Metso

Manufactured sand application guide

Why not natural sand?

Sand is the most consumed natural resource on the planet besides water. It is the primary raw material that modern cities, glass and technology equipment are made from. Concrete, in particular, requires massive amounts of sand. The sand used to make concrete must have an angular shape, so the sand found in the beds, banks and floodplains of rivers, lakes and sea shores is more suitable than other natural sand (such as desert sand). The enormous demand for this raw material has led to overexploitation of the natural deposits, which results in the significant negative consequences for the planet.

Why manufactured sand?

Manufactured sand serves as a substitute for river sand, but its production involves a carefully designed and controlled manufacturing process to meet the specific product specifications required for various applications. It is also more environmentally friendly since less natural sand is dredged from a dynamic environment.

Manufactured sand is produced from rock quarry crushed fines surplus or other quarry waste materials. When unsellable crushed fines or quarry waste materials are transformed into saleable premium quarry products, it creates a win-win situation for the environment.

Nowadays there are several manufactured sand specifications and standards for the different product applications. Thanks to modern technologies and an improved understanding of aggregate behavior, various crushed waste materials can be processed into high-quality products, suitable even for concrete applications.

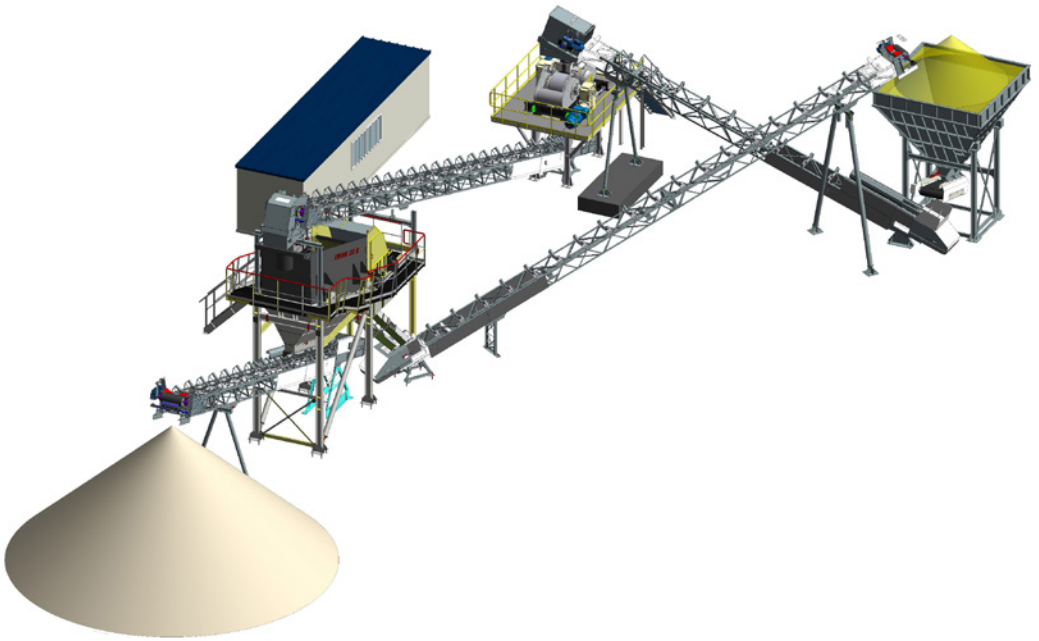
Here are some definitions for sand by fraction and geology.

Silt 0.002 – 0.063 mm	Sand 0.063 – 2mm	Gravel 2 – 4 – 64 mm
Definition by fraction and standard: • Fine aggregate • Fine naturally graded aggregate • EN standard sand • ASTM Unified soil classification **Definition by intended use:** • Structural sands • ASTM C33 concrete sand • EN Fine concrete aggregate • Asphalt sand • Functional sands	0.8 – 2 mm	0.063 – 6.3 mm 0.063 – 8 mm 0.075 – 4.75 mm 0.063 – 8 mm (10 mm) 0.063 – 4 mm 0.063 – 8 mm

By using high-quality manufactured products in cement and liquid applications, manufacturers can save significant costs. Moreover, it is better for the environment, as the reduction in CO_2 footprint during construction is directly related to the use of manufactured sand. The biggest advantage of manufactured sand, however, lies in its quality control. While manufactured sand may never behave exactly like natural sand, a high-quality production process can minimize variations in behavior. Customers can rely on the consistent quality of the manufactured sand product, ensuring reliability and consistency.

The consistent quality is determined by these three factors:

- Clean rock
- Grading meets the specification
- Cubical shape

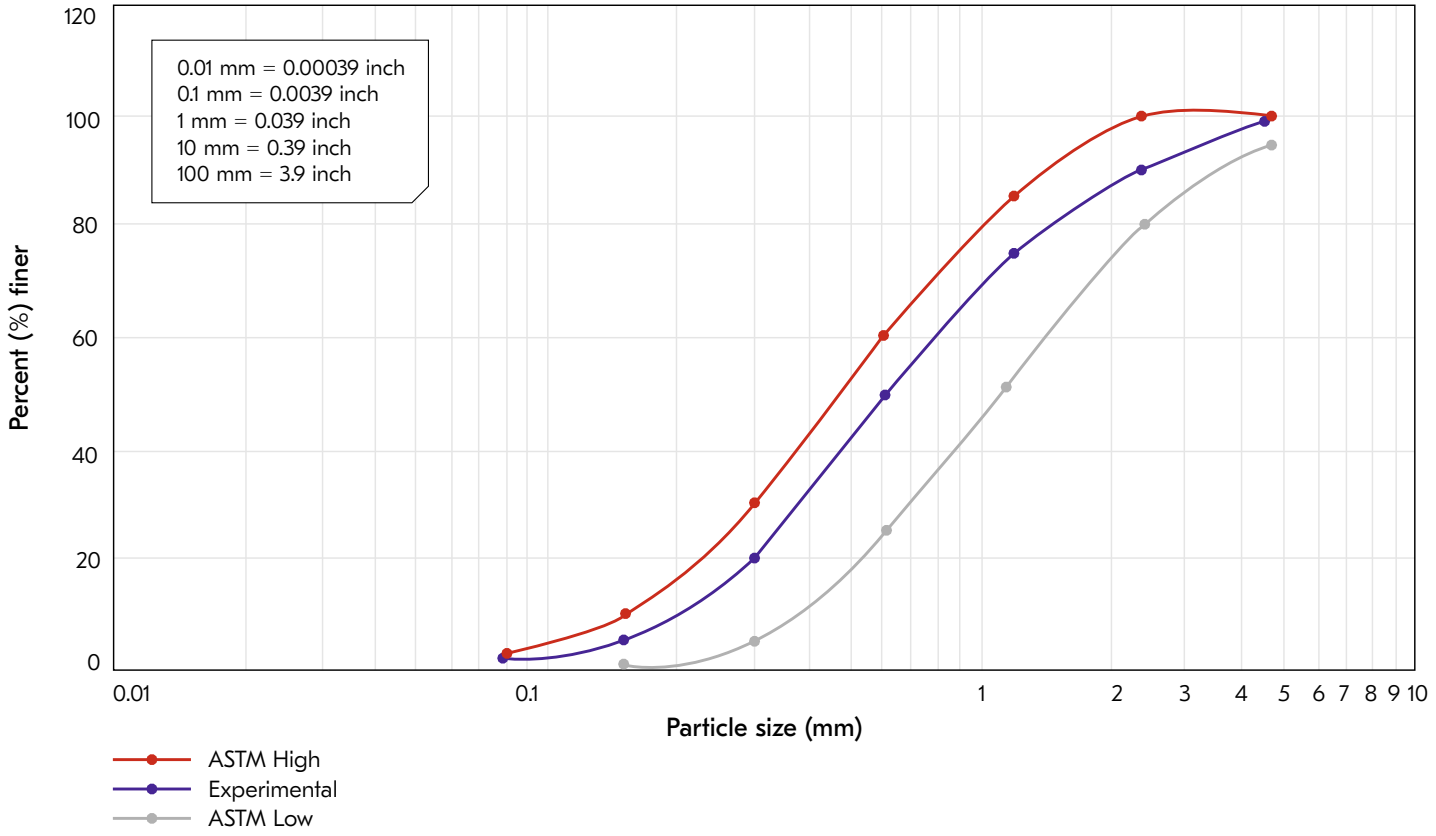


Manufactured sand: Metso's process

One of the main reasons customers look for natural sand alternatives is because they require a consistent product quality. Natural sand gradation curves are severely affected by natural phenomena like river floods, heavy rain, weather conditions and so on, whereas manufactured sand is always the same.

In large infrastructure projects like hydroelectric dams, extensive tests on massive concrete revealed that some required concrete properties were achieved only by replacing the use of natural sand with manufactured sand. It was very difficult to achieve similar results with natural sand due to the excess of fine particles (<4.75 mm and >2.4 mm) that needed to be rejected or re-crushed. These particles become almost uncrushable due to the very low mass, and they have to be broken into smaller pieces to fit into the gradation curve required to meet the sand specifications.

Example of the concrete sand specification under ASTM C-33 Specs:



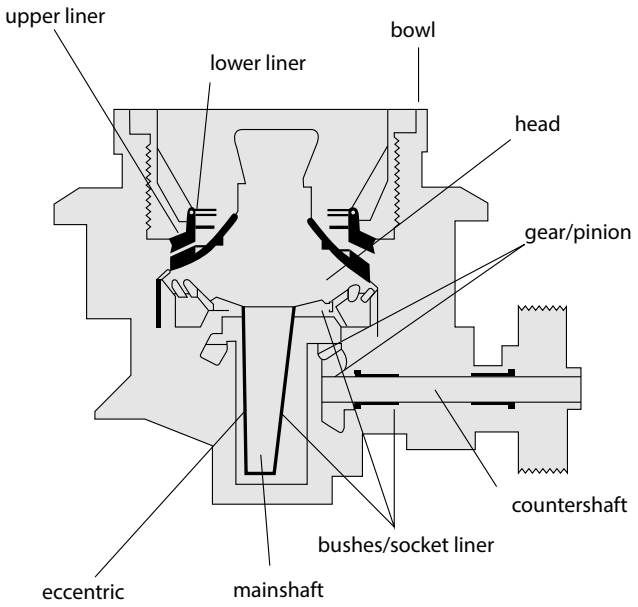
Old technology that inspired the new ones

Nordberg, now part of Metso, designed the Gyradisc cone crusher. This crusher fit into an appropriate flow circuit and can re-crush all the particle sizes, producing well-graded manufactured sand. The Gyradisc was a machine designed with a very heavy-duty design and special crusher dynamics to achieve very high comminution of particles inside the crushing chamber.

