Quality in sample preparation for the cement industry
HERZOG is one of the cement industries’ leading partners in the development and establishment of laboratory systems. Innovative production processes as well as the increasing diversification of cement types involve higher demands on laboratory systems. HERZOGCement meets these demands with an exceptionally stable construction principle, a machine portfolio specifically designed to comply with the demands of the cement industry as well as the offer of integrated, complete laboratory solutions.

The harsh conditions within a cement production plant make it essential to use highly robust machines. HERZOG machines are constructed in such a way that they can withstand the extreme temperatures and the dusty environment without any problems. This is a prerequisite for several decades of reliable operation with a minimum of maintenance.

Every single step of the production control, from the sample taking process to transferring samples to the analyzing apparatus, complies with the specific demands of cement production.
Typical sample material for process control in a cement plant

Raw meal
Raw meal is a specific mixture of various raw materials for the production of clinkers in a rotary kiln. It mainly consists of limestone and argillaceous rocks. Those natural and industrial raw materials contain the main oxides like lime (CaO), silica (SiO₂), aluminum (Al₂O₃) and iron (Fe₂O₃) required for the production of cement. Ingredients for the raw meal are limestone and minor clay, shale and sand.

This raw mix undergoes mechanical and thermal treatment to make clinker.

Klin feed samples
Samples are taken to check the consistency between raw mill product, kiln feed and clinker analysis.

Cyclone samples/
Hot meal
Hot meal is a term used for the raw material mixture when it enters the rotary kiln.

Clinker
Clinkers are produced by sintering the raw materials in a rotary kiln at high temperature. Those nodular clinkers are commonly composed of tricalcium silicate or ‘alite’ (C₃S), dicalcium silicate or ‘belite’ (C₂S), tricalcium aluminate (C₃A) and tetracalcium aluminoferrite (C₄AF). After sintering, the clinkers are blended with other additives like gypsum, slag, fly ash and ground to a fine and homogenous powder. Those additives are used to control the properties of the finished cement.

Sampling

The manner and extent of sampling at a cement production process varies from plant to plant depending on the used raw material, machinery and quality specification. Representative sample taking is of increasing importance to guarantee reliable analysis results necessary for the process control. HERZOG-Cement offers failsafe and cost-efficient solutions for sampling and pneumatic transport tailored to the requirements of each customer.

HERZOG delivers a wide variety of sampling equipment for powder and lump material like, e.g., clinker or limestone. Usually, samplers are installed for the following material: Raw meal, kiln feed, hot meal, clinker and cement.

Samplers are available as manual devices for collecting the sample material at site into a container. In this case, the operator has to take care of the sample transport into the laboratory.

Alternatively, in order to guarantee a reliable and quick sample transport, the samplers are connected to automatic sending stations. In this case, the sampling material is automatically dosed into a carrier and transported into the laboratory via pneumatic tubes. Several sample increments can be collected and homogenized within a mixer upstream of the plant station. A representative and homogenized sample is taken from the mixer and transported to the laboratory. Subsequently, surplus waste material is returned to the system using the injector feeder system. Furthermore, mixer and plant station are automatically cleaned. The sample taking protocol (sampling time, frequency and amount) of each sampling station can be easily adjusted using the Prepmaster software.

Screw samplers for coal dust can be delivered as ATEX-certified equipment.

Cement
Samples are taken to check the mill operation and the composition after addition of gypsum and additives.
Screw sampler HR-SN

The HR-SN screw sampler is designed for the sampling of powder and fine-grain materials from vertical or inclined drop chutes. The semicircular-section trough of the sampler projects into the material flow with the open side facing upwards. The screw conveyor transports the sample material via a downcomer directly into the downstream process station. The sampling cycle is controlled by the controller of the process station.

