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Quality Assurance during the Construction Process

Assurance de qualité pendant la réalisation d'une construction

Qualitätssicherung während des Bauprozesses

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SUMMARY
This contribution presents some ideas to the complex field of quality assurance from the contractors standpoint. First some thought will be given to the cost-benefit optimization in the construction process wich shows that any decision on cost benefit optimization must be based on total life time costs. In a second part quality assurance measures to be taken in more or less formalized quality assurance activities are proposed and discussed.

RESUME
Cette contribution présente quelques idées concernant l'assurance de qualité du point de vue de l'entrepreneur. Premièrement, des problèmes liés à la recherche d'une solution optimale entre coût et bénéfice sont abordés. Il en résulte que chaque décision vers une telle solution optimale doit considérer les coûts totaux pendant toute la vie d'une structure. Dans une deuxième partie, des mesures à prendre pendant le projet, le calcul et l'exécution des ouvrages pour assurer la qualité exigée sont discutées.

ZUSAMMENFASSUNG
Dieser Beitrag enthält einige Ideen zur Qualitätssicherung aus der Sicht des Unternehmers. Zuerst wird die Kosten-Nutzen Optimierung während des gesamten Bauprozesses angesprochen. Dabei zeigt sich, dass entsprechende Entscheidungen die Summe der Kosten, die während Errichtung und gesamter Nutzung eines Bauwerks anfallen, in Betracht ziehen müssen. In einem zweiten Teil werden Qualitätssicherungsmassnahmen während der Planungs- und Bauzeit vorgeschlagen und diskutiert.

1. Introduction

Growing logistic demands at the one hand side - e.g. housing, industry, transport and energy facilities etc. - and decreasing resources of material, and capital at the other hand side require the permanent development of advanced engineering technologies under increasing economical constraints. Parallel, the amplification of risk potentials inherent in modern technologies and the contineous degradation of environmental conditions have caused a growing social concern for quality and reliability of engineering structures.

At least two principle prerequisites must be given to assure success in this modern challenge for the engineering profession:

1) Precise knowledge of the complex material and structural behaviour under usual or accidental action scenarios.

2) Adequate strategies to organize the interactive decision process in a way that human cross errors during planning, design, execution, use, maintenance and eventual repair of engineering structures can be detected before impeding the required quality.

Analysis of material and structural damages observed in recent years has clearly shown that their causes go back as well to errors committed during planning, design and practical construction as to inadequate use. Predominently damages are caused by human cross errors however insufficient knowledge of the real structural behaviour under complex loading and environmental conditions has also been manifested.

While in general increasing insight into the material and structural behaviour has been rather instantaneously implemented in technical guidance documents when damage evidence proved the need - e.g. improved regulations for the design of coupling joints in prestressed girders after unexpected crack developments observed in german bridges - a corresponding improvement of the organizational aspects of quality assurance to avoid or limit human cross errors has not been observed very often.

The following communication will therefore focus on organizational aspects of quality assurance during the period of construction.

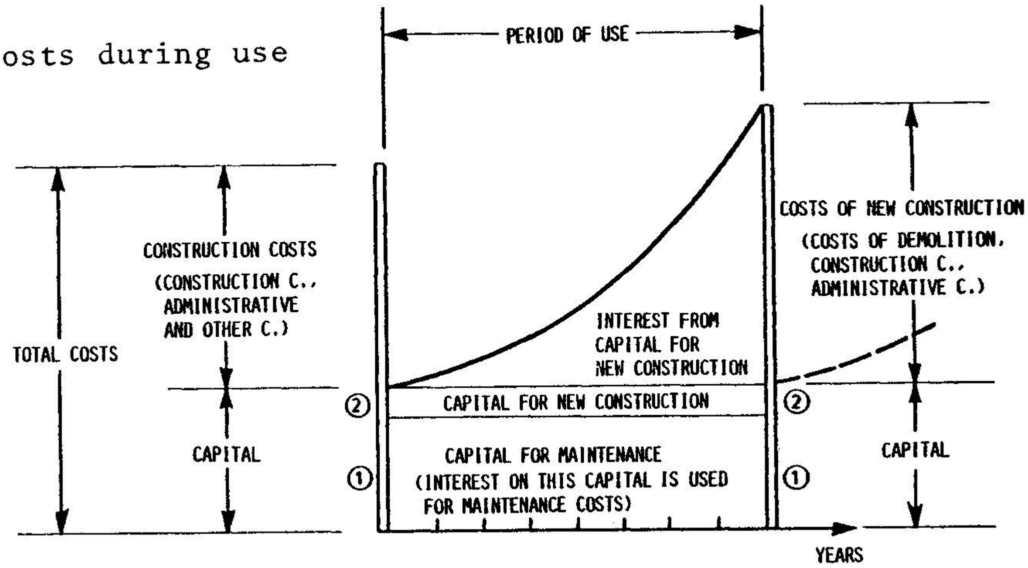
First some thoughts will be given to the cost-benefit situation at the construction market.