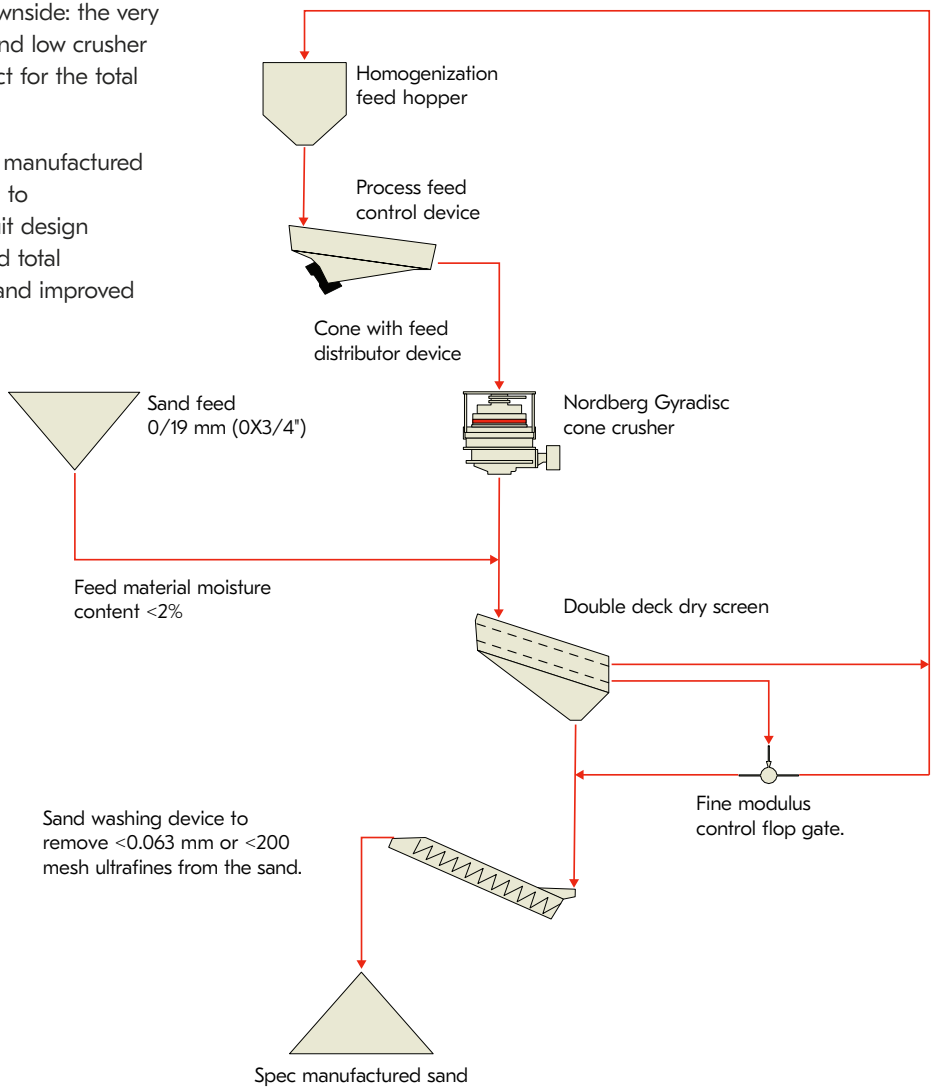
Well-graded manufactured sand assisted concrete producers in maintaining consistent concrete quality for their batches and also contributed to cement savings.

However, this technology had a downside: the very high circulating load in the circuit and low crusher performance in terms of net product for the total volume processed and kW applied.

The same principle of the Gyradisc manufactured sand process is successfully applied to other technologies and similar circuit design configurations, resulting in increased total production volume of net product and improved product quality.



The Nordberg Gyradisc Crusher



Typical process arrangement with the Nordberg Gyradisc cone crusher in C-33 manufacturing sand

New generation cone crushers in manufactured sand

For hard and abrasive materials, cone crushers are utilized in several manufactured sand applications.

To produce fine, well-graded manufactured sand with cone crushers, the crushing circuit process configuration should be very similar to Gyradisc. However, if the machine runs in a closed circuit to 2.4, 3.2 or 4.75 mm screen opening, the crusher configuration would have to be very carefully selected as it is extremely sensitive to moisture and packing. The packing effect occurs when the excess of fines in the crushing cavity becomes incompressible, causing the crusher behavior to resemble that of a piece of steel passing through the machine. Avoiding this condition is crucial.

Cone crushers must operate constantly at choke feed conditions to achieve high density in the crushing cavity and obtain the best product quality in terms of product gradation and shape, maximize energy efficiency and optimize the wear of liners. That is why it is important to have a surge bin ahead of the crusher and an automated feed control.

The product shape received from cone crushers is angular, making it ideal for diverse manufactured sand uses, even for concrete. Achieving a high inter-crushing effect from a high-density choke feed cavity will produce the best particle shape from cone crushers, and, depending on the feed material characteristics, amounts of <200 (0.074 mm) mesh in the sand from average 5-10%.

For most fine manufactured sand applications, the top feed size should be limited to 20-25 mm, depending on the crusher size and liner configuration

High circulating load is also a common characteristic in these circuits, so the screen area should be carefully selected in order for the process to be effective. The correct selection of screening media is also one of the most important elements for this arrangement to work.

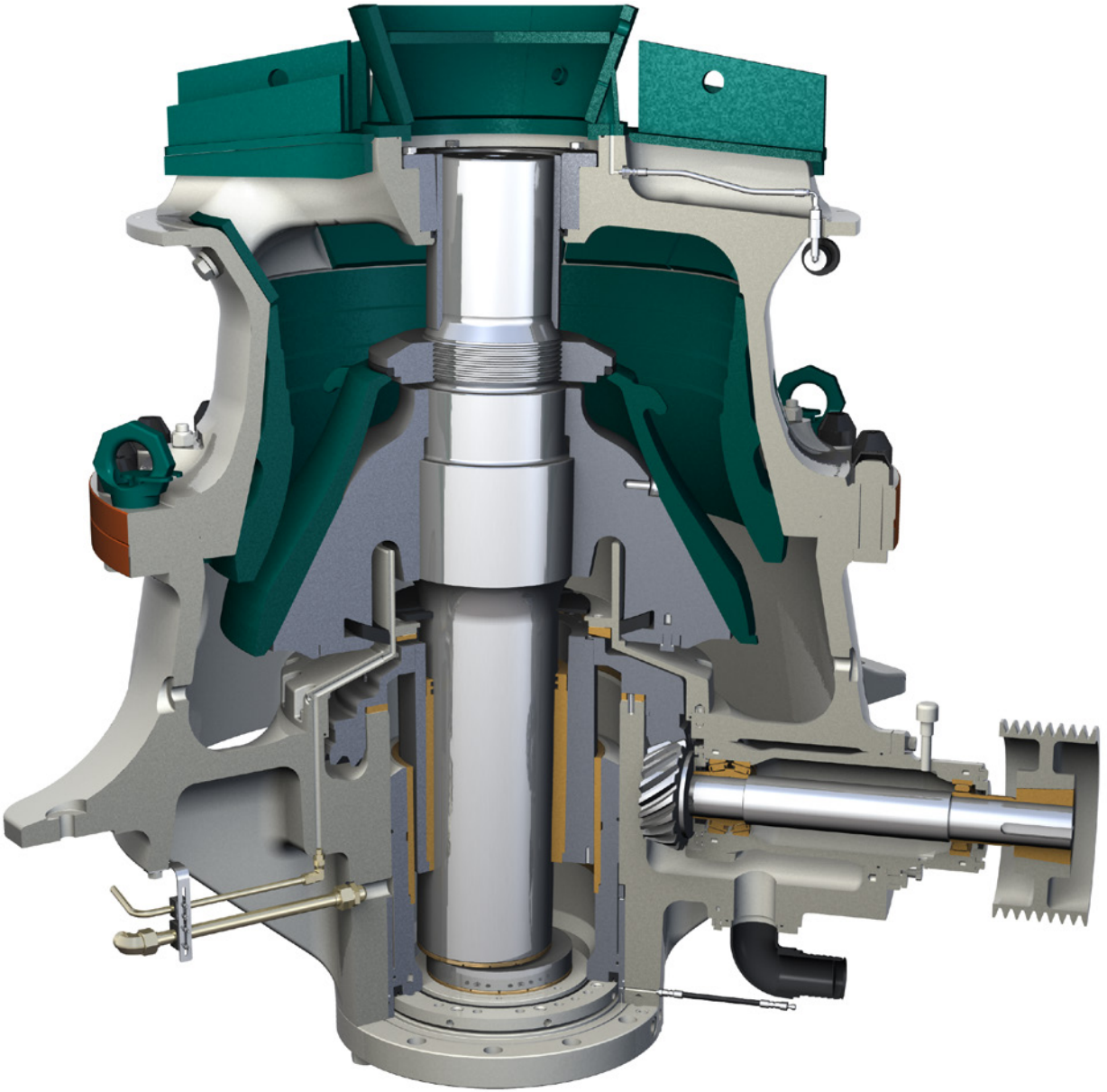
In general terms, all cone crushers should be configured with a fine or extra fine crushing chamber for those applications. Compressive crushers can have a much better cost per ton compared to impact crushers in similar applications.

In a well-operated manufactured sand operation, compressive crushed sand will meet the requirements of the concrete industry, while the sand may be described as showing harsh workability, the manufactured sand will create high compressive strength concrete as already proven in several large infrastructure projects around the world.

