The mixing process of a new core sand mixer and a method of evaluation of mixers used in foundries

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Within the process of development of a new core sand mixer extensive studies have been undertaken to optimize the mixing process. Thereby, a procedure of evaluation has evolved enabling the judgement of qualitative and quantitative criteria of immediate practical importance regarding modifications of the tools and parameters characterizing any given mixing process. Aside of this, a comparison of various mixers also becomes viable.

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Technical requirements regarding core sand mixers

Today, core sand mixers are required to meet increased demands in comparison with earlier times. Foremost, such demands are as follows:
- Mixing capacity is demanded to increase.
- Quality of the mixture must improve.
- Residues of sand remaining after discharge must decrease, as these cause the quality of subsequent charges to diminish.
- Residues, i.e. those bound to movable parts increase wear, so residues, again, must decrease.
- Accessibility to vital machine functions must improve, as this eases operation and maintenance.
- The size of the processed batch must be made variable, as this limits intermediate storage of sand when small cores are needed.
- Automatic operation is required, as personnel costs cannot be sustained.

Principles of operation of known rotary blade mixers

Within a moist batch the rotation of the blades is partially conveyed to the batch itself, thus reducing the apparent motion between the blade and the batch. Thereby, the entire batch may appear to be rotating with the blades. Aside of an increase of wear, any deliberate increase of rotational speed will, therefore, not necessarily yield an increase of obtained mixing intensity.

In order to counteract the tendency of the batch to 'move along with' the blades, mixers with a vertical rotational axis are equipped with spoilers mounted above the blades onto the inside of the mixer's drum. As a result, the respective area of the drum cannot be cleaned by rotating scrapers.

The new mixer

Figure 1 shows the new mixer designed for a maximum batch size of 120 kg. The front cover has been removed. The interior of the drum reveals the blades. The latter along with the drum's inside surface have been lined with a wear-

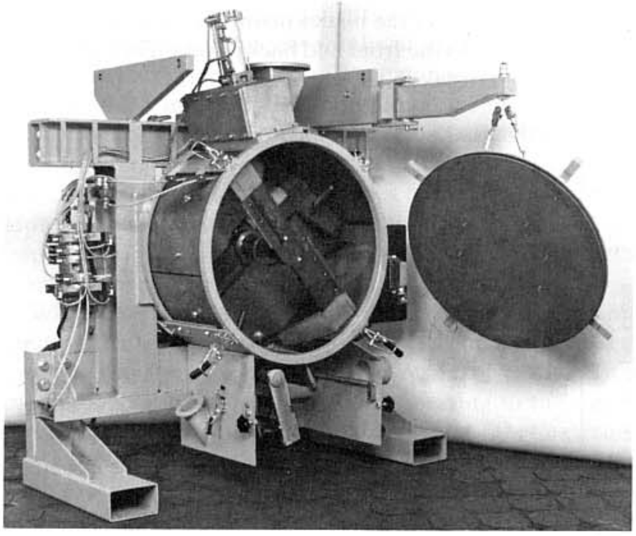

Figure 1. The new mixer with its front lid opened (batch size 120 kg)

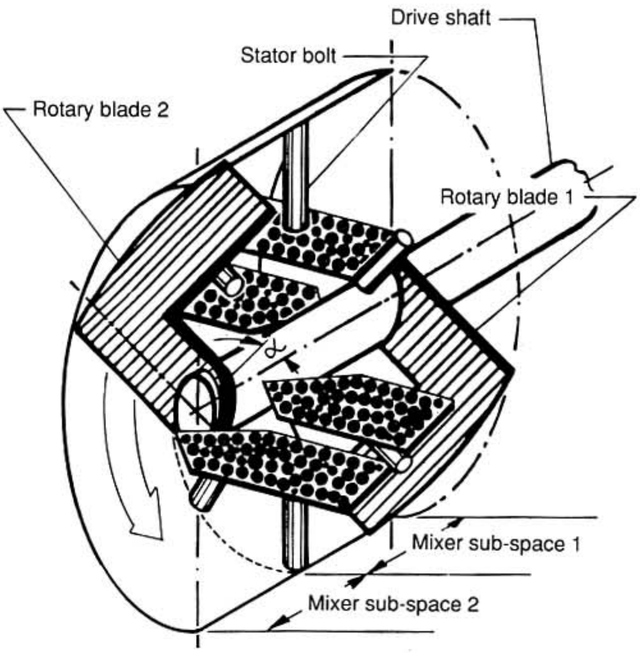

Figure 2. Schematic view of structure and function of the new mixer (*type Statormix*)