Then considerations will be made how quality assurance measures can be implemented in the construction process. These considerations will take into account studies and enquiries made by various national and international bodies such as Deutsches Normen-Institut (1, 2), Deutscher Ausschuß für Stahlbeton (3), Schweizer Ingenieur- und Architekten-Verein (4, 5), Norwegisches Normungsinstitut (6), Comité Euro-International du Béton (7), Joint Commitee on Structural Safety (8) and American National Standard Institute (9). Furtheron reference is made to publications authored by D. Jungwirth (10,11), H. Blaut (12), G. Thielen (13), H. Blohm (14) and H. Fromm (15).

2. Cost-benefit optimization

Different qualities of technical products will lead to different prices. A reasonable optimization of costs must consider the quality of a technical product or more precisely must refer to the requirements this product is expected to meet during its entire service life. This means that the total costs spent during the life time of a structure to assure its required performance is the most sensible parameter for cost optimization. Thus the ambiguous statement: "Quality costs but safes money" makes sense.
Let us consider in a simplified presentation the development of total cost during service life as shown in fig. 1.

Fig.1:
Total Costs during use



The total cost is added up by the sum of the real construction costs, maintenance and administration costs and finally the amounts transferred to investment funds providing the financial means for new constructions after taking out of service of the old building. The relation between maintenance costs and total costs is shown in fig.2 for the example of bridge structures.

Fig.2:
Dependence of Maintenance Costs on Construction Costs.
Example: Construction of Bridges

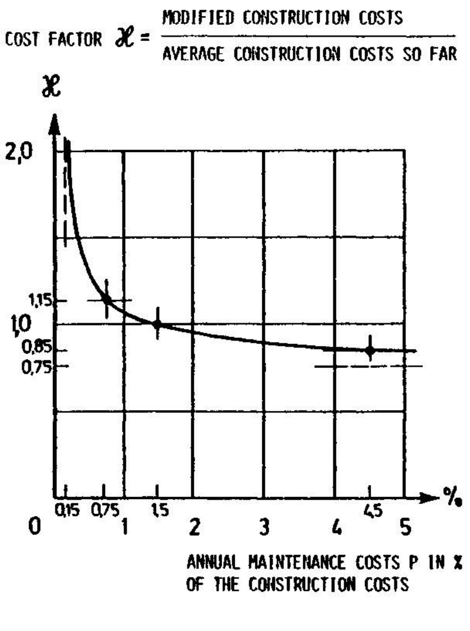


Fig.3:
Minimum of Total Costs

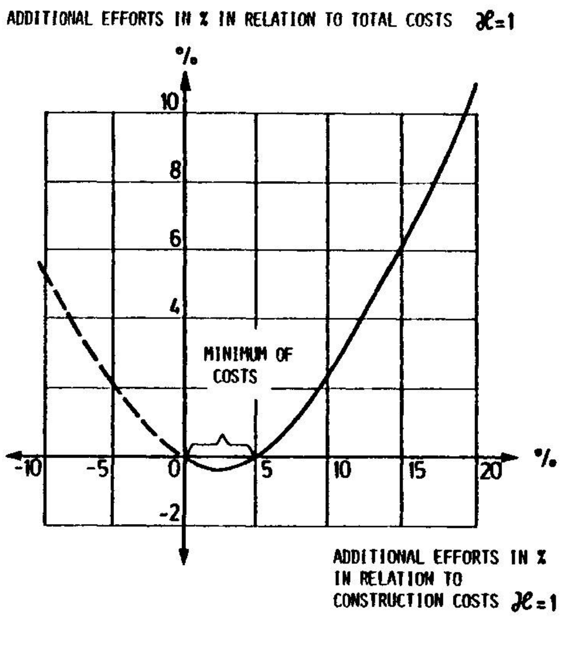


Fig. 3 summarizes these relations by showing how negative and positive increments in construction costs effect the total costs and how this relation allows to derive a minimum of total costs.

More details concerning cost development and cost relations in construction processes are given in (10).

An important question which must be raised here concerns the conditions necessary to assure that decisions based on an optimum of total cost become effective in real building processes.

First of all the owner has to play an important part in clearly basing his decisions on total costs. This requires to evaluate offers for a particular project on the basis of the required performance this project has to show during its service life, which again is preconditioned by the need to clearly specify these performance requirements. A decision only based on pure construction costs however seems not adequate to reach this aim. Possible strategies for example may include to ask construction firms for tendering not only construction but also maintenance of buildings or to claim extended terms of guarantee.

Secondly the contractor must show explicit concern for quality which means that under the constraints imposed on him by prices, construction delays and quality the latter must always deserve particular efforts. To achieve this, incentives should be given to the contractor. These may comprise selection for further jobs, premiums for excellent quality etc. It should be noted that efforts to improve quality become most effective by motivating and rewarding those who bear professional and financial risk in the case of unsatisfactory performance.

3. Quality Assurance Measures during construction

Quality Assurance measures require first of all the quality to be well defined in terms of required performances expressed in technical terms. Furtheron rules must exist how to achieve, measure and evaluate the required performances.

