Dry mortars have become highly efficient building materials to which high production standards are applied. In particular, the excellent cubicity of the sand particles plays a key role in making the mortar easy to use and easy to pump. Carefully designed crushing equipment can efficiently and economically produce dry mortar sands that correspond exactly to the formula.

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BHS-SONTHOFEN

Plant design for production of sand for dry mortar

Two units RPM 1513 for dry mortar sand production in the UAE

1 Introduction

Since dry mortar was invented in the mid-1930s, it has become widely established as a building material. Use of mineral-based plaster and dry mortars has grown dramatically, especially over the past 20 years. The formulas have been continuously improved, and specialized dry mortar varieties are now available for virtually every type of building application. With the development of lightweight and high-grade plasters, the dry mortar industry has embraced the trend toward lighter, heat-insulating wall-building materials.

Mineral-based plaster and dry mortar are produced from natural raw materials. They are mainly composed of the following:

» limestone sand, dolomite sand, quartz sand and glass sand used as aggregate and filler
» cement, lime (quick lime), gypsum and anhydrite, used as binders.

1 The impact mill of type PM 1010 with a maximum throughput of 100 t/h is ideal for pre-crushing

Crushed sand is usually relied on when no natural sand is available. When it comes to grain-size analysis and formula-specific proportions of the various constituents, the binders and aggregates in the dry mortar sand must meet certain requirements.

To achieve the desired quality of sand, merely crushing the rocks and separating out the off-spec particles is not sufficient. Instead, the crushed material must be separated into fractions and then combined to produce a defined grain-size curve that corresponds to the desired formula. The preferred fractions range from 0.09-1.2 mm. Within this spectrum certain fine-grain fractions, e.g. 0.09-0.5 mm, with high mass and quantity proportions, are preferred in certain cases.

2 Impact crushing

Impact crushing is an effective crushing method in the production of high-quality aggregates and binders. To best meet quality standards and quantity requirements, BHS-Sonthofen has developed three machine systems now being used successfully around the world.

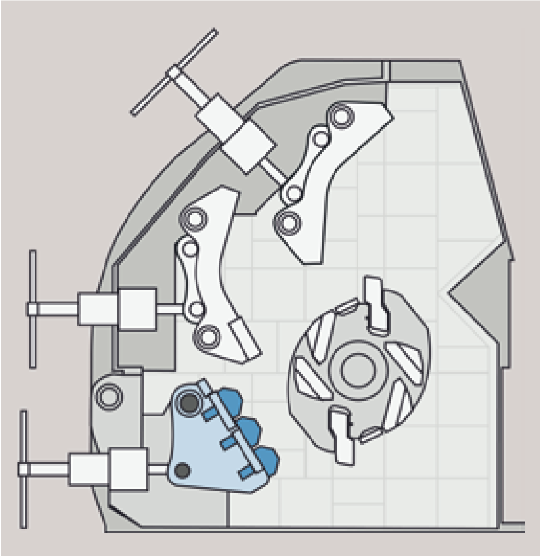
1. Impact mills and impact crushers with horizontal shafts used for pre-crushing all types of rock (Fig. 1).
2. Rotor centrifugal crushers with vertical shafts for all types of rock, especially highly abrasive and hard materials (e.g. quartz sand or granite)
3. Rotor impact mills with vertical shafts to produce sand with low or moderate abrasiveness (e.g. limestone, dolomite, gypsum, anhydrite, quick lime) (Fig. 2).

What all of these machines have in common is the production of the cubical grains required for dry mortar sands. The BHS impact mills and BHS impact crushers with horizontal shafts are used exclusively as pre-crushers for coarse grinding. Rotor crushers with vertical shafts are used to process smaller sized fractions and are also known as vertical shaft impactors (VSI). Depending on the feed size and type of rock, rotor centrifugal crushers and rotor impact mills can be used as primary, secondary or tertiary crushers.

The most important feature differentiating the machine systems is the design of the rotor and the different resulting crushing processes within the machine.