Main features:
- Screw length according to application between 240–460 mm
- Capacity approx. 2.3 l/min
- Built-in places: Horizontal in vertical or inclined drop chutes
- Maximum sample grain size 200 μm

Airslide sampler HR-RN

The HR-RN air slide sampler is designed for the sampling of powder and fine-grain materials from horizontal air conveyor troughs. A perforated collecting tube located vertically in the air conveyor trough retrieves the sample from the material flow. The perforations in the collecting tube are rotated into the material flow for the purpose of sampling. In the closed condition, the holes are turned in the opposite direction. The collecting tube is driven pneumatically. Once retrieved, the sample can be transported through a downcomer directly into a downstream process station. The sampling cycle is controlled by the controller of the process station.

Main features:
- Pneumatic rotary cylinder
- Continuous sampling from horizontal processes
- Sample volume approx. 40 ccm per 5 sec.
The HR-KNH sampler is designed for the sampling of hot powdered and fine-grain material from inclined drop shafts.

Once retrieved, the sample material is discharged through a downcomer onto a conveyor screw. At the end the sample discharge is located with a connection to a process station. The conveyor screw is cooled by the air flow from a separate fan. The screw is equipped with a tubular shroud for this purpose. The system can be used for both cross-sectional and random sampling. The sample quantity can be adjusted by control of the sampling strokes. The sampling cycle can be controlled by the controller of a process station.

Main features:
- Slotted piston with pneumatic drive
- Cooling system with fan
- Maximum sample grain size 200 µm
- Max. sample temperature 900 °C

The HR-PN piston sampler is designed for the sampling of powder and fine-grain material from vertical or inclined drop shafts.

A pneumatic operated sampling piston is moved into the material flow, and retrieves a precise sample quantity defined by the volume of the piston. The sample is transported by tube systems or vibratory chutes to the downstream components. The sampling cycle is controlled by a programmable logic controller.

Main features:
- Housing with discharge funnel and connecting flange
- Sample volume approx. 150 ccm per movement
- Maximum sample grain size 200 µm
- Max. sample temperature 200 °C
Scoop Sampler for Clinker

The scoop sampler is an extremely robust spoon sampler for clinker material with a vertical flow. The hydraulic operated spoon is swung out into the clinker stream upon demand and retrieves a defined sample material as determined by the spoon volume. The sample is then transported by a tube system to the downstream component like, e.g., sample box, crusher, clinker plant station.

Main features:
- Scoop sampler
- Hydraulic operated
- Maximum sample size 50 – 100 mm
- Max. sample temperature: 100 °C

Clinker sampler HR-KN

The HR-KN clinker sampler is designed for the sampling of coarse-grain material from vertical material shafts located beneath the belt discharge point. A hydraulically operated sampling chute is swivelled upon demand into the material flow, and retrieves a precise sample quantity defined by the chute volume. The sample is then transported by tube systems or a vibratory chute to the downstream components (e.g. a jaw-breaker). The sampling cycle is controlled by a programmable controller.

Main features:
- Housing with discharge funnel and connecting flange
- Maximum sample grain size 50 mm
- Max. sample temperature 100 °C
- Connection to clinker plant station HR-LKC with vibratory conveyor and crusher possible
The HERZOG airtube transports the samples reliably into the laboratory. The airtube can be configured manually or automatically with fully integrated samplers and laboratory equipment. In automatic systems, dosing of the sample material into the airtube carrier takes place in the plant station. In the laboratory station, the required sample amount for XRF analysis and average samples are dosed within the receiving station.

Installation of airtube components is feasible even under difficult spatial conditions or at long distances. The sending and receiving stations provide for the automatic integration of sample information into the connected control software. The perfect interaction between hardware and the HERZOG Prepmaster system guarantees smooth and fast transport from the plant to the laboratory.

Sending station HR-BM

The HR-BM is a fully automatic plant station with mixer (also available without mixer) which is designed for the collection, homogenization and dispatch of sample material in the production process. The fully automatic station collects the individual samples from a sampler in a mixer and homogenizes the material each time new material is added. When the sample is complete, the mixer is automatically emptied and part of the sample material dosed in a pneumatic tube capsule for transport into the laboratory. The remaining waste material is returned to the production flow by the waste return system (HR-FRG).
Tube diverter HR-W2
The fully automatic tube diverter HR-W2 is suitable for use in either the plant or the laboratory. Two pneumatic tube lines from the plant can be united in the diverter to a single line. The direction of capsule transport is controlled by displacement of a rotary tube within the diverter.