Based on these requirements and on appertaining criteria and rules the construction process comprising final design, shop drawings, site planning, material supply etc. has to be clearly organized. Two distinct but interrelated organizational pattern are necessary to provide adequate conditions:

a) Standing organization of the firms involved in the building process.
b) Project organization for a particular job.

Quality assurance or safety plans should provide rules governing both. In detail these plans must include the following features:

* Definition of directive and executive functions
* Hierachy and continuity of responsabilities within a company and in external relations
* Partition of duties
* Assignment of authorities and rights of decision
* Inspection, control and acceptance procedures
* Regulations concerning information network and documentation

Especially information exchange between both bodies and corresponding responsabilities have to be fixed to assure successful cooperation between standing specialist departments and site management.

It should be noted that quality assurance measures may be grouped according to different levels of requirements as proposed in (5) and shown in fig.4.

Fig.4 : Requirements on Quality Assurance According to SN o29100 (5)

Requirements	Degr. A	Degr. B	Degr. C
Q -system	●	◐	
Organization	●	◐	○
Requirements on the product	●	◐	○
Development and construction	●	◐	
Documents on execution	●	◐	○
Documents on supply	●	◐	
Deliveries and services	●	◐	
Identification	●	◐	○
Special procedures	●	●	
Tests during production	●	◐	○
Tests of the finished product	●	●	◐
Measuring and testing equipment	●	◐	◐
Storage, packing and transport	●	◐	
Status of tests	●	◐	
Non-conforming products	●	◐	○
Corrective measures	●	◐	
Documentation	●	◐	○
Monitoring the QA-system (Audit)	●	◐	

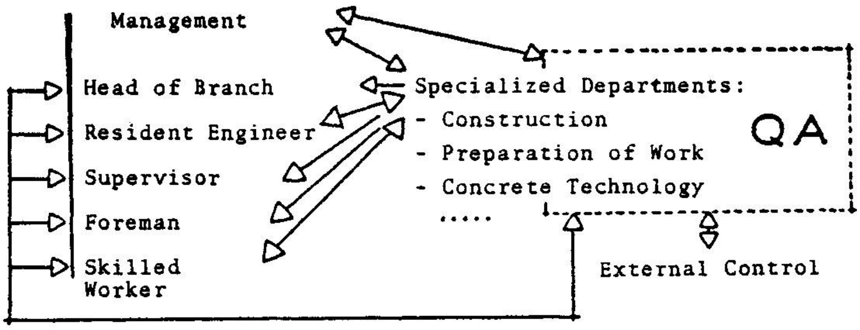
Legend:
● Requirements degree A
◐ Reduced requirements against ●
○ Reduced requirements against ◐

General principles of quality assurance should be laid down in technical guidance documents. Particular quality assurance plans for a given job nevertheless should be developed by the contractor since he bears the main professional and financial risk. The owner however - having specified the requirements - must approve these plans.

Furtheron accurate methods to measure well defined quanties which express the constructed quality and objective rules to accept or reject the results are needed.

Internal control for quality assurance has to be integrated into the construction process. This is shown in fig. 5. The QA-department, for example, is integrated into the production process (QA-engineer) and only a QA-agent monitors the functioning of the system, reports directly to the management and maintains contacts with the staff responsible for external control. An independent quality department parallel to production departments is not efficient but expensive.

Fig.5 : Organization of Quality Assurance



External control of a "QA-Association" has to check the total system by random tests. External pressure forcing the contractor to high quality work together with corresponding incentives for successful performance play on important role in achieving high quality construction.

Finally as stated earlier successful realization of the required quality depends on actions to be taken by persons involved in the building process. Quality assurance maesures aiming to detect human gross errors must assure correct decisions and corresponding actions which depends on qualification and motivation of persons.

Careful personal planning and regular employment of young staff to assure continuity at all levels and positions is of greatest importance. Any quality assurance plan has to focus on adequate education and training programs. Furtheron stimulus in form of awards and promotion should motivate and provoke efforts. An important condition for successful work means also to take away undue pressures and divergent duties from the performing people. This includes also to provide sufficient time for the various operations.

4. Summary

Structural damages go back to errors committed during the entire building process. Mistakes are caused by unsufficient knowledge or human errors. In general improvements in knowledge are directly implemented in revised building codes. Quality assurance measures to exclude or minimize human errors are less often specified.

Different quality levels lead to different price levels. Adequate judgement of optimal costs need to consider total costs caused not only during construction but also during the entire service life of a structure.

Improvement of quality needs action by all parties involved in the building process. Quality assurance during the construction process can be provided by means of quality assurance plans. These comprise all organizational aspects apt to detect human errors in the decision process.

General principles of quality assurance should be laid down in technical guidance documents. Particular quality assurance plans for special jobs must be proposed by the contractor and approved by the owner.

Effectiveness of quality assurance measures is given by motivating those who bear the greatest risk. Incentives in the case of good performance and disapproval in the case of bad performance provide adequate means for this.

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