Table 1. Facilities and materials used

Mixer	New mixer, charge of 50 kg New mixer, charge of 120 kg Vibratory mixer
Sand	Grade F32
Binder	Resin 4513, activating agent 4514, catalyzer GH3 (Hüttenes Albertus)
Dosing of sand	Balance
Dosing of binder	Bellow doser
Core shooter	Designed and built for the purpose of the trials
Tester for bending strength	Self-designed and equipped with electronic value assessment and recording of the breaking load

resistant synthetic material. The case with its segment-like seal for the sand's admission can be seen mounted onto the drum's upper side. Mounted underneath the drum the drain with the opened flap can also be seen.

The outer edges of the blades maintain a small gap to the drum as well as to the front and back covers. Thereby, accumulations of crusts can largely be avoided.

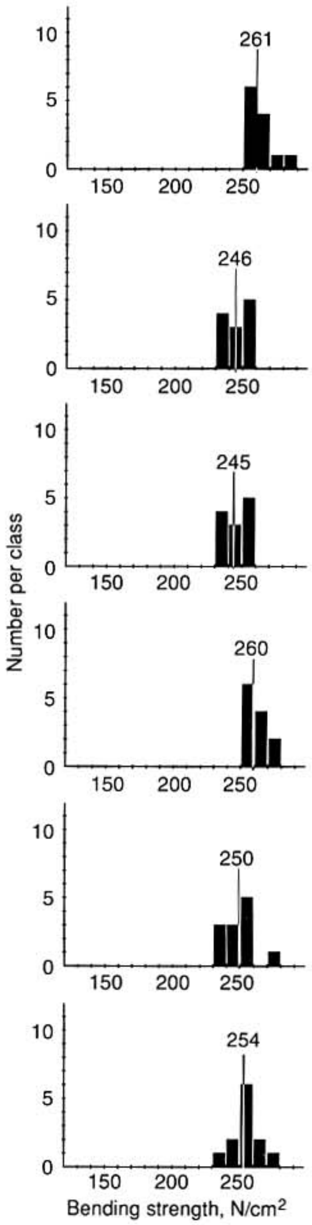

Figure 4.

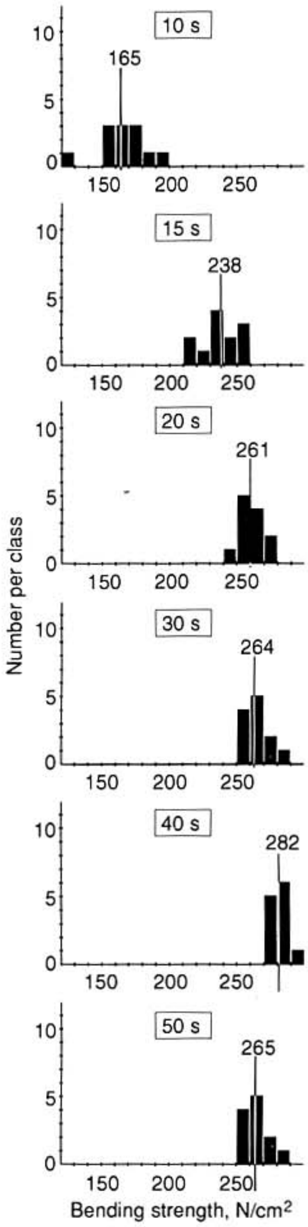

Figure 5.

