Possibilities and limitations of modern vibrating systems in concrete block machin

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The subject of my paper "vibrating systems for concrete block machines" refers to one of the most important conditions for a successfuly and quality-orientated production of concrete paving blocks. Beside vibration other factors are: a reliable moisture control of the concrete mixture, quality control of materials like aggregates and sands with constant sieve lines, and efficient filling by means of a sophisticated filling system for the main and face concrete.

The importance of the compaction is emphasized by the fact that the strength of optimized compacted concrete is approx. 10-times higher than of non-compacted concrete.

It is a well-known fact that with an unsufficient compaction system it is impossible to provide the required compressive strength, even with ideal material conditions. For instance, compressive strength can only be improved by adding cement to a certain degree.

The economic aspect of the installation of an opitmized and efficient vibrating system is the following: the investment for an efficient vibrating system has to be done only once, the higher consumption of costly cement does increase the production costs permanently. During my paper I will talk about the following sub-complexes of the vibrating systems:

A Introduction with short survey of the features which define vibrating systems

B Interpretation of important physica laws in context with vibrating systems

C Short description of the critical points of conventional vibrating systems

D Description of the advantages of modern vibrating systems stressing the points
- -measuring techniques
- -control techniques
- -drive techniques

A Introduction with short survey of the features which define vibrating systems

Feature 1 - Table Vibrators

All vibrating systems for paving block compaction - with a few excepti are installed in vibrating tables. Mould vibrators are mainly used for compaction of high products, like hollow blocks, kerbstones and similar elements. The application of mould vibration for compact products like paving blocks with high compressive strength is rather limited. Using

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mould vibrators the above mentioned products are mainly produced with moulds made out of sheet metal. The acceleration of the concrete particles is generated by the thin mould walls which are deformed by the mould vibrator.

Due to the fact that concrete paver moulds have only a height of normally 6 - 10 cm the installation of vibrators attached to the mould is not possible. The mould has to be a very sturdy construction, which, in turn, means that the transmission of the vibrating forces through the mould walls is extremely limited.

Feature 2 - Knocking Effect

For the compaction of paving blocks the necessary acceleration of the concrete particles is created by knocking of the vibrating tables against the bottom side of the mould. The table vibration is generated by 2 unbalanced shafts which are installed parallel in the table body. One of the two is rotating clockwise the other one anti-clockwise so that the table will move up and down in distance of the amplitude (peak to peak).

The high acceleration for the compaction of concrete with such a low water-/cement-ratio as with paving blocks is only possible by utilizing this knocking effect.

Now we should have a look at the difference between vibrating systems of multi- and single-layers which is the following:
With multi-layers the vibration, as mentioned already, is transmitted directly from the vibrating table into the mould, meaning the vibrating table knocks against the bottom part of the mould, i.e. steel against steel.

With single-layer machines the vibrating table is equipped with so-called wear rails which are knocking against the lower part of the wooden or steel pallet, in turn the bottom side of the mould, meaning steel against wood/steel and wood/steel against steel.
The knocking intensity varies with the hardness of the pallets, meaning with each pallet in the circuit. Moreover, the table up and down movement (at the peak to peak distance of the amplitude) has to bridge the air gaps between mould and pallet as well as pallet and vibrating table. The width of these gaps is depending on the quality of the pallet used.

Feature 3 - Difference between Multi- and single-layer vibrating systems

The multi-layers are equipped with an unproblematic vibrating system with a low amplitude (peak to peak) and relatively high vibrating frequency, whereas the single-layers have to be

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equipped with a vibrating system where the amplitude (peak to peak) is high. The vibrating frequency is relatively lower.

3 Interpretation of important physical laws in context with vibrating systems

I like to introduce the physical laws which are the reasons for using table vibration for compaction of paving blocks and the difference of the vibrating systems in multi- resp. single-layer machines. They also explain the critical points of conventional vibrating systems for single-layers, which will be described under point C.

