

# Transfer of Innovative Research Results into the German Cement Industry

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**Abstract.** The transfer strategy, worked out by the consortium “WiTraBau – Knowledge Transfer into the Construction Industry” (“Wissenstransfer im Bauwesen”) funded by the “German Federal Ministry of Education and Research” (BMBF, “Bundesministerium für Bildung und Forschung”) (Reichling 2017) was used to communicate and discuss relevant research results with the German Cement Industry. The VDZ gGmbH (VDZ) is one out of seven joint research-partners in the WiTraBau-consortium.

In the thematic call “NanoTecture – Nano Technology in Building Industry”, several research results were identified to be of potential interest for the Cement Industry. These results were classified into application options. One example for transferring the scientific findings into a potential practical application is a compilation of suitable cements for the application in Ultra-High-Performance Concrete (UHPC). In three out of eleven research projects the applicability of different cement types acc. to EN 197-1 and cements with lower clinker content for UHPC were investigated in laboratory tests and in field side projects. Based on these results VDZ has proposed a list of suitable cements to the committee which is currently preparing a new guideline for UHPC under the aegis of the German Committee for Structural Concrete (Deutscher Ausschuss für Stahlbeton e. V., DAfStb).

**Keywords:** Transfer · Exploitation · Methodology · Materials · Nanotechnology · Cement · Ultra-high-performance concrete

## 1 Results from the Completed Projects in the Thematic Call “NanoTecture”

Between 2009 and 2012 the BMBF granted funding within the thematic call “NanoTecture” as a contribution to the so-called “High-Tech Strategy” of the Federal Government. The main focus was on the development of nanotechnological procedures and materials, which will lead to savings in energy in the construction sector and which have a high economic potential. The following issues were focused:

- energy efficiency
- durability and
- strength of construction materials and components.

An evaluation concept has been performed in order to accelerate the launching of completed projects in the field of NanoTecture onto the market. The main issue of this

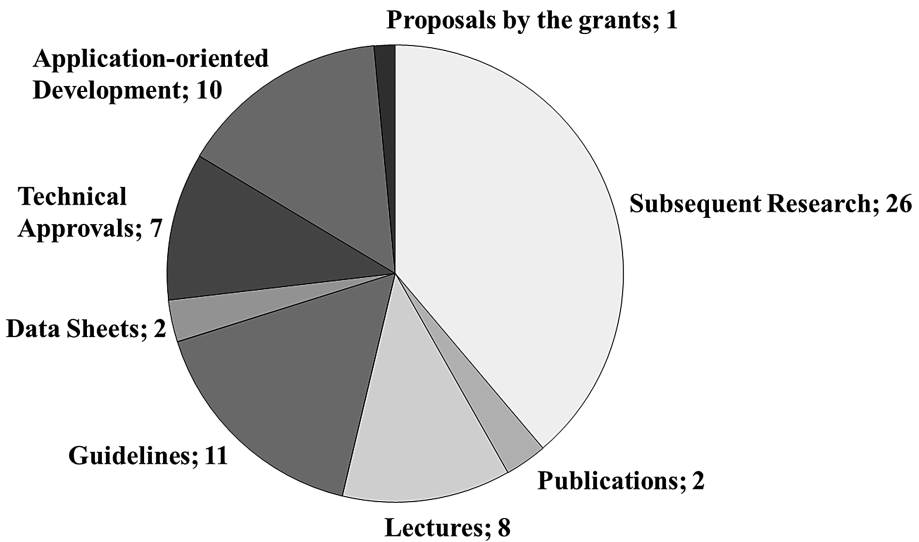
concept is to identify relevant project results and to prepare documentation with a short project description. For this purpose a scientific expert system was founded in which results were documented online and saved in a database. The expert system is based on evaluations of final reports and interviews with the respective project managers of the joint-research projects. Commonly developed Levels of Cognition in WiTraBau (e.g. basic research, product development) and application options (see Reichling 2017) simplify the systematic assessment of the joint research projects up to the level of individual results.

### 1.1 Application Strategies Are Developed

On this basis for every individual result an application strategy is developed. For example a result is presented in a standardization committee. This may lead to an adaptation of a regulation and enables or simplifies the promotion of a new product. By means of publications or information sheets experts can be informed about new technologies and their applications, whereby new markets can be opened. That is also accelerated by a targeted communication in the networks of the WiTraBau-partners.

Over all, based on the eleven “NanoTecture” industrial joint-projects 78 major findings were identified and assigned to a Level of Cognition. These major findings were assigned to 302 Options of Exploitations (OoEs) (Reichling 2017).

From these 78 major findings 38 were identified to be of potential interest for the cement industry. These 38 findings were assigned to 67 OoEs (see Fig. 1).



**Fig. 1.** Number of the chosen OoEs for the cement industry from NanoTecture

Based on the evaluated results, Level of Cognition and Options of Exploitations VDZ is working out suggestions for optimal exploitations. These suggestions are currently discussed in the VDZ technical committees “Concrete Technology”, “Cement Chemistry” and “Environment and Process Technology” as well as in its sub-committees and ad-hoc groups. In order to design this process transparently and to document it an online platform is used. This platform is for communication and discussion of the research results in order to prepare the initiation of exploitation activities.

## 1.2 First Research Results Are Implemented into Standardization

Four out of eleven joint research projects within the NanoTexture program dealt with research on construction components made of ultra-high-performance concrete (UHPC). UHPC is defined as concrete with a compressive strength significantly above the highest compressive strength class for high-performance concrete C 100/115 as defined in EN 206. Depending on the composition and production method compressive strengths between approx. 150 MPa and 250 MPa were reached.

## 1.3 DAfStb Working Group “UHPC”

For the application of UHPC in practice governed by construction regulation currently national technical approvals or project-related approvals have to be applied. One practical example for the application of UHPC for the production of superstructure with a project-related approval is the Gärtnerplatz bridge which was opened in 2007 (Fig. 2).



**Fig. 2.** Gärtnerplatz bridge in Kassel as the first UHPC construction in Germany; Photo: University of Kassel

In Germany there does not exist a standard or guideline for UHPC. The German Committee for Structural Concrete (DAfStb) intends to change this situation and plans the publication of such a guideline for this innovative construction material. Thereby, the national approvals and project-related approvals in the individual case could be dispensed and the new construction material could be made applicable in many fields.

#### 1.4 Practical Experience and Substantial Research Results

In this respect the research projects from NanoTexture can be used as an input for the development of the guideline. In 2015, VDZ provided the DAfStb working group UHPC with an overview of cement types with which already experience has been gained in the production of construction components or production from UHPC and/or which have been investigated within research projects in a very detailed way. As result of the above-mentioned evaluation process within WiTraBau VDZ has integrated in this overview also cement types from the following NanoTexture joint-research projects:

- nano-technologically optimized, sustainable, energy-efficient and, in particular, application-friendly UHPC (OLAF)
- multi-functional roadways from nano-optimised concrete (UHPC<sub>ROAD</sub>)
- cold curing ceramics by means of nano-technological structure optimization
- research on the nano-material UHPC for the application in the special underground construction taking into consideration economic and ecological aspects.

Table 1 gives an overview about construction elements and demonstrators made with UHPC which were fabricated in research projects from the thematic call NanoTexture. The Projects' summaries were amongst other published in the proceedings of the HighTechMatBau Kick-Off-Conference (HighTechMatBau Kick-Off-Tagung 2015), held in 2015.

In principle, standardization foresees the national technical requirement for the processing and provision of practical experience with the application of a new construction material in construction components. In the event that such experience exists, general applicable construction works can be transferred into technical rules. Thus, the DAfStb guideline shall give answers to the question with which cement types the production of construction components made from UHPC is possible and has been proven in practice. Here the results from the afore-mentioned NanoTexture-projects contributed substantially to a selection of suitable cement types from the total choice of possible cement types what could be implemented into the draft of the guideline.

The example shows that the assessment of industrial joint-research projects from the Federal Ministry of Education and Research (BMBF) up to the level of individual results is necessary in order to finally launch product innovations into a broader application. The DAfStb guideline for UHPC is expected to be published in the year 2018.

**Table 1.** Construction elements and demonstrators with UHPC

Construction element and demonstrators	Compressive strength	Cement	Publication
Passenger car ramp (d = 6 cm)	165 MPa	CEM X (S-V-LL) 52,5 R (OLAF-compound)	OLAF (HighTechMatBau Kick-Off-Tagung 2015)
	190 MPa	CEM II/B-S 52,5 R (Nanodur® compound 5941)	
Facade elements	150 MPa	CEM X (S-V-LL) 52,5 R (OLAF-compound)	
Parabolic reflector			
Element for fish breeding pools			
Machine base		CEM II/B-S 52,5 R (Nanodur® compound 5941)	
Multifunctional road made of UHPC	130 MPa	CEM III/A 42,5 N	UHPC <sub>ROAD</sub> (HighTechMatBau Kick-Off-Tagung 2015)
UHPC drill bits	200 MPa	N. i. a	Drill bits made of UHPC (HighTechMatBau Kick-Off-Tagung 2015)

N. i. a.: no information available

## 2 Outlook

Currently the representatives of the member companies of VDZ are discussing the results with regard to the relevance for the cement industry (see Fig. 1) in its technical committees “Concrete Technology”, “Cement Chemistry” and “Environment and Process Technology” as well as in its sub-committees and ad-hoc groups. An online platform is used for communicating the scientific findings and discussing them in order to prepare the initiation of exploitation activities.

## 3 Conclusion

It was outlined that the results from NanoTecture-projects substantially contributed to a selection of suitable cement types for the application in UPHC. These findings were implemented into the draft of the guideline “UHPC” to be published by the German Committee for Structural Concrete (DAfStb).

**Acknowledgement.** Within the research-project “WiTraBau” the “German Federal Ministry of Education and Research” (BMBF) does not just focus on gathering new technical results but thankfully acknowledges and supports their transfer into practice, which - at the end - may lead to an acceleration of the anticipated achievements.

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