HR-LA
The HR-LA is a fully automatic laboratory station for the receiving of granulate and powder samples and return of the emptied capsules to the plant. The HR-LA opens the pneumatic dispatch capsules and discharges the sample material into a hose proportioning facility. The capsule is then closed again and returned to the dispatch station in the plant. The HR-LA can be integrated into a linear system with the HP-CA, HP-MA, HP-PA and HP-MP.

HR-LSP
The HR-LSP is a fully-automatic laboratory station that can receive and forward samples using conveyor belts or robot. The rear side of the station is open, providing direct access by a robot. Furthermore, the station is fitted with a door on the front for manual operation for removing or inserting of airtube capsules.

HR-HSK
The sample material is inserted manually into the pneumatic tube capsule. The capsule is closed by means of the integrated manual capsule opener, and then placed in the insertion point of the station. After having inserted the capsule it can be dispatched to the laboratory at the touch of a button. A light on the receiving station indicates that a capsule has been received. The manual station can be employed in the laboratory to return empty pneumatic dispatch capsules to the plant. The manual station can be fitted with an additional display for the input of sample identification. The HR-HSK/L is a specially designed airtube laboratory station for robot automations. It can also be used for manual carrier receiving and sending.

Prepmaster
Our SCADA system Prepmaster is a high calibre process visualization system for the uncomplicated and intelligent monitoring of our sample preparation and analysis procedure.

Our Prepmaster is designed to guarantee top functional standards, a user-friendly surface, scalability and openness interfacing with all SPS and spectrometer systems.

Outstanding features of the PrepMaster are:
- Adaptive and priority-controlled intelligent administration of samples
- Sophisticated and flexible alarm systems
- Redundancy through backup-systems
- Web-based design with remote control and remote maintenance

The Resultmaster enables storage, visualization and evaluation of the data of the sample preparation and analysis process. Fast and specific monitoring and modification of the sample preparation flow can take place with close feedback to the Prepmaster. The universal program architecture means that the data can easily be transferred to MS SQL databases and superordinate management systems. This makes fast and precise surveillance of the production process possible.
Sample preparation and analysis within any production or general service laboratory have to provide fast and reliable data for quality control (QC) and quality assurance. Typically, the equipment in a cement laboratory consists of a fine-grinding mill and a press for preparation of pellets for XRF/XRD analysis. According to the customer requirements, further components can be added like, e.g., crusher/splitter, grain sizer, fusion machine, and average sample magazine. Based on various criteria as sample throughput, sample type, analytical requirements and labour costs the customer defines whether the QC laboratory will be operated manually or automatically. For both the manual and the automatic laboratory concept, HERZOG Cement offers the right solution.

Variety of different laboratory configurations

Sample preparation and analysis within any production or general service laboratory have to provide fast and reliable data for quality control (QC) and quality assurance. Typically, the equipment in a cement laboratory consists of a fine-grinding mill and a press for preparation of pellets for XRF/XRD analysis. According to the customer requirements, further components can be added like, e.g., crusher/splitter, grain sizer, fusion machine, and average sample magazine. Based on various criteria as sample throughput, sample type, analytical requirements and labour costs the customer defines whether the QC laboratory will be operated manually or automatically. For both the manual and the automatic laboratory concept, HERZOG Cement offers the right solution.