On of the most important parameters of the concrete compaction is the acceleration of the material particles in the mixture. Is the acceleration described as the multiple of the acceleration due to gravity, it directly terms how much under vibrating conditons the particle weight is actually higher than under static conditions. The actual weight increase must be higher than the retaining forces between the particles, so that they can be moved out of their position. The acceleration leads to an arrangement where the big particles are lined-up.

In case of the concrete for paving block production, meaning with low water-/cement ratio the retaining forces between the particles are rathe high. By using crashed aggregates the retaining forces are higher than by using natural material. This basic connection also explains that critical compaction systems cannot be compensat by a longer compaction time. The parameters generating the acceleration amplitude are the displacement amplitude and the vibrating frequency, meaning acceleration (b) equal amplitude (a) times vibrating frequency (f^2

As mentioned before the multi-layers are equipped with an unproblematic vibrating system with a low amplitude (peak to peak) and relatively high vibrating frequency, whereas the single-layers have to be equipped with a vibrating system where the amplitude (peak to peak) is high. The vibrating frequency is relatively lower. In practice the acceleration (g) of the unloaded, sinusoidal free moving vibrating table for single- and multi-layers is approx. 10 g (a x f^2 = 10 g). For single-layers a high amplitude is a must, the vibrating frequency is 50 cycles, - for multi-layers 90 cycles. For single-layers the amplitude of th unloaded, sinusoidal free moving tabl (peak to peak) is computed by using above formular to 2 mm, for multi-layers to 0,6 mm.

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The knocking of the heavy vibrating table at high displacement amplitude increases the acceleration up to a level of 35 g, with the lightweight vibrating table and the low displacement amplitude of the multi-layer the knocking of steel against steel increases the acceleration to a level of 70 g.
Using mould vibration such acceleration values required by the low water-/cement ratio and the short vibrating time are not practicable. To meet such level of acceleration the deformation of the mould walls has to be 6,9 mm resp. 4,3 mm.

C Short description of the critical points of conventional vibrating systems

On basis of the described physical rules it is easy to recognize the essential critical point of the conventional vibrating systems in single-layers.
In point A of my paper it was already explained that the displacement amplitude at single-layers has to be selected in the matter that two air gaps between table upper side and pallet as well as between pallet and bottom side of mould are bridged.
A high amplitude is necessary.
During production the pallets fatique and absorb also a part of the displacement amplitude.

Also this speaks in favour of a high table amplitude.

However, during the filling process a high table amplitude is disadvantageo because especially the rough grains o the mixture are stimulated to jump. They penetrate the face mix which affects the appearance of the finishe block negatively.
The correct vibrator adjustment of the single-layers for pre-vibration and final compaction is always a critical point. Another point is that the pallets of the material handling circuit have to be exchanged after a certain time of usage. The vibratior has to be adjusted correctly as well for the old, weak pallets as also for the new hard ones.

Point D now is describing a vibrating system where the above mentioned critical points are eliminated.

D Description of the advantages of modern vibrating systems stressing the points

- -measuring techniques
- -control techniques
- -drive techniques

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KNAUER Vibrating System for Singlelayers

Type: Tuning Vibrator
Amplitude and frequency variable **during operation!**

Advantages:

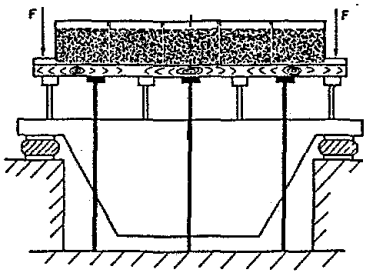
- **optimum pre-vibration**
  i.e. the correct values for amplitude and frequency are stored for the vibrating conditions during mould filling
- **optimum main vibration**
  Current types of vibrating systems for singlelayers do not permit adjustment of amplitude and frequency values during operation.
  These values are either too strong during pre-vibration or too weak during final compaction.
  The KNAUER Tuning Vibrator eliminates this problem.
- **constantly rotating vibrator shafts**
  i.e. the need for constant starting and stopping of the vibrators is eliminated.
  In addition, this system eliminates the renance (critical frequency) caused after the vibrators are started and just before they are braked.
  For example: The electric motors used to drive vibrators are started and stopped up to three times during one working cycle:
  i.e.: pre-vibration, intermediate vibration and final compaction. As such they are exposed to considerable thermal stress caused by the power and frequency of the starting and braking current.
  This thermal load is already so high that it cannot be increased any further. Therefore, a further reduction of cycle times is not possible. Moreover, this load often leads to the breakdown of the electric motors.
- **Optimum vibrating intensity** for the respective transmission qualities of the pallets
  During pre-vibration, the KNAUER Tuning Vibrator can adjust itself automatically to deal with the varying pallet densities. This is accomplished by means of a sensor which detects the conditions needed for final compaction. This sensing is done during the vibration phase of the cycle. During the between pre-vibration and main vibration, the system automatically tunes itself to the necessary amplitude and frequency parameters needed for final compaction.
  In the past, the vibrating systems in single-layers would not allow for fine tuning **during** the working cycle. The results of this inability were:
  a) too strong vibration caused by the transmission qualities of new pallets
  b) too weak vibration caused by the absorption of vibration by old and weak pallet

- **pre-selection of the correct amplitude for each product**
  This pre-selection is made at the control panel. Formerly, when amplitude adjustments had to be made, they were done by manually adjusting the counterweights inside the vibrator housing. This was a very time consuming procedure and was, therefore, for the most part omitted in practice.

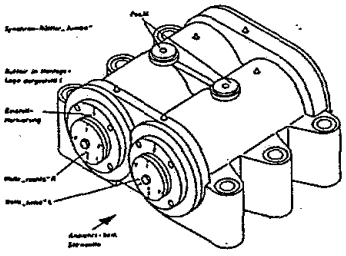
The function principle for achieving these advantages

- permanently rotating vibrator shafts
- variable amplitude adjustable from control panel during operation and in standstill
- variable frequency adjustable from control panel during operation and in standstill
- automatic adaption of the vibration to the transmission qualities of the pallet presently used

The vibrating table used has the same size as the pallets and has all advantages of a conventional one-piece table.

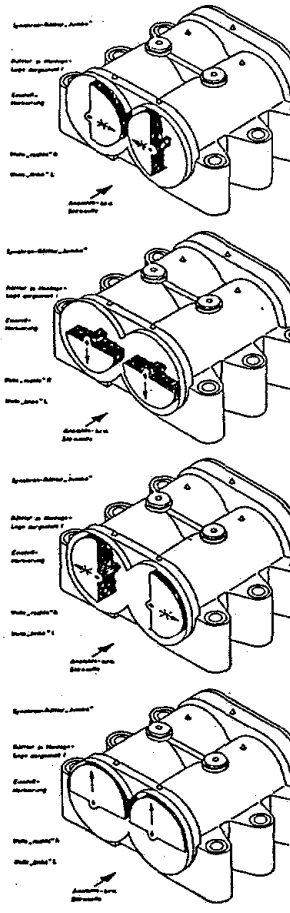


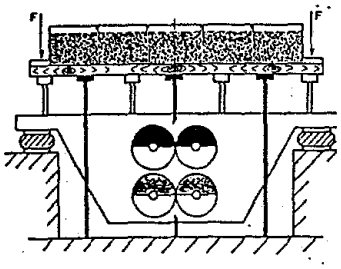
The arrangement practiced with all vibrating tables of two parallel to the axis unbalances running synchronously in opposite sense cause an exclusively vertical vibrating movement of the table.

