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Quality Assurance in Construction

Assurance de la qualité lors de l'exécution

Qualitätssicherung in der Bauausführung

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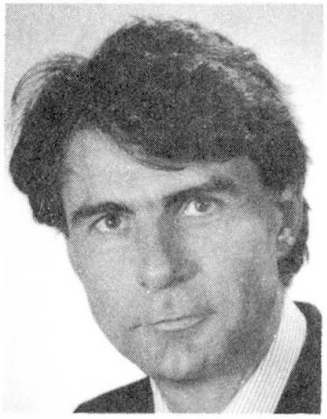

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SUMMARY

The paper outlines how a building contractor aided by a Quality Assurance Department copes with conditions adverse to good construction quality. One example is poor sealing, often a main reason for insufficient performance of concrete structures. Experts of the QA-department provide consulting and feedback to construction and design departments. They check the specifications and the execution of crucial work performed by the construction departments and by subcontractors on a random basis, unless special difficulties or the importance of the project call for permanent quality control by experts of the QA department.

RÉSUMÉ

L'exposé montre comment une entreprise de construction, avec son propre département d'assurance de la qualité, agit face aux facteurs ayant un effet négatif sur la qualité de la construction. Souvent ce sont les joints d'étanchéité des constructions en béton qui fonctionnent mal et diminuent la durabilité des constructions. Les ingénieurs du département d'assurance de la qualité conseillent les départements de projet et d'exécution. Ils contrôlent au hasard les spécifications et les constructions difficiles exécutées par des sous-traitants. Lors de difficultés extrêmes ou lorsque l'importance du projet l'exige, les ingénieurs du département d'assurance de la qualité exécutent un contrôle permanent.

ZUSAMMENFASSUNG

Die Ausführungen zeigen, wie ein Bauunternehmen mit einer eigenen Qualitätssicherungsabteilung Einflüssen begegnet, die ein Risiko für gute Betonqualität darstellen. Ein Hauptgrund für das unbefriedigende Verhalten von Betonbauwerken sind häufig unwirksame Abdichtungen. Die Ingenieure der QS-Abteilung sorgen für die Beratung und Rückinformation der planenden und ausführenden Abteilungen. Sie überprüfen die Spezifikationen und die Ausführung besonders kritischer Arbeiten, besonders jene, die von Unterauftragnehmern durchgeführt werden, durch Stichproben, es sei denn, spezielle Schwierigkeiten oder die Bedeutung des Bauvorhabens verlangen eine durchgehende Qualitätskontrolle durch die Ingenieure der QS-Abteilung.

1. Drastic Changes are Taking Place Within the Building Process

Customers from industry, electric utilities, public agencies as well as prospective owners of single-family homes ask for the lowest price, rarely with appropriate concern for quality and maintenance cost. Construction site managers meet their short-term goals and move on to their next construction job without consideration of the long-term problems they leave behind for others.

Demands upon the contractor are increasing, especially for safety related constructions, e.g. nuclear power plants. The skill of qualified personnel is diminishing in design as well as in construction. Inadequate quality is due to insufficient planning and organization, to poor detailing and construction mistakes. As a result, there is a trend to spread the risk by involving subcontractors, rising the number of supervisors, and by insurance coverage.

2. The Cost of Quality is Less than the Amount we are Spending Today to Correct our Mistakes

Speakers at an American conference on "Quality Assurance in the Building Cummunity" /1/ identified the most significant contributors to bad quality, which also prevail in Germany:

- Poor specifications which do not properly define quality standards.
- Under-financed owners squeezing architect/engineer's fees to the point that adequate detailed contract documents cannot be properly developed.
- Lack of field experience of the design team.
- Poor contractor management of quality.

3. The Cheapest Subcontractor Gets the Order

Another fact which contributes to poor quality is the common practice in building construction that the general contractor assigns tasks to subcontractors. Significant prerequisites for high-quality construction works are the contractor's practical experience in evaluating and selecting subcontractors, as well as reasonable prices. If the experience is missing, the lowest price will get the preference over technical skill and quality.