Variety of different laboratory configurations

Stand alone solutions

HERZOG Cement provides a wide variety of stand-alone machines that are ideally suited for the use in the cement industry. Depending on their demands, our customers can choose from a selection of manual machines with different equipment levels like, e.g., manual pulverizers with manual vessel cleaning (model HSM) or automatic sample dosing and vessel cleaning (HP-M100P). Accordingly, the manual presses are fitted with a hydraulic hand pump (model TP), an electrical hydraulic aggregate (TPE), or a PLC controlled high-precision pelleting system (HTP). Furthermore, semi-automatic machines are available that can be used as stand-alone machines. The combined pulverizer/pellet press HP-MP is a typical example for semi-automatic equipment often found in the cement industry. Semi-automatic machines are fitted with magazine-, cleaning- and dosing-functions that allow a stable and easy laboratory operation with significantly reduced manual intervention by the operator. At a later stage, these PLC controlled machines can be integrated into linear or robot automations.
Linear automations

Each semi-automatic machine can be connected to other equipment in a linearly mechanized solution. This design concept allows the fully automatic and consecutive preparation of samples. According to the required automation degree, the linear design may include the sample receipt from the airtube system, dosing, drying, pulverizing, pelletizing and transport to the XRF/XRD device. The linear automation is usually under control of the Prepmaster software which also performs sample registration, sample administration and communication with the analyzer and superordinate HOST computers.
Robot automations

The robot automation offers significant advantages. Sample handling by the robot allows a faster and more flexible preparation compared to a linear automation. New equipment can be easily added if sample frequency increases or new preparation steps have to be integrated, e.g., grain sizing or colour measurement. Robot automation easily allows alternative sample routing, i.e., one sample may be pelletized and the following reference sample is prepared using a fusion machine.

Laboratory equipment

Crushing

Lump samples like clinker or limestone have to be crushed before being pulverized. According to the customer’s needs and preferences, the crushing can take place in the plant or the laboratory. It can be done manually or automatically in a stand-alone machine or as a integral part of the plant sending station.

BB500/BB300/BB200

The crushers BB500, BB300, and BB200 are specially designed for the preparation of laboratory samples, but they can also be used to make samples and product in small quantities in industrial plants.

With the type BB500, the jaw opening width is 60 x 60 mm and the maximum feed size 50 mm. The type BB200 has a jaw opening width of 100 x 100 mm and a maximum feed grain size of 90 mm, the BB300 has a maximum feed grain size of 150 mm. The gap width can, according to model, be infinitely adjusted from 0 to 20 and 0 to 40 mm respectively.
The jaw crusher BB50 is engineered for fast but gentle crushing of medium – hard, hard, brittle and tough materials. These units are particularly suitable for processing stone, minerals, ores, glass, ceramics, construction materials, brittle metal alloys, slag, synthetic resins and many other hard and brittle substances.

The model BB50 was developed especially for specimen preparation in laboratory operations. The space – saving, dust – tight unit will fit on any laboratory bench.

HP-C/ HP-CA

The automatic jaw breaker, Model HP-C/HP-CA can easily be combined with other modular HERZOG machines such as feed and discharge magazines, an automatic pulverizing mill HP-M/HP-MA, an automatic pellet press HP-P/HP-PA, or an automatic fusion machine.

After each crushing cycle the jaw-breaker is cleaned automatically by compressed air. The resulting residual dust must be removed by an external dust exhaust facility.

<table>
<thead>
<tr>
<th>FEED GRAIN SIZE (MM)</th>
<th>QUANTITY (ML)</th>
<th>GAP ADJUSTMENT (MM)</th>
<th>TUNGSTEN CARBIDE</th>
<th>MANGANESE STEEL</th>
<th>CHROME STEEL</th>
<th>STAINLESS STEEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP-BB 50</td>
<td>35</td>
<td>2 – 10</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>HP-BB 200</td>
<td>90</td>
<td>1 – 30</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
</tr>
<tr>
<td>HP-BB 300</td>
<td>150</td>
<td>0 – 40</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
</tr>
<tr>
<td>HP-BB 500</td>
<td>50</td>
<td>0 – 20</td>
<td>• • •</td>
<td>• • •</td>
<td>• • •</td>
<td>• • •</td>
</tr>
</tbody>
</table>

HERZOG pulverizers are designed for use in the cement field. Usually, the grain size of the pulverized material has to be less than 75µm to guarantee a reliable XRF analysis. Our pulverizers and grinding vessels are specially designed for cement material with a hard mineral phase and abrasive features like clinker.