3 BHS impact mills and BHS impact crushers

The impact mills and impact crushers are the ideal crushing machines for all rock types, especially for rock that is less abrasive and moderately hard, as well as for very large feed sizes. They are used for coarse crushing of grain sizes larger than 63 mm.



2 Compared with an impact crusher, the impact mill is equipped with an additional grinding track beneath the rotor shaft

The main distinguishing feature of this crusher is the rotor with horizontal shaft. Blow bars attached to the rotor itself serve as the actual crushing elements. The number of blow bars is basically determined by the rotor diameter. Depending on the size of machine, two to four blow bars are common. Depending on the rock type, machine size and size of the input material, the peripheral rotor speed can reach up to 70 m/s.

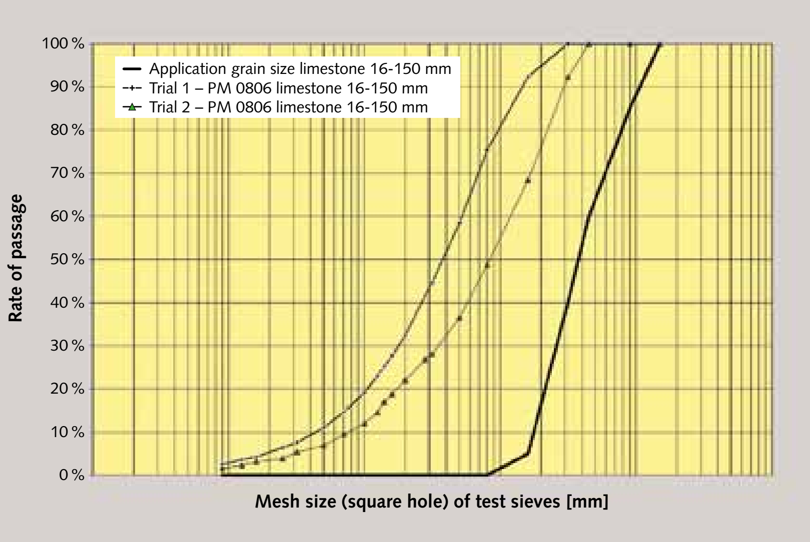
Once it enters the impact chamber of the rotor, the material fed to the crusher is first crushed by the impact effect. The blow bars then accelerate the material at high speed toward the impact plates, where the impact serves to crush it further. On rebounding from the impact plates, the rock is caught by the rotor blow bars again. The crushing process repeats until the material is able to exit the machine through the discharge chute. Crushing can be controlled within a broad range by varying the peripheral rotor speed and the size of the gap between the rotor and impact plates.

The impact plates are an essential component of these machines. A special mechanism allows the size of the gap between the rotor and the impact plates to be adjusted manually or hydraulically. The crusher housing can be mechanically or hydraulically opened for maintenance and to replace wearing parts.

The third grinding track in the impact mill serves to retain the material in the crushing chamber for longer, which further enhances the crushing action.

3.1 Practical example: impact mill

The grain-size curves in Figure 3 illustrate the output material discharged from a BHS type PM 0806



3 **Grain-size curve for a BHS impact mill of type PM 0806 used to crush limestone with a feed size of 16-150 mm**

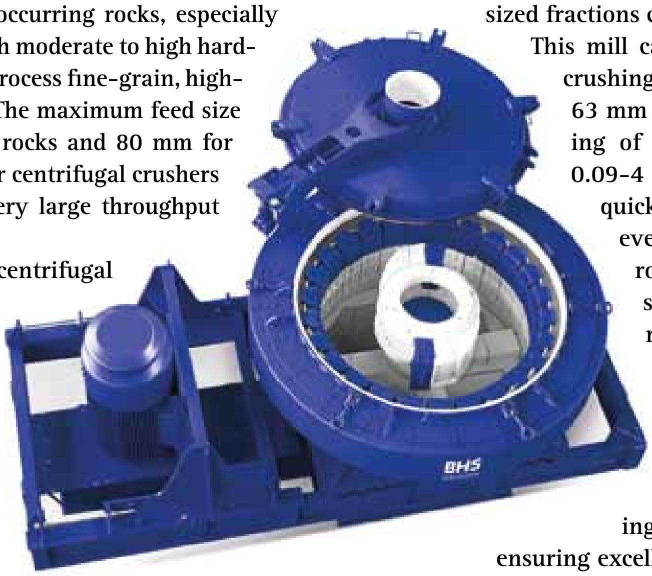
impact mill after crushing limestone with a feed size of 16-150 mm. In the dry mortar industry, this crusher is used as a pre-crusher for coarse rock particles; it supplies the required feed size for rotor centrifugal crushers and rotor impact mills used as secondary crushers.