The requirements for technical and QA measures must be clearly defined in the tender documents and must be reflected in the general project organization and the price format. The site managers, who are responsible for the quality of the construction, which is expected to meet the requirement during its entire service life-time, often need assistance.

The practical experience of the HOCHTIEF QA-department shows that QA experts help to minimize technical risks for those works and services which are normally not performed by the general contractor itself, because no special departments are installed nor skilled personnel is contracted.

4. Tasks and Aktivities of a QA-Department

Difficulties with durability and structural serviceability require increased emphasis on quality assurance. QA is necessary in the entire building process, not only in the context of structural collapse. The size and the structure of a company will influence the implementation of a QA organization.

Two organization forms of QA within a company are being discussed in a controversial manner:

1. Integration of QA-engineers in the production process /2/

2. Installation of an independent Quality Assurance department

The HOCHTIEF-company prefers an independent QA-department because it is more efficient and economic than the integration of QA-engineers into the production process. Permanent controlling would weaken the carefulness and quality awareness of the responsible engineer and of the supervising QA-engineer, respectively.

4.1 Sealings

The durability of concrete structures is criticized. In my opinion the reason for poor durability are insufficient sealings in many cases. The most severe defects come from the failure of bridge-sealings when chloride-ions by de-icing salts penetrate through the concrete and corrode the steel reinforcement of prestressed bridge-constructions.

Sealings of flat roofs, bridges, park decks and buildings founded below the ground water level require detailed planning and strict execution control. The sealing-works are generally performed by subcontractors. The qualification of personnel in the trade of sealings is usually good. However one has to consider also unqualified workers, because the price-squeeze may also spoil capable firms in the course of time. It is a prerequisite of good planning that architects master the technical detail.

For instance, weak points have to be known so that mistakes can be prevented as early as possible, beginning during planning and design.

This requires first sealing experts, which can assist in and supervise the sealing works, and secondly an organisation which registers all construction sites.

4.2 The Registration of Construction Sites According to Quality Characteristics

In our company each construction project is registered with an "order-form" containing up to 20 different quality characteristics. These order-forms are electronically evaluated. The listing includes a classification of the construction sites according to quality characteristics. The QA-department decides on the basis of an implemented system of selection principles which construction sites shall be supervised (Appendix A).

4.3 The Performance of Quality Control

It is a prerequisite that the experts of the QA-department are in their respective field of specialty at least as qualified as the engineers in the design departments, the site management and the foremen in execution.

Our sealing experts are civil engineers with a sound theoretical background and extensive practical experience in actual production. Their tasks are:

- Technical assistance to the design departments.

- Checking the documents of planning and submission for correctness and completeness.

- Adding missing details.

- Training qualified personnel on the sites for continuous inspection of the works of subcontractors.

- Supervision of the works on the site, more frequently and intensively at the beginning of the works.

- Taking samples for chemical analyses and mechanical testing in the laboratory of the QA-department in case of uncertainty.

- Establishing testing and selection procedures for material, equipment and services.

Similar to the special branch of sealings, we organized the branches on the left-hand side of the following organization chart.

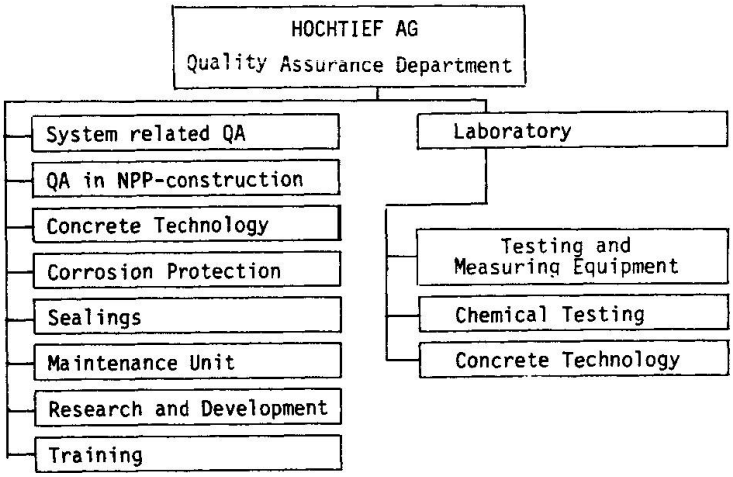


Fig. 1. The organization chart of the QA-department of the HOCHTIEF-company.