Cone crushers can be selected for manufactured sand applications when:

- The material to be processed is very hard and abrasive
- To produce coarse sand (normally <6 mm)
- In fine sand production applications, the feed material should be clean and the fines content of <6 mm and <4.5X2 mm must be carefully controlled to avoid the “packing effect”
- The feed material should be dry, but with moisture content tolerance up to <2% in some cases depending on the feed curve, the type of sand to be produced and the crusher cavity selected
- If a cone crusher is selected to process soft materials, the feed must be dry
- Moisture in the feed material in manufactured sand applications affects the process screening efficiency, making it very difficult for the cone crushers to run under a high amount of fines returning to the machine.


metso
HRC™8



GP Cone crusher technology

Metso GP series cone crusher

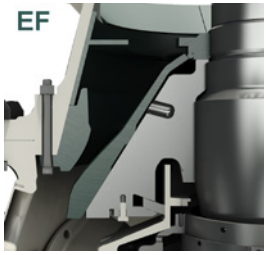
Metso GP series cone crusher is a machine with a floating shaft. The floating shaft rests on a hydraulic piston that allows moving the mantle up and down to change the crushing cavity setting. This movement is allowed even during the crushing by applying or removing oil pressure to the piston zone.

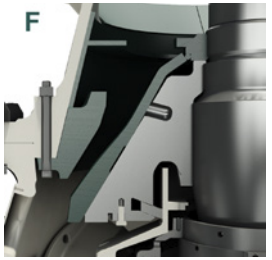
In manufactured sand applications, the automation system or a GP cone crusher IC50C can monitor and control the feeder speed according to the crushing chamber's feed hopper level as well as the crushing cavity setting, the piston pressure and power draw. The automation system adjusts the parameters according to the process needs to maximize the crusher efficiency and protects it at the same time.

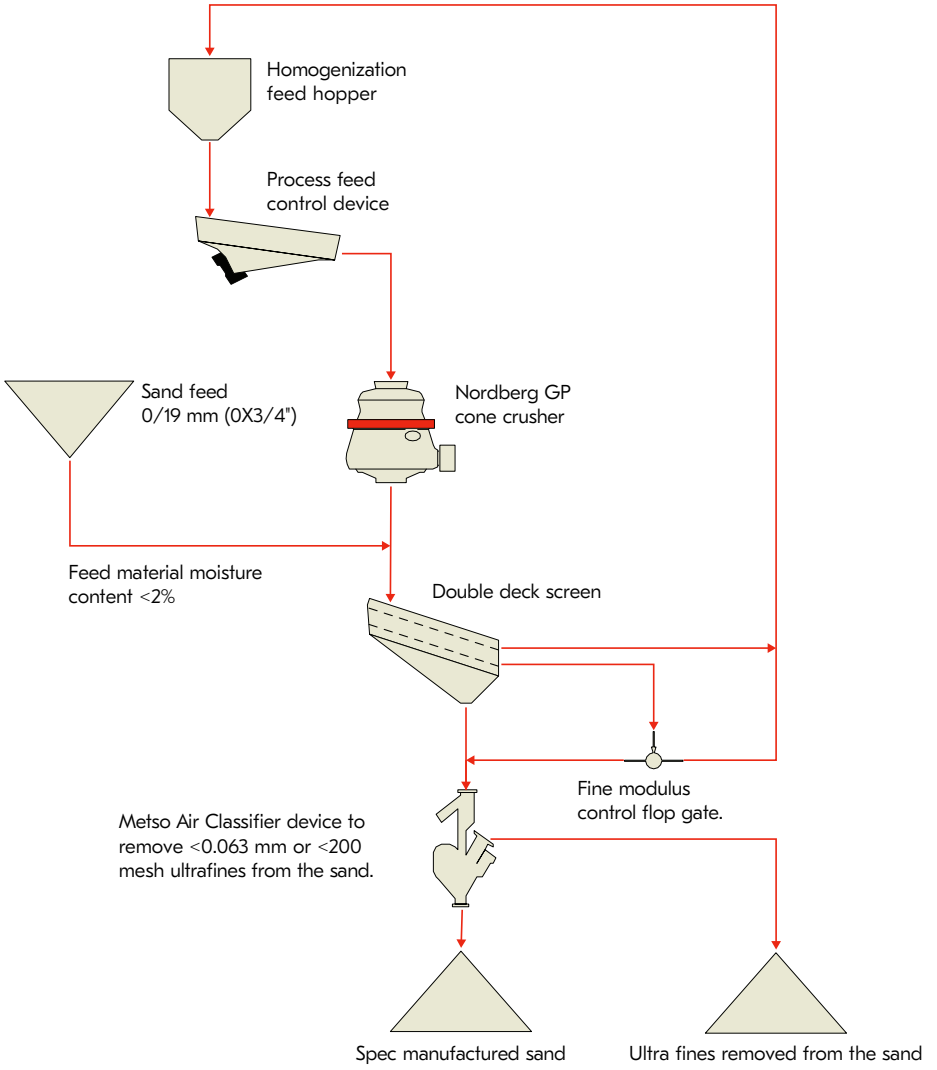
Depending on the application, fine (F) or extra fine (EF) cavities could be used in the GP cone crusher for manufacturing sand. Due to the high-density requirements in the crushing chamber, constant power and piston pressure monitoring are done by the IC automation system to protect the machine.

A series of tests have been performed in India on a GP220 equipped with a 220 kW motor and very good results were achieved in terms of product gradation. Fine and extra-fine cavities were utilized in the test, feeding 5x30 mm and 5x70 mm granite rock, combining 28 and 36 mm strokes at 12 and 16 mm CSS.

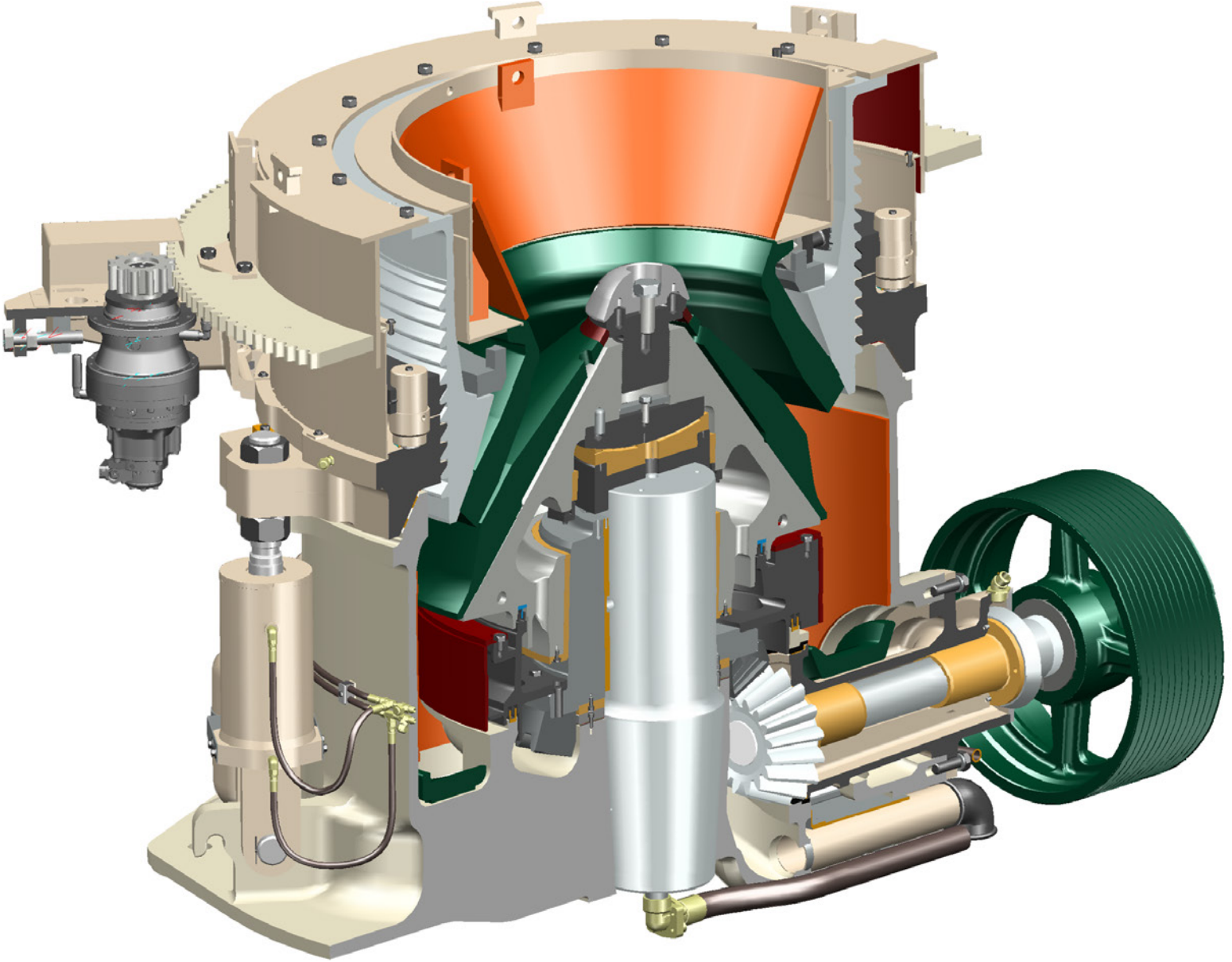
An average of 43 MTPH was the production 100%<4.7 5mm, feeding an average of 165 MTPH to the crusher. It was proven that by configuring a GP220 to a F for EF cavity, it is possible to produce manufacturing sand.







Typical process arrangement with the Metso GP cone crusher in manufacturing sand



HP Cone crusher technology

Metso HP series cone crusher

The main difference between the GP and HP technologies is the fixed main shaft in the HP cone crusher. To adjust the crushing cavity closed side setting (CSS), the upper part of the bowl can be moved up and down by a hydraulic motor which rotates it on a threaded external surface.

This operation can be only performed when the crushing cavity is empty, oposite to the GP crusher which can be adjusted under load. When the CSS is achieved, the threads are locked into a position by a hydraulic piston.

