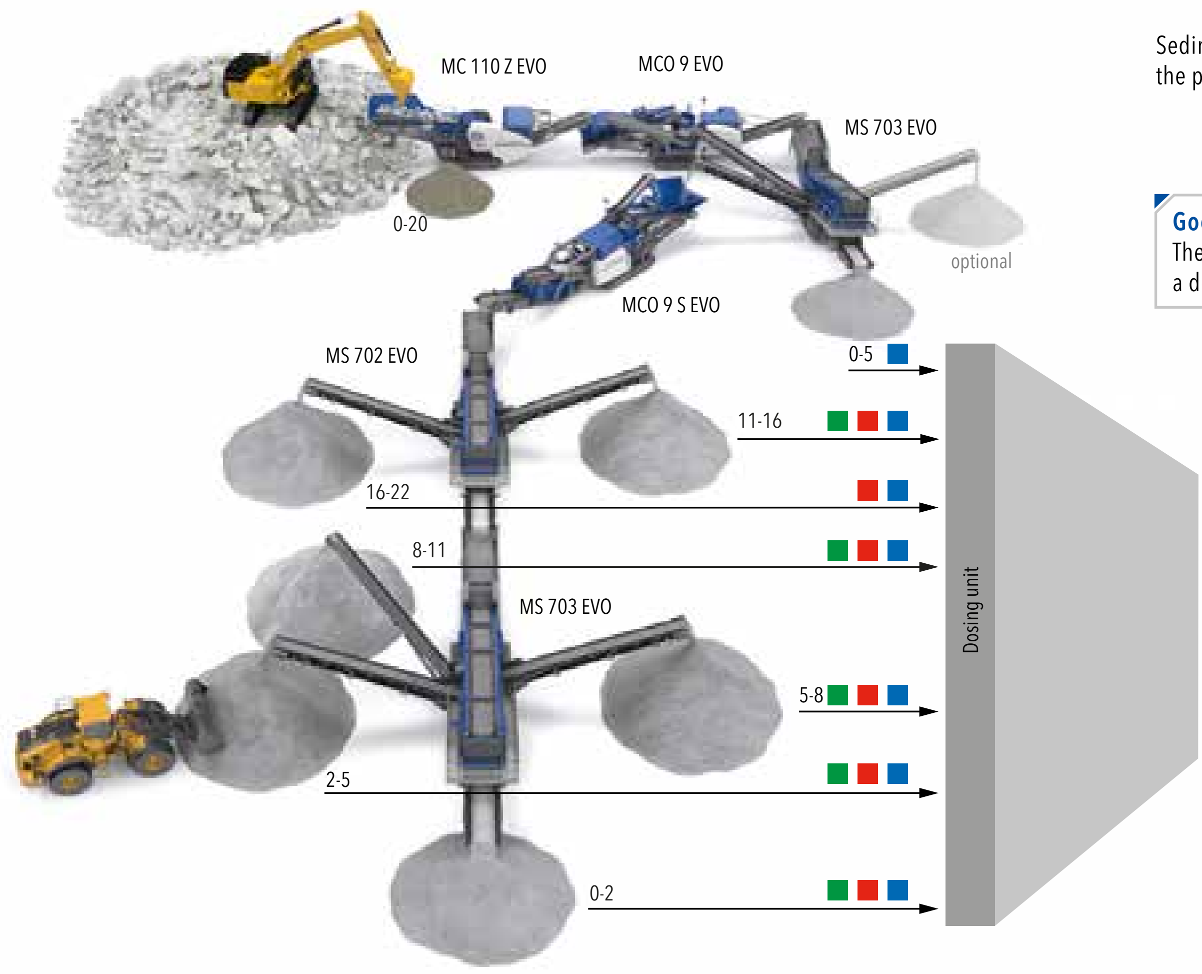
Special features

- Particularly weather-resistant
- Generally high polished stone value (PSV) and thus ideal for asphalt overlays
- Sometimes extremely high energy requirements during crushing stage

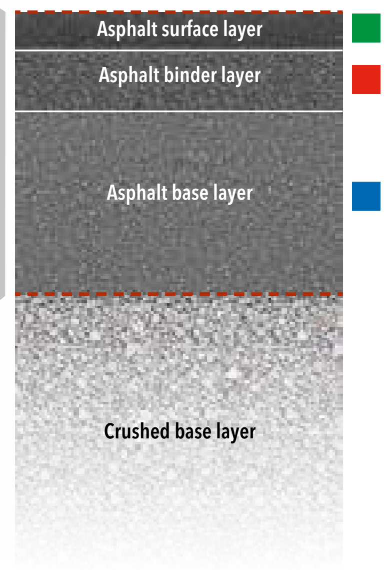
2 Applications in mobile processing

■ Production of standard asphalt grain sizes

Various combinations of plants are suitable for producing standard grain sizes depending on the final product.