4.4 QA-Activities in Concrete Technology

The German Code DIN 1045 - Concrete and Reinforced Concrete - deals with design, analysis and construction of concrete and reinforced concrete structures and structural components. Section 8 of DIN 1045 states:

"for site-mixed concrete grade BII (abbreviation for concrete with nominal strength not less than 35 N/mm²), precast components, reinforced concrete and ready-mixed concrete a quality control consisting of an internal and external control must be carried out. The specifications for quality control are laid down in DIN 1084.

In order to obtain authorization to manufacture such concrete, the manufacturer must fulfill QA-requirements set up by the building authorities. For the purpose of external control he must sign a control contract with an authorized testing institute or become a member of a quality control association. HOCHTIEF is a member of the quality control association GOB-BII. The GOB-BII checks a BII-site at 6 month intervals and prepares a quality control report which is sent to the manufacturing branch and to the Board of Directors of the company. At HOCHTIEF the Board passes the QS-report to its QA-Department. The QA-Department notes the most frequent deficiencies and puts special emphasis on their elimination.

4.5 Feedback of Information

Each of the inspections conducted on the site by the QA-Department would remain an isolated case and would be uneconomical if a feedback of information did not ensure that future building tasks could be performed better, having gained from previous identified mistakes. Furthermore, highly sophisticated construction methods raise urgent questions that require a periodic review of findings and experience. Once a year, the Department holds an internal meeting during which papers are presented and discussed and then compiled in a report volume, which is passed on to more people in the company. We call these meetings "Concrete Construction and Quality Assurance Colloquia". The series of reports currently comprises six volumes. The last report volume includes the table of contents of all previous volumes. This ensures that the compendium of technical issues concerning concrete construction is extended on an on-going basis.

A further work aid is a listing of incompatible building materials, which is updated by the Quality Assurance Department. The list shows at one glance the causes and remedies in problem cases, for instance when steel and magnesia cements, aluminium and lime water, stainless steel and normal steel, PVC strips and bitumen come into contact with each other.

4.6 Acceptance Testing of Ready-mixed Concrete

It is a well-known fact that the properties of concrete can be appreciably disturbed by incorrect concrete treatment. For quick instruction of the man on the site, who is all too often an unskilled labourer but in charge of acceptance testing of the ready-mixed concrete, we have developed a handy instruction paper. We are translating the information of the German Concrete Society in the form of a concrete "wall news-sheet" into Turkish and Yugoslav.

Most likely everyone is familiar with the consistency tester, a manual electric tool which enables the consistency of the fresh concrete to be tested quickly on the vehicle.

4.7 Research and Development

As already mentioned, quality must be further-developed by use of the most advanced production technology. In the research shop, which is part of the Quality Assurance Department, we are concerned essentially with the further development of building methods and with trying out new testing systems. In this context, I would like to say a few words on the tunnel construction method which is known under the name "extruded steel fibre concrete" (Appendix B). With this kind of mechanized process, control after execution would be ineffective. The work involved in this process concerns more than one field and department and places great demands upon the willingness of project engineers and concrete technologists to cooperate with one another.

The illustrations show the principle of the tunnel driving method that was first used for a sewage drain in Hamburg, then for the Frankfurt underground and now for the Métro in Lyon under the Rhône and Saone. The steel fibre concrete is pumped, pressure-controlled, into a chamber formed by the secondary heading blade of the tunnel driving machine between the foundation and a tubbing formwork, behind a front formwork. Intensive vibratory compaction is not possible because the steel fibres would precipitate due to the force of gravity. The concrete itself must therefore be easy to compact. Quality Assurance here is especially concerned with the concrete. Numerous QA

measures have to be taken throughout the entire production process and constantly reviewed to check their effectiveness. Insufficient care and inadequate quality would threaten the lives of the men who work underground.

