Mixing clay-bonded moulding sand

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1. INTRODUCTION

Mixing is a major part of moulding sand preparation. Most of the mechanical and physical properties of the moulding sand determining the success of the moulding and casting process are dependant on the quality of the mixing process. Instead of mixing often the tummulding is used. In this way the expression is only used for mixing in a machine with tummulding wheels or rollers.

The mixing efficiency of clay-bonded moulding sand has returned to the focus of interest on account of fairly recent laboratory experiments (1), (2), (3), (4), (5) in which a cumulative mulling procedure yielded values well above the known ones.

These results give rise to the question whether current mixing methods make sufficient use of the potential bonding power of bentonite.

Another question is whether in view of the results of cumulative mulling the evaluation of the bonding properties of bentonite should be studied critically again. For, the present test method yields much lower values.

It is also wondered if more information could be obtained about the mechanism of mixing clay bonded sand and the various apparatus used in the process.

Questions gave cause for exhaustively studying the effects of type of mixer, mixing method and sand composition.

2. PREVIOUS STUDIES

A previous study (6) on sands from 15 systems of circulating units sand served to determine the effective bonding power, expressed as green compressive strength.

With a view to eliminating the influence of the moisture content, the sands were evaluated at equal degree of moisturizing, namely at which the water still is just physically present. This condition is reached when the riddle density of the sand is 0.8 kg/dm³, or the compactability 45%.

Dividing the strength measured at this degree of moisturizing by the clay content yielded a measure of the specific bonding power of the bentonite in the mixture.

The bentonite content (dry matter) was calculated from the methylene blue value.

In the mentioned types of sand, the effective specific green compressive strength (called effective compressive strength) had an appearance of 2 to 2.7 N/cm² percent of bentonite. Additional mulling in a laboratory muller for five minutes increased the values to an average of 2.8 N/cm². Differences between the various types were slight.

A specific compressive strength calculated from the strength obtained with cumulative mulling in which fresh sand and Wyoming bentonite (4) are used amounts to approximately 4 N/cm²/%. This would suggest a minimum potential specific compressive strength of 4 N/cm²/%, which will further on be referred to as potential compressive strength.

Close consideration of the effective compressive strengths measured in the system sands shows that they amount to only 50 to 85% of the potential values. Even additional mulling in a laboratory muller mixer fails to raise the value beyond 70% of the potential. It is important to know to what extent the remaining divergence from the potential value should be attributed to insufficient mixing of the system sand or to any other causes.

For the evaluation of the bonding power of bentonite it is customary to use a single mixing treatment of 5 to 10 minutes. The effective green compressive strength then obtained is roughly 2.5 N/cm², which is considerably less than the potential compressive strength of the bentonite. The question arises how to interpret the results of such bentonite tests.

A special feature of cumulative mixing is that it is made up of several cycles. Each cycle starts with a relatively high moisture content and ends when the mixture has dried so far as to be loose and crumbly. A mixer ensuring very intensive mixing is needed to promote evaporation of the water.

Mixing is discontinued when the strength has reached its maximum. This may take several cycles with a total mixing time of ½ to 1 hour. Such a long mixing time in one cycle at constant moisture content results in a much lower effective compressive strengths (7). It should be noted, however, that the basis for comparison because divergent types of basic sand and mixers were used. The two mixing procedures will have to be compared on the basis of identical sand mixtures, and using the same type of mixer to obtain more reliable findings in this respect.

3. INVESTIGATIONS

The investigations covered 7 test series. The conditions are set out in table I.

Series 1 and 2 are comparative tests for studying the mixer type and dosing sequence. Mixing was done at constant moisture content. The loss of moisture was continuously made up for.

In test series 3 to 7 a cumulative mixing method was followed, using the high-speed muller with a horizontal wheel because the mixture dries fairly rapidly in it, shortening the cycle time. In these test series the effects of cumulative mulling of the bentonite type, the basic sand and the addition of calcined bentonite were studied. The last series served to determine the maximum achievable effective strength of the bentonites present in a circulating system sand.

The result of the mixing treatment was evaluated by reference to the development of the green compressive strength as a function of the mixing time. The numbers of the curves in the charts indicating the changes in strength correspond with the test numbers of table I. The green compressive strength consistently related to a riddle density of 0.8 kg/dm³ (a compactability of 45%) This means that a strength value was obtained at one and the same degree of moisturizing, for determining this value, two measurements were taken when, owing to the mixture drying, the density approached 0.8 kg/dm³. The exact value was then obtained by interpolation or extrapolation to the riddle density of 0.8 kg/dm³.