Plant train – asphalt surface, binder and base layer



Asphalt surface, binder and base layer

A multistage crushing process is required for the production of standard asphalt aggregates. Only this way can the grain qualities required be achieved with regard to their distribution and grain shape. Pressure crushing machines are generally used because of their cost-effectiveness and efficiency. Observing the required grain shape is challenging during the production of asphalt aggregate grain sizes. The material flows must be carefully adapted to each other to ensure continuous and efficient processing. The cone crushers used in the second and third crushing stage must be loaded continuously with mixed aggregates.

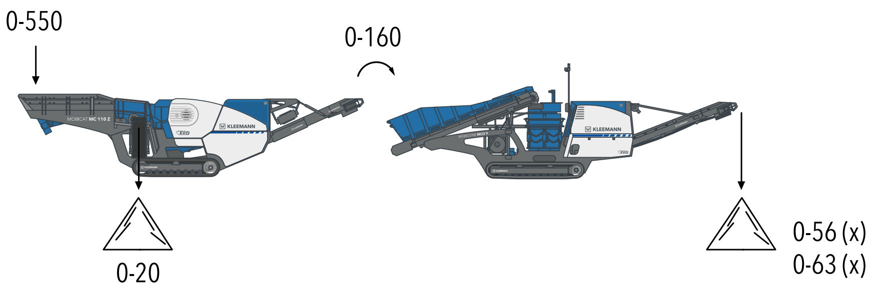
Sedimentary rocks, e.g. limestone, which are processed using an impact crusher, can also be used for the production of asphalt base layers.

Good to know

The mixed aggregates required for the individual bituminous bound asphalt layers are mixed using a dosing unit.

Processing natural stone

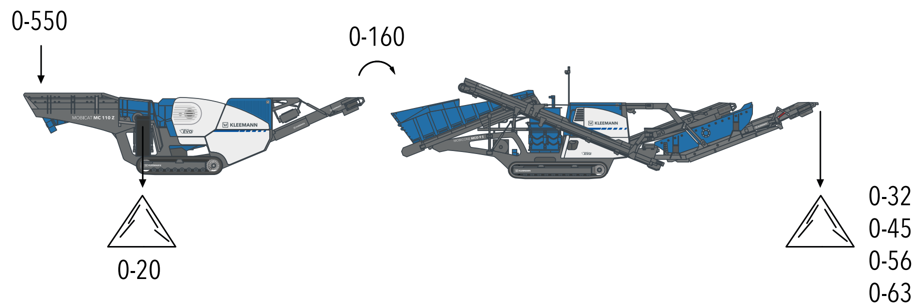
Variant 1



1st crushing stage, jaw crusher	2nd crushing stage, cone crusher
Feed material 0-550 mm, blasted	Feed material 0-160 mm, 1x precrushed
Prescreen: Equipment of primary screening, see page 162, acc. to chap. "Setting up primary screening", depending on ▷ Degree and size of impurities ▷ Type of impurities, e.g. sticky, cohesive (clay) or conveyable (wood, coal, humus) ▷ Quantity and quality of sand content ▷ Required feed size for the cone crusher In selected example: UD: Slotted grate, AGW 65 mm LD: Wire cloth, CMS 25 mm	**Prescreen:** Not required if primary screening of upstream jaw crusher is active. The 0-5 mm content of fines produced by the jaw crusher are tolerated by the cone crusher.
Jaw crusher: Adjustment of the jaw crusher, see page 181, select acc. to chap. "Setting up jaw crusher", depending on ▷ Desired intermediate product ▷ Required performance of secondary crusher ▷ Required feed size for the cone crusher In selected example: Tooth shape of crusher jaws: Regular Teeth Crushing gap CSS: 90 mm (optimal capacity)	**Cone crusher:** Adjustment of the cone crusher, see page 188, acc. to chap. "Setting up cone crusher", depending on ▷ Desired grading curve ▷ Continuity of material flow ▷ Optimal utilisation of cone crusher In the selected example: Crushing tools: Standard medium/coarse, 18% Mn CSS: According to desired final grain

Aggregates for the production of road substructure

Variant 2



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	Secondary screening unit: Equipment of the secondary screening unit, depending on ▷ Desired final product (mixed aggregates) In the selected example: Screen media: Wire cloth, CMS 35, 50, 62, 70 mm