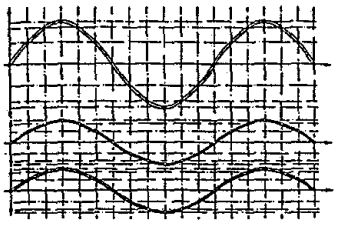


The reason for this is the phenomenon that the centrifugal forces created by the unbalances running in opposite sense neutralize each other when they are directed horizontally while they are added when they are directed vertically.

The necessary maximum value for the vibrating force which varies depending on vibrating table size and concrete elements to be produced is created by two externally driven synchronized double shaft vibrators, i.e. conventional vibrators.
We use the inner components of our well proved KNAUER double shaft vibrator type JUMBO.







For the engineering of the KNAUER Tuning Vibrator we utilized the phenomenon of the addition of the centrifugal forces acting in one direction as well as that of the neutralization of two forces acting in opposite direction.

The centrifugal forces of the two synchronized double shaft vibrators, however, are either added (see fig. 1) or neutralize each other (see fig. 2).

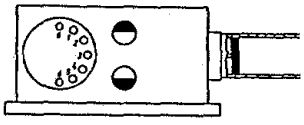


fig. 1

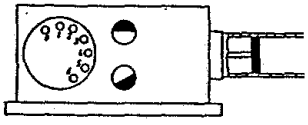
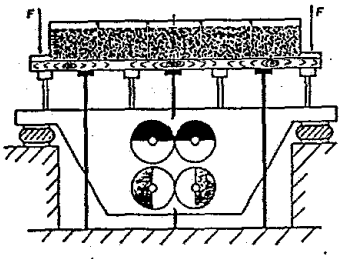
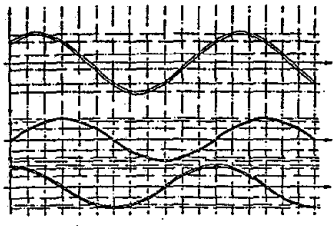


fig. 2





The vertical arrangement of two JUM80 vibrators one above each other is one of the two pre-conditions for the utilization of the above described phenomenon.
The second pre-condition is to use an adjustable power divider gear box the parallel to the axis shafts of which can be displaced during operation in their relative position.

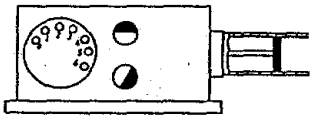


fig. 3

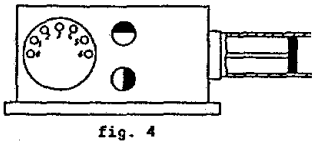
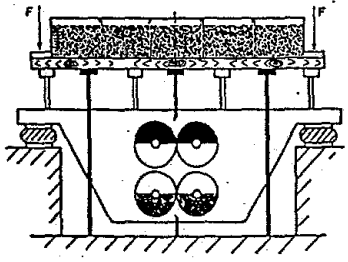
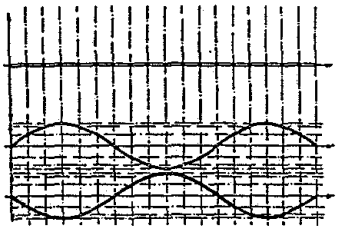


fig. 4





The relative position of the shafts can be steplessly adjusted from 0° to 180° which makes a stepless adjusting of the vibrating table amplitude possible.
Figure 4 shows that a relative position of 90° entails a phase shift of 90°.

The addition of the two vibrators' amplitudes is 70,5 % compared to the max. vibrating table amplitude.

