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durcrete Maschinenbauteile und Elemente aus Ultra High Performance Concrete UHPC

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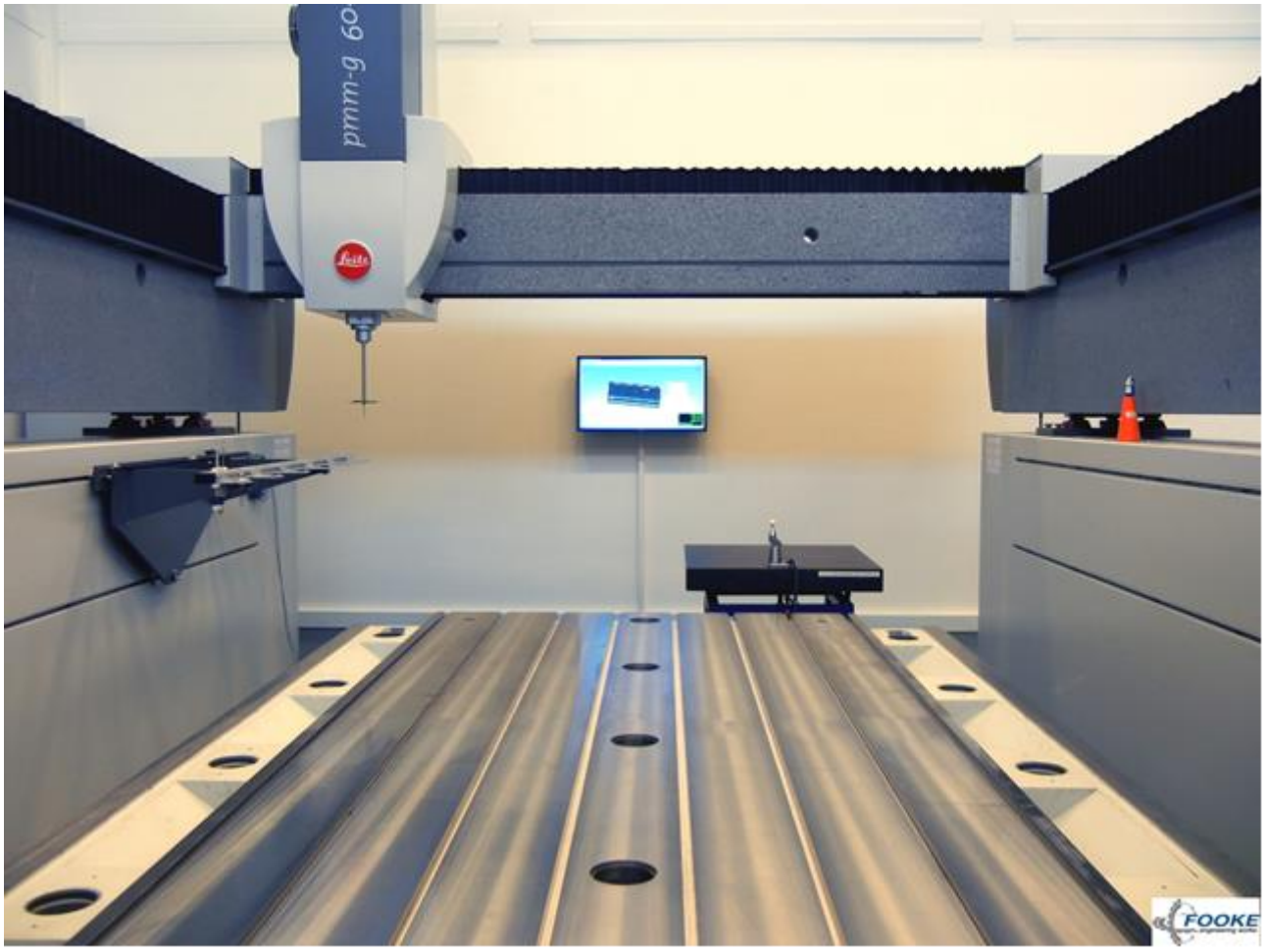
Convincing test results with Nanodur concrete and its superior deformation stability

A comparative research project at the RWTH Aachen University of Technology on the selection of material for machine beds finds conclusive results.

The concrete deformation stability of machine beds made of Nanodur, the innovative ultra-high-performance concrete (UHPC), satisfies the strictest of requirements. This assessment is the result of a study conducted at the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, in Germany. In addition, ultra-high-performance concrete such as Nanodur is characterized by further advantages over machine beds made of conventional materials such as grey cast iron or welded steel.



3D-measuring machine made of Granite, test specimen made of Nanodur-Concrete

The loadbearing and supporting elements of a machine tool are the machine beds mounted on the machine foundations and integrated into the tooling machines — and not the machine foundations themselves. It is in fact these base frames on which the individual functional elements — such as the linear guiding rails and the drive units — are mounted. The size and design of these elements basically depend on the process required. Machine beds can accordingly range from masses less than one metric tonne to sizes with very large dimensions. The selection of the materials used is critically significant for the functionality of a machine bed. In addition to the production-engineering and economic standpoints involved, the mechanical characteristics of the various materials play a key role here, since they decisively determine the characteristics of the component parts in use. A characteristic of prime importance here is the Young's modulus, which influences elastic deflection as well as material damping and thermal behaviour. Long-term geometrical consistency — i.e., only minimal plastic deformation after application of a load — is expected as absolute prerequisite for all component materials used in this context. If this prerequisite is not met, the linear guiding rails lose their evenness and parallelism, which had been achieved in tedious and expensive precision working.

Advanced high-performance concrete in machine construction

In the past, machine beds were primarily made of steel, cast steel, or grey cast iron.
In the course of the past 30 years, as a result of stricter engineering and economic requirements placed on machine tools, and in addition to the introduction of machine beds made of grey cast iron, frame components made of materials such as cast mineral or epoxy-resin-bonded polymer concrete have become well established. Steel and cast components can support the greatest loads but are very expensive and energy-intensive in their production. Massive materials such as polymer concrete and natural stone, on the other hand, are in extensive use owing to their more favourable prices and their engineering advantages. By now, advanced ultra-high-performance concrete (UHPC) has become solidly established in machine construction. In addition to its cost-effectiveness, concrete offers benefits related to the vibration and thermal behaviour of machine tools, and it has replaced conventional materials such as grey cast iron and welded-steel components. Ten years ago, a patent application was submitted for the high-performance binder Dyckerhoff Nanodur. Since then, Nanodur has had highly decisive influence on the world of ultra-high-performance concrete. It has especially been in the field of advanced machine tools that this innovative, high-tech material has provided forward-oriented stimulus. For a number of years now, a number of specialized precast plants have successfully produced machine components made of Nanodur concrete. Productions plants of machine beds are already located in Czech Republic, Switzerland and China. Other countries will follow soon.

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Comparative studies made on creep behaviour

To evidence the special concrete deformation stability and especially the satisfactory long-term geometrical stability of Nanodur as a material for machine tool frames, extensive comparative tests on creep behaviour have been recently conducted at the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, in Germany. “Creep” in this context is used to designate time-dependent deformation of structure under load. If force is applied to mineral bodies, they experience elastic deformation. If this force is not directly relieved, additional time-dependent, plastic deformation of the material takes place. The material thus reacts to the impressed force by undergoing creep. The purpose of the above-stated study was to compare the deformation stability of components made of Nanodur concrete to the stability of alternative materials such as hard natural stone and polymer concrete. To facilitate assignment of the results, test samples made of commercially available hard natural stone and epoxy-resin-bonded cast mineral were tested in parallel. For testing, Nanodur E45 concrete was used: a standard mix without fibres. Test samples without heat curing were stored for four weeks in a climate chamber before passing to the testing procedure. Samples with heat curing were heated for two days to approx. 80 °C immediately after demoulding. The chemical hardening process — i.e., the hydration of the cement — is thereby accelerated and concluded, with enhancement of form stability. The hard natural stone originated from a recognized German precision company in the measurement-equipment industry, and the epoxy-resin-bonded cast mineral with round quartz granulation was taken from a recognized quality-inspection company. All tested slabs were cut out of 160 x 40 mm x 40 mm prisms with a test-equipment saw and were pre-stored until their respective testing in a climate chamber. The Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University designed a special test-bench concept to determine the long-term geometric consistency over a period of 90 days. This test concept enabled measurement-engineering recording of the expected minimal deformations.

These comparative tests disclosed that the tested hard natural stone absolutely demonstrated the least time-dependent deformations. The long-term stability, expressed by the coefficient of creep, of the heat-cured, cement-bound Nanodur concrete lay at a comparable order of magnitude. The cast mineral bound with synthetic resin demonstrated the greatest deformations, both for short-term elastic deformations as well as for the additional plastic deformations arising from creep.

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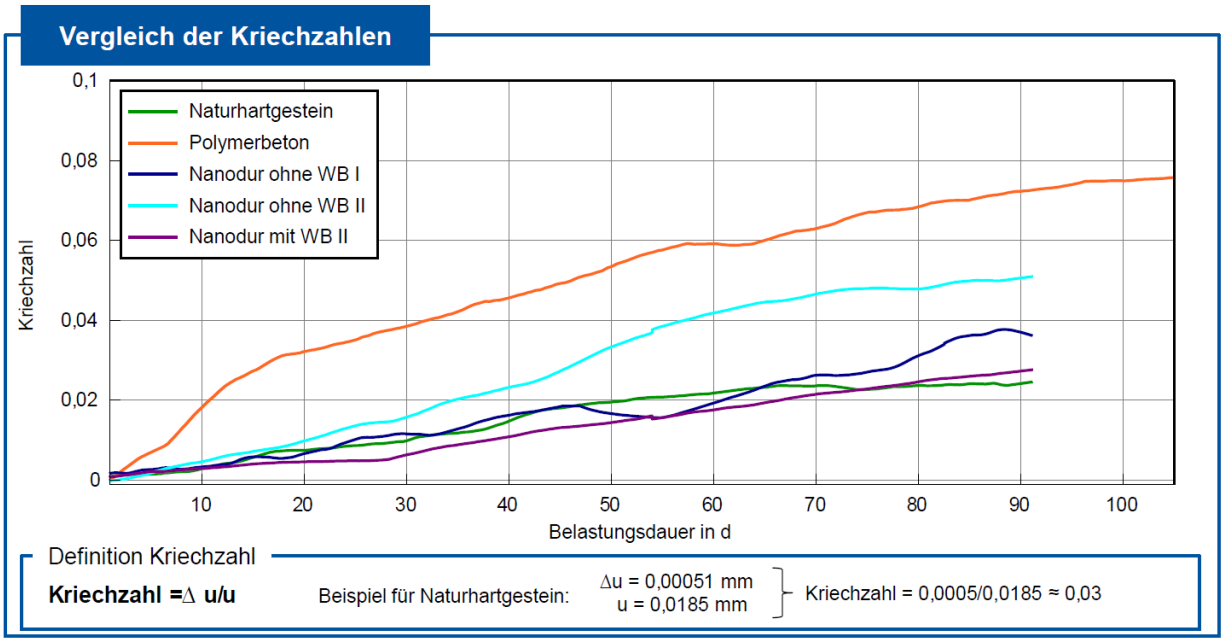
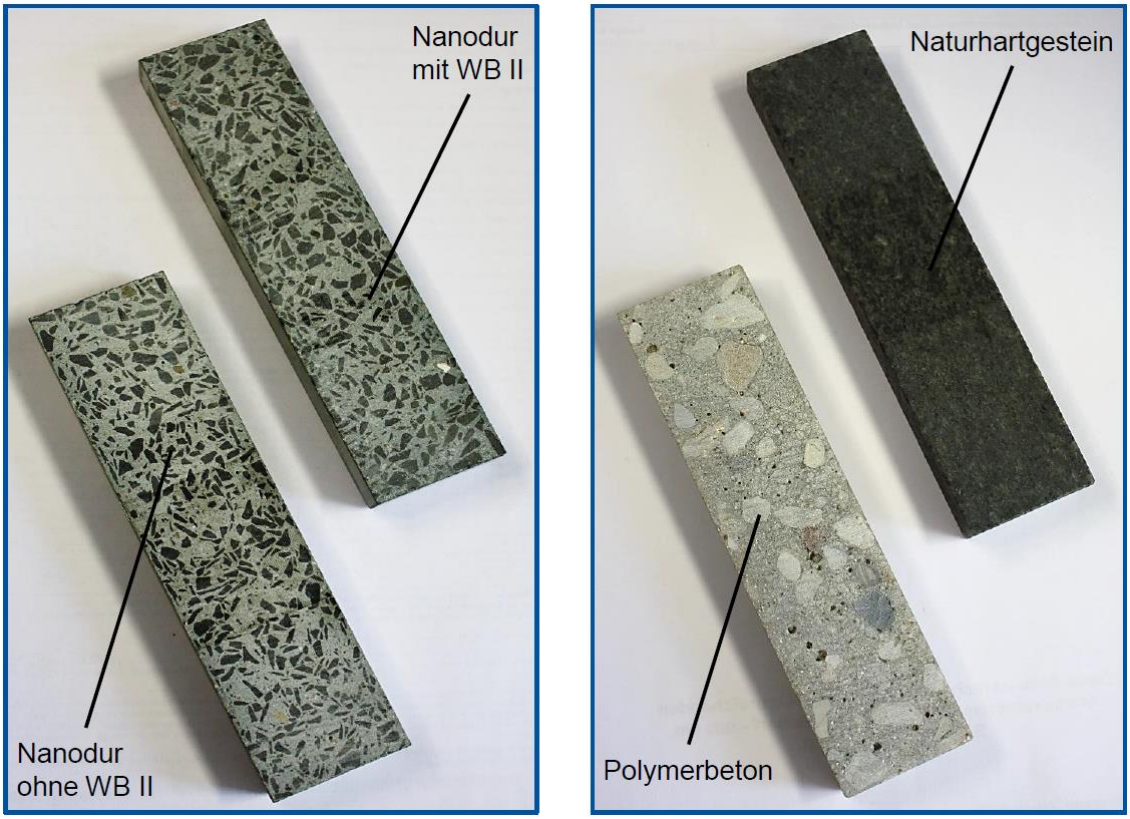


Comparison of characteristic creep values of natural stone (green), various samples of Nanodur-Concrete und epoxy bound mineral cast (red)



Tested speciments made of Nanodur-concrete, epoxy based mineral cast and natural stone