During mulling at a constant moisture content, samples were taken from the muller and dried in air to the required density by moving them over by hand.

The effective (specific) compressive strength can be derived from the green compressive strength found by dividing the value mentioned first by the percentage of bentonite on the basis of dry matter, which was 5.4%. The moisture content of the bentonite was 10%.

From a practical point of view the total mixing time, which was about one hour, would seem rather long. Allowance should be made, however, for the fact that mixing in a sand system is cumulative. The constantly rising strength will already have reached its maximum, when the short mixing times are added up, is subjected to mixing which lasts over one hour for most of the sand.
<table>
<thead>
<tr>
<th>Test Mix No.</th>
<th>Type of Mixer</th>
<th>Charge (kg)</th>
<th>Base sand</th>
<th>Type of Mixture</th>
<th>Constant moisture content</th>
<th>Method of mixing</th>
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<tbody>
<tr>
<td>1</td>
<td>Muller muller wheel (fig. 1)</td>
<td>15</td>
<td>W. European tertiary deposit</td>
<td>Muller mixture</td>
<td>2</td>
<td>Mixing time: 10 min.</td>
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<td>2</td>
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<td>2</td>
<td>Na+ Wyoming</td>
<td>Na+ Wyoming</td>
<td>(2.2 ± 0.1%)</td>
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<tr>
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<td>Na+ Wyoming</td>
<td>Na+ Wyoming</td>
<td>(2.2 ± 0.1%)</td>
<td>Sequence: water - bentonite</td>
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<tr>
<td>5</td>
<td>Muller muller wheel (fig. 3)</td>
<td>5</td>
<td>W. European tertiary deposit</td>
<td>Muller mixture</td>
<td>4a</td>
<td>Mixing time: 10 min.</td>
</tr>
<tr>
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<td>Muller muller wheel (fig. 1)</td>
<td>6</td>
<td>Dune sand</td>
<td>Dune sand</td>
<td>15</td>
<td>Mixing time: 10 min.</td>
</tr>
<tr>
<td>7</td>
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<td>7</td>
<td>Na+ Wyoming</td>
<td>Na+ Wyoming</td>
<td>(2.2 ± 0.1%)</td>
<td>Sequence: water - bentonite</td>
</tr>
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<td>8</td>
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<td>(2.2 ± 0.1%)</td>
<td>Sequence: water - bentonite</td>
</tr>
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<td>Na+ Wyoming</td>
<td>(2.2 ± 0.1%)</td>
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<td>14</td>
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<tr>
<td>15</td>
<td>Muller muller wheel (fig. 3)</td>
<td>15</td>
<td>Na+ Wyoming</td>
<td>Na+ Wyoming</td>
<td>(2.2 ± 0.1%)</td>
<td>Sequence: water - bentonite</td>
</tr>
</tbody>
</table>
3.1 Mixers

The study covered four different laboratory mixers:

1. A high-speed muller mixer with a horizontal wheel (fig. 1).

![Fig. 1 - High speed laboratory muller with a horizontal wheel. Max. charge 18 kg.](image)

2. A laboratory muller mixer with vertical wheels (fig. 2).

![Fig. 2 - Laboratory muller with vertical wheels. Max. charge 6 kg.](image)

3. A rotating arm mixer, in which the sand is forced into the narrowed portion between the bent arm and the outer wall (fig. 3). At the end of the arm, where the sand flows through a narrow opening, relatively high shear forces arise.

![Fig. 3 - Laboratory rotating arm mixer. Max. charge 3 kg.](image)

4. A cycloidal mixer (fig. 4). It allows three speeds. The tests were carried out at the lowest and highest speeds of 140 and 590 r.p.m.

![Fig. 4 - Laboratory cycloidal mixer. Max. charge appr. 2 kg.](image)

The results are set out in fig. 5. As could be expected, the result obtained with the cycloidal mixer running at the lower speed was very moderate.
sequence is less important according as greater forces are exerted on the mass during mixing. Such forces arise when the roller pressures are higher, or in rapidly revolving mixing elements.

A feature of the low-speed muller mixer was that it produced a fairly slow strength development in the beginning (curve 2).