HSM

Due to the robust design with twin eccentric disk bearings the HSM mill achieves a long service life with a minimum of maintenance. The pulverizing parameters of the Herzog HSM mill are controlled by a PLC program. This allows an easy operation of the machine and complete flexibility in selection of processing parameters. A wide variety of different sizes and materials can be selected for the grinding vessels – according to the requirements of the customer.
HP-M100P

The grinding vessel is firmly attached to the vibrating aggregate and can be opened and closed by a handle. The good accessibility enables fast and clean filling of the grinding vessel. The grinding vessel lid is locked pneumatically.

After grinding, the sample material is filled into a stainless steel cup and can be removed at once at the output position during the cleaning of the vessel. The grinding vessel is cleaned automatically after every grinding process. Thus, the work place dust load is much decreased. The handling of heavy grinding vessels is therefore completely eliminated and the work load of the operator significantly reduced.

HP-MA

The HP-MA is a automatic grinding mill. After pulverizing the grinding vessel is automatically emptied and the ground material is made available at the discharge point. Three automatic cleaning features namely compressed air, sand cleaning (option) and wet cleaning (option) allow a sufficient material removal. Using the different cleaning functions, cross contamination can be reduced to a low ppm level. Furthermore, spoon sampling (option) during the material input provides the possibility to pre-contaminate the grinding with the subsequent sample. The HP-MA can be used as a stand-alone machine, with 30 or 60 position magazines, and in combination with the pellet press HP-PA or other components. Due to the modular design of the machine different and completely flexible configuration set-ups are possible.

HP-M

The HP-M is an automatic pulverizer offering a wide variety of options is available for the HP-M to meet all requirement of the customer. These options include loading magazine for 26 sample cups, magnetic separator for extracting metallic particles, cooling device for the grinding vessel, dosing device for grinding aid and blank sample, wet and sand cleaning as well as chromium steel and tungsten carbide grinding vessels.

The HP-M is specially designed for integration into robot automations. It is also possible to connect the mill with a transport belt to a HP-P.

HP-MP

The HP-MP is a compact automatic pulverizer and pellet press ensuring extremely fast and reproducible analytical results. The space saving design with the integration of the machine components for pulverizing and pelletizing in one machine housing makes this machine ideal for laboratory environments.

The individual operations for pulverizing and pelletizing can be carried out separately. The hydraulic unit allows the automatic monitoring and control of the applied pressure for optimal results. The system is designed to allow the integration into automatic linear and robot sample preparation systems with the use of specially designed cleaning and magazine systems for steel rings.
Overview about available pulverizer types

<table>
<thead>
<tr>
<th>MATERIAL OUTPUT</th>
<th>OPTION</th>
<th>OPTION</th>
<th>OPTION</th>
<th>OPTION</th>
<th>VOLUME GRINDING VESSEL (CCM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MANUFACTURING</td>
<td>AUTOMATIC</td>
<td>SPOON DOSSING</td>
<td>PILL DOSSING</td>
<td>DRY CLEANING</td>
<td>WET CLEANING</td>
</tr>
<tr>
<td>MANUAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10 50 100 250</td>
</tr>
<tr>
<td>HSM 50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSM 100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSM 100 H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSM 100 P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSM 100 A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSM 250 H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSM 250 P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP-M 100 P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP-M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP-MP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP-MA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP-MS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP-MP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+ CAN BE SIMULATED
S = STAND-ALONE
L = LINEAR AUTOMATION
R = ROBOT AUTOMATION

HERZOG presses produce high quality pellets with a smooth surface necessary for optimal XRF results. No matter whether manually or automatically operated, HERZOG presses achieve the desired uniformity and density of each individual pressed pellet with a maximum of reproducibility. Depending from the analytical requirements the operator can choose between four different pressing processes: Pressing in steel rings, pressing in aluminium shelters, two-component-pelletizing, and free pressing. For automations, pelletizing is limited to steel rings.

