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Technology	*Aspect*	*Country*
Ventilation, heating, hot water, cooling, transmission characteristics	Quality of the works	Germany

CRITICAL SITUATIONS ON THE CONSTRUCTION SITE AND IDEAS FOR QUALITY ASSURANCE PROCEDURES: THE GERMAN PERSPECTIVE

The outcomes of the EU IEE project QUALICHeCK with a focus on improved quality on the construction site were mirrored in a dedicated workshop with 15 research experts in the field of energy efficient new buildings, renovations and energy efficient city quarters. The experts have assessed critical situations emerging on construction sites that were collected within the IEE project and have discussed quality assurance procedures available and needed in Germany.

Residential buildings ☑	Non-residential buildings ☑	Specific buildings: Whole city quarters
New buildings ☑	Existing buildings ☑	

Context

"EnergieEffizienzBauen" is the new umbrella brand for the two research initiatives "Energy Optimised Buildings (EnOB)" [1] and "Energy Efficient Cities (EnEff:Stadt)" [2], both financed by the German Federal Ministry for Economic Affairs and Energy. Both research initiatives contain a series of high level pilot projects of either energy efficient buildings (up to net zero energy buildings and plus energy buildings) or energy efficient city quarters (up to plus energy quarters). Additionally, they support technology and tool developments in the two sectors. Fraunhofer Institute for Building Physics IBP is a member of the accompanying research team [3] that evaluates the projects, determines trends and benchmarks and contributes to the communication and dissemination of the initiatives. One of the tasks of the accompanying research team is to hold semi-annual meetings for the project managers in charge of the individual projects that are part of these research initiatives. The meetings include interactive workshops for the exchange of experiences among the project managers and the accompanying research team. A workshop topic featured in a project manager meeting addressed the experiences made on the construction site regarding quality and the necessary quality assurance procedures. Fraunhofer IBP used the work and outcomes of IEE QUALICHeCK to introduce the topic with trigger presentations, and prepared posters and tasks that allowed mirroring the international work with the perspective of German demonstration project managers on high performance buildings and city quarters. In total, 15 project managers participated in the workshop.

Objectives and problems addressed

Feedback was sought especially regarding the most critical situations on the construction site with impact on the energy efficiency of the building and regarding advisable quality assurance schemes that help to overcome faulty realisations.

Critical situations on the construction site

IEE QUALICHeCK has collected 70 potential critical situations on the construction site, ranging from general issues like poor specifications, time pressure or language barriers to issues in connection with the building envelope (e.g. inadequate insulation material, incomplete insulation layers, wet material, incomplete air or moisture barriers) to issues connected with the building services systems like wrong system components, wrong settings of controls, no hydraulic calibration, etc. They are presented in the report "Documented examples of existing situations regarding the quality of works" [4] and have been accompanied by relevant studies or documented experiences and best practice solutions to avoid low quality realisations. The report also contains an Annex giving clarifications with respect to critical situations.

Critical situations compiled by IEE QUALICHeCK

The following critical situations have been gathered by the IEE QUALICHeCK team:

Critical situations on the construction site			
Very general			No or poor specifications of product performances
			No or poor specifications of execution performances
			No framework for control of performances
			Time pressure
			Language barriers at construction sites
			Insufficient knowledge of new technologies/construction workers not adequately trained
			Necessary specialists not part of the construction team
			Poor communication between planners and contractors
			Lack of technical details (improvisation on construction site)
			Constructed building components/ technologies not documented as a basis for subsequent maintenance
Building envelope	Opaque	General	Wrong (insulation) material: λ-value, thickness, etc.
			Incomplete or incorrectly installed insulation layer: gaps, uneven surfaces
			Incompatible (insulation) material to specific situations: e.g. vacuum insulation
			Damages of insulation material during construction
			Wet (insulation) material: storage on site, protection during construction
			Incorrect waterproof layers in wet areas (bathrooms, etc.)
			Not enough drying time for built-in moisture (concrete, wood)
			Wrong airtightness material
			Incomplete air or moisture barrier
			Damages of air or moisture barrier during the implementation
			Joints not realised with insulation according to requirements/design
			Joints not watertight/airtight
			Incorrectly realised joints due to installations (pipes, ducts)
		Components to ground	Wrong (insulation) material: water resistance
		Base slab/foundations	Wrong (insulation) material: pressure resistance
		Ventilated roof	Not enough air space for ventilated roof
			Not enough openings for ventilated roof
		Cool roof	Wrong coating for cool roof
	Transparent	General	Wrong windows or façade elements: U-value
			Wrong windows or façade elements: g-value, τ-value
			Joints between windows and walls not insulated
			Joints between windows and walls not watertight/airtight
		Shading systems	Top mounted roller shutters uninsulated at contact surface to wall
			Blinds without sufficient rear-ventilation
Building service systems	General		Wrong system components installed: collector peak load, inverter efficiency, fan efficiency, pump efficiency, etc.
			Incorrect setting of hydraulic flows
			No hydraulic calibration
	Fixation		Incompatible mounting material: anchors, etc.
	Pipes/ducts		Wrong diameters of pipes/ducts
			No/poor insulation of pipes/ducts
			No accessibility for cleaning
			Duct connections not airtight
			Joints with other system components not airtight: fan, AHU
	Control		Wrong settings: night setback, CO_2/humidity/temperature controls

