Behaviour of recirculating bentonite sands, especially in consideration of bentonite-graphite systems

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In order to further improve the tolerances and surface properties of castings manufactured in bentonite-bonded moulds it is necessary to achieve a high degree of uniformity and reproducibility in mould production. Knowledge of the binding clays in recirculating sands is here especially important.

In the industrialized countries 65 to 70% of castings are produced in clay-bonded sand moulds. The advantages of casting production in this material are:

- low moulding material costs: sand, bentonite, carbon carriers and water are comparatively cost-effective raw materials;
- low material consumption: it is only in the hotter regions near to the casting itself that the bentonite loses its binding capability together with decomposition of the lustrous carbon producer;
- high productivity: the current moulding processes enable fast production of moulds;
- good environmental compatibility: bentonite quartz sand and, to some extent lustrous carbon producers, produce no or only small amounts of pollutants.

Castings will also in future continue to be primarily produced in clay-bonded moulds because it will be possible to improve their quality (dimensional accuracy, surface property, freedom from defects) as well as to increase the productivity. Achievement of this necessitates the reproducible and highly uniform production of sand moulds. It is necessary that there be a change of attitudes regarding sand control in the preparation and moulding technologies. Efforts are being made to change from the previous preventative sand control to exact control through separation of core sand from the recirculating sand.

There has to be a deeper knowledge of the behaviour of the binding clays in recirculating sands. If one investigates the properties of binding clays in new sand mixtures or in the clays themselves and compares the measured values with the properties in recirculating sands, one can see that there is a very high discrepancy. It is to be welcomed that recent research in Freiberg has been more concentrated on the properties of bentonites in re-circulating sands. Table 1 presents information from the Gießerei-Institut der Bergakademie Freiberg [1]. It is also worthy of note that elsewhere in this work it is stated that with a mixing operation of 5 min bentonites S and B have higher basic compressive strengths than bentonite C.

Limits of the assessment of bentonite control in new sand mixtures is also recorded elsewhere. Boenisch [2] refers to the differences in the strength of bentonite sands with various pretreatments. In his tests he achieves strengths between 1 N/cm² and 3 N/cm² with the same sand composition and the same compactibility. He refers to the fact that different bentonites behave differently in new and recirculating sands.

From these tests it can also be deduced that bentonites can only be assessed in recirculating sands. Because up to now such assessment has only been made sporadically, an attempt should be made to lay down criteria for the assessment of bentonites in recirculating sands. We propose the following parameters for such an assessment:

- behaviour of development during mixing,
- behaviour of development with pre-moisturization of the recirculating sand,
- thermal wear,
- influence of core materials (gases, vapours, sands),
- influence of sand additives,
- behaviour during reclamation.
Table 1. Thermal resistance and specific binding capacity of various bentonites

<table>
<thead>
<tr>
<th>Bentonite type</th>
<th>Specific binding capacity* in N/cm²</th>
<th>Rate of thermal loss** in %</th>
<th>Necessary binder addition*** in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>2.58</td>
<td>5.29</td>
<td>0.49</td>
</tr>
<tr>
<td>C</td>
<td>1.83</td>
<td>10.50</td>
<td>1.16</td>
</tr>
<tr>
<td>G</td>
<td>2.83</td>
<td>6.00</td>
<td>0.43</td>
</tr>
<tr>
<td>S</td>
<td>2.24</td>
<td>7.20</td>
<td>0.64</td>
</tr>
<tr>
<td>EG</td>
<td>1.50</td>
<td>3.50</td>
<td>1.13</td>
</tr>
</tbody>
</table>

* The specific binding capacity is given in N/cm²/s bentonite. This property was determined in cumulatively processed sands. The bentonite sands were re-processed until such a time that the highest green compression strength was achieved.

** The loss of bentonite was in each case determined with an iron/sand ratio of 0.25. The loss is stated as a % of the binding clay content, the active content being determined by the methylene blue method. In this test the bentonite content of the individual test sands was set at various levels in order to achieve a desirable green compression strength of 20 N/cm². The iron/sand ratio was 0.25.

*** The necessary binder addition was the amount of bentonite that had to be added to the recirculating sand in order to maintain a green compression strength of 20 N/cm². The iron/sand ratio was 0.25.

Behaviour of development during mixing

During mixing the bentonite should be finely distributed around the sand grains. Large particles should be avoided. Likewise, fines that are not deposited on the sand grains are undesirable. Boenisch here coins the expression dispersity, meaning the depositing of finely distributed bentonite layers on the sand grains.

Also here there is a different behaviour in recirculating sands after long mulling times. Figure 1 shows the coating of sand grains after 20 circulations when using bentonites D and E. Bentonite D has a coarser primary particle structure. This is also more clearly recognizable after 20 circulations.

The basic compressive strengths have reached their final values after 10 preparation cycles. Figure 2 shows the increase in basic compressive strengths of various bentonites, whereby type QB was produced by the mulling of bentonite D together with graphite. It can be seen that it is not possible to assess the bonding capability after the first preparation cycle.

The development of strengths in recirculating sands also depends on the types of mixers used. The tests in Figure 2 were based on the use of a pug mill mixer. With use of a high-speed mixer the strength increases more rapidly but
the final values are not so high. High strengths are only achieved with sand well coated with bentonite and this is then only possible if the used sand is previously optimally moisturized.

