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SUMMARY
Most of the following contributions were circulated by the respective authors to the participants of the workshop prior to the workshop meeting. Originally it was intended to give only a summarizing survey within this Report on the main aspects raised in the various contributions in order to avoid inevitable repetitions of certain general items