IFF Institut für Fertigteiltechnik und Fertigbau Weimar e.V., 99423 Weimar, Germany

The influence of base plates on compaction in concrete block machines

Concrete goods find wide application in construction work for road traffic areas, gardening and landscaping. They are manufactured in a great variety of shapes and colours.
The major part of concrete goods produced in Germany and Europe is manufactured in concrete block machines which mould and compact the products on base plates. The products are then transported further and stored in high racks on these same base plates.
A very intensive shock vibration procedure is employed for shaping and compacting the concrete mix in the concrete block machine. In this, periodic impact sequences of determined intensity are generated through the coordinated movement of certain subassemblies in the manufacturing system – the working masses. This activity is conducted into the concrete mix being compacted via the moulding subassembly. Base plates belong to the working masses of a block machine's vibratory component subassembly.

Dr.-Ing. Jörg-Henry Schwabe,
Dipl.-Ing. Jürgen Martin, IFF Weimar, Germany

A vibratory component subassembly is a complex oscillation system that is of cardinal importance in the quality attained with concrete goods.

Besides concrete mix quality, the interplay of these working masses (elements) i. e.
- vibration table
- mould
- base plate
- imposed load

is a decisive factor in the results of the shaping and compacting process and as a consequence in the properties of a product.

Figure 1 shows a simplified discrete multimass model of a block machine's vibratory component subassembly with its working masses.

The area marked in red shows the "base plate" working mass. The oscillation behaviour of the base plate within the vibratory component subassembly is determined by its mass (m^2), plus rigidity and damping characteristics (c_2, k_2, c_3, k_3, c_7, k_7).
Base plates are manufactured and utilised in various materials, material combinations and design structures. A differentiation is made in the oscillation properties of base plates in relation to their material and structure characteristics which thus influence the effects of compaction.

From an operator's point of view, it is important to be acquainted with the following facts concerning base plates and their properties for manufacturing concrete and ensuring its high quality:
- What are the vibration characteristics (parameters) of a base plate that influence the compaction process?
- What quantitative correlations exist between the characteristics (parameters) relevant to compaction and compaction quality?
- What are the vibration characteristics (parameters) of differing base plate designs?
- How do vibration characteristics change during operating life?

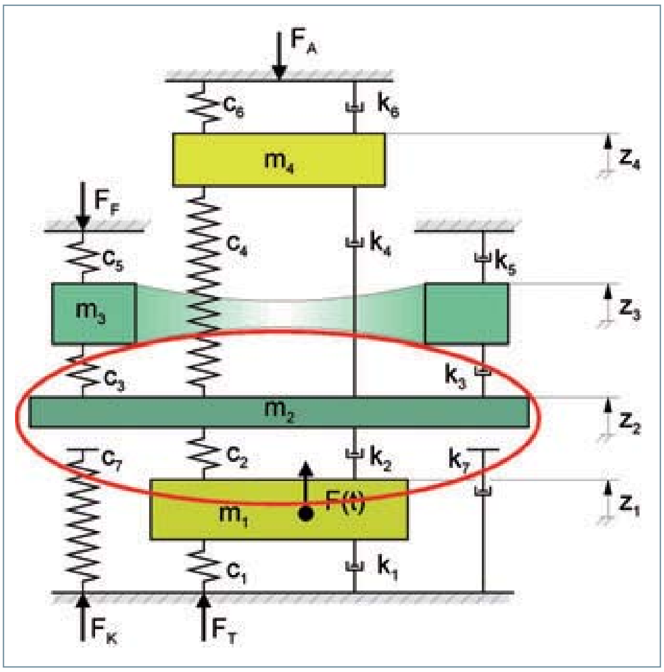

Fig. 1: Discrete multi-mass model of a block machine's vibratory component subassembly [1]