5. Quality Assurance and Costs

Quality Assurance costs money. But it reduces damage and identifies areas of the building process in which large sums may be unnecessarily wasted: formalistic controls, poorly coordinated quality requirements, unclear objectives and complicated information routes. Building processes that are backed by a good Quality Assurance always lead to the most economical solution. The fact that Quality Assurance measures lead to better quality, lower reject rates and finally to higher customer satisfaction, without increasing the overall cost, is shown in the chart of different accompanying cost functions in relation to the degree of quality achieved.

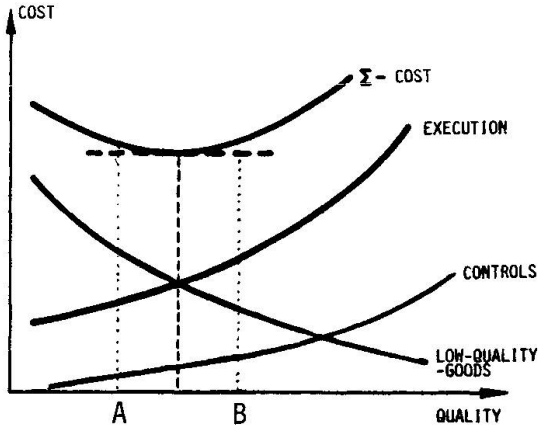


Fig. 2. Cost functions in relation to the degree of achieved quality. The higher "Quality B" can be got for the same price as the lower "Quality A".

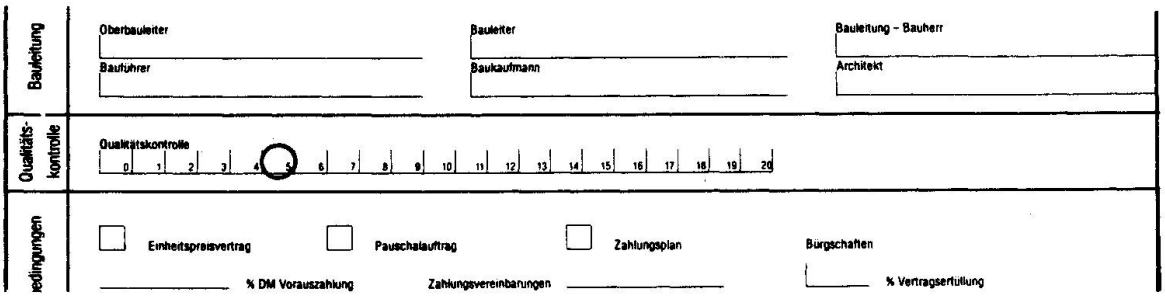
6. Training of Personnel

The final consideration of my presentation concerns a further important element of Quality Assurance, i.e. the qualification and training of all personnel involved in the building work. We are currently teaching planning and design engineers the most common waterproofing faults that we have noticed during five years of practice, and are training site foremen and craftsmen in the repair of concrete buildings. If we succeed in improving the know-how of our designers, resident engineers and workers in other areas as well, an important QA demand will be fulfilled and an important step be made towards solving many of the problems that are now pressing us. Therefore the training of our engineers, whatever their subject, is one of the most important tasks, both at universities and in professional practice.

REFERENCES

/1/ J.M. Shilstone, Quality Management: Too Often Counted Least but Needed Most. Building Design Jounal, May 1983.

/2/ D. Jungwirth, G. Thielen, Quality Assurance during the Construction Process. IVBH, Rigi 1983.



The quality characteristics relevant for the specific construction project are marked in the row "Qualitätskontrolle" of the "order-form".

	Construction projects with special quality requirements
1	Special project proposal / Risk in planning and design
2	Foundation piles / Injection anchor / Chem. soil stabilization
3	Shell structure / Folded plate structure / Towers
4	Structure with zones of concentrated load transfer
(5)	Prestressed concrete
6	Concrete grade BII-construction site / Fibre reinforced concrete
7	Sealings against groundwater
8	Caissons / Cantilever method of construction
9	Climbing shuttering / slip-form
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The back of the order-form contains the quality requirements and the number code.