Figure 4. Results of the examinations based on unchanged mixing parameters

Figure 5. Impact of the mixing period on the obtained quality of the core material (new mixer, 50 kg sand F32, 0.7%/0.7% of binder)

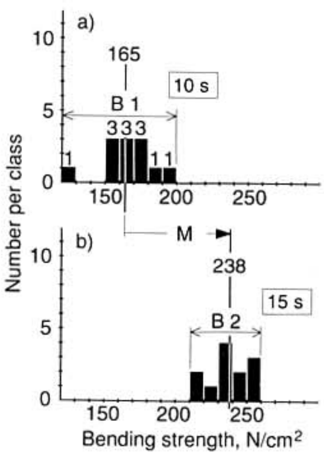

Figure 3.
a) Distribution of bending strengths of 12 specimens among classes of width 10 N/cm² each (10 s mixing period);
b) Change of results at an extended mixing period (15 s)

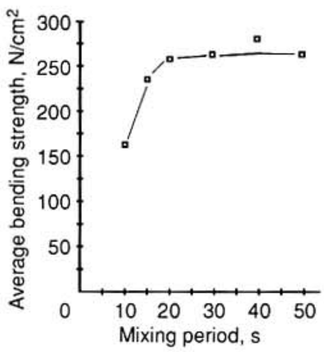

Figure 6. Average bending strengths versus the mixing period (new mixer, 50 kg sand F32, 0.7%/ 0.7% of binder)

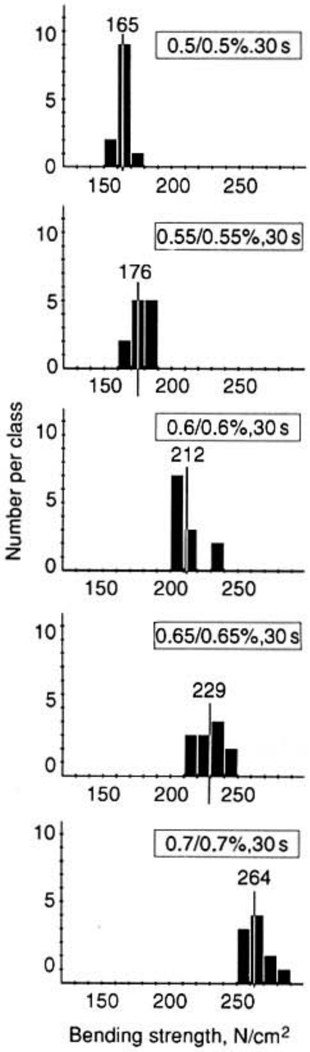

Figure 7.

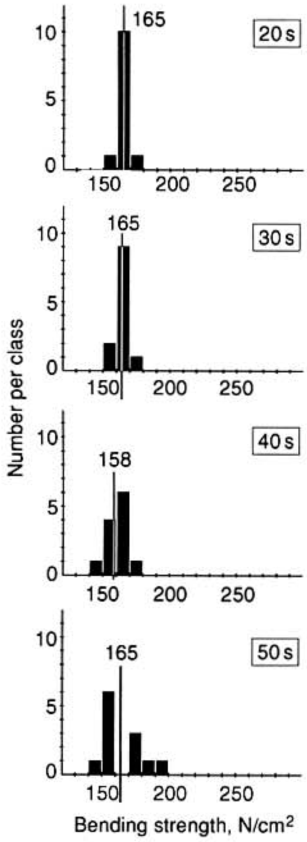

Figure 8.

Figure 7. Changes of core material based on variations of binder content from 0.5%/0.5% to 0.7%/0.7% (new mixer, 50 kg sand F32, 30 s mixing period)

Figure 8. Changes of core material based on variations of the mixing period while employing reduced binder amounts (new mixer, 50 kg sand F32, 0.5%/0.5% of binder)

Furthermore, a pneumatic self cleaning system has been integrated into the blades and interior linings. Activating this system before prolonged pauses of machine operation blows residues off of contact surfaces, leaving manual maintenance to be done to a very limited extent only.

Figure 2 shows the construction of the new mixer and clarifies its function. Several rotary blades are attached in phased alignment to the drive shaft. The blades are shaped so as to closely conform to the drum and cover surfaces. Blades and drive shaft are positioned at an angle α to each other.

Stator bolts fastened to the drum's wall in a single plane perpendicular to the drive shaft divide the interior space of the drum into two sub-spaces. Rotary blades are assigned to each of the two sub-spaces. The binder's components are injected by the stator bolts.