The grain-size curve shows that sand in the desired particle size is produced even during pre-crushing. Because of its cubical shape, it can already be used in mortar production and does not require further processing in the secondary crusher. The total proportion of usable particles is thus increased, while the undesirable dampening effect of the sand when crushed in secondary crushers is avoided.

3.2 BHS rotor centrifugal crushers

The rotor centrifugal crushers (**Fig. 4**) are used to crush all naturally occurring rocks, especially high-wear rocks with moderate to high hardness. They can also process fine-grain, high-wear quartz sands. The maximum feed size is 150 mm for soft rocks and 80 mm for hard rocks. The rotor centrifugal crushers are also used for very large throughput quantities.

The rotor centrifugal crusher contains a compact rotor with two generously sized centrifugal chambers mounted on a vertical shaft. The input material is fed centrally from above and passes into the two centrifugal chambers of the rotor (**Fig. 5**).



4 **The rotor centrifugal crusher of type RSMX is ideal for soft, medium-hard or hard rock with a throughput of 30-400 t/h**

The high peripheral rotor speed of up to 70 m/s accelerates the material in the centrifugal chambers outward at high velocity where it is forcibly expelled from the rotor's discharge outlet. The rock is crushed mainly as a result of the optimized single impact of each particle against a fixed, ring-shaped wall, which consists of either an anvil ring or a stable rock shelf in the upper part of the housing. This produces cubical grains with an excellent shape.

The material flow within the rotor causes the formation of an independent, automatically renewing material layer. During acceleration of the particles, the exterior of this material bed serves as a slideway. The innovative design of the patented BHS twin-chamber rotor also reduces energy input.

3.3 Practical example: rotor centrifugal crusher

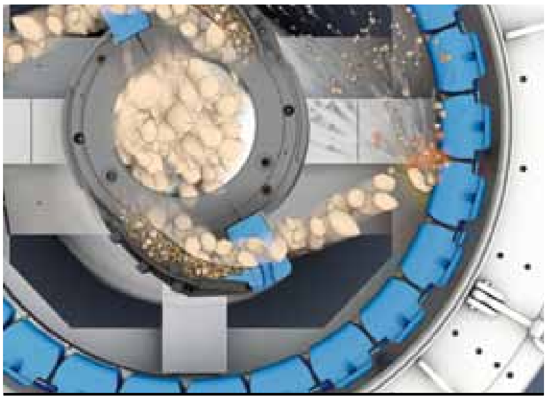
The grain-size curves (**Fig. 6**) represent the output material discharged from the BHS RSMX 1222 rotor centrifugal crusher in rock shelf mode after crushing quartz sand with a feed size of between 1-2 mm. The goal of the tests was to generate a high proportion of fine grains for production of dry mortar fractions.

The grain-size curve shows that the crushing effect increases along with faster peripheral rotor speeds and the sand is tangibly more refined. Because of the high-wear factor of quartz sand, BHS recommends operation in rock shelf mode for this application. Customers use the machine as both a primary and secondary crusher.