TP

This manually operated hydraulic press allows all the compacting operations common in the laboratory. The hydraulic pump is operated by a hand lever. The TP can reach maximum pressures between 200 and 600 kN.
HP-P

The automatic pellet press HP-P can be fitted with magazines for sample cups, steel rings as well as pressed pellets. The HP-P is specially designed for integration into robot automations. Furthermore, it can be used as a stand-alone machine and in linear automations.

TP20E

The TP 20 E is the bench-top laboratory press for easier and more efficient preparation of pressed pellets for XRF analysis. The pressure is built up automatically using an electric hydraulic aggregate instead of a hand pump. This means significant reduced physical workload and increased efficiency for the operator.

HTP

The pelletizing process of the HTP is controlled by the PLC program. This leads to improvement in reproducibility of sample preparation and consequently more precise analysis results. Pelletizing parameters such as total pressing force, incremental increase and decrease of pressure as well as pressure holding time can be preset on the HMI panel.

HP-PA

The automatic sample operation of the HP-PA guarantees a high sample throughput whenever required. The HP-PA can be fitted with magazines for sample cups, steel rings and pressed pellets. The HP-PA can be easily integrated into linear automation systems together with a crusher (HP-CA) and pulverizer (HP-MA).

HERZOG offers the full range of high-frequency fusion devices—from bench-top machine to the fully automated system including dosing and cleaning. HERZOG provides you with the optimal way of preparing homogeneous glass beads for accurate and reproducible analysis results. The high-frequency technology gives you complete control of the fusion parameters. It enables monitoring and exact regulation of all heating and cooling steps. The crucibles are oscillated during the melting process which guarantees through mixing of the molten mass. Therefore, fusion technology leads to samples of exceptional precision contributing to your analytical excellence.
HAG-M-HF

The HAG-M-HF is bench-top machine for economic preparation of fused beads. Sample material and fusion agent have to be weighed, mixed and inserted manually. The heating process to the preset temperature is automatic. During the heating process the crucible is oscillated in a circular movement to improve homogenization of the melt. After cooling the glass bead can be removed either from the crucible or the casting dish.

HA-HF 16

The HA-HF 16 is equipped with a large input/output magazine and an integrated automatic handling system. It therefore allows the processing of a significant sample batch without intervention of the laboratory staff. The operator inserts the crucibles with the pre-dosed sample/fusion agent in one of the 16 pockets of the input magazine. Up to two independently working heating systems guarantee a high sample throughput. After cooling only intact beads are forwarded to the delivery chute or can be buffered within the magazine.

HAG-HF

The HAG-HF is a fully automatic system covering the following preparation steps: dosing, fusion, quality control, cleaning. All modules are integrated within a compact machine base. The sample transport within the HAG-HF is handled by a robot and linear conveyor systems. The HAG-HF can be used as a stand-alone machine or easily integrated into laboratory automations. Different dosing modes can be defined for different sample types. Hygroscopic material can be protected from moisture absorption, wetting agents can be added using a peristaltic pump. During the fusion process, the steplessly variable temperature is continuously controlled using infrared pyrometer. The HAG-HF can be connected to all common analyzers. Crucible and casting dish can be automatically cleaned and dried.

Overview about available fusion systems

<table>
<thead>
<tr>
<th></th>
<th>HAG-M-HF</th>
<th>HA-HF 16</th>
<th>HAG-HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSING</td>
<td>X</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>RELEASING AGENT</td>
<td>X</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>CRUCIBLE INPUT</td>
<td>X</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>FUSION</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>CASTING</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>SAMPLE OUTPUT</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>CLEANING</td>
<td>X</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>SAMPLES/H CEMENT*</td>
<td>4</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

* CALCULATED WITH AVERAGE FUSION PROCEDURES OF EACH MATERIAL