HOCHTIEF AG AUFTRAGSSTATISTIK – QUALITAETSKONTROLLE STAND 31/10/84

NL	GS	BAU	UNR	BAUVORHABEN BAUSTELLENANSCHRIFT	AUSBAU-STUFE	BAU-BEG.	BAU-ENDE	QUALITAETS-KRITERIEN 1	2	3	4	5	6	7	8	9	10	11	12
02	060	93247	000	ARGE TBL AHAUS	3	8410	8606						6				10		
02	090	91631	000	BRUECKE HENGSTEYSEE	3	8410	8506			2			6						12
07	000	93808	000	ARGE SCHUETTMUEHLE SPANDAU	1	8410	8512						6			9			
07	000	93809	000	NIXDORF PRODUKTION BERLIN	1	8409	8506				4	(5)	6						
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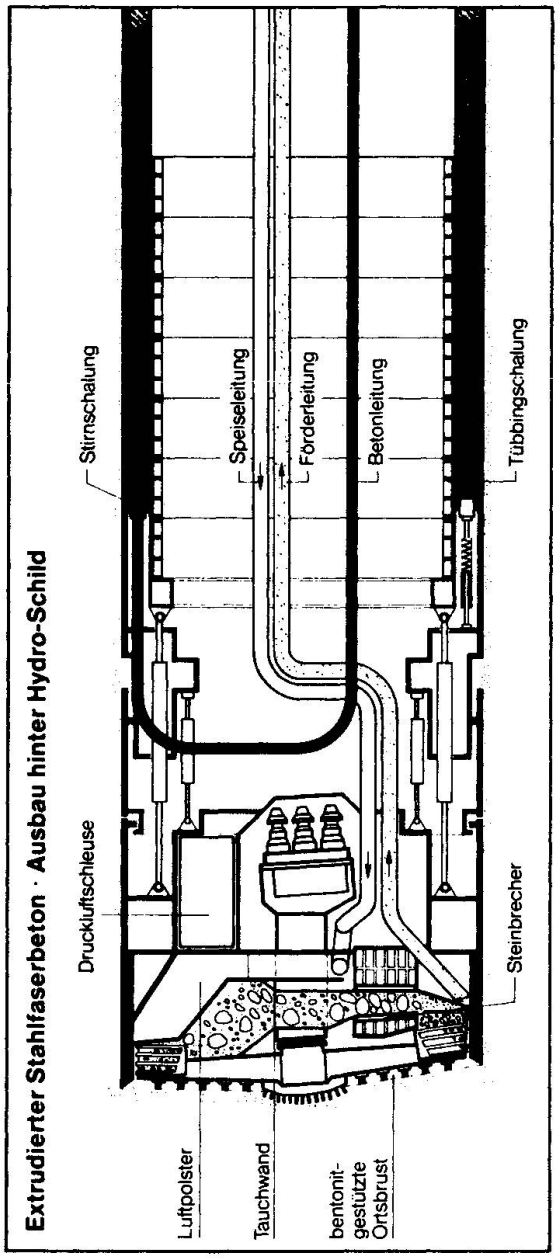
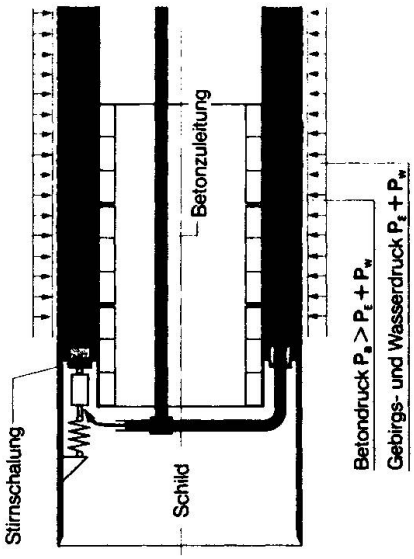
List of construction sites as the result of the electronically evaluated order forms.

REGISTRATION OF CONSTRUCTION SITES
ACCORDING TO QUALITY CHARACTERISTICS





TUNNEL CONSTRUCTION METHOD
WITH "EXTRUDED STEEL FIBRE CONCRETE"