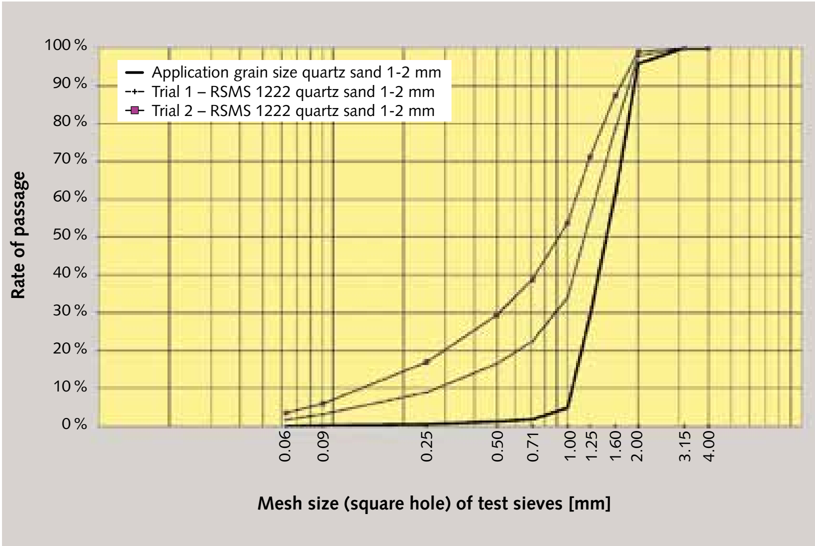
3.4 BHS rotor impact mill

The BHS rotor impact mill is ideal for producing dry mortar sands since it creates precisely the right sized fractions called for in the formula. This mill can be used for primary crushing of grain sizes up to 63 mm as well as post-processing of off-spec particles from 0.09-4 mm. When crushing quick lime, the feed size can even go up to 120 mm. The rotor impact mill is well suited for crushing soft rocks or input material with low or moderate abrasiveness (**Fig. 7**).

The sands that it produces consistently exhibit an outstandingly cubical grain shape, ensuring excellent pumping character-



5 Functional principle of the rotor centrifugal crusher with anvil ring and material bed in the centrifugal chamber



6 Grain-size curve for a BHS rotor centrifugal crusher of type RSMX 1222 with rock shelf, used to crush quartz sand with a feed size of 1-2 mm

istics of the mortar. Depending on the hardness and grain size of the input material, BHS rotor impact mills achieve a sand yield of up to 80 %.

The rotor to which the horseshoe-shaped impact elements are attached is mounted on a vertical shaft. When it hits the rotor, the rock is accelerated outward due to centrifugal forces – generated by the high peripheral rotor speed of up to 70 m/s – where it is caught by the horseshoe-shaped impellers and repelled against the anvil ring. The impact begins to crush the rock.

The narrow gap between the anvil ring and the impellers causes the material to rebound, where it again hits the impellers, is further crushed and then thrown back against the anvil ring. This process repeats until the material is small enough to pass through the gap between the impeller tip and the anvil ring, and is thereby discharged.

Crushing results can be controlled by varying the peripheral rotor speed and the size of the gap between the rotor and the anvil ring. The mill can be operated alternately in clockwise and counter-clockwise directions, which reduces impeller wear.

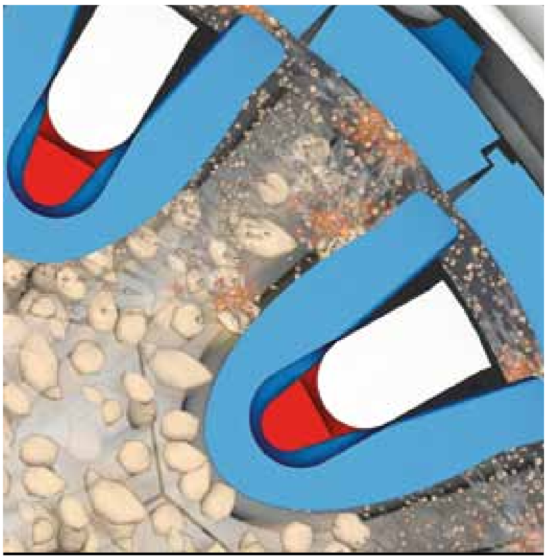
3.5 Practical example: rotor impact mill

The grain-size curves (Figures 8 a and b) show test results for the production of dry mortar sand from limestone with a feed size of between 0 and 45 mm. This was provided by the PM 0806 impact mill from BHS, which was used here as a pre-crusher. A high proportion of fine sand between 0.063 and 1.25 mm was desired in this case. Accordingly the mill has to be operated with a high peripheral rotor speed and small gap of only about 12 mm between the impeller tips and the anvil ring.