Table 1: Critical situations on the construction site as compiled by the IEE project QUALICHeCK

Critical situations on the construction site (cont.)			
Building service systems (cont.)	Technologies	PV system	Damaged PV cells
			Not enough rear ventilation
			Cables: no mechanical protection
			Cables: Mistakes regarding parallel vs. series connection
			No connection to inverter
			Insulation behind the arrays not resistant to high temperatures
			Incorrect installation on the roof, causing water leakage
			Incorrect installation on the roof, causing damages on the roof/PV cells after storms
		Solar thermal	Not enough distance/insulation behind collectors at walls/roofs
			Insulation behind the panels not resistant to high temperatures (e.g. integrated in facades)
			Storage feed-in at middle/top
			Wrong type of antifreeze liquid
			Safety valve not fitted to container/ container not empty
		Heat pump	Setting: no priority for DHW
			Storage feed-in at top (DHW) and middle (heating)
			Too low refrigerant quantity
			Incorrect positioning of the outdoor unit (too close to walls, in an attic) -> poor performance
			Time for defrosting of the outdoor heat exchanger set at a too low value -> poor performance
		Wood boiler	Incorrect flue gas exhaust at boiler
			Incorrect ventilation openings in boiler room
		Ventilation system	Setting of airflow rate on default instead of specific necessary setting/wrong air flow rates
			Required filters not included
			No electrical connection of the auxiliary heating
			Installation without accessibility for maintenance
			Noise: ventilation unit in wrong position
			Noise: silencers not properly installed

Table 1: Critical situations on the construction site as compiled by the IEE project QUALICHeCK (cont.)

Critical situations as experienced by the German project managers of demonstration projects on high performance buildings and city quarters

During the workshop the project managers were asked to reflect which of the critical situations on the list made by QUALICHeCK have occurred on the construction sites of their projects. The term ‘projects’ related not only to the current research and demonstration projects, but to their general expertise with regard to building projects. The situations were presented on posters, and the project managers indicated (similar to a tally sheet) which situations matched their personal experiences. Nearly all critical situations seem to occur (also) on German construction sites. The situations with the most matches including the number of matches were:

- ✓ Incorrect setting of hydraulic flows (14 out of possible 15 matches)
- ✓ No hydraulic calibration (12)
- ✓ Wrong settings: night setback, CO_2/humidity/temperature controls (10)
- ✓ No framework for control of performances (10)
- ✓ Time pressure (9)
- ✓ No or poor specifications of product performances (7)
- ✓ Insufficient knowledge of new technologies/construction workers not adequately trained (7)
- ✓ Lack of technical details (improvisation on construction site) (7)
- ✓ Wrong system components installed: collector peak load, inverter efficiency, fan efficiency, pump efficiency, etc. (7)
- ✓ Setting of airflow rate on default instead of specific necessary setting/wrong air flow rates (7)
- ✓ Installation without accessibility for maintenance (7)

Additional critical situations reported by the German project managers of demonstrations projects on high performance buildings and city quarters

Additional critical situations have been collected on stickers and allocated to the four main areas as defined in the QUALICHeCK report [4]:

1. Poor specifications at level of projects, standards and/or regulations

Experiences included planning material not updated according to the current design or modified boundary conditions, missing functional descriptions, missing installation manuals, missing return valves that caused back flow and ill-conceived technologies.

2. Lack of competence at designer level, at execution level or language barriers

Here many different experiences have been made. It seems that the responsible persons often lack general understanding for energy efficiency. In many cases problems occur at the interface of two competences. In addition the following concrete situations were identified:

- ✓ faulty or lacking hydraulic calibration of heating surfaces
- ✓ estimated heating load (wrong or missing calculation of the heating load)
- ✓ wrong adjustment of pumps („auto adapt“)
- ✓ wrong installation of monitoring devices
- ✓ no optimisation of the heating system
- ✓ incomplete design documents at the sub-sub-sub-subcontractor level
- ✓ operation/installation manual not read
- ✓ mistakes in the EP calculations
- ✓ no or not enough planning details
- ✓ wrong airtightness concepts
- ✓ wrong materials (vapour barrier not UV-resistant)
- ✓ wrong wiring of the ventilation systems

3. Critical economic conditions (financial or timing)

The participants pointed out that it is a problem with bids from public building owners that always the cheapest bid has to be taken, without considering the quality and the references of the bidder. Additionally, negative experiences have been made due to insolvency of constructors or operators during the construction time. Furthermore, the need of approval despite faults, because of time pressure to get the building into use, was reported.