Summarizing, the conclusion must be that clay-bonded sand can be prepared according to various mixing principles. The speed at which the strength develops is mainly a question of the amount of energy introduced into the sand. If this is smaller than in the slow-running machines, the strength development will likewise be slower. If the mixing forces exerted on the mixture are too low, as in the low-speed cycloidal mixer, the bonding force will not develop to a maximum even after prolonged mixing.

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**3.3 Cumulative mixing**

In the cumulative mixing test, each mixing cycle was started at a riddle density of the sand of 0.5—0.6 and ended at 1.2 kg/dm³. An attempt has been made to reproduce the

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**Fig. 6** — Influence of dosing sequence on green strength at a mixing time of 10 minutes.

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**Fig. 7** — Influence of cumulative mulling on the strength development.

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**Table:**

<table>
<thead>
<tr>
<th>Order of addition</th>
</tr>
</thead>
<tbody>
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<td>bentonite, water</td>
</tr>
<tr>
<td>water, bentonite</td>
</tr>
</tbody>
</table>

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**Figures:**

- **Fig. 6**
- **Fig. 7**

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**References:**

1. Mulling with constant moisture content (2.2 ± 0.1%)
2. Cumulative mulling

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**Graphs:**

- **Graph 1**
- **Graph 2**

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**Diagrams:**

- **Diagram 1**

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**Charts:**

- **Chart 1**
- **Chart 2**
refined described in the relevant literature (4) by using the same mixer and cast out in fig. 7. The strength attained by one hour cumulative mixing (curve 5) is substantially higher than that achieved in an equal mixing time with continuous mixing at constant moisture content (curve 1). And yet the first trial, even after mixing for about one hour, covering six cycles, failed to produce the strength which the listed researchers (4) (3) had found. The calculated compressive strength was 34 N/cm², whereas in a study mentioned in (4) an effective compressive strength of 4 N/cm² had been obtained. The observed difference was due mainly to a different base sand, as will be enlarged upon later when the influence of the base sand is discussed.

3.4 Clay

The investigations concerned, of which the results are shown in fig. 8, covered three types of clay.

The investigations have shown that the final strength of the studied types of bentonite hardly varies. The strength development at short mixing times of Ca-bentonite and alkali bentonites is noticeable shorter than when Wyoming bentonite is used. This agrees with the findings of other researchers (3) (5) (9).

Fig. 8—Influence of the type of bentonite on strength development with cumulative mulling.

5. Wyoming bentonite
6. Activated Bavarian bentonite
7. Ca+-bentonite from Mississipi

3.5 Base sand

The present study has compared four different kinds of silica sand. The results (fig. 9) show that the development of great strength when dune sand II (curve 9) is used is much quicker than with ordinary silica sand (curve 5). In addition, a higher final value is reached with the former sand. The effective compressive strength is then approx. 42 N/cm² per part cm of bentonite. This value is roughly level with that found by the investigators mentioned earlier (3) (4).

In mixtures with dune sand I (curve 8) and river sand (curve 10) the strength develops less quickly then when dune sand II (curve 9) is used. A striking feature is the relatively slow strength development in the siliceous sand from European tertiary deposits (curve 6). The reason is probably the smooth and inactive surface of the sand which offers the clay little to adhere to. By contrast, the dune sand suggests a light stony surface which presumably contains more bonding elements (OH groups?) promoting the adhesion between the bentonite and the sand grains. This assumption is supported by tests (10) in which the silica sand is first calcined, during which treatment OH groups are separated off. A sand of this type results in much lower strength values. The grain size has no noticeable influence on the green strength, which agrees with other studies (11).

Fig. 9—Influence of the base sand on strength development with cumulative mulling.

5. Silica sand from West European tertiary deposit.
6. Dutch dunesand I (AFS Gr. F.N. 55)
7. Dutch dunesand II (AFS Gr. F.N. 51)
8. Dutch riversand (AFS Gr. F.N. 40)

3.6 Adhesion and dispersion promoting agents

Some researchers (12) (13) have first treated the base sand inter alia with hydroxides and found the strength to have increased. Treatment with alumina, however, drastically reduces the strength (10). It is obvious that as soon as a reduction in adhesion turns the adhesive bond into the weakest link, the strength begins to decline. Tests with various types of sand have shown, however, that the strength development, too, is accelerated by improved adhesion.