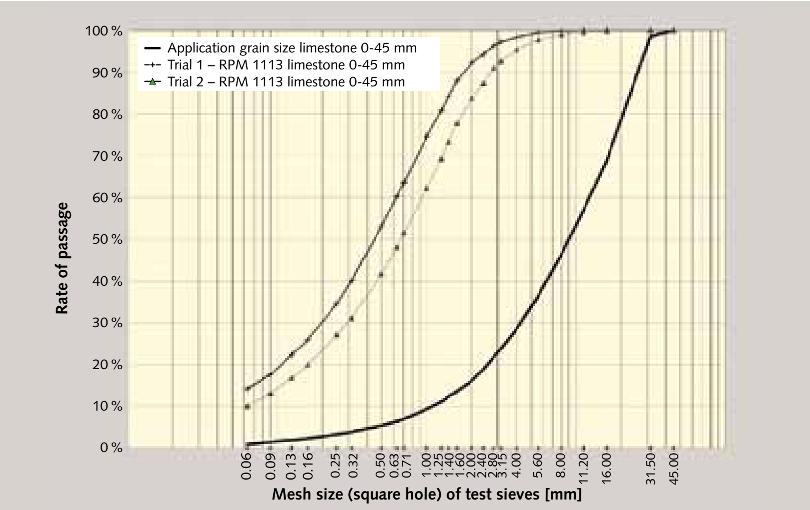
The proportion of fine sand was further increased by processing off-spec particles sized between 1.25 and 5.6 mm with a downstream BHS rotor impact mill; the off-spec particles would otherwise be dumped or sold at a low price. This significantly increases the flexibility of dry mortar plants as it makes it much easier to adjust fraction quantities if formulas are later modified. The grain-size curves show the grinding product achieved in processing of off-spec particles 1.25-5.6 mm in size.

4 Testing in our BHS technical center

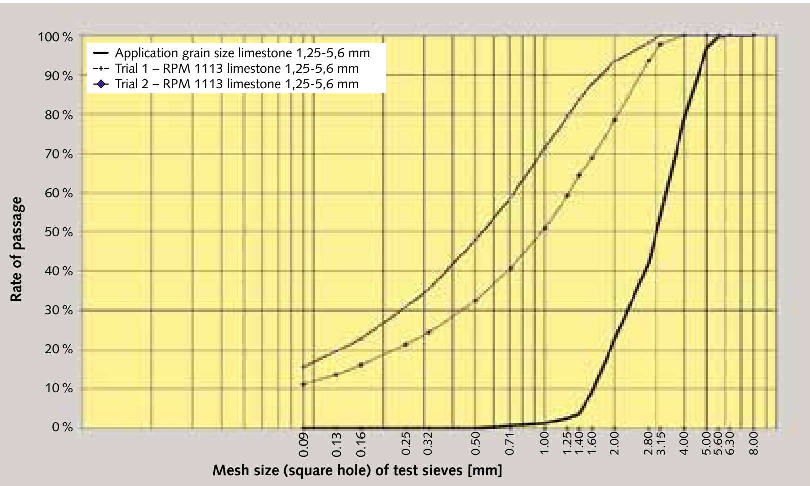
Testing in the BHS technical center, where the above practical examples are drawn from, is vital to ensuring efficient machine operation. The tests reassure customers that they have made the right investment decision and that the new plant is future-proof. To achieve optimal and realistic crushing results in the tests, original machines are run at various peripheral rotor speeds.



7 Functional principle of the RPM rotor impact mill used in the production of sand



8a **Grain-size curve for a BHS rotor impact mill of type RPM 1113 used to crush limestone with a feed size of 0-45 mm**



8b **Grain-size curve for a BHS rotor impact mill of type RPM 1113 used to crush off-spec particles of limestone with a feed size of 1.25-5.6 mm**

Grain-size analyses are produced based on the material samples. The optimum grain-size curve for the customer and the projected throughput then form the basis for designing the process. The test results determine the size of the machine and the electrical drive capacity.