3 Economic operation of mobile plants

3 Economic operation of mobile plants

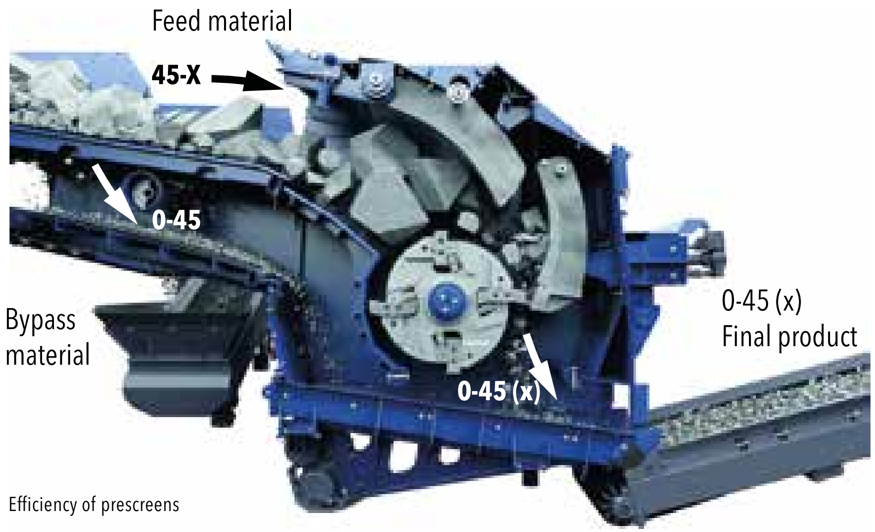
Equipment of the prescreens

⊳ For the equipment of the prescreen the expected screen passages must be roughly estimated. The increasing number of applications where feed material must be processed with a very high content of fines causes a very high strain on the prescreens. An unfavourable grading curve leads to an overloading of the lower deck and thus an inadequate screen quality. The constant switching on and off of the prescreen damages the drive in the long run.

Good to know

The dimension X is dependent on the machine and can be measured for example when changing the lower deck screen media.

The material flow in the lower deck of a prescreen can be checked by lifting the rearward sealing rubber. It can be observed whether the material touches the distance tube.



Efficiency of prescreens

The 0-45 mm prescreen material with corresponding quality can be supplied to the final product, which increases the final product capacity.

⊳ Prescreens and vibrating feeders with integrated grate insert are estimated with a 75% efficiency within the process calculation. In terms of selectivity, as well as proportions of oversize and undersize grain, they cannot be compared with classifying screens. The often contaminated or inhomogeneous feed material behaves differently on the prescreen owing to its granulometric composition. In general, the actual AGW_{UD}, SH_{UD} and CMS_{LD} chosen are greater that would be for a classifying screen, see page 162, chap. "Setting up the primary screening". The undersize of the lower deck therefore does not always meet the standard requirements. It is usually a grain size of 0-25 to 0-40 mm. This material is used, for example for road shoulders, the construction of forest roads or for unsurfaced fairgrounds.

⊳ In the case of feed material with a high content of fines which is easy to crush, the plant is often operated at a feed capacity which is too high for the prescreen in favour of a high output capacity.
To what extent the then sharply reduced screening performance of the prescreen leads to an inadequate final product quality must be checked on a case-by-case basis. A separate primary screening, e.g. with a scalper upstream from the crushing plant, can be applied where necessary.

⊳ If a prescreen is equipped with a frequency converter, the speed of the screen drive can be reduced for sticky feed material and at the same time the amplitude can be increased by adjusting the unbalance weights. Both the load limits of the drive motors, as well as the load limits of the entire structure, must be observed. An increase of the amplitude by changing the unbalance weights with retention or even an increase of the operating frequency is not permitted in most cases.

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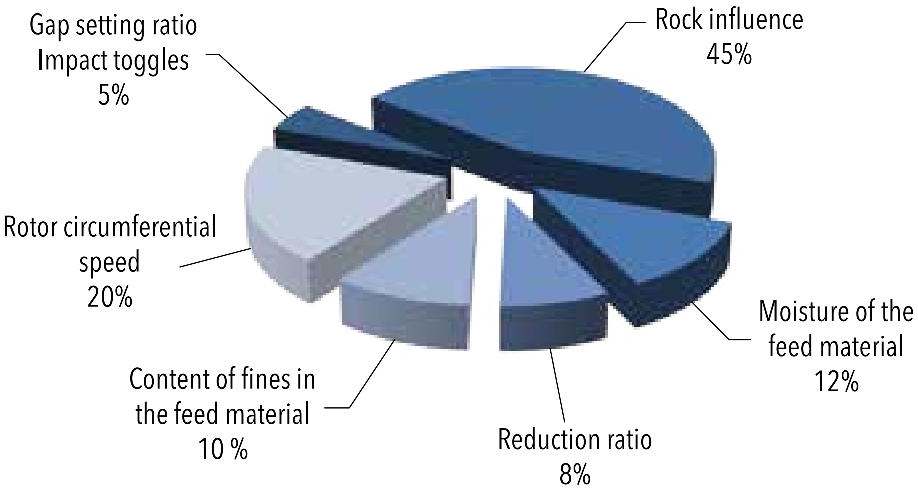
Influencing factors on the rotor ledge wear

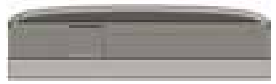


As the rotor ledge wear makes up the largest component with approximately 70% proportion of costs, particular attention must be paid to it. The diagram shows the influencing factors on the rotor ledge wear and the weightings. In addition to the specific rock influence, the rotor circumferential speed, as well as the content of fines and the moisture of the feed material, play a significant role in the wear of the rotor ledges.