**Behaviour of the development of recirculating sands**

Bentonite development is to be understood as the complete covering of the montmorillonite laminae with water and their enlargement. This property is inter-related and closely coupled with the increase in the green strengths and plasticity. In order to understand these processes it is absolutely necessary to consider the crystal structure of the montmorillonite, the laminae of which have a typical $\text{TOT}$ structure ($\text{SiO}_2$, tetrahedron $= \text{T}$, $\text{MeO}_3$, octahedron $= \text{O}$) [3]. With montmorillonite the uncontrolled (isomorphous) exchange of the aluminium by magnesium takes place in the octahedrons. The resultant negative loading of the lamina is compensated by the addition of $\text{Ca}^2+$, $\text{Mg}^{2+}$ and $\text{Na}^+$ ions on the lamina. These ions normally have a hydrate envelope and thus separate the laminae. If the surface ions lose their hydrate envelope during heating the laminae collapse. The resultant coulombic binding forces are very high. On account of the binding forces the surface ions are partially drawn into the tetrahedron lattice.

With sufficient availability of water the renewed widening of the spacing between the laminae is dependent on the size of the laminae, the charge of each elementary cell and the type of ions present ($\text{Ca}^2+$ or/and $\text{Na}^+$). With $\text{Na}^+$ widening of the laminae occurs after hydration of all ions, with $\text{Ca}^2+$ ions already after part of them has been hydrated.

In practical terms this means that bentonite development is a time-dependent process and is only little influenced by additional mixing energy. During the development of used sand it obtains its requisite high plasticity and binding force through the addition of water, without the use of additional energy. The wet tensile strength in pre-moisturized used sands thus still increases after 8 to 10 h.

**Figure 3** shows the influencing of the rate of development. The increase in the wet tensile strength can be evaluated as a measure of the development. The development rate of bentonite QB is distinctly faster than that of type D.

**Thermal wear**

The thermal wear of a bentonite in moulding sand is dependent on the temperature of the sand during and after pouring. The following additional factors are also important:

- the particle size: the smaller the montmorillonite laminae the greater is the influence of the thermal loading;
- the crystal structure: for example, iron in the lattice greatly reduces the thermal stability;
- the coverage of ions on the lamina: iron and magnesium ions can block the binding forces through the formation of hydroxide: potassium ions lead to the formation of ilite. Additionally, reduction and oxidation processes as well as reactions with salts play a part in thermal wear.

It becomes clear that assessment of the thermal stability can only be measured in recirculating sands. Table 2 shows test results for the determination of thermal wear.

A test over 20 circulations began with the use of 92% quartz sand and 8% binder. Up to the 5th casting, in each case 0.8% bentonite was added to compensate for losses. After the 5th circulation it was endeavoured to achieve a green compression strength of 16 N/cm$^2$ and maintain this up to the 20th circulation for the determination of the wear figures.

The thermal loading on the sand was high, the iron/sand ratio being 1:3. The castings cooled in the mould for 3 h.

**Influence of the core materials**

It is accepted that condensates and core materials negatively influence the strengths. Some core binders have a very great influence. Boenisch [4, 5] refers to the fact that liquid condensation products liberated from cold box cores considerably worsens the binding capability of the bentonite.

Operational figures from recirculating sands also show that core materials in which potassium ions are present lead to higher bentonite consumption (Table 3).

The tests were carried out in the same way as those in Table 2, the figures here being those after 10 circulations. It was also here endeavoured to maintain a green compression strength of 16 N/cm$^2$. As with thermal wear the influence of core materials can only be determined in recirculating sands. Up to now there have been hardly any investigations of this type.

**Influence of sand additives**

This influence is also accepted. In an earlier work Boenisch investigated the influence of pit coal dust in recirculating sands [6]. Condensation products from the carbon...
carrier also cause reduction of the strength properties in bentonite sands.

The influence of graphite in recirculating sands has been investigated. It was also possible to observe a number of changes. A moulding sand which is bonded with a bentonite-graphite mixture instead of bentonite alone showed a higher packing density with the same amount of compacting work. The differences in the packing density increase with an increasing number of circulations. The flowability of the sand during moulding thus increases with the number of circulations. This can also be deduced from the reduction in the wear (Figure 4) and the improvement in the stripping of the mould from the pattern (Figure 5).

**Figure 4.** Resistance to erosion with mixing times of a) 7 min and b) 15 min

**Figure 5.** Stripping properties (5% carbon carrier, 8% bentonite, 40% compactability, 25 mm core length)

**Figure 6.** Soft reclamation of bentonites

**Figure 7.** Example from a foundry with a flaskless shoot-squeeze moulding plant: a) moisture and b) temperature curves of the sand measured over 3 months

**Behaviour during reclamation**

With the reclamation of return sands in accordance with the tests in Table 2, bentonite D and E behave the same. Reclamation of recirculating sands containing the bentonite-graphite binder is considerably better (Figure 6).

The properties of bentonites and other binders in clay-bonded sands will in future be assessed in recirculating sands. Only then is it possible to assess wear figures, the necessary binder contents and also the moulding properties.

**Examples for the assessment of the behaviour of binders**

In conclusion, two examples from foundries clearly show that it is indeed only possible to assess the behaviour of the binder in this case bentonite QB, in the recirculating sands.

**Example 1:** This foundry uses a flaskless moulding plant (shoot-squeeze), for the production of coreless castings. It was here possible to considerably reduce the mixing time after the introduction of a bentonite-graphite system.
References


... frequently also carbon carbons could be reduced.

The added amount of binders and the dry curing of the sand as well as reduction of the benzene concentration. The avoidance of defoamers and the loss of shrinkage, better mold fill, more uniform and higher mold compaction, better green strength and better molded shapes are some of the advantages of using bentonite-graphite systems. All foundries using bentonite-graphite systems on this...