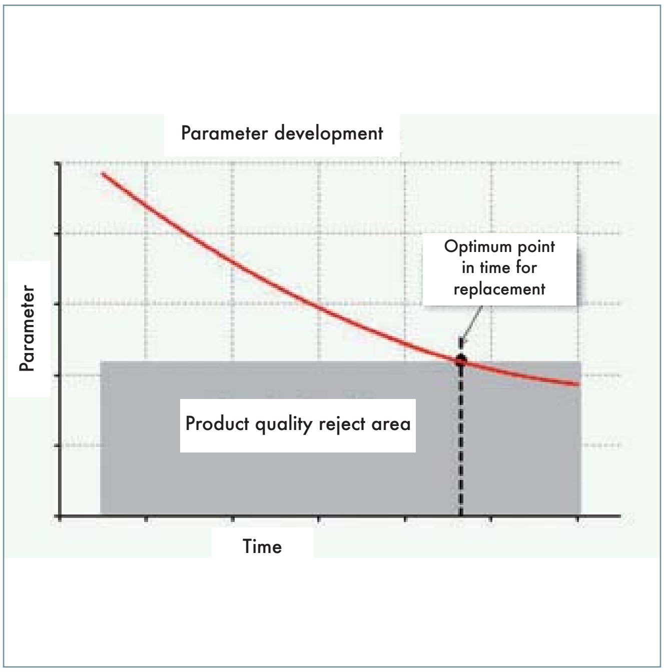

Fig. 2: Parameter development (assuming a qualitative time line)

For operators of concrete block machines featuring circulation systems, an important example would concern determining the most suitable point in time for replacing the entire stock of the plant's base plates. Base plates are subject to heavy wear and ageing due to the manufacturing process. It must be assumed that vibration characteristics change during their operating life.

Product quality often worsens, even at the same machine settings and with an unaltered concrete mix, because of the base plate's changed oscillation transmission and compaction effect. Replacing the base plates would bring about an improvement in production again. On the other hand, the stock of plates, amounting to approximately 3,000 to 5,000 pieces in a circulation system, is a very expensive investment item which should be utilised as long as possible.

Information about ongoing parameter developments would be advantageous (see assumption in figure 2) for a prognosis concerning the optimum point in time for replacing a stock of plates with a view to both utilising the investment item in the best possible way and avoiding any undesirable worsening in quality.

Although there is obviously a correlation between a base plate's material, or the type of material, and its condition as regards ageing or wear and the product quality to be expected, up to now no parameters are known which

- can describe the relevant technical state of oscillation for base plates objectively,
- can be easily measured and,
- can provide an effectual, safe prognosis of the product quality to be expected.

The aim of the investigations described in the following was to compile base plate parameters which have a bearing on concrete mix compaction. Parameters specific to a working component were to be determined on this basis.

Besides ascertaining appropriate parameters, the task also involved determining the correlation between parameters and compaction effect i.e. product quality. This information about the correlation between definable plate parameters which alter over a course of time and compaction results should lead to the development of a measuring instrument. This device was to have a process-oriented application that would enable a concrete plant employee to check the state of base plates in a rapid and uncomplicated manner.

Dr.-Ing. Jörg-Henry Schwabe studied mechanical engineering/applied mechanics from 1988 until 1993 and gained his doctorate in 2002 at Chemnitz University of Technology. Dr. Schwabe has been engaged at the Institut für Fertigteiltechnik und Fertigbau (institute for precast component technology and prefabricated construction) Weimar e. V. since 1993 where he is involved in the area of machine dynamics in machines for construction materials and is member of the technical committee "Simulation of fresh concrete flow" in RILEM

j-h.schwabe@iff-weimar.de

Dipl.-Ing. Jürgen Martin studied technological and precision engineering from 1975 until 1979 at Dresden University of Technology. He has been engaged at the Institut für Fertigteiltechnik und Fertigbau Weimar e. V. since 1997 where he became deputy director of research on precast component technology in April 2006. The main focus of his work is the design and construction of machines for manufacturing construction elements, especially vibration moulds and exciter systems.

j.martin@iff-weimar.de

Parameters relevant to compaction

The operative compaction effect with the shock vibration method is based on periodic impacts between the base plate and the moving table ledges in their upward movement as well as between the base plate and the impact ledges fixed to the frame in their downward movement plus impacts between the base plate and mould, if applicable.

On account of the dynamics of this process, those base plate characteristics must be examined that indicate a correlation to kinetic momentum and force properties when appropriate parameters are recorded.

Selection of parameters

The spatial area in a typical impact process was examined more closely with regards to selecting suitable parameters (see figure 3). From the viewpoint of deformation, local areas with expansion, shearing and compression of the material can be deduced visually, although no statement can be made about the quantitative fractions of the load stress nature in the deformations. In the first place, material parameters come into question as parameters relevant to compaction.