The crushing dynamics generated by the HP cone crusher design allow for a higher hold-down force of the upper part of the crusher. This force, when applied to the fixed shaft, results in a high crushing force that will be exerted on the feed material, leading to a higher reduction ratio. Along with the optimized combination of crusher speed, eccentricity and cavity profile, it enables HP technology to achieve higher capacity with greater density in the crushing chamber. As a result, it achieves more interparticular crushing compared to GP technology. However, this interparticle crushing effect, while necessary for producing high-quality fine manufactured sand, also makes the crusher very sensitive to an excess of fines in the feed and to the moisture content in the feed material.

The crusher can be applied in tertiary or quaternary applications for manufacturing sand, but in fine sand applications the ideal configuration is the extra fine cavity configuration.

The IC automation system is also available for the HP technology, and it is necessary in manufacturing sand applications to optimize the process performance.

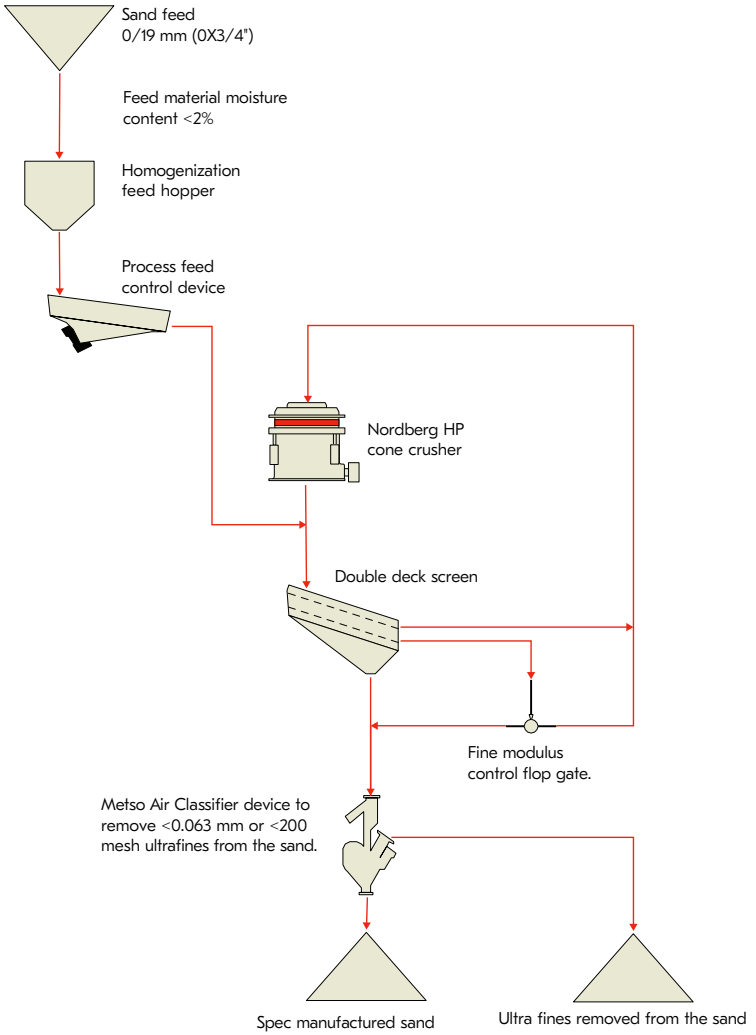
In a recent test run (27 tests in total) with HP100 using EF liners, with countershaft speeds variation from 1050 to 1250 RPM, the following average results were obtained:

- 51.4% of sand <6.3 mm
- 31% of sand <4.75 mm
- 19.1% of sand <2 mm

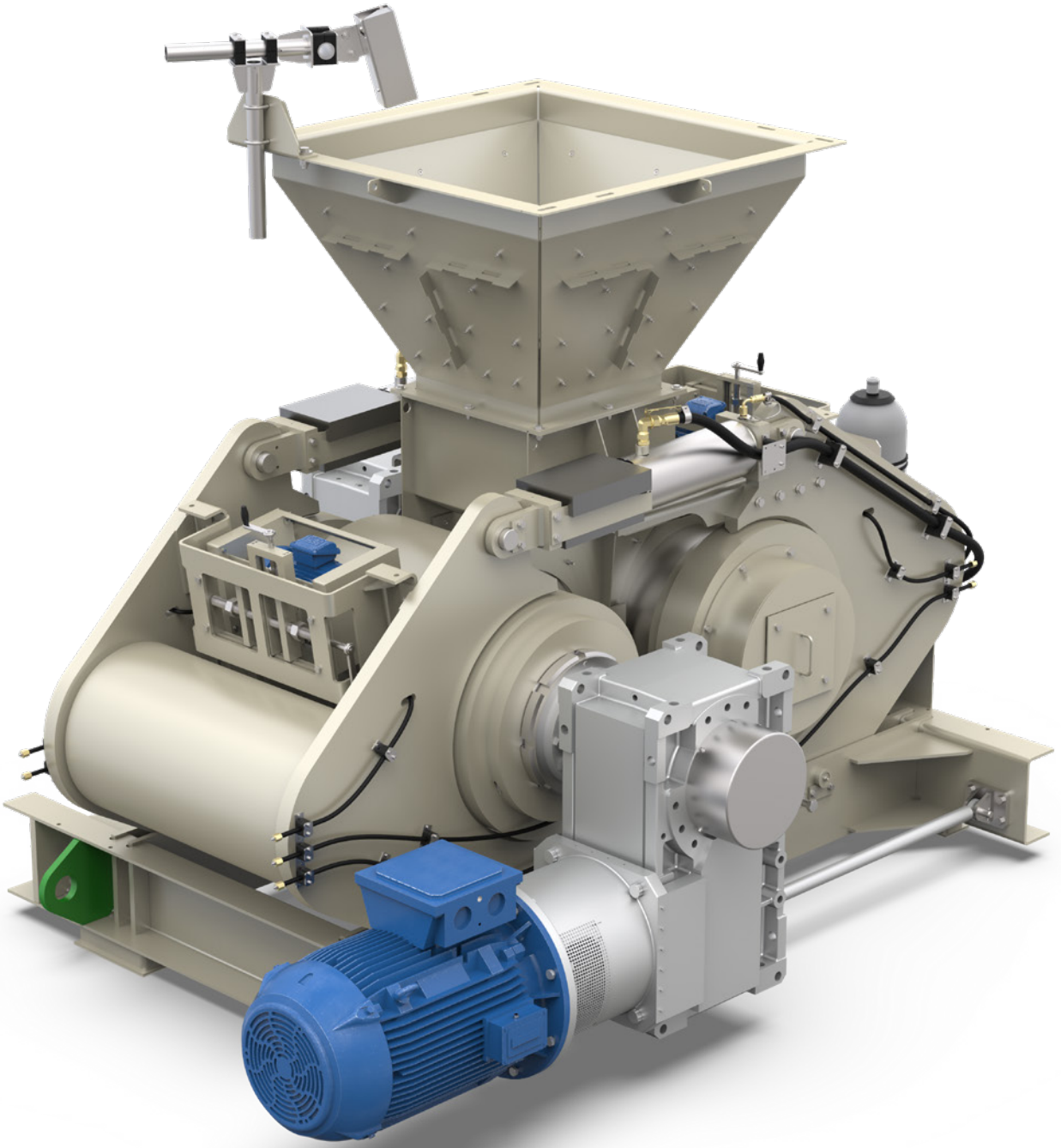
The scale-up of those results can be projected to larger machines utilizing the same cavity profile. The average content of <0.074 mm in the sand was 12.7%.

By using these test results and several other applications, it has been proven that HP crusher technology equipped with F and EF cavities can produce manufactured sand and meet several specifications for asphalt and concrete applications.

The process must be configured to achieve the purpose, and the screening efficiency as well as the process automation control play a very important role.



Typical process arrangement with the Metso HP cone crusher in manufacturing sand



HRC8 crusher

Metso High-pressure roll crusher (HRC)

Since cone compression crushers can perform very well in manufacturing sand applications, especially in hard and abrasive rock materials, engineers have been pondering for years how to design a crusher that wouldn't be so sensitive to "packing" due to the presence of a high percentage of fines and moisture in the feed, while also being automated and reducing the cost of high-quality sand production.

The engineers were seeking to create a solution that would apply very high crushing forces to a well-graded grain distributed feed material, making it easier to get a high interparticular crushing effect and control it.

They aimed to avoid high velocity as wear increased relative to the square of the speed. Additionally, the machine needed to be robust without an easily damageable mechanism.

The high-pressure roll (HRC) crusher was their solution. The slow-moving rolls, with almost no material friction or griding compared to other technologies, promised to have a very long life to the wear parts. Hydraulic cylinder with modern oil control valves allowed the application of high crushing forces to the feed material. A very sensitive control capability facilitated easy changes to the product gradation, providing a quick reaction to relieve the overload from non-crushable materials.

From the process point of view, the HRC works like a compressive crusher. The material is squeezed between the two rollers, their circular arc comes closer until the smallest point between the rollers. There is the point with the highest crushing force in the bulk bed between the roller surfaces which allows a very high interparticular crushing.

Furthermore, there is a possibility to adjust the crushing force by changing the hydraulic pressure in the system. This means that the product gradation and performance can be adjusted to the process and material needs. With the ability to adjust the roller's speed, the entire HRC performance can be fine-tuned precisely to the material requirements, optimizing production. The crushing process and capacity are not directly linked and can be adjusted individually.

As the HRC operates as a slow and continuously moving machine, noise, dust and vibration emissions are minimal, thus the plant layout remains simple.

Compared to cone crushers, HRC is not sensitive to fines in the feed, since this machine implements the crushing force in a controlled way. There are less voids in the bulk between the rollers, meaning that the operation gap stays bigger, but the crushing force remains the same, which allows to achieve a high crushing cavity density. It can also handle sticky material with high moisture and some impurities in the feed like organics, clay or other deleterious materials.