By virtue of the new mixing principle, the sand is enforced to move by each rotary blade, which latter is angled

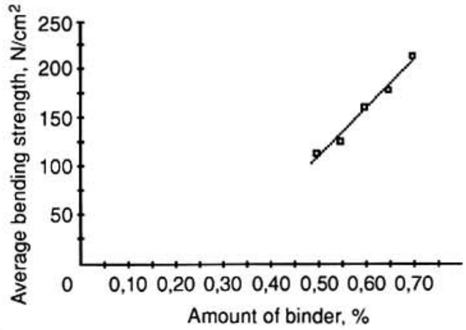

Figure 9. Average bending strengths versus the binder amount (new mixer, 50 kg sand F32, 30 s of mixing period)

so as to induce movement of the sand also in a direction parallel to the drive axis. The sand is kept rotating and, moreover, is continuously exchanged between the sub-spaces. On its way from one sub-space to another, the respective motion is frictioned by the stator bolts which cause considerable shear action to occur within the mixer's charge, thereby intensifying the action of mixing. The effect of the stator bolts was measured.

The course of the trials

In order to evaluate the new mixer at its stage of development, the bending strength of trial specimens of cores was chosen as the key criterion. Preliminary trials yielded 12 specimens to suffice for the assessment of data.

Prior to the trials, the temperature of the sand was confirmed at 21 °C and the temperature of the binder at 20 °C.

Each trial mixture was prepared according to the following procedure: Dosing of sand, start dosing of binder = start of mixing action, mixing, end of the mixing process = opening of the outlet hatch; removal of the mixer's contents and probing of approx. 5 l of the ready mixture to make specimens for trials of bending strengths; assessment of the mixture's temperature, then allowing for a span of maturity of 10 min, shooting of the core, hardening, and breaking. **Table 1** displays the utilized facilities and materials.

The method of examination

The chosen method of examination was required to yield quantitative and transparent results of immediate practical impact. A mere comparison of appearance of a number of specimens will not meet the given requirements. Within examinations of specimens of cores on behalf of their standard deviations, as they are often cited within respective publications, the importance of mavericks remains suppressed. However, making cores proves mavericks to be of specific importance, as the ones with under-limit values of strength would suffer breakage at their removal from the box.

While developing the vibratory mixer earlier, the loss on ignition (LOI) of a specimen of 10 g of the newly mixed mixture was taken to evaluate the result of a trial. This method allows only for conclusions referring to the mixer itself, without incorporating the dosing and other external devices. Now this method of evaluation appears rather far from practical importance, so a modified method of evaluation was conceived to assess the new mixer. The obtained values of bending strength of the specimens were classified into groups, each of which represented a values' range of

10 N/cm² allowing for a groupwise representation by bar charts.

Figure 3 shows such a bar chart. The period of mixing spanned 10 s, the average value for all 12 values was found at 165 N/cm². This allows for the following practical conclusions to be drawn:

- The obtained values of bending strengths are distributed over 8 classes. The quality of the mixture increases at a decrease of number of classes of a given width. An ideal mixture would require all obtained values to lie within a single class. The width of a class was chosen in such a manner as to have changes of mixing parameters to be clearly reflected by 12 specimens.
- The minimum values were found with the class ranging from 120 to 129 N/cm². Minimum values are very important, as they give an indication as to the possibility of the core to be removed from the box in undamaged state.
- The average of the 12 obtained values represents the general level of obtained bending strength.

The bar chart clearly reflects changes of the mixing parameters. **Figure 3** illustrates the influence of the mixing period changing from 10 s to 15 s:

- The scatter of values is reduced from B1 = 8 to B2 = 5 classes.
- The minimum bending strength increases from the class between 120 to 129 N/cm² to the class ranging from 210 to 219 N/cm².
- The average obtained bending strength increases by "M" from 165 N/cm² to 238 N/cm².

The procedure of examination is delineated according to conditions in practice. Variations occurring at the process of making the specimens have been given respect to by the obtained results. Such variations possibly are deviations in dosing sand and/or binder, changes in temperature, variations of the mixing process itself, as also variations of the core shooting process.