For this reason, the idea was developed of creating an adjusted parameter for the base plate's rigidity property under the effects of impact, which

- takes into consideration the complex deformations (compression, expansion) of the impact process,
- can be determined in the dynamic reciprocal effects between force, deformation and speed of deformation under measurement conditions close to the real process and
- can be measured as a kinetic momentum and/or force property.

In the following, the denotation S_K, impact rigidity, will be adopted for this adjusted parameter.

Damping D provides another parameter. This is a measurement for the transformation of oscillation energy into another energy form – mostly heat – and is computed from kinetic momentum in relation to time.

Parameter description

For ascertaining these adjusted parameters

- impact rigidity S_K and
- damping D,

the following approach was developed as a measurement principle. The functional surfaces of the base plate (measurement object) were exposed to dynamic activity to such an extent that deformations and deformation velocities were generated as in shock vibration. Measurement techniques were used to record the force and kinetic momentum properties in relation to time at the point of contact or directly adjacent to it. The base plate was supported so as to safely prevent local deformations (e.g. plate bending).

Several solutions for one measurement method were compiled from this measurement principle. Out of these, preliminary investigations were made into the "drop hammer" measurement method with a laboratory version technique, which was further developed and constructed as a process-oriented measuring instrument and then tested.

The "drop hammer" measurement method is closely aligned in its functionality to the shock vibration manufacturing principle (see figure 4). In this, the base plate is clamped to a rigid – from an oscillation point of view - support plate on a surface opposite the measuring point. A drop weight with a mass m falls by dint of gravity from a height of h_0 and meets at velocity v with the test specimen being measured, i.e. the base plate.

Mass m of the drop weight and drop height h_0 have been so calculated that similar deformations and deformation velocities occur as in a shock vibration compaction process.

The drop weight is delayed and rebounds subject to the base plate's rigidity and damping characteristics. After another airborne phase, the drop weight strikes the base plate again and causes another impact. This process is repeated continually until the drop weight comes to a halt.

The drop body's movements are recorded as the acceleration time behaviour by means of an acceleration sensor with a sufficient sampling rate. A time sequence as in the example in figure 5 can be observed.

Rigidity and damping characteristics can be determined from this primary data in the following way.

Rigidity characteristic – impact rigidity S_K

The height of the first impact impulse $\hat{a}_1$ is determined to a major extent by the rigidity characteristics of both impact partners.

Assuming that the drop weight rigidity is very much greater than that of the base plate (which is the case for all known wooden and composite plates), then the height of the first impact impulse will be essentially determined by the rigidity of the base plate. Only with steel base plates are the rigidities of both impact partners equal.

Alongside material properties, the structural characteristics of the test specimen also determine its rigidity. With a solid homogeneous body, it is the plate thickness in the measurement arrangement described. This results in the first impact impulse â1 being a

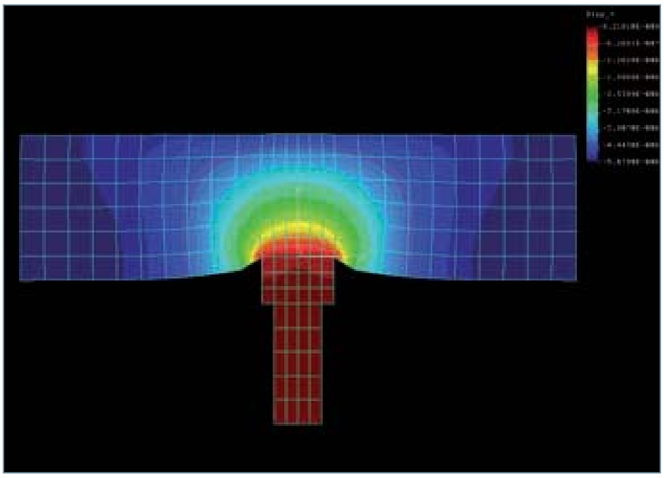

Fig. 3: Calculations of deformation during the impact process between base plate and table ledges