It has furthermore been found that clays which are more readily dispersable, because the clay conglomerates display less cohesion, also tend to envelop the grains more quickly. An example is Ca bentonite, which disintegrates more easily when excessively moist, thereby displaying a more rapid strength development.

Substances promoting adhesion and dispersion are likely to accelerate the strength development. It is not always possible, however, to decide which of the two actually has the desired effect.

3.6.1 Calcined clay

Moulding sand mixtures made from fresh components are rarely used in practice. The usual procedure is to use sand systems in which the sand circulates and in which disassociation products of the clay (calcined clay) and of additives such as coal dust accumulate. It is useful to know the influence of such substances on the development of the strength. For the purpose of determining the effect of calcined clay, 5% calcined Wyoming bentonite was added to mixtures made of fresh components.
Various temperatures were applied for calcining. The calcining time was two hours. As appears from fig. 10, the calcined bentonite (curves 11, 12, and 13) noticeably accelerates the strength development, viz., according as the calcining temperature is lower. The final strength is also increased and reaches approx. 6 N/cm² per per cent of bentonite. This means an increase by about 1 N/cm² per per cent of bentonite.

This increased strength is presumably attributable to a broadening of the bonding bridges by the burnt clay. The accelerated strength development is no doubt due, however, to either a more rapid adhesive bonding process of better dispersion of the bentonite.

Fig. 10 — Influence of addition of calcined bentonite (Wyoming) on strength development with cumulative mulling.

1. Silicasand with 5.4% bentonite
2. Mixture 5 with 3% bentonite heated at 650°C
3. Mixture 5 with 3% bentonite heated at 700°C
4. Mixture 5 with 3% bentonite heated at 750°C
5. System sand

The increase in strength of three types of unit sand subjected to cumulative mulling can be derived from fig. 11. The curves indicate that the gain in strength through this mulling method differs in the three types but is moderate on average. The average effective compressive strength after cumulative mulling was only 3.2 N/cm²/2. This value is much below the potential compressive strength of the bentonite used in these sand systems, which is approx. 4 N/cm².

38 Other properties

Although the green compressive strength is often applied as a measure of the cohesion of the moulding sand mixture, it is by no means a standard applicable as regards the variety of properties important to the moulding sand casting process. To study these properties, test methods have been developed which simulate practical conditions and yield measuring factors directly related to the behaviour of the moulding sand in practice (14).

Some of these properties were included in the study. As far as moulding is concerned, major aspects are the

Fig. 11 — Strength development with cumulative mulling of unit sand from 3 different moulding units

Fig. 12 — Influence of cumulative mulling on several properties of silicasand with 5.4% bentonite.
important part both in regard to the rate at which the strength develops and the maximum that is reached. The results give the impression that the adhesive bonding has to develop further for ensuring maximum compressive strength than necessary for the other properties. In the latter, the cohesive bonding presumably forms the right link. It is supposed that the maximum cohesive bonding force is reached already after a short mixing time, when also the moisture content and high-temperature properties have reached optimum values.

4. DISCUSSION OF RESULTS

4.1 Mechanism of mixing

Various effects observed during the tests allow the following hypotheses regarding the mechanism of mixing: for the purpose of spreading the clay in a layer of uniform thickness around the sand grain it has to be dispersed and the particles fixed to the grains. When clay conglomerates and sand grains are rubbed together under pressure during the mixing process, bentonite remains on the grains, causing the conglomerates to split up and ultimately disappear. This effect is promoted by increased adhesion and reduced cohesion of the clay conglomerates. On the basis of this mechanism, the influence of various factors on the strength development is easy to explain. If water is added before the test, it immediately absorbs the water, swells and lumps together. However, strong friction may divide the clay conglomerates. In a mixing process involving considerable kneading or impact forces, the mixing sequence therefore carries little effect. If the sand is moistened and kneaded until it has fixed itself to the grains, and the formation of conglomerates is checked, then the mixing forces need not be so strong.

Cassiterite does not swell and shows little cohesion when moistened excessively. The clay conglomerates are therefore more easily divided up. Activation causes the tendency to swell to increase; cohesion at higher moisture rates increases and the clay conglomerates become larger. The Wyoming bentonite shows the strongest swelling tendency (15) and the slowest strength development. The favourable effect of cumulative mixing is attributed to more effective disaggregation of the clay conglomerates during the period when the moisture content drops. Additional, the conglomerates become brittle and break up more easily. Mixing at a higher moisture content increases the adhesion to the sand grains.