The quality of the procedure of evaluation itself can be assessed by means of various mixtures which have been provided with identical parameters. **Figure 4** shows the results obtained from 6 mixtures made with identical settings:

- Average values fall into a range of 245 to 261 N/cm². The scatter can be found to lie between –3.03% and +3.3%.
- 4 ± 1 class are represented.
- Minimum values of any respective mixture lie in the class ranging from 240 to 249 N/cm² ± 1 class. This allows for a dependable judgement of the specimens.

Examination of the impact of various parameters on the result of mixing

The impact of the period of mixing

Figure 5 shows how the period of mixing changing from 10 s to 50 s takes effect upon the bending strengths. A charge of 50 kg was processed with the new mixer using 0,7%/0,7% of binder. After a period of 20 s to 30 s

- the final strength is actually obtained,
- the number of classes is minimized, and
- the maximum values of the weakest specimens are reached.

Figure 6 shows a plot of the average bending strengths versus the period of mixing. It can clearly be seen that the mixture reaches a most desirable state after about 25 s. This required only 0.038 kWh yielding an increase of the mixture's temperature of 1 K. 50 s of process time yielded 3 K respectively.

Changing the amount of binder

Figure 7 reflects obtained results after a mixing period of 30 s for binder contents from 0.7%/0.7% to 0.5%/0.5%. Besides the achieved values of core strength to naturally be increased at increased binder contents, the mixture containing 0.5%/0.5% proves a considerable improvement of homogeneity. 10 of the obtained values of core strength fall into the same strength class leaving but one to fall into the next superior or the next inferior class respectively.

Core strengths obtained with 0.5%/0.5% binder after a mixing period of 20 s to 50 s are displayed within **Figure 8.** The observation of excess mixing periods not yielding any advantages when using 0.7%/0.7% of binder deserves to be underscored when referring to the results obtained with 0.5%/0.5% of binder: Thereby, exceeding mixing periods over 30 s actually yields an inferior result:

- While maintaining the average strength, the number of obtained classes increases.
- The resulting bending strength of the weakest specimen falls by one class.

A plot of the average bending strength versus the used amount of binder is displayed within **Figure 9.** Within the chosen boundaries of examination linear behaviour can be observed.

The size of the mixed batch and its impact

Many binder systems suffer a loss of obtainable core strength if use of the ready core mixture is delayed. In order to limit such delays, batch sizes must be made adaptable within a wide range.

Examinations were made to determine the change of obtained results when varying the batch size processed within a mixer of the new type capable of holding 50 kg. Such results obtained with 0.7%/0.7% of binder based on batch sizes varying from 10 kg to 60 kg after 30 s of mixing are displayed in **Figure 10. Figure 11** reflects the average bending strength versus the change of batch size. Charging the mixer with 60 kg clearly reduces obtained strengths. The excess space within the drum necessary to allow for flow and circulation of the batch obviously becomes too small. Yet, a fairly small decrease of core strength at a decrease of batch size below 50 kg counts for the principle of the mixer. Security for frictional and shear forces to act sufficiently upon the batch is accounted for at a broad range of partial batch sizes.

The size of the mixer and its impact

The capacity of the mixer must be adapted to the demand of core material of the core shooter or the respective group of machines. If large quantities of core material are being needed, process periods must be similar to those when needing smaller quantities of core material.

As a comparison to the mixer holding 50 kg of core material already taken into examination a mixer holding 120 kg was also examined. **Figure 12** shows accordingly ob-

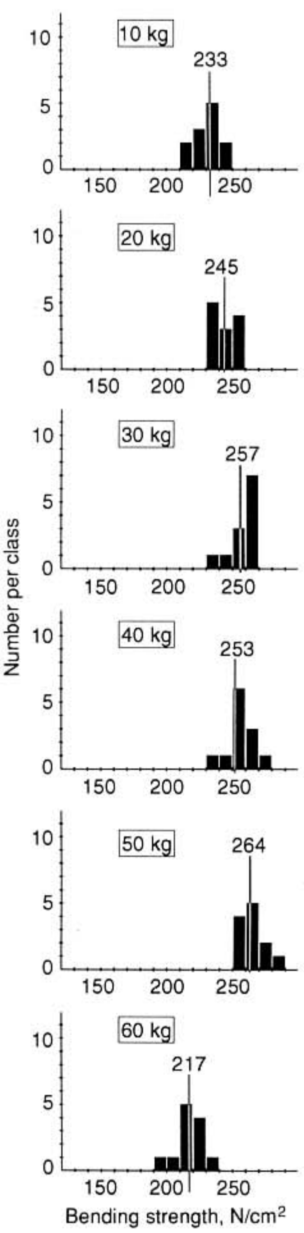

Figure 10.