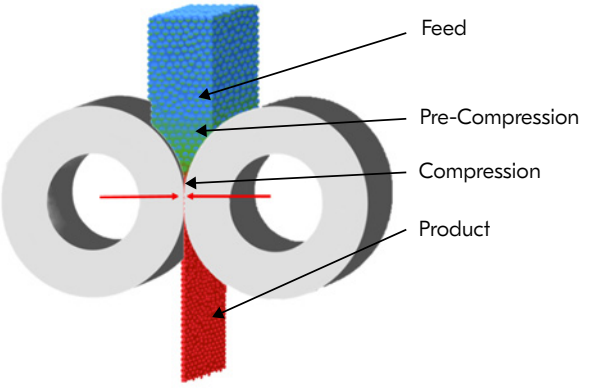
While abrasive, wet, contaminated and fines-containing feed combinations create a lot of wear in other comminution equipment, the HRC has demonstrated long lifetimes on its rollers in long-term operations. This makes it an ideal crusher for sand and gravel applications or for wet manufactured sand processes.

It is also reported that HRC reduces fine fractions, resulting in an excellent angular shape. The operation with low voids in the feed and high pressure creates the best cubical shape for asphalt and concrete applications.

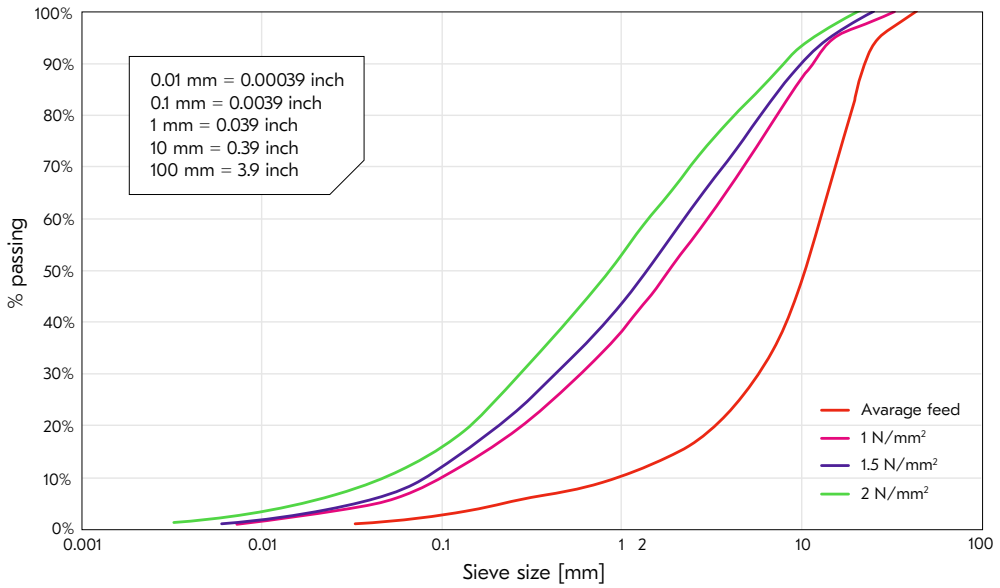
The adjustable high crushing force makes the HRC to be the machine with the best reduction ratio for sand fractions. Additionally, it produces more sand in open crushing circuits than other crushers. This capability allows to produce manufactured sand in a closed process with less recirculation and less load on the product screen.

Less circulation due to higher crushing work means less power is needed for sand production, making the HRC one of the most power-efficient crushing equipment options. When combined with the long lifetime of the rollers, it appears to be the most cost-efficient machine for manufactured sand production.

Furthermore, the HRC generates less dust. As it quickly achieves the desired sand fractions in the product, fewer fines are created compared to VSI and compressive crushers.



The Metso HRC crusher principle of crushing

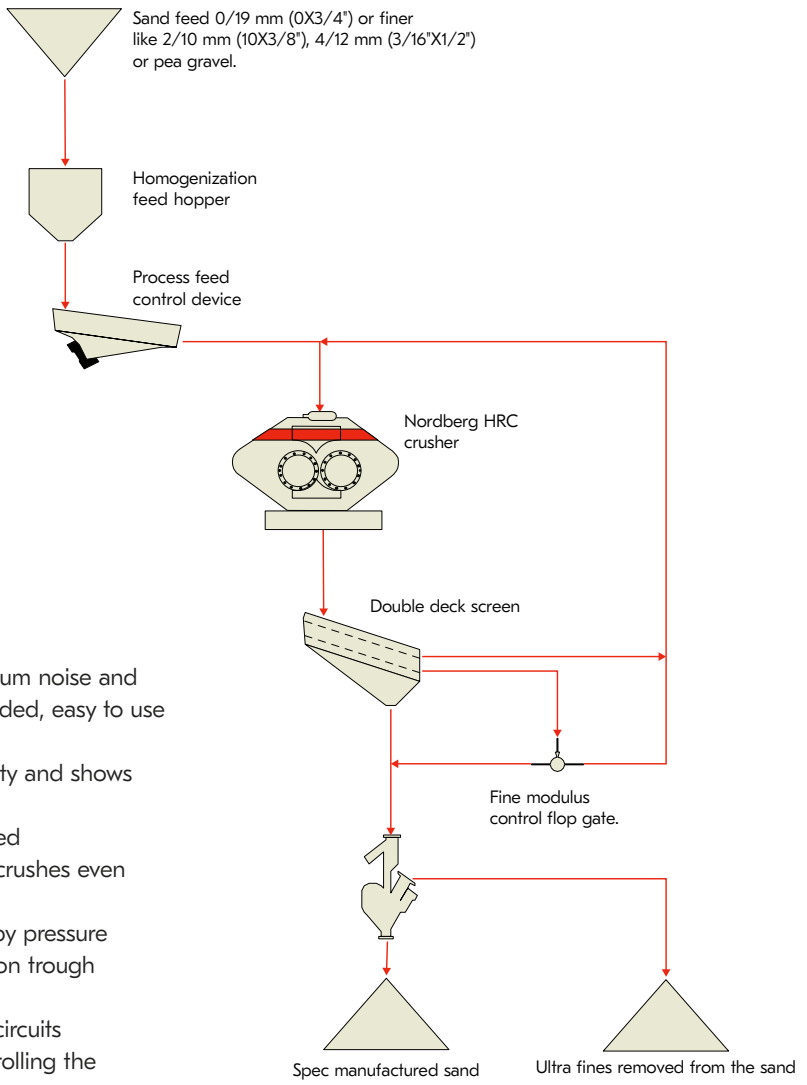


Product gradation from different crusher technologies to produce <4 mm sand

The crushing force can be adjusted, which is a substantial benefit, as the discharge curve of the HRC product can then be optimized to the manufactured sand production needs. Test with different forces showed a direct relation to the product PSD. The same tests also revealed that the coarse end and the fines end of product PSD don't change a lot with the different pressures, but the middle fraction in the range of the desired sand envelope is heavily influenced. The changes of the production (0/2 from 42% (1N/mm²) to 58% (2.5N/mm²)) are visible in the test result diagram.

HRC conclusions:

- The HRC can turn waste materials into high-value products, it can process feed materials where other crushers can´t or don't do it efficiently enough
- It produces more sand with fewer ultra-fines <0.074 mm
- It has less power consumption in sand production (up to 50% less)
- Compact design, no vibrations, minimum noise and dust, no scalping or prescreening needed, easy to use
- It can process high-abrasive materials
- It crushes materials with low crushability and shows a high reduction ratio
- It is not sensitive to moisture in the feed
- It is not sensitive to fines in the feed, crushes even sand fractions <6 mm or 4 mm
- The product curve can be optimized by pressure adjustment even from a remote location trough automation
- Steady production in open or closed circuits
- The capacity can be adjusted by controlling the rolls speed
- Minimizes energy and wear cost
- Limited max feed size 32 mm for the HRC8
- HRC must be operated in choke feed condition
- It is an ideal technology to produce high-spec manufactured sand with a strict FM control



Typical process arrangement with the Metso HRC crusher in manufacturing sand

*FM: Fineness modulus is an index number which represents the mean size of the particle in the mix.

Metso impact crushers

Impact crushing is a process that uses speed in combination with the fragile behavior of the material to be crushed. The easiest and most compact way to create speed is to turn a rotor and create a very high speed on its perimeter. The crushing action with shattered fragmentation takes place in three ways:

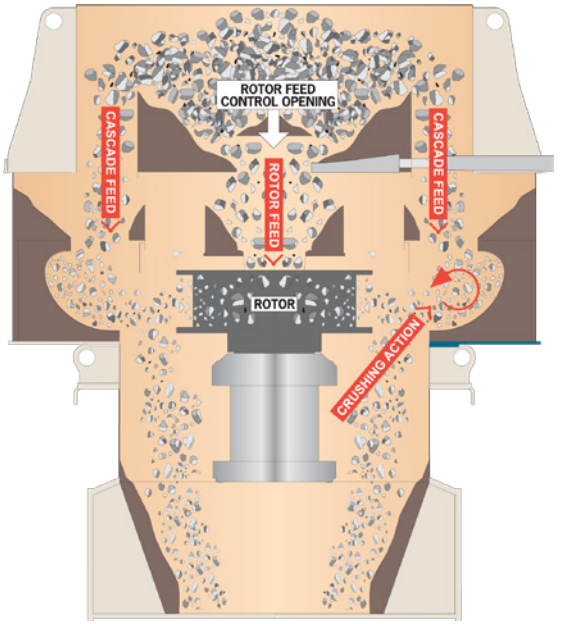
1. High-speed surface hits a particle
2. High-speed particle hits a surface
3. High-speed particle hits another particle

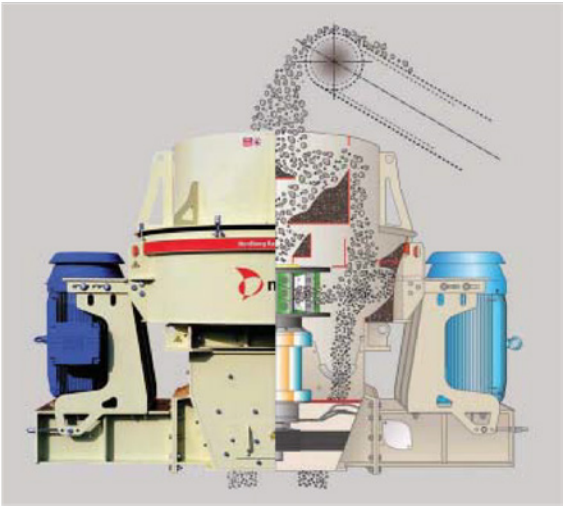
The energy that breaks the rock is not a static force (e.g., when you squeeze a rock between two surfaces). It comes from the dynamic impulse that is stored in the high-speed movement. The impact, when an impulse is transferred to and from a particle, creates an enormous shock inside the texture of the material. These shock waves go along the crystal surfaces and break the particle. As a result, a homogeneous particle size distribution is created.