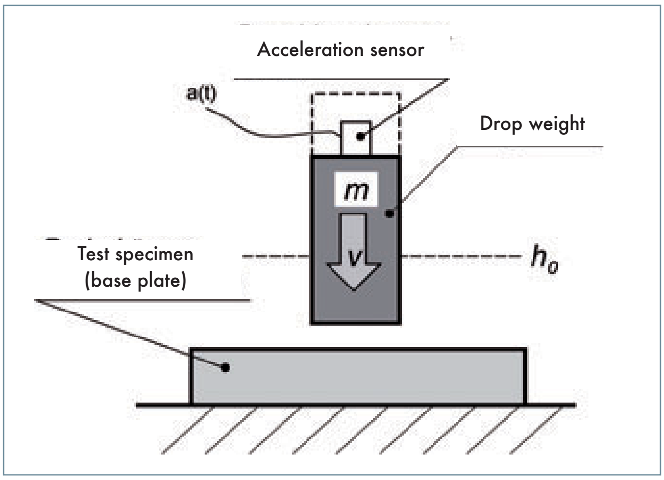

Fig. 4: Diagram of the drop hammer functional principle

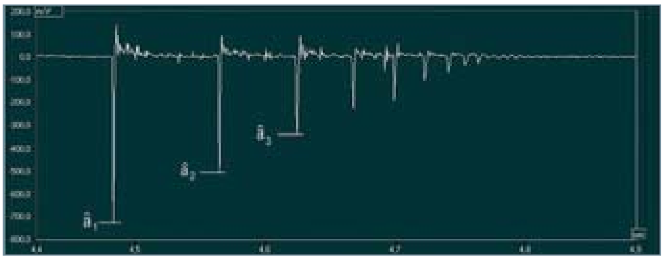

Fig. 5: Recording of acceleration time sequence (measurement example)

measurement for base plate impact rigidity S_K as a parameter that is easily definable with measuring techniques.

$S_K \sim \hat{a}_1$

Damping characteristics – impact damping D

Damping D is calculated as a lineal amplitude ratio $\Delta\hat{a}_{rel}$ and as a logarithmic decrement Λ from the values of the first and second or the n^{th} and $(n+1)^{th}$ acceleration amplitude.

$$\Delta\hat{a}_{rel} = \frac{\hat{a}_1 - \hat{a}_2}{\hat{a}_1} = \frac{\hat{a}_n - \hat{a}_{n+1}}{\hat{a}_n}$$

$$\Lambda = \ln\left(\frac{\hat{a}_n}{\hat{a}_{n+1}}\right)$$

$D \sim \Delta\hat{a}_{rel}$ or $D \sim \Lambda$

Parameter measurement

Measuring equipment on a laboratory scale was created for implementing the measurement method in a practical way and for determining specific component parameters (see figure 6). Parameters for base plates were determined in series of measurements. Influencing factors, such as

Fig. 6: View of the experimental laboratory testing apparatus

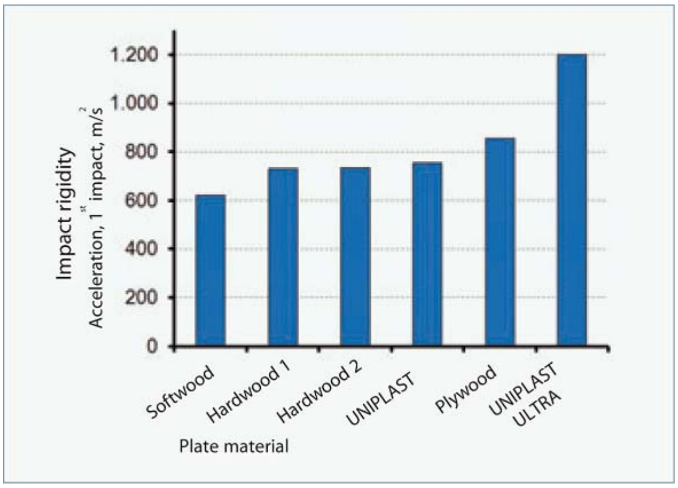

Fig. 7: Impact rigidity in relation to plate material

Fig. 8: Impact rigidity in relation to the operational lifetime of softwood plates

- material
- moisture content (with wooden plates)
- age or degree of wear

were also investigated.