Wear characteristics of the rotor ledges

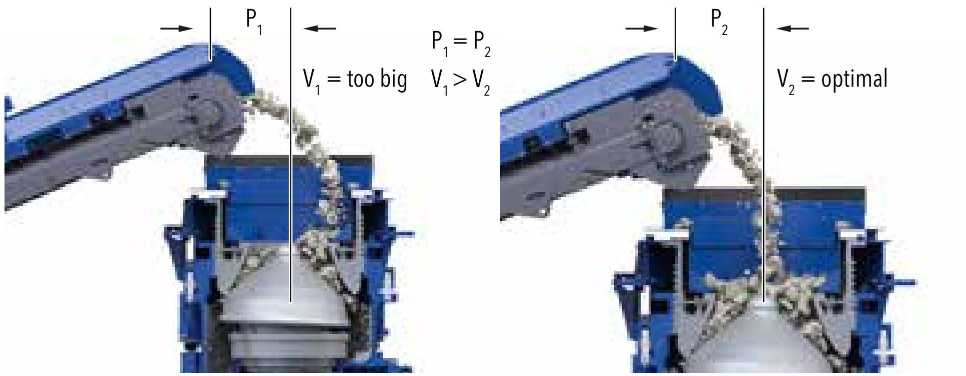
The wear formation on rotor ledges is dependent on many factors. Some factors can be influenced by the correct use of the plant, i.e. the correct setting of the crushing parameters and the correct setting of the material flow. Then again other factors are dependent on the feed material and can barely be influenced at all.

The following table provides some useful information on obvious reasons for wear patterns and tips for possible remedies.

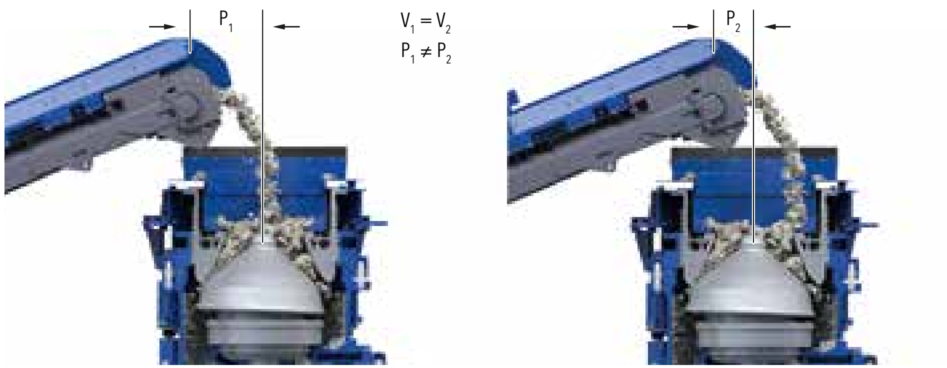
Wear pattern	Cause	Remedy
	▷ Optimal, even feeding with very homogeneous feed material, e.g. for use in secondary crushing	
	▷ High content of fines in the feed material, which drift to the side, e.g. gravel ▷ Clogged crushing chamber: The abrasive wear increases with incrustations at the inner side walls of the crusher	▷ Clean crushing chamber regularly ▷ Check primary screening ▷ Also see page 229, chap. "Examples from practice, lateral wear"
	▷ Large, coarse feed material with low content of fines ▷ Inhomogeneous filling of crushing chamber ▷ Prescreen blocked at the sides, thus less crushing at the sides ▷ Inadequate primary screening	▷ Correct material guidance and primary screening if necessary ▷ Also see page 230, chap. "Examples from practice, central wear "
 	▷ For rotor ledges with ceramic inlays partial missing, broken-out ceramic elements, e.g. as a result of uncrushable elements in the feed material or due to inaccurate integration of ceramic inlays in the wear-resistant casts ▷ Too large feeding size	▷ No feeding of uncrushable material, particularly with use of rotor ledges with ceramic inlays ▷ Only use original wear parts ▷ Do not exceed the maximum feed size
 	▷ Increased oversize grain returning ▷ One-sided feeding unit due to inclined position of plant ▷ Cohesive material / Incrustations	▷ Check positioning and loading of plant ▷ Correct material flow with suitable primary screening

3

Eccentric loading of the cone crusher



Speed of feeding conveyor



Position of feeding conveyor

Two parameters influence the loading:

1. The speed V of the feeding conveyor influences the discharge parabola.
2. The position P of the discharge point influences the impact point of the material.

> **Good to know**
> For a cone crusher with a variable conveyor speed, a setting must be chosen so that the belt conveyor loads the cone crusher centrally in automatic mode.