Certain substances are capable of changing the grain surface, improving adhesion. They form, as it were, a bridge between the bentonite and the sand grain. It may be that such substances, such as calcined bentonite, moreover facilitates the cohesion of the clay conglomerates. If there is presence of calcined clay in circulating system sand will greatly increase the mixing effect. As the sand passes the mixer a number of times, a cumulative mixing effect arises, so that a relatively short mixing time suffices for each cycle. A considerable portion of the mixing time is needed to distribute the water and re-activate the clay. Once a small part of the mixing time is available for dispersing the freshly added clay and enveloping the new sand grains.

4.2 The effective bonding power of bentonite

The green compressive strength of 5-10 minutes' mixing time is usually taken as a measure in evaluating the bonding power of bentonite. If mixing is so short, the particular sand has been proved inferior on the result. To permit reliable comparison of the results, the sand type used should therefore be standardised.

The compressive strength obtained with such short mixing is sometimes less than the effect of clay with the same cohesive mixing. The measured factor provides an indication of the strength development of a certain type of bentonite rather than giving any information about the potential bonding strength. Both readily dispersible bentonites are rated favourably. This does not apply to the sand content in regard to other bonding properties which, as the investigations have shown, reach their optimum more quickly, and the clay is more cohesive, although after short mixing times of 5-10 minutes the potential bonding power has again not fully developed in this respect.

The bonding power of the clay is likewise not fully utilised in sand mixtures used in practice. In mixtures consisting mainly of fresh components only 40 to 65% of the maximum achievable compressive strength is reached. The result is again affected of course by the condition of the grain surface and the dispersibility of the clay.

The effective compressive strength, reached with circulating system sand is slightly higher than in mixtures made up of fresh components because mixing is cumulative and the calcined clay improves the mixing efficiency. However, presumably because of the higher strength of the casting process the effective compressive strength does not go beyond 50-70% of the potential value.

Very intensive mixing might raise it to about 80% but this is not warranted economically and not necessary from a technological point of view. For, at a mixing intensity which results in 60-70% of the potential compressive strength the other bonding properties come very near the optimum. The gain produced by more intensive mixing is then no longer proportional to the extra effort.

Experience with various sand systems (6) has shown the mixing effect to be sufficient if 60-65% of the potential compressive strength is reached. This can be easily verified by subjecting the sand to additional mixing in laboratory mixer (6). The specific compressive strength should then not increase by more than 10-15% of the ultimate value.

4.3 Main features of the moulding sand mixer

4.3.1 Mixer type

The investigations have shown that any mixing method whereby sufficient forces act on the sand-clay mixture to break up the clay conglomerates and rub them on to the sand grains is suitable to bring about the bonding effect. The mixing forces can be produced by rollers, kneading elements or by the impact principle involving rapidly rotating vanes or rotors (15).

On the one hand, the mixing forces must be sufficiently great to break up the clay conglomerates and cause them to produce the bonding effect, but on the other hand the effect will not longer be proportional to the energy applied if the specific pressures are too high. The optimum specific pressure is dependent on the material to be mixed. Sand with clay conglomerates from water-moistened and swollen Na-bentonite or from fat natural moulding sand requires greater specific mixing force. For instance, it applies also to sand containing dry and solid lumps.

4.3.2 Mixing rate

If optimum mixing forces are applied, the quantity of material subjected to them per unit of time is a measure of the mixing speed. The larger the mixing speed, the greater the power needed. The quantity worked depends on the surface area of the mixing, kneading or beating elements and the speed at which they move in the mass. A condition is, however, that the flow of material in the mixer ensures continuous and intensive contact between the kneading or beating elements and the mixture. The plows must therefore function well and be adjusted to the consistency of the mass. Moulding sand which has a high moisture content and is plastic often requires a different setting than a drier, more crumbly material.

The energy applied to the mixing elements can roughly be derived from the power consumed by the driving motor or, at full motor load, from the energy losses. For slow-running mixers the installed motor power is 30-50 kW per ton of charge, and high-speed mixers require between 80 and 120 kW per ton. This power is not fully utilised. Batch-type mixers partly deviate during lifting and discharging. During mixing, more power is consumed after addition of water as the mixture becomes more plastic.