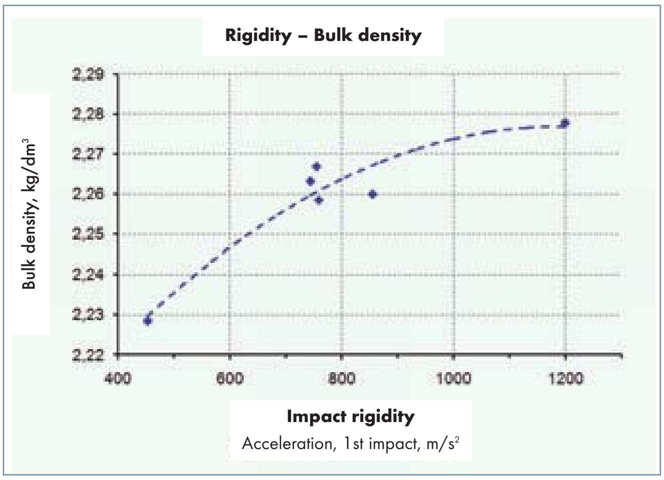

Fig. 9: Compaction effect (bulk density) in relation to impact rigidity

The following diagrams illustrate selected results from these measurements for determining parameters.
For example, the diagram in figure 7 shows the rigidity parameters ascertained for various plate materials using the acceleration amplitude of the first impact.
In the diagram in figure 8, parameters of softwood base plates are illustrated with their differing operational lifetimes.

Correlation parameters – compaction effect/product quality

The base plates measured are employed with concrete block machines for producing paving blocks which were examined with regards to the bulk densities and compressive strengths attained. Concrete blocks were produced on two different concrete block machines with their respective parameter adjustments and then tested.
The diagram in figure 9 illustrates the correlation between impact rigidity and compaction effect with bulk density as the evaluation criterion. The measurement points represent average density values from several concrete blocks produced on one type of base plate (softwood, hardwood, composite). In a strict sense, the diagram is only true for the machine setting chosen.

Conclusion from determining parameters

With the drop hammer measurement method thus described, i.e. with defined mechanical actions on a base plate and by measuring kinetic momentum in relation to time during the action, it is possible to determine parameters from the values measured. These describe the oscillation characteristics of this base plate with regard to its application in the shock vibration procedure for manufacturing concrete.
The following appropriate and measurable parameters were ascertained:

- the first acceleration amplitude $\hat{a}1$ as a measurement for rigidity characteristics, here described as impact rigidity S_K
- the linear amplitude ratio $\Delta\hat{a}_{rel}$ and the logarithmic decrement Λ as a measurement for damping D.

In laboratory testing on a small scale, parameters were determined for the types of base plates currently utilised. Investigations were made into the influence of plate material, moisture content and operational lifetime on oscillation characteristics. In processing tests at constant settings with concrete block machines, quantitative correlations were determined between parameter impact rigidity SK and the compaction effect or the compressive strength product characteristic in paving blocks.

Measuring instrument for concrete production facilities

A measurement apparatus was developed, constructed and tested under industrial conditions for utilising the measurement procedure in practical process applications. The measuring apparatus is engineered for use in concrete block-making plants featuring circulation systems and is composed of 3 sensor heads for measuring plate characteristics at several places on the base plate.
Figure 10 gives a view of the CAD model of a sensor head with a description of the most essential components for this measurement procedure. In figure 11, the finished measuring apparatus is pictured before being inserted into the block maker.

In a first series, measurements were performed on 200 base plates made of softwood (pine) with a previous operational time span of 2.75 years.
A statistical evaluation produced the following values:

- Average value, total 457 m/s²
- Standard deviation 89,7 m/s²

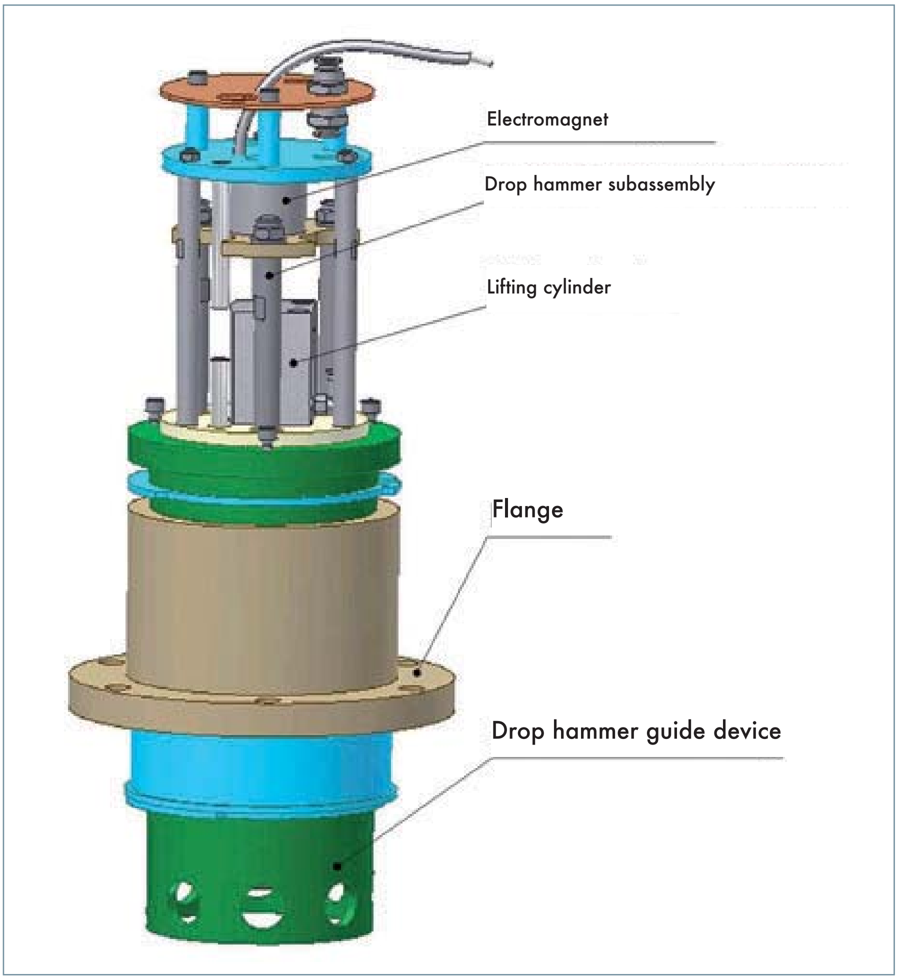

Fig. 10: View of CAD model of a sensor head

A series of measurements for recording the parameters of the entire pallet stock is planned for 2010. Measurements in cyclical intervals are foreseen for measuring parameter behaviour over time.

Application possibilities for the measurement procedure

Both manufacturers of base plates and operators of concrete block making facilities