With centred feeding of the cone crusher, the mantle is loaded approximately evenly around the whole crushing gap. Eccentric loading leads to increased and uneven wear. Also see examples from practice.

For cone crushers with oversize grain returning, the oversize grain should always be merged in front of the crusher, i.e. already on the feeding conveyor. Otherwise, one-sided wear of the crusher may occur on the side of the oversize grain entry.

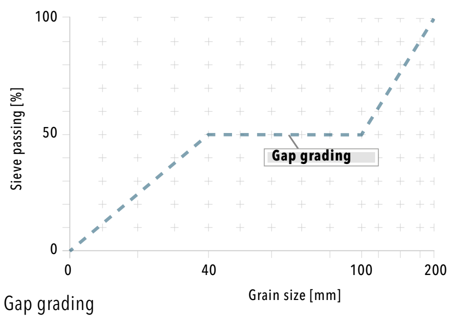
Tips for correct setting of the feeding conveyor:

1. Perform rough setting of discharge point by positioning the feeding conveyor.
2. Set desired crushing gap, if necessary measure at liners.
3. Check the final product quality and correct CSS if necessary.
4. Check optimal fill level in the crusher inlet and if necessary correct the feeding conveyor speed. The conveyor speed is thus constant with homogeneous feeding, i.e. the Continuous Feed System (CFS) controls the conveyor speed within a small range.
5. Move the feeding conveyor so that the discharge parabola meets the mantle in the centre in automatic mode.

Function of gap gradings

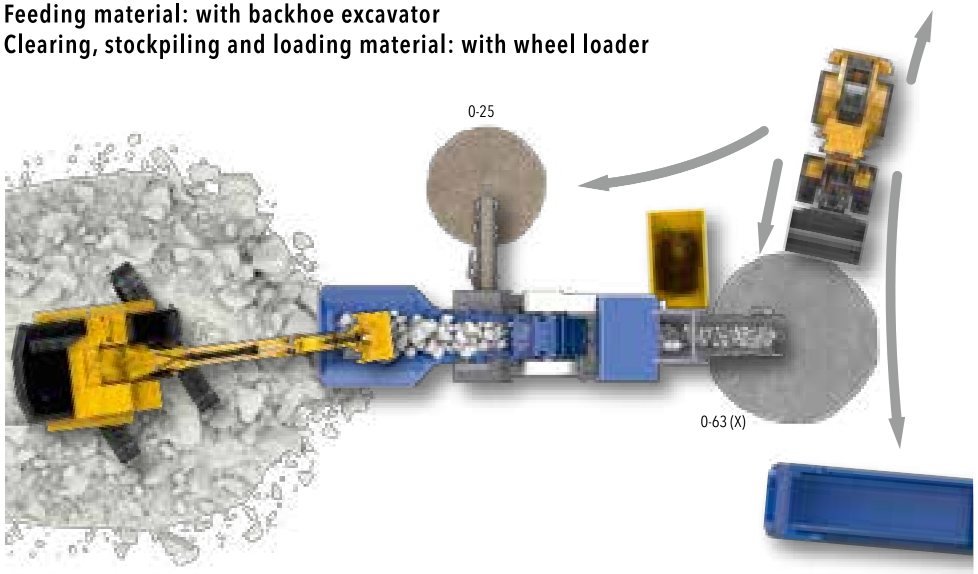
The function of gap gradings leads to partial washouts in a cone crusher.

In the example shown the grain sizes 40-100 are missing entirely with a feed size 0-200.



Gap grading

Variant 1
Feeding material: with backhoe excavator
Clearing, stockpiling and loading material: with wheel loader



Operating with excavator and wheel loader

Applications

- Very suitable for all recycling and natural stone applications
- Particularly economical and efficient with inhomogeneous feed materials such as rubble and demolished concrete
- High daily outputs attainable

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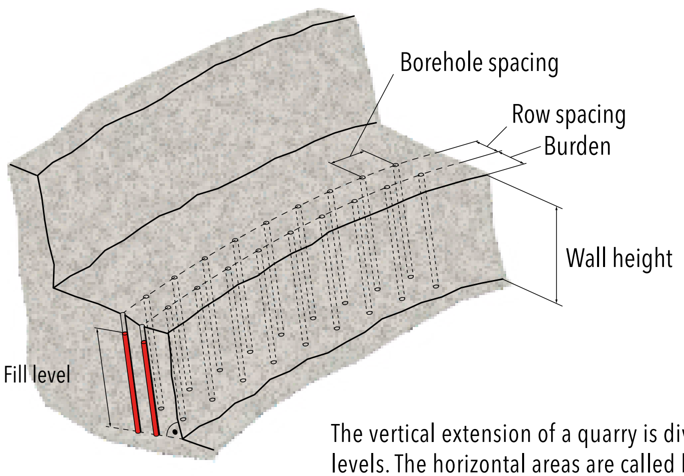
Benefits	Disadvantages
Good view on the feed material Possible preselection of uncrushable material or material that is too big Possible preselection of extraneous materials such as foils and films, insulating material or wood	Wheel loader required for clearing stockpiles and excavator for loading plant Additional personnel costs Additional machine costs Higher fuel consumption Additional transport of wheel loader to operation site required
Consistently short distance to processing plant Material flows at the plant subject to ongoing monitoring, e.g. oversize grain returning, prescreen conveyor, discharge of iron Continuous material feed thanks to short loading cycles	
Good view of material feeding area Better distribution of the feed material in the vibrating feeder With proper selection of excavator and bucket size, a material bed always remains in the vibrating feeder up to the feeding of the next bucket	