Similarly, as the shock waves are distributed in almost all directions inside the mineral matrix, the shape of the progeny particles has a highly cubical characteristic.

The impulse is determined by the product of mass and the speed. This causes those small particles to have less impulse. During the collision, the sand size particle has less energy to transfer, and this energy may be too small to break it. This explains the rule of thumb that coarse crushing goes with moderate speed and fine crushing with higher speed.

Fragmentation effect in the crushing actions of fines appears too. As the energy is less likely to break the whole particle, the surface texture can still be influenced and result in chipping and attrition fragmentation. Therefore, impact crushers designed for fine crushing in tertiary and manufacturing sand applications show a well-shaped and rounded sand product.





Barmac VSI crusher

Barmac VSI rock on rock principle of crushing
Metso VSI crushers have a reputation of producing the best particle shape compared to compression crushers. When designing the Barmac VSI crusher, the goal was to make a smaller rotor, position the axis to have vertical rotation and feed the material into the center. These properties result in a low speed at the feed point, with speed increasing parallel to the acceleration of particles as they move from the center to the radial openings of the rotor. Limited impact allows Barmac rotors to reach speeds of up to 45 to 75 m/s, nearly doubling the previous speed. Consequently, the kinetic energy of flying particles in a horizontal shaft impactor is quadrupled, enabling effective crushing of finer grain sizes.

The second part of this invention involved using the rock-on-rock principle for crushing to reduce wear. As material exits the rotor in a horizontal ballistic movement, a rock box filled with material creates the impact zone. The advantage of it is that there is less wear and one impulse is used to impact two particles.

The Barmac is primarily used in a shaping process. The secondary and tertiary crushing material is fed into the Barmac, it breaks mainly the flaky and elongated particles. It also breaks off the edges and sharp rims of the coarser aggregates.

Another usage for Barmac is as sand making machine, since it creates the best rounded manufactured sand. For years, Barmac crushers have been integral to sand production in many plants.

The Barmac VSI type crusher is a very robust process machine. This processing machine with no production gap, like a close side setting CSS, is less sensitive to fines and other variations in the feed. The only limitation is the top size of the stones fed into the rotor. The large model B9100SE can pass around 50 mm stones through the rotor channels. It is also insensitive to capacity variations.

Despite of the very different parent rock crushability or the initial particle shape, the Barmac can process most of the possible rock types.

It is proven to be one of the greatest machines for sand manufacturing, since the end-product has a good, evenly rounded shape, and the quality is not influenced by CSS. The shape of the sand can be described as equidimensional, with the sizes down to 1 and 2 mm. A test showed that Barmac influences the shape of particles down to the fine fractions as well, but the best shaping work is done when particles are over 1 mm.

Low speed is optimal for shaping and for size reduction between 55 and 65 m/s. The crushing behavior of the mineral influences the shaping and crushing performance of a Barmac as well, and very good results have been reported for limestone.

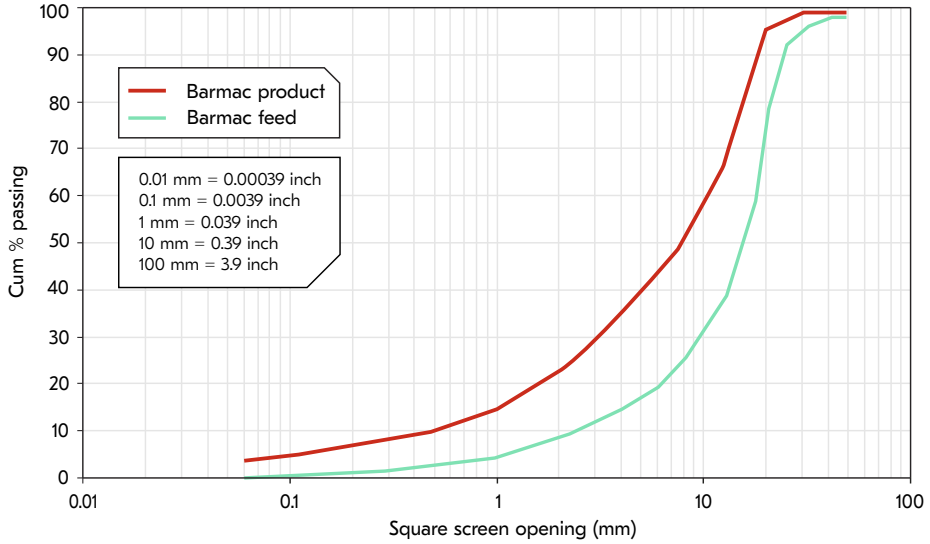
Creating a good equidimensional and almost rounded sand particle means that the small edges need to be broken away. This results in increased fines and super fines. The number of fines generated during VSI crushing is influenced by the resistance of fragmentation of the processed rock materials. A properly adjusted crusher can also process abrasive material in a cost-effective way.

As impactor crushers are more sensitive to abrasion, the Barmac crusher is designed to have good maintenance access, and wear parts are small and easy to exchange. There is a man door for quick access to the crushing chamber and to the rotor. The upper part of the Barmac can be lifted and removed to have full access from above.

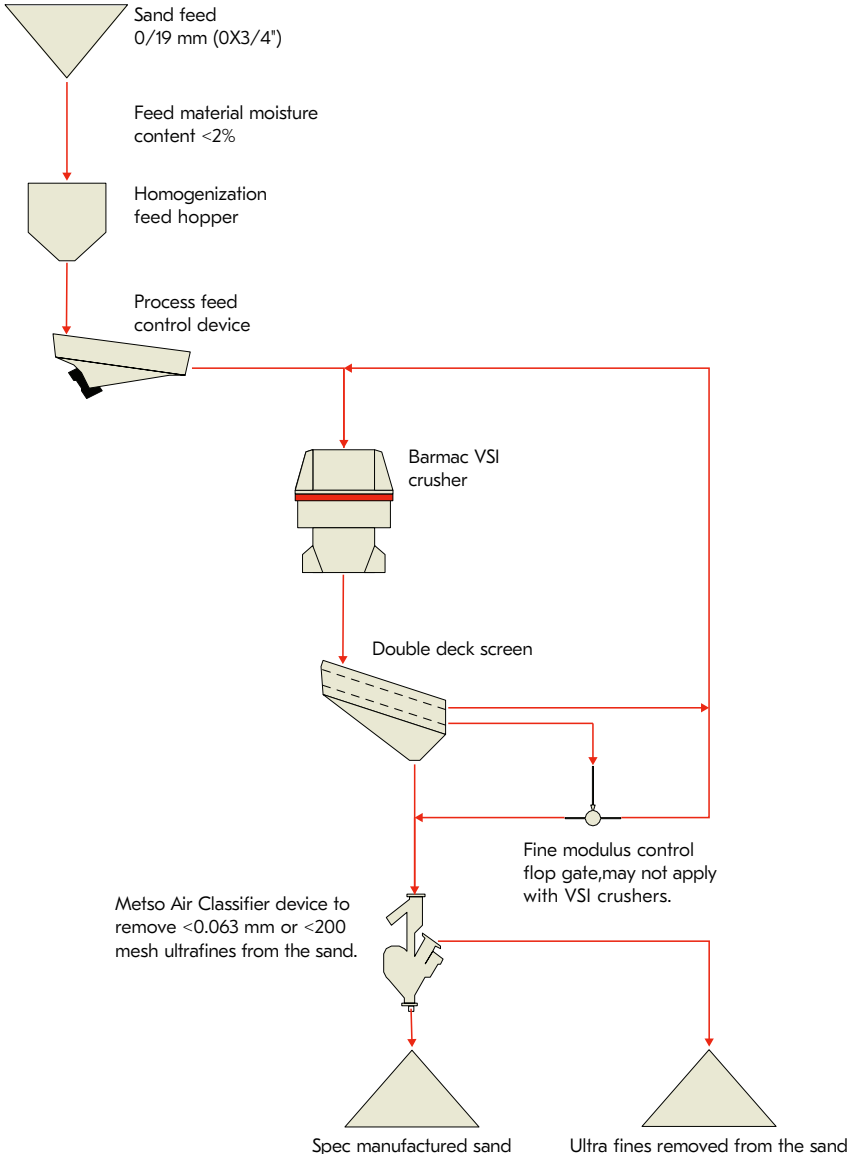
The Barmac is a user-friendly machine to operate and repair. It can be easily installed in a manufactured sand process without complicated feed arrangements. While it is recommended to have surge capacity to feed the Barmac consistently, choke feed is less critical than in compressive crushing. The best performance and well-shaped manufactured sand particles produced by the Barmac are obtained in combination with a dry production screen in a closed crushing circuit.