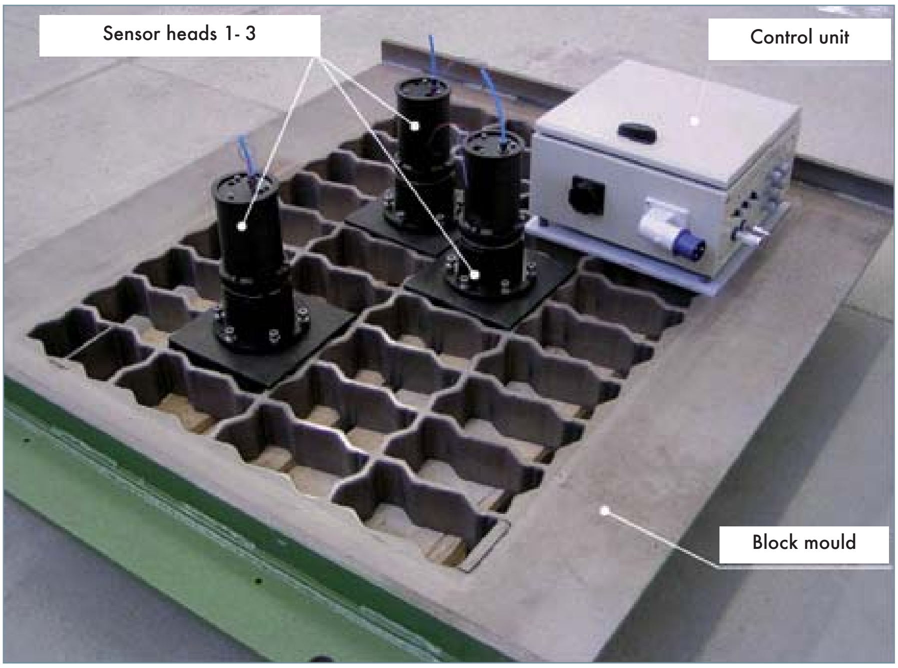

Fig. 11: View of finished measuring apparatus

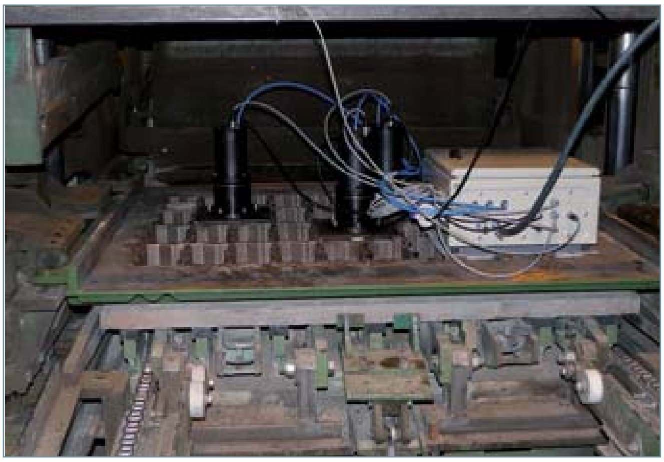

Fig. 12: View of measurement apparatus in a concrete block machine

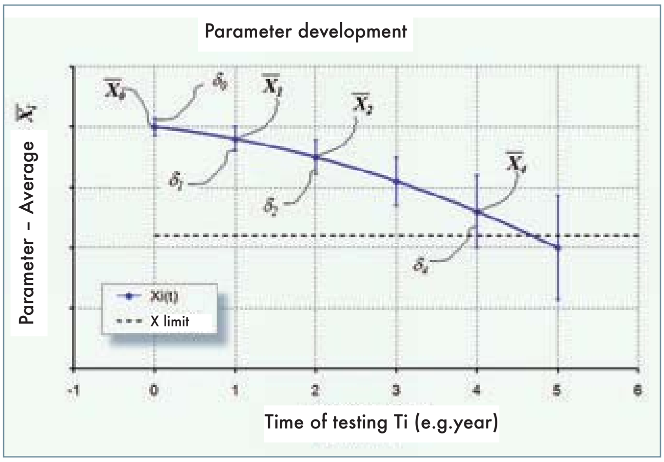

Fig. 13: Parameter development of a stock of plates (assumed example)

can take advantage of this newly developed measurement procedure.

The following application possibilities can be envisaged from the viewpoint of a base plate manufacturer:

- To enable the measurement and evaluation of dynamic board characteristics in the manufacturer's production facilities and at the customer's premises as a check on and proof of quality.
- To provide proof of oscillation characteristics for deliveries of replacement base plates (e.g. when small quantities of replacements are needed) for existing manufacturing plants.
- To permit the manufacture and delivery of base plates with defined characteristics in harmony with the properties of other working masses in a vibration subassembly.

For concrete block machine operators, there are the following application possibilities:

- To be already able to select base plates in the planning stage of a block making plant in relation to machine and process constraints and the desired product quality.
- To be able to identify base plates with insufficient compaction effect, and, if necessary, to eliminate and replace them selectively.
- To be able to record and evaluate the development of plate characteristics over a period of time by means of cyclical measurements and provide a prognosis of the optimum point in time for exchanging the complete stock of plates (see diagram in figure 13).

Knowing the progression of parameters with their average values and dispersion over a period of time can provide objective measurement values to support a decision concerning the right point in time for changing plates.

Summary

Parameters for the oscillation characteristics of base plates were defined. Measurement procedures and measuring equipment were developed and tested for determining these parameters. This makes objective measurement values concerning characteristics relevant to compaction available to manufacturers and users of base plates.

The results of this research were compiled in the course of a joint research project carried out by

- Fritz Herrmann GmbH & Co., Betonsteinwerke KG, Eisenberg
- Wasa Pallets GmbH & Co. KG, Neubrunn
- Institut für Fertigteiltechnik und Fertigbau Weimar e. V.

The project was further undertaken within the framework of the PRO INNO programme (programme for promoting innovation competency in medium-sized companies) sponsored by the German federal ministry for economic and technological affairs (project number KF 0031713UK7).

References

[1] Kuch, H.; Schwabe, J.-H.; Palzer, U.: Herstellung von Betonwaren und Betonfertigteilen – Verfahren und Ausrüstungen, Verlag Bau + Technik, Düsseldorf 2009

FURTHER INFORMATION

IFF Institut für Fertigteiltechnik und Fertigbau Weimar e.V.
Cranachstr. 46
99423 Weimar, Germany
T +49 3643 86840
F +49 3643 868413
kontakt@iff-weimar.de
www.iff-weimar.de