The advantage of a high-speed mixer is that it takes less time to accomplish comparable results than a shackle mixer. The shrinkages are indeed more pronounced, however, of a lower homogenising effect in the sand system. The high speed rate makes moisture adjustment during mixing more difficult.
4.3.3 Mixing capacity

The mixing energy which system sand requires per cycle for recovery, depends mainly on the thermal load, i.e., the metal/sand ratio during casting. According to the thermal load increases, more fresh bentonite water and sand are necessary. All this calls for more intensive mixing.

The energy which the mixer can apply to the mixture is variable within certain limits through choice of mixing time and charge volume, but this choice is also directly linked with the capacity of a particular mixer. The requirement calculated on the basis of continuous maximum power of the driving motor varies between 0.5 and 2.5 kWh/t. Depending on the metal/sand ratio, 1 to 2 kWh/t has to be reckoned with for unit sand.

Backloading will require less. Preparation of moulding sand from fresh components needs over 2 kWh/t. Smaller mixers demand more because, by proportion, their mechanical losses are bigger.

Of the installed motor power, only 50 to 80% is efficiently used for mixing. The remainder is unused owing to insufficient adaptation or poor functioning of the mixer, or is lost through friction in the driving mechanism.

4.3.4 Continuous and batch mixing

A continuous mixer has the advantage that a constant flow of sand passes the mixer. The charge is constant, so that the power consumed likewise hardly fluctuates. The installed power is thus better utilised. There is no idle running when filling and discharging. A drawback is the more difficult proportioning of the substances added in the mixer.

4.3.5 Disintegrating effect

Most mixers display a certain disintegrating effect but also a tendency to allow conglomerates to form. In mixers in which the first effect predominates, the mixer contributes to better desegregation of the sand. With high specific roller pressures or rapidly moving mixing elements producing a beating effect are at an advantage in this respect. (15) Lumping is obliterated only by beating effect.

4.3.6 Effective mixing time

The gross mixing time which is available is not fully utilised in batchtype mixers. The mixing effect is very low during filling and discharging, which means that this time is practically lost. If for a certain mixer the total mixing time is reduced, it is the effective mixing time that suffers because the filling and discharging periods do not change. The effective mixing time is thus relatively amenable in short mixing cycles. In this respect, the high-speed mixer would thereby be at a disadvantage, but on account of the higher speed the discharging time is shorter.

(15) To obtain a reliable picture of the effective mixing time, it should be related to the gross mixing time. Depending on the gross mixing time the effective mixing time will be 75-90%.

As long as the sand mixture does not contain the required amount of water, reactivations of the clay is not effective. The water should therefore be added as quickly as possible, while uniform distribution over the contents of the mixer will speed up its mixing with the sand.

4.3.7 Service life and maintenance

The operational reliability of a moulding sand mixer is extremely important. Trouble-free operation is a basic condition for an uninterrupted process. Besides, the service life and maintenance costs have some effect on the cost of the sand.

5. CONCLUSIONS

The results of the investigations will undoubtedly contribute to better insight into the various aspects of the process of mixing clay-bonded moulding sand.

Means of increasing the effective bonding power under certain conditions are the method and intensity of mixing, the condition of the surface of the sand grains, and additives promoting adhesion and dispersion. The moulding sand mixer displays a number of important features which will have to be taken into account in deciding on a particular type.

REFERENCES

1. C. E. Wenninger, Transactions AFS 74 (1966) p 221-228
2. C. E. Wenninger W. J. Lang, Transactions AFS 77 (1969) p 39-44
5. C. E. Wenninger, Transactions AFS 71 (1973) p 177-178
7. W. Patterson, D. Baensisch, Exchanging paper 24th Foundry Congress IFC, Stockholm paper 16, p 402-416
8. C. E. Wenninger, Transactions AFS 76 (1966) p 521-528
9. F. Hofmann, Giesserei 65 (1968) no. 13 sect. p 577-583
11. A. B. Drapers, Transactions AFS 76 (1965) p 529-539
12. E. Dimpfl, Giesserei 27 (1943) p 257-262
15. K. Piasek, Exchange paper Foundry Congress IFC Amsterdam 1949 p 200-218
16. H. B. Ries, Transactions AFS 81 (1973) p 256-300