Features of Metso Barmac VSI:

- Limited feed size max 25-50 mm depending on Barmac's size and application
- Good process variations tolerance (except feed size and intermittent feed)
- Small feed rate effect
- Limited reduction potential with more fines in the feed
- Rock-on-rock crushing that uses less sand flow time and creates more rounded sand than the use of anvils
- Barmac in closed circuit makes well shaped rounded product but increases the ultra-fines generation (<200 mesh or 0.063 mm)
- Less rotor speed leads to coarser sand product
- More cascade leads to coarser sand product
- Constant performance independent of wear parts' life
- Moisture effect on shape and product curve is minor but causes a huge wear increase
- Speed variation is the main factor to be modified in order to change the crusher output curve
- Meeting manufacturing sand gradation specifications could be difficult especially in very hard rocks
- Product shape is of the best quality, sometimes compensating for the lack of some fractions in the product gradation curve
- Can generate a very high volume of circulating load which requires a lot of power



Barmac typical product curve feeding granite (Cr. Value 25, hard rock) top size 30 mm

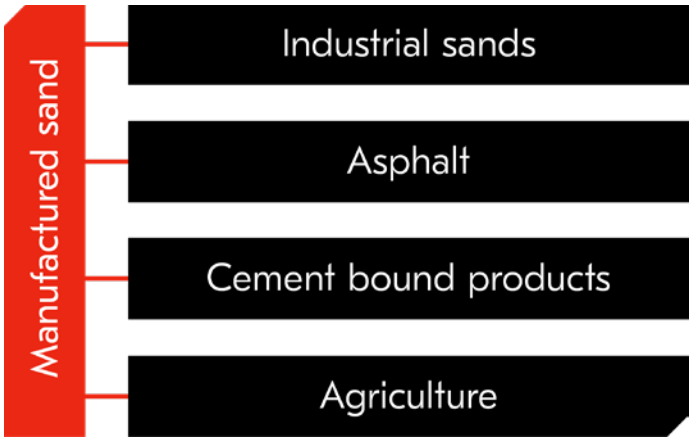


Typical process arrangement with the Metso Barmac impact crusher in manufacturing sand

Manufactured sand applications

There are many sand applications where the sand grading is not as fine as in the applications presented. For those applications, the circuit process could be simpler and without the need for FM flop gate control.

Different technologies here may apply and be suitable to produce the different product specs.



Detailed application areas of manufactured sand		
Concrete sand	Concrete products (pipes, blocks and pre casts) of all kind Plasters and mortars, where sand has a full roll role as aggregate	Spec sand (below 4.75 mm with FM control)
Asphalt sand	Different types of mixes Several spec gradings	Spec sand (below 6/4.75 mm with FM control)
Industrial sands	Foundry sand Frac sand Filter sand Safety sand for playgrounds Golf course sand Horse track sand	Fine sand (4.75/2)
Agriculture sands	Soil improvement Soil mineralization Fertilizers	Spec sand (below 2 mm)

In coarse sand applications, especially in soft and low to mid abrasion materials, the HSI (horizontal shaft impactor) could also be an alternative together with the technologies mentioned before.

HSI Technology in coarse manufacturing sand

There are some recommendations for the use of NP cushers in manufactured sand applications.

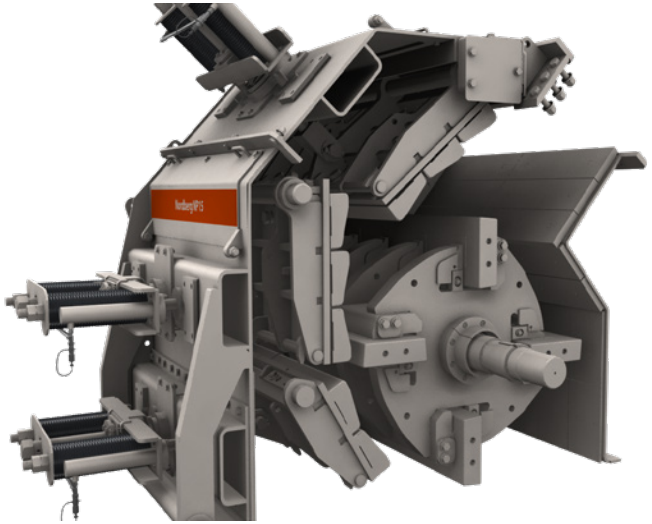
Particle shape received from an NP Crusher is excellent, since it is more angular than rounded. As a process machine, NP is not sensitive to fines in the feed and is a nearly ideal machine for closed circuits. The NP crushers are reliable machines and not sensitive to feed fluctuations and sticky materials.

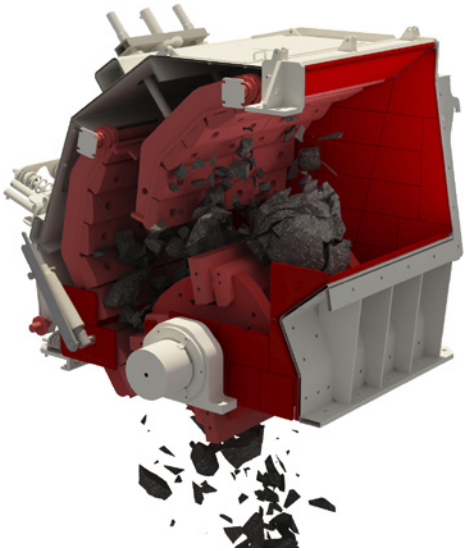
Metso NP HSI crusher
Excessive fines and sticky materials can have a curbing effect and cause additional wear and energy consumption due to extra mass flow through the machine, but NP HSI crusher can handle the process.

HSI's simple design shows a high reduction ratio, works perfect with less abrasive material and is an easy-to-use process machine. It is also less sensitive to tramp material.

The NP crusher's speed is between 30 m/s and 50 m/s. With those possible speed limits, it can be applied for primary and secondary crushing. It also creates certain amount of sand with reasonable properties. But it will not be able to crush the excessive near sand size fractions. Sand will always be a byproduct.

Automation in NP crushers





Parameter increase ↗	Effect on the process					
	Capacity	Product fineness	Shape	Blow bar life time	Power consumption	kW/t
Abrasiveness	=	=	=	↘	=	=
Crushability	↗				↘	↘
Feed rate	↗	↘			↗	
Moisture				↘		
Setting	↗	↘	↘		↘	↘
Feed size	↘				↗	
Wear (blow bar)		↘	↘		↘	
Rotor speed	↘	↗	↗	↘	↗	↗

Influences to impact crushing

HSI has been used for years to produce crushed fines. It is a very popular technology utilized in low abrasion and soft rocks to produce aggregates and coarse manufactured sand <6 mm. It's also used for industrial and asphalt sands production. The new generation Metso of HSI crushers NP13, NP15 and NP20 are utilized as secondary and tertiary crushers in many applications worldwide.

More throughput, less recirculation
The Nordberg NP13, NP15 and NP20 impact crushers have been designed in an innovative way that increase feed material penetration to the rotor. Specifically for secondary and tertiary applications, the optimized, steeper design provides many benefits as the discharge curve is less sensitive to blow bar wear. This allows to produce more consistent end-products without changing the blow bars.

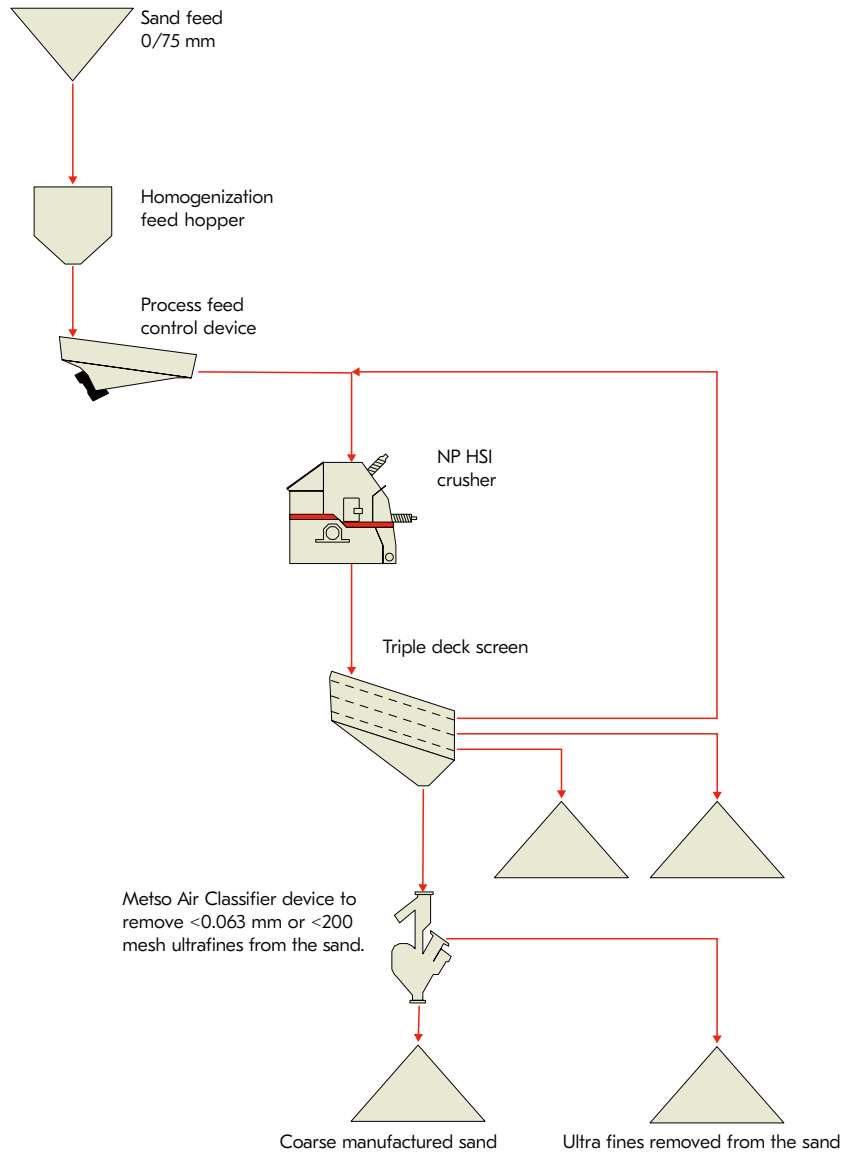
To further improve the productivity, the maximum available power has been increased to 315 kW for the NP13, 355 kW for the NP15 on a single drive and (2)X355 kW for the NP20.

Cost effectiveness and high Metso quality
Metso IC20C crusher automation ensures high availability with the push of just a single button. The system increases long-term profitability and provides better control of the crusher along with a complete view of the parameters for more accurate crusher monitoring. Among other benefits, the automatic setting calibration ensures accurate control of the discharge curve, even with abrasive materials.