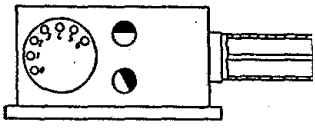


fig. 5

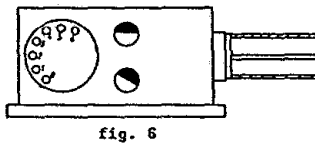


fig. 6

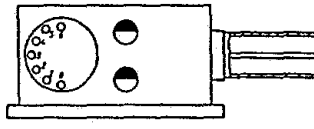
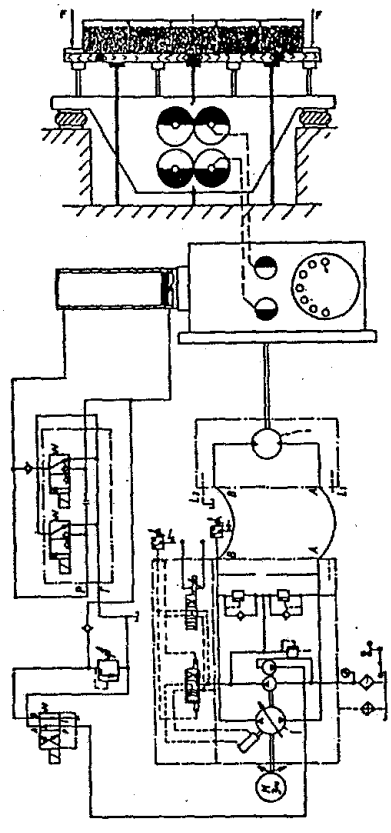


fig. 7

the vibrator shafts of the JER Tuning Vibrator are run- permanently and due to ir excellent run-up qualities is not necessary to use 3- se motors for their drive, rpm of which can only be ad- ted and changed by means of itional electronical frequen- converters.

the vibrator drive KNAUER s a hydrostatic unit, con- ting of a hydraulic motor and axial piston variable dis- cement pump (necessary for adjustment of the vibrating quency), meaning we use well wn components as they are al- utilized in forklift trucks, el loaders, street rollers .



One important component of the "KNAUER Tuning Vibrator System" is the sensor that is installed on

One important component of the "KNAUER Tuning Vibrator System" is the sensor that is installed on the bottom side of the vibrating table.
This sensor recognizes the table's acceleration of the amplitude and frequency value.

With an unloaded vibrating table the acceleration shows a sinusoidal graph (see fig. 1).

During the compaction process, when the vibrating table with its wear rails knocks against the pallet, the acceleration increases considerably and the run of the graph is changing (see fig. 2 and 3).

With old and weak pallets this change in acceleration and run of the graph is insignificant (see fig. 2).
With new and hard pallets, however, the run of the curve differs considerably from the one of the unloaded table (see fig. 3).

These deviations made visible on the screen of an oscilloscope are also recognized by the memory programmable control system (SPS) of the KNAUER Tuning vibrator and it automatically adjusts the acceleration value (out of frequency and amplitude) that is presently required for the transmission qualities of the pallet used and the compaction of the respective product.

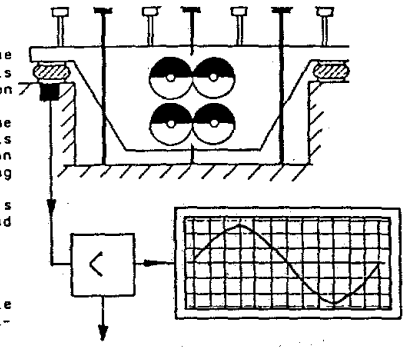


fig. 1

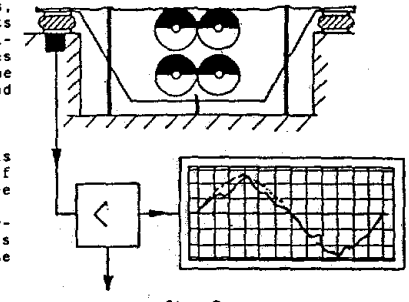


fig. 2

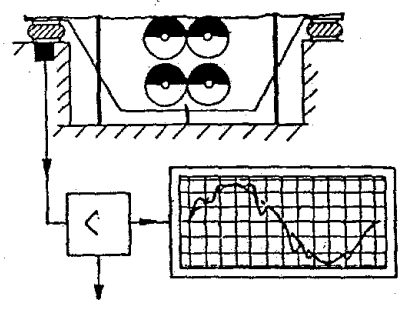


fig. 3