The tests are also of paramount importance for designing the screening equipment: The results provide guide values for calculating the required sieve areas within the plant. The plant manufacturer also uses the test results as the basis for producing the detailed plant overview, including the precise locations of the crushing machinery, screening equipment, conveyors and other components.

5 Design of dry mortar plants

In the three configurations described below for plants to produce dry mortar sands, it is assumed that the rock is crushed into precisely graduated fractions that are stored separately. The crushing equipment and sorting machines can thus be fed with defined input materials in the form of fresh material or off-spec particles and can produce the desired grain composition for the dry mortar.

The individual fractions are shown according to standard European grain-size curves. Modifications are possible, however, to meet customer and operator needs. After these determinations, the classifying and sorting equipment must be selected, such as the separators and screens. The choice of machinery depends in large measure on the requirements and desired classification precision. The technology can be modified in response to the rock properties, as well as quantities and required fractions. The technology variants discussed below can therefore be used as the basis for designing a plant.

5.1 Variant 1 – RPM rotor impact mill for primary and secondary crushing

Variant 1 is a basic version in which a single rotor impact mill is sufficient for primary and secondary crushing. The rock must have good crushing properties and a low proportion of off-spec particles, however. The maximum feed size for this variant is limited to 63 mm. In this case, BHS recommends the RPM rotor impact mill, which produces a higher proportion of usable grains compared to the PM impact mill. The dryer must then be upstream of the crusher so that off-spec fractions do not have to be run through the dryer again.

This variant has the advantage of lower investment costs, but the configuration offers less flexibility.

5.2 Variant 2 – One primary and one secondary mill

Two machines are used when the rock is hard to crush and when it is likely that the proportion of undesired off-spec fractions will be high. For feed sizes larger than 63 mm, the BHS PM impact mill is used as the primary mill, while the BHS RSMX rotor centrifugal crusher or BHS RPM rotor impact mill is used for smaller feed sizes. The secondary mill serves exclusively to process the off-spec grains discharged from the primary mill.

A sieve upstream of the primary mill reduces its load as useful grains are filtered out of the input material and not processed unnecessarily. Sieves and screens must be carefully selected in view of these conditions since the composition of the input material is variable.

5.3 Variant 3 – Primary, secondary and tertiary mills

If the rock properties or intended formula result in a high incidence of off-spec particles, a tertiary mill should be used for intensive fine grinding, preferably a BHS RPM impact mill. Using three crushing machines also drastically improves the plant's flexibility since it is easy to modify the fraction quantities if the formula changes later.

If the feed size of the primary material is larger than 63 mm, a primary mill must be located upstream of the dryer, such as a BHS PM impact mill or BHS RSMX rotor centrifugal crusher – depending on the feed size. If it is less than 63 mm, there is no need for a primary mill. The secondary mill (BHS RSMX rotor centrifugal crusher or BHS RPM rotor impact mill) then performs primary and secondary crushing.

Placing a silo upstream of the tertiary mill helps to return small off-spec fractions to the cycle in a controlled manner (Fig. 9).