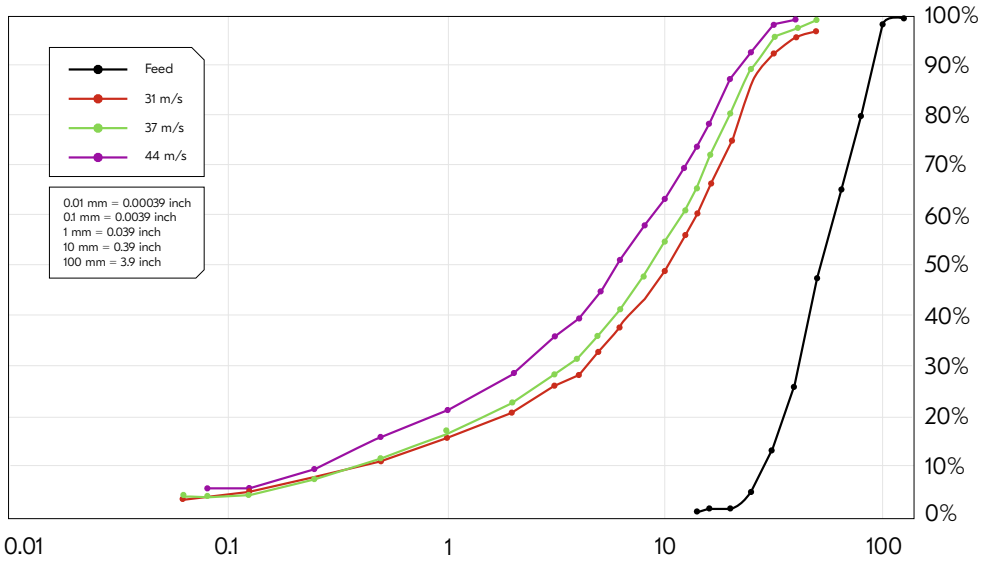
The selection of seven different blow bars gives the assurance of having the right tool for all applications, despite the abrasiveness of the crushed material. It's possible to choose manganese, martensitic steel or chromium iron for the blow bar material in combination with ceramic inserts. The extra-large opening of the new frame provides better access to the breaker plates during wear part replacement.

Metso has also designed a new breaker plate cassette. This patented solution consists of a removable assembly that allows an easy and safe breaker plate liner change outside the crusher.

The new maintenance bridge provides safe access to the rotor while changing blow bars. The maintenance bridge also allows to access the side liners, including the ones located highest, quickly and easily.



Typical process arrangement with the Metso NP impact crusher in manufacturing sand.



Typical NP HIS product curves at different rotor speeds

Material	Limestone
French abrasiveness	40 [g/t]
Solid density	2.5 [t/m^3]
Bulk density	1.5 [t/m^3]
Crushability	52 [%]
Dynamic fragmentation	30 [%]

Crusher	NP1007
Installed power	90 [kW]
1st BP setting	70 [mm]
2nd BP setting	20 [mm]

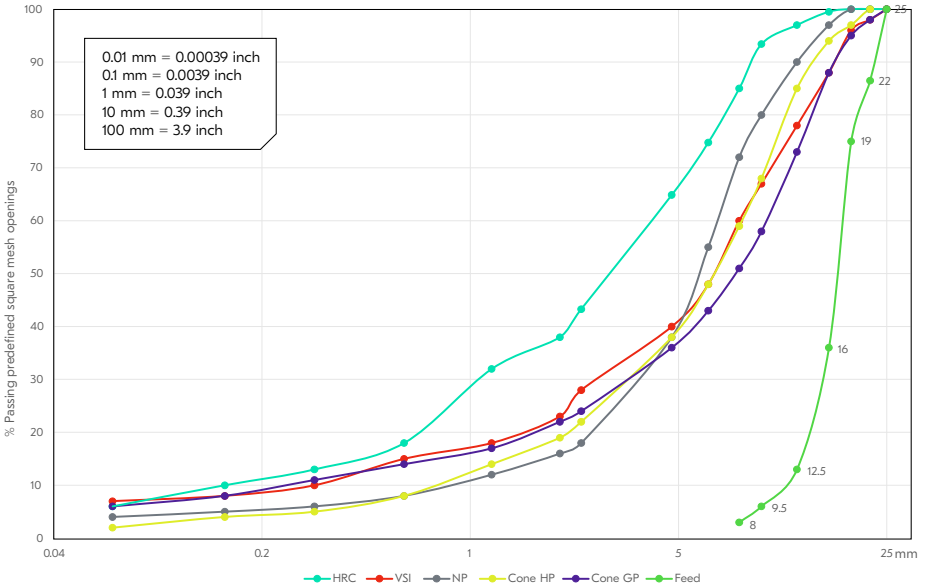
Higher rotor speed:
- Finer production
- Better shape
- Higher power consumption
- Lower throughput

Summary

Metso can provide several solutions to manufacture sand. By using the right crushing equipment, manufactured sand can be produced in a comparable way as sand is formed naturally. Choosing the right process design and the right crusher is essential to meet the necessary requirements.

In the manufactured sand process, customers can obtain much better grain proportions using Metso's different crushing and classifying technologies such as cone crushers, horizontal shaft impactors (HSI), vertical shaft impactors (VSI), and high-pressure grinding rolls (HPGR). Depending on the application, the type of material to be processed, the type of sand required, and the specifics to be meet, Metso can propose the most suitable technology or combination of technologies to meet the customer's needs.

8/25 mm feed vs. HRC & Other crushers product gradation curves



Feed material Amphibole 0-30 mm, crushability 32%

Crusher technology options in manufactured sand production

Crusher type	Type of manufactured sand			
	Concrete sand	Industrial sand	Asphalt sand	Agriculture sand
Cone crusher	X	X	XX	
HSI NPXX series crusher	X	X		X
VSI Barmac crusher	XX	XXX	X	XX
HRC High pressure roll crusher	XXX	XX	XXX	XXX

X - Good
XX - Very good
XXX - Best technology

	Concrete sand		Agriculture sand Industrial sand Asphalt sand		
Type of crusher	"Rounded" particle shape	FM*	Gradation curve	% < 0.064 mm	"Angular" particle shape
Barmac VSI	☀	☁☀	☁☀	☁	
Barmac VSI with anvils		☁☀	☁☀	☁	☀
NP HSI		☁	☁☀	☁	☁☀
HRC		☀	☀	☁☀	☀
GP Cone F and EF		☁☀	☀	☁☀	☁
HP Cone F and EF		☁☀	☀	☁☀	☁

Different properties to meet in manufacturing sand applications

Cone crushers can produce manufactured sand to meet some of the sand requirements. The crusher must be properly configured for the application by selecting the appropriate type of cavity, the correct stroke (in case of GP type cone crusher) and speed (in case of HP technology). The process must also be configured accordingly; the crushers need to be choke fed all the time with an automatic control and have enough and efficient screening area. Cone crushers are very sensitive to the presence of fines in the feed and to the moisture in manufacturing sand applications.

The Barmac VSI produces the best particle shape for concrete sand, but it may lack some particle sizes in the final product gradation to meet the concrete specification curve depending on the application and the type of rock processed. It may also produce excess of fines <0.063 mm. In asphalt sand, it produces great quality product; the anvil ring configuration could be the best one to use in this type of application if the feed material characteristics allow a cost-effective operation. Barmac manufactured sand is well accepted for industrial and agriculture sand applications.

*FM: Fineness modulus is an index number which represents the mean size of the particle in the mix.

The HRC technology can produce good particle shape for concrete sand, a very good product gradation curve to meet the concrete sand specifications curve and the FM required depending on the application and the type of rock. It may also produce less fines <0.063 mm.

In asphalt sand, it produces excellent quality product. Also, HRC sand is well accepted in agriculture and industrial sand applications. HRCs are not sensitive nor to the high percentage of fines in the feed materials, neither to the presence of moisture in the feed.

Following is an example of energy consumption between 3 different technology crushers with the same feed gradation to maximize production of 0/4mm (0/3/16"), and measure the energy requirements per net Ton of final product:

Equipment	**Power installed**
HP3 cone Crusher EF	(250 kW/350 hp)
Barmac VSI R/R conf.	(250 kW/350 hp)
HRC800	(220 kW/300 hp)

	Barmac	HP	HRC
Capacity (tph)	175	190	135
Energy / ton throughput	1,45	1,15	1,65
% 0 - 4 mm / 0-#5	25%	45%	65%
t/h 0 - 4 mm / 0-#5	45 t/h	85 t/h	85 t/h
Energy / ton sand	5,5	2,95	**2,6**

HRC, HP and Barmac have different behaviour

NP HSI produces crushed fines that customers use as manufactured sand specifically in industrial sand applications and asphalt, but it is very difficult for HIs to meet a fine sand specifications.

		HSI NP Range	Barmac VSI	HP Cone crusher	HRC High Pressure roll crusher
Operation	Installation	+++	+++	+	+++
	Maintenance	++	++	+++	+++
	Feed size	+++	++	+++	++
	Humidity in the feed	++	++	++	+++
	Fines in feed	++	++	+	+++
	Noise	++	++	+	+++
	Dust generation	+	+	++	+++
Performance	Fine feed (<10 mm)	-	++	-	+++
	Coarse (>32 mm)	+++	++	+++	+
	Reduction ratio	+++	+	++	+++
	Cost Ton	++	+	+++	+++
	Hard and abrasive materials	+	+	+++	+++
	Fine high spec sand	+	++	+	+++
	Low circulating load (m, sand)	+	+	+	+++
Quality	Shape (no sharp edges)	++	+++	+	++
	Extra fines (<0.074 mm)	+	+	+++	++
	Cubical	++	++	+	+++
Cost	Energy efficiency	++	+	++	+++
	Wear	+	+	++	+++
	Investment	+++	+++	+	+

Considerations to take when selecting a crusher for manufacturing sand applications

\+ Sensitive
++ Good
+++ Best alt.

Metso is a frontrunner in providing sustainable technologies, end-to-end solutions and services for the aggregates, minerals processing and metals refining industries globally. By helping our customers increase their productivity, improve their energy and water efficiency and environmental performance with our process and product expertise, we are the **partner for positive change.**

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