Figure 10. Impact of the batch size on the obtained quality of the core material (new mixer, 50 kg, 0.7%/0.7% of binder, 30 s mixing period)

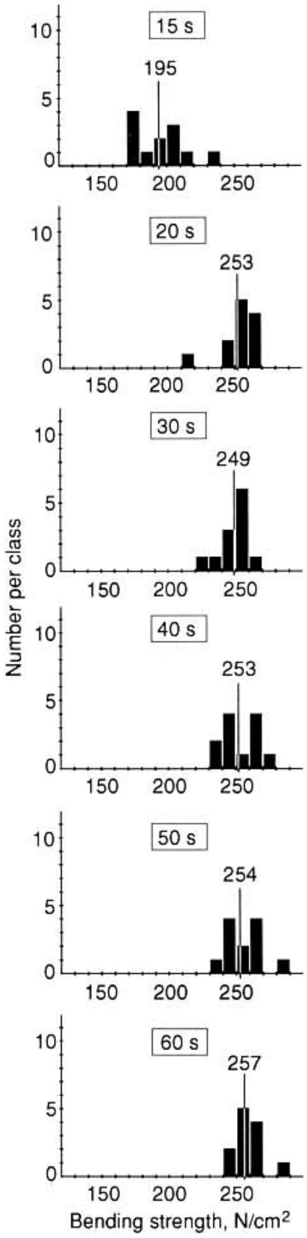

Figure 12.

Figure 12. Impact of the mixing periods on the obtained quality of the core material (new mixer, 120 kg sand F32, 0.7%/0.7% of binder)

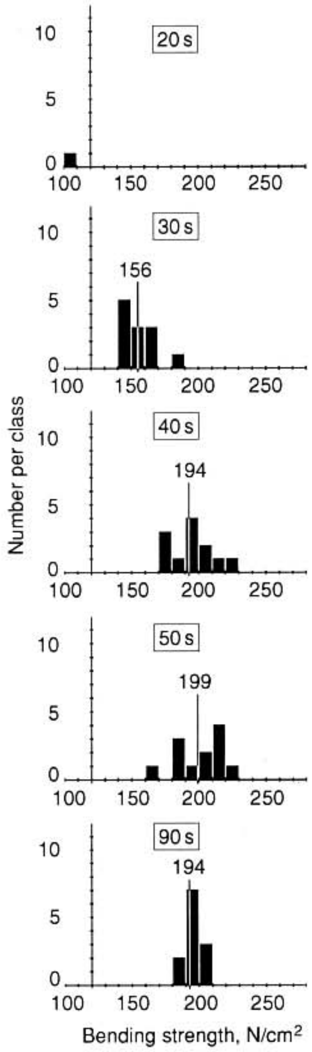

Figure 14.

Figure 14. Impact of the period of mixing on the obtained quality of the core material (vibrating batch mixer, 23 kg sand F32, 0.7%/0.7% of binder)

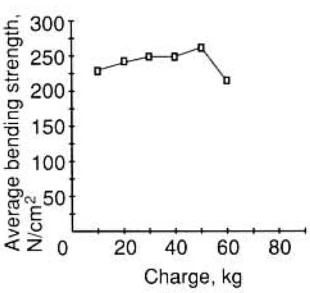

Figure 11.

Figure 11. Average bending strengths versus the batch size (new mixer, 50 kg of sand F32, 0.7%/0.7% of binder, 30 s mixing period)

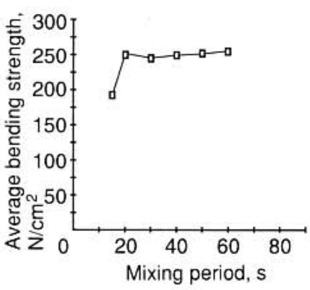

Figure 13.