Blasting systems

In the quarry the local solid rock is generally mined and precrushed by drilling and blasting. The maximum desired piece sizes of the blasted rock extracted in this manner are based on the capacity of the primary crusher. With the jaw crusher this is calculated using approx. 90% of the feed opening depth, whereas with the primary cone crusher the so-called ball dimension is the determining factor. The stones which are bigger than the feed opening of the primary crusher are called boulders. The quality of a blast is defined by a low number of boulders, the fragmentation of the blasted rock and a flat, level bed where possible at the base of the wall, which enables simple loading of the blasted rock.

A blast can only be performed by an authorised blaster who holds a certificate of competence. If the boreholes have a depth greater than 12 m and a diameter greater than 50 mm, this is called large diameter bore hole blasting. The authorised blaster requires an additional qualification for this purpose, which must be entered on the certificate of competence.



Drilling and blasting

The vertical extension of a quarry is divided into staircase-shaped levels. The horizontal areas are called bedding planes and berms and the vertical areas are called quarry faces or quarry walls. The interface between a bedding plane and quarry face is called an upper or lower breaking edge.

The attainable fragmentation of the solid rock is determined by the specific explosive requirement of the local rock type. This is defined as the quantity of the explosive used per cubic metre of local rock.

The explosive is passed to its field of activity, the rock, via an almost vertical borehole. The inclination of the borehole to the vertical position is identical to the inclination of the quarry face to be blasted.

The boreholes are arranged in a row parallel to the breaking edge. The distance between the idealised upper breaking edge and the line of boreholes is called burden. The burden cannot fall below a certain value. If the burden selected is too small or is reduced by breakouts in the wall, fly stone occurs, as the effect of the explosive after ignition is not absorbed as necessary. If the quarry face exhibits no breakouts but has a relatively smooth surface, a burden of approx. 4 m is sufficient. The distance between the individual boreholes is called hole spacing.

Blasting systems can also be designed in multiple rows. The distance between the individual drill rows is called row spacing.

The so-called borehole pattern is determined from the hole spacing and burden. Multiplying the product of hole spacing and burden by the borehole length gives the idealised eruption volume, which is to be blasted from the wall through a single borehole.

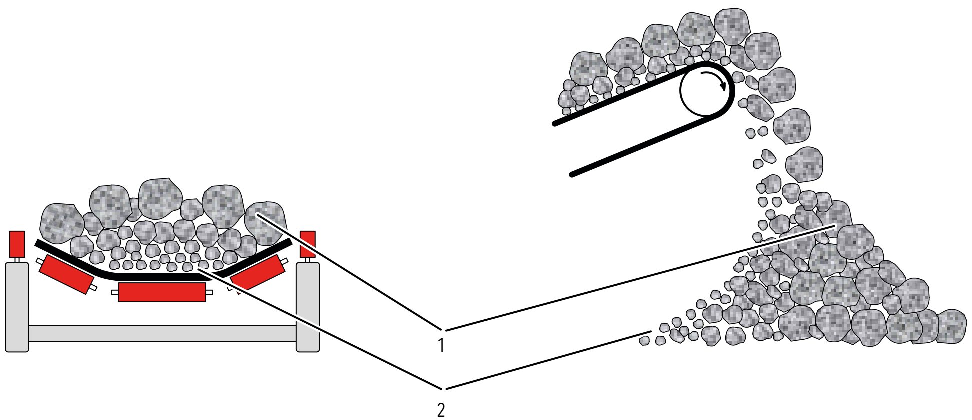
Good to know
Details on the borehole diameters, number, spacing and arrangement of the boreholes, quantity measurement and specific explosive material requirements, can be found in the respective literature.

The borehole length is determined based on the wall height.
In general, the lower bed is tunnel-bored to the extent that a beam at a right angle to the borehole axis cuts the lower breaking edge.
If the borehole is shorter or the same as the wall height, "toes" arise. They are firm elevations on the bed formation level, which significantly impede loading with a wheel loader or excavator.
If the lower bed is tunnel-bored too wide, the blasting vibrations are increased, as the rock must be extracted by "force".

4 Quality of the final product

Taking and evaluating material samples

Samples can be taken from belt conveyors, stockpiles or also from the bucket of a wheel loader.