6 Summary

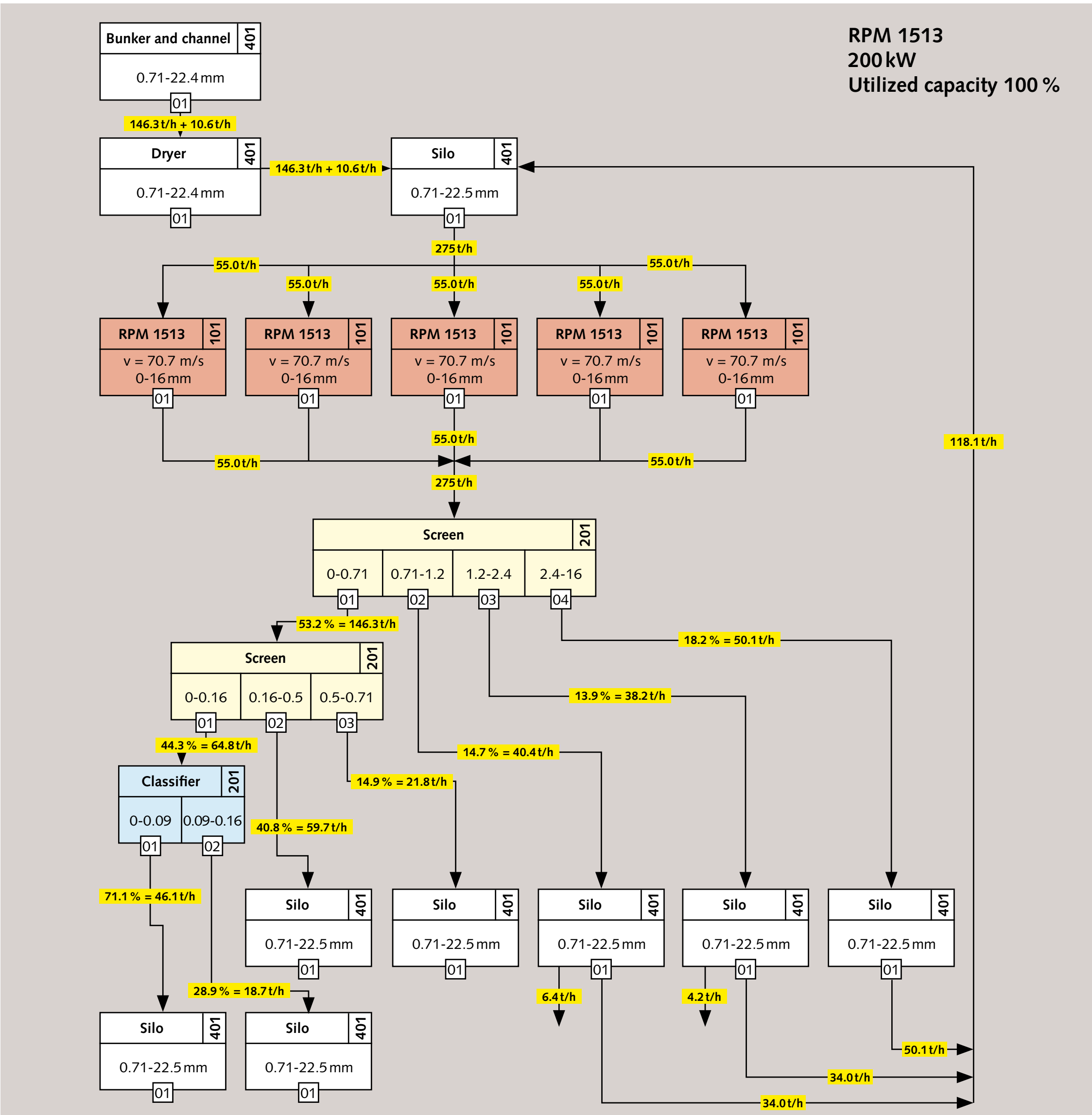
BHS-Sonthofen has developed specialized rotor crushers to produce dry mortar sands which, depending on their intended application, can process materials of moderate to high hardness, as well as high-wear materials, especially rocks.

The plants produce outstanding sand cubicity, meaning that the requirements of high quality and easy processing of dry mortar sands are fully met in accordance with the applicable standards and guidelines.

BHS impact mills and impact crushers are ideal pre-crushers for large rock grain sizes, while BHS rotor centrifugal crushers and BHS rotor impact mills are used both for pre-crushing and as secondary crushers. These machines allow for flexible modification of formulas, guaranteeing consistent quality.

With different plant configurations, dry mortar formulas and the individual fraction quantities can be quickly and efficiently adjusted and optimized at any time, even in specialized applications.

Production-scale machines are on hand in the BHS technical center for testing and trial purposes.



9 Process diagram for a dry mortar plant currently under construction in South-East Asia with five rotor impact mills of type RPM 1513 and a total output of 275 t/h