Figure 13. Average bending strength versus the period of mixing (new mixer, 120 kg sand F32, 0.7%/0.7% of binder)

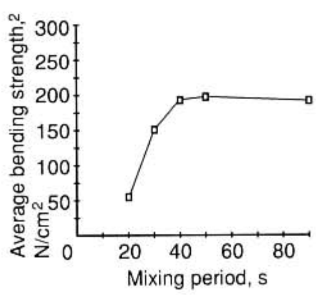

Figure 15.

Figure 15. Average bending strength versus the period of mixing (vibrating batch mixer, 23 kg sand F32, 0.7%/0.7% of binder)

tained results of the mixed product. Average bending strengths as a function of the mixing period based on 0.7%/0.7% binder amount are plotted in **Figure 13.**

Again, the fairly short span of the necessary mixing period of optimally 30 s is worth noting. The obtained values for mechanical strengths lie about 10 N/cm² below those obtained with a 50 kg mixer. Obviously, mixers based upon the new mixing principle can be produced in various sizes.

A comparison with a conventional mixer

As for the purpose of the comparison, a vibrating batch mixer was chosen, as this mixer has proven to be a reliable tool at numerous foundries with varying conditions of use world-wide.

Figures 14 and **15** show the influence of the mixing period. Evidently, homogeneity takes longer to be obtained while finally not reaching the previously attained levels of quality:

- After 20 s of mixing only one specimen exceeded a bending strength of 100 N/cm^2.
- The scatter of the obtained strength values exceeds prior values.
- Based on a binder content of 0.7%/0.7% the obtained strength remains at a level decreased by about 70 N/cm^2.
- The required period of mixing is larger.

Figure 16 summarizes important results. Based on the batch size, periods of mixing and auxiliary time spans mixing capacities in t/h can be derived. As the quality of the core material depends upon the period of time available for mixing, this being implicitly a term of the mixer's capacity, a diagram can be drawn plotting the average and the minimum obtained bending strength versus the respective mixer's throughput. Connecting the upper set and the lower set of points yields a line of average bending strengths and a line of minimum bending strengths obtained. The area between the two lines characterizes the mixer on basis of according binder amounts. A comparison of distinct mixers is viable if all parameters are kept equal. **Figure 16** underscores the advantages of the new mixer in terms of capacity, quality of the core material and savings of binders. ■

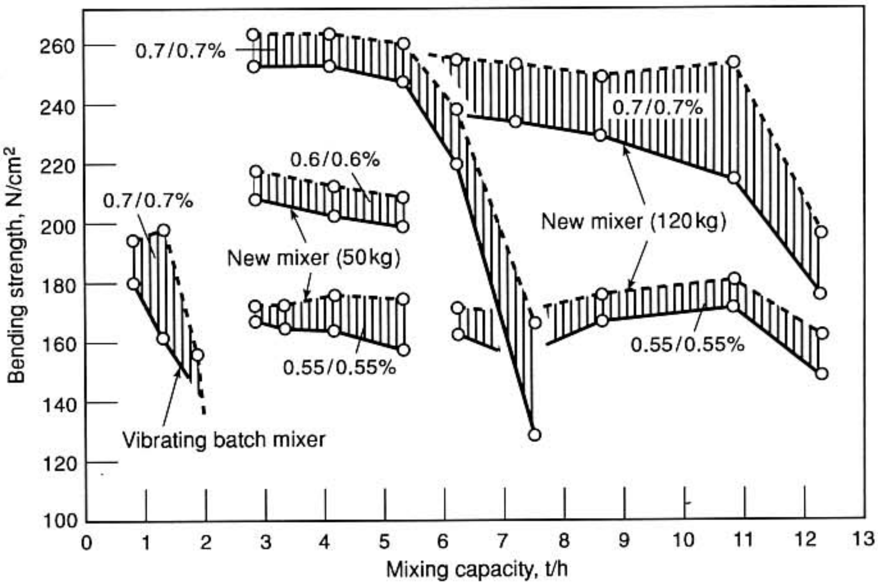

Figure 16. Comparison of the new mixer (cleaning cycle not regarded) with the vibrating batch mixer at different binder amounts

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