Grain distribution on belt conveyor and stockpile

1 Coarse grain
2 Fine grain

The mixed aggregates tend to separate inhomogeneously in containers and stockpiles. In order to obtain reliable data for the crushing capacity of a machine and the grain sizes produced, a few points need to be observed when taking samples:

Whenever possible, the sample should be taken from a belt conveyor, which transports an average material quantity and grain size.

The material removed from the belt conveyor allows the calculation of the following values:

- Throughput of machine (in t/h)
- Grain size distribution of material on belt conveyor

Prerequisites for sampling

The following prerequisites must be satisfied for sampling:

- Only take a sample if the machine produces continuous crushing results and it is properly adjusted for oversize grain returning. No faults may occur during the operation.
- The belt conveyor must be stopped using the emergency-stop function of the machine
- Unless otherwise agreed in the contract, up to 4 samples are taken during a test phase
- Corrections are made to the settings of the machine or equipment between two test phases before the next test phase has started
- Each sample must be taken over at least 1 metre of the conveyor belt. The weight depends on the maximum grain size. The table shows the minimum quantity of the sample (also see DIN EN 932-1, Methods for sampling)

Grain size max.	Min. sample
2 mm	15 kg
6 mm	25 kg
10 mm	30 kg
20 mm	45 kg
63 mm	75 kg

Tools and accessories for sampling

For effective sampling it is recommended to have ready appropriate tools and equipment:

- Sampling shovel
- Frame
- Plastic trough for holding the sample
- Dustpan and brush for holding the fine material
- Sample bags made from durable material
- Pen for marking the sampling bags and forms

The hammer has a mass of 14.8 kg. The anvil has an outer diameter of 90 mm and a mass of 3.7 kg. The vessel has an inner diameter of 90 mm and a depth of 100 mm.

- Have 500 grammes of the grain size 8-12.5 mm ready
- Place the sample in the test vessel and put into the testing device
- Position the anvil on the test vessel
- Pull the hammer up to 400 m 10 times and allow to drop
- Remove the test vessel, mix the material and place test vessel into testing device again
- Pull the hammer up to 400 m again 10 times and allow to drop
- Place sample onto a screen with 8 mm passage and screen undersize grain
- Weigh the undersize grain and determine the Shatter Index value in % according to the following formula:

$$SI\,[\%] = \frac{M_{-8\,mm}}{500} \times 100$$

Example: 160 g / 500 x 100 = 32%

SI % = Shatter Index as a percentage
$M_{-8\,mm}$ = Mass of screened undersize grain

- Perform at least one more test and take an average of the results

Classifying the test result

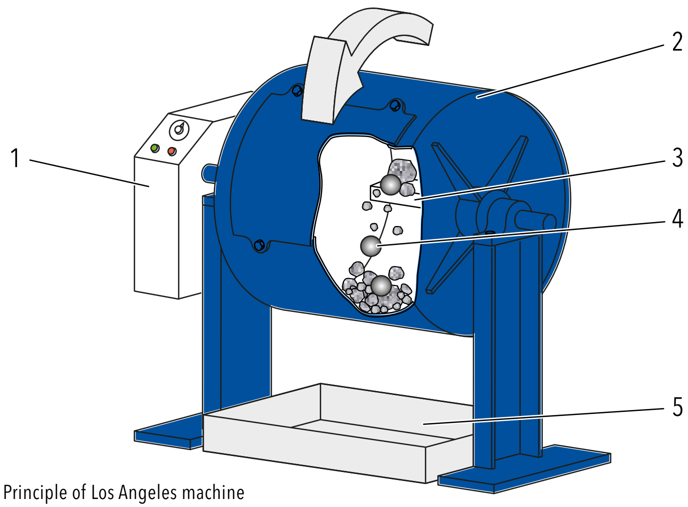
Using the result the Shatter Index value of the rock can be classified into the following gradations:

Shatter Index	
Shatter Index	SI [%]
very easy	>40
easy	35-40
medium	30-35
difficult	25-30
very difficult	<25

Determining the Los Angeles coefficient

The resistance of a rock to fragmentation can be determined using the LA coefficient.

Performing a test



1 Speed control
2 Test drum
3 Shelf
4 Spherical steel balls
5 Collecting container

Principle of Los Angeles machine

Los Angeles machine

Spherical balls, LA test

The procedure is described using the example of the grain size class 10-14.
The weighed rock sample is added to the test drum with the spherical steel balls. This is rotated 500 times at 32 revolutions per minute.

The stones and spherical steel balls are lifted by the shelf with every revolution and thrown against the stones in the test drum.

- Add 5 kg of the rock of grain size 10-14 mm (of which 60-70% < 12.5 mm) to the test drum
- Add 11 spherical steel balls (Ø 48 mm)
- Allow the test drum to run for 500 revolutions at 32 rpm
- Place rock sample into the collecting container and then onto a sieve with 1.6 mm passage and sieve undersize grain
- Weigh oversize material and determine the Los Angeles coefficient according to the following formula:

5 Machinery

Use

Jaw crushers are used for the coarse and primary crushing of brittle, medium-hard and hard rocks. They are used most frequently as primary crushers.

Jaw crushers are seldom able to produce a standard final product. In some recycling applications crushed base layers can be produced for secondary road construction with small jaw crushers. The permissible reduction ratio of 4:1 is often exceeded in practice in order to produce, for example, a marketable final product 0-56. This only functions over the long term for materials whose compressive strength is < 100 MPa. With harder material such an application causes damage to the crusher structure, bearings, shaft or the rocker.

Typical misuses and their effects include:

- Underloading of the crusher due to inadequate material supply. An inadequately filled crushing chamber leads to a poorer grain shape and higher wear.
- Exceeding the permissible reduction ratio, mainly in hard feed material and thus excessive use and premature malfunction of rocker, bearings and shaft.

Good to know
Reduction ratios of different crusher types, see page 338, chap. "Determining the reduction ratio".


Damaged clamping wedges

- Inhomogeneous grain outputs, e.g. when processing ashlar waste material (façade elements, tombstones and worktops) lead to irregular crusher jaw wear and damage to bearings and shaft
- Exceeding the maximum permissible feed size
- Use of inferior quality wear parts causes greater wear on neighbouring wear parts
- Frequent uncrushable elements in the feed material (e.g. massive steel components > CSS)
- Overloading of crusher through improper primary screening

Features	Jaw crusher
Typical crushing stage	primary
Abrasiveness of the feed material	low – high
Influence on grain shape	tends to create flaky grain
Content of fines in the crushed material	low
Reduction ratio at compressive strength	7:1 at <100 MPa 5:1 at < 150 MPa 3-4:1 at < 300 MPa

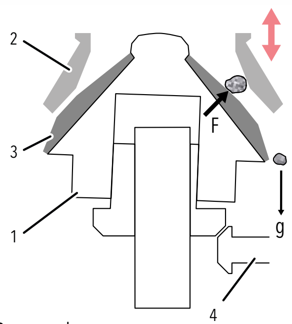
Applications of jaw crushers

Natural stone	Limestone	Sandstone Gritstone	Greywacke	Gravel	Granite	Gneiss	Marble	Quartzite	Diabase	Gabbro	Basalt	Iron ore	Coal	Clay
Recycling	Demolished concrete	Reinforced demolished concrete	Rubble								Asphalt	Blast furnace slag		Steel slag

Operating principle

Crushing mechanism of cone crusher

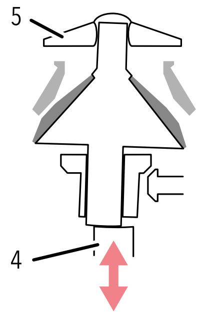
Crushing mechanism of cone crusher



Cone crusher

With these crushers the crushing is effected by pressure crushing in an opening and closing crushing gap between the bowl liner and mantle. The opening and closing are effected simultaneously on the opposite sides of the crushing chamber.

With the KX cone crusher the crusher axle is pressed into the main frame. The mantle support **1** is mounted on an eccentric hydraulic drive **4**. The gap between the mantle **3** and bowl liner **2** is opened continuously with the rotation of the hydraulic drive. The grain size to be produced is changed by lifting or lowering the bowl liner.



Gyratory crusher

In contrast to the cone crusher, which has a fixed shaft, on which the hydraulic drive and the mantle support rotate, the gyratory crusher has a hydraulic main shaft which can be moved in a vertical direction, on which the mantle support is firmly shrunk. The shaft is supported axially at the bottom on a thrust bearing **4**, which is on the adjusting piston. The crushing gap adjustment is effected by lifting and lowering the adjusting piston and thus also the main shaft. At the top the horizontal crushing forces are transferred to the top part of the crusher via the head bearing, which is integrated in a crossbeam **5**, the so-called "spider". As the spider is able to obstruct the material flow to the crushing chamber especially with smaller models and for large pieces of feed material, gyratory crushers are distinguished into secondary crushers, as well as tertiary and quaternary crushers.

Owing to its design, the height of a gyratory crusher is generally significantly greater than that of a comparable cone crusher. Secondary gyratory crushers have a slim mantle support and generally have a three-piece crusher housing. The mantle support of a tertiary or quaternary gyratory crusher is also compact, like that of a cone crusher.

Final product quality

The quality of the final product produced depends significantly on the integration of the cone crusher in the overall process. Subject to compliance with the permissible conditions such as feed size, granulometric composition and reduction ratio, a cone crusher produces standard grain sizes if the rock properties permit this.

Costs

The operating costs of a cone crusher are slightly higher than with a jaw crusher. However, they are significantly lower in hard, abrasive stone than with an impact crusher.