4. Lack of control

The participants reported about untidy construction sites and faulty approvals by the building owner or his representatives. The check of the realisation according to the EPC was not always done. In some cases the installed building service system (heating/ventilation) was not exactly according to the concept specified in the EPC. The installed automation system needs to be controlled for each data point. Sensors have been incorrectly installed, wrongly connected, not tested or wrong converter figures have been used. The change of the control strategy between summer and winter has not been made. Controls have been set wrongly or not at all. Components have been defect.

Quality assurance procedures

After the exchange of experiences with critical situations, quality assurance procedures used in Germany were collected and discussed. Subsequently, additionally needed procedures have been proposed by the participants such as:

1. Procedure for commissioning and training of a commissioning manager

The commissioning or hand-over of a complete building or a building service system seems to be a situation in which many mistakes are made. In most cases, the reason for these mistakes is lacking competence on the part of the building owners or their representatives. Buildings in general contain various building services system components and in the case of the demonstration projects of the German research initiative also innovative (new or advanced) system components as well as complicated control strategies and control systems were used. Building owners or their representatives are in many cases not up to the task of checking the correct functioning and setting of the systems. A procedure such as a detailed guideline including checklists for each system component and the controls would facilitate the commissioning process and lead to a more thorough check of the completed building and a well-functioning and, mostly, also more energy efficient building.

A second idea was that the task of checking the building and its components might require a specific education or at least training. The job of a commissioning manager could be trained and even certified.

Within the LEED procedure [5] such a detailed commissioning process is suggested and will add to the rating.

2. Coupling of training and certification to insurances

If the installation of insulation or a particular building service system reaches a certain level of complexity, specific training of the installers helps to improve the quality of the building. Such training and certification schemes are available in many countries. A further step in the developing the training and education schemes is coupling these quality assurance procedures to insurances for the correct realisation, as used for example by CIGA [6]. CIGA is a quality framework for the insulation of cavity walls. The Cavity Insulation Guarantee Agency is an independent body that provides 25 year guarantees for cavity wall insulation fitted by registered installers in the UK and Channel islands. The standard guarantee covers traditionally constructed residential property, although a CIGA commercial guarantee is also available to owners of qualifying non-residential property. By the addition of an insurance, the building owner has the guarantee that the installed system or insulation will be correctly installed, because in case mistakes are found later on, the insurance will pay for the costs of the necessary repairs. The German project managers deemed this a very interesting scheme.

3. Procedure and training for detailed analysis of existing buildings

The inspection of a building as one of the first steps to develop a concept for the energy efficient renovation or issuing a calculated energy performance certificate requires profound knowledge of building components and building service systems in order to determine the input parameters for the calculations. There are a few simplification rules [7], [8], checklists [9], [10] and basic tools [11], [12] available that support the building inspector. However there is no fixed procedure defined or training scheme offered with this focus. A common understanding on the level of detail of the building analysis and agreed default values in case of unascertainable data, such as the thermal conductivity of wall materials in the case of missing plans, would lead to more reliable calculation results. The procedure could be fixed in an official national guideline, and on this basis training schemes could be developed.

4. Coupling of the bidding system to experienced and certified constructors

The tendering procedure for public buildings (new buildings or buildings to be retrofitted owned by public authorities) requests that the contract has to be given to the most economically efficient (cheapest) bid. The workshop participants suggested that not only the price of the bid should be the basis of the decision, but also the experience and maybe even existing quality certificates of the construction companies should be considered. This could certainly improve the quality of work on the construction site. Clear decision criteria regarding the price of the offer and the other criteria (e.g. in percentages) are necessary. Alternatively the presentation of earlier work and references can be included as a pre-condition for the bidding. This is possible in the public tendering procedure already now and can be transferred to private or commercial tender processes as well.

5. Product developments to reduce the error-rate

The development of building and building service products that are less error-prone can be a very good way to increase the quality of work on the construction site. This can be done either by the product itself or by better installation guides that are easier to follow. The installation guides should include less text (which is often not read by the installers because of time pressure) but instead more graphics, where suitable. An example for a product development that can prevent mistakes on the construction site is a bathroom radiator that can be connected from both sides to either supply or return flow with the help of an extra 2-way valve [13] based on an earlier patent for a connecting device [14].

Compliance concerns related to EP certificates and to the QM approach

No reporting ☐	Wrong reporting ☑	Not meeting the performance requirements ☑

Compliance concerns related to EP certificates (see QUALICHeCK terms and definitions)

All included quality assurance procedures have the aim to improve the quality of works on the construction site. They can primarily lead to a construction that meets the performance requirements and accordingly also prevent wrong reporting.

Overall evaluation

The discussion of the IEE QUALICHeCK outcomes with the project managers of energy-efficient buildings and city quarters within the two German research initiatives EnOB and EnEff:Stadt has shown that nearly all of the gathered critical situations have also been experienced on German construction sites. Apart from some general issues like time pressure, poor specifications or lack of knowledge/training of the construction workers the most critical situations are on the side of building service systems like incorrect settings of controls, air-flow rates and missing hydraulic calibration. A brainstorming for helpful quality assurance procedures came up with five interesting ideas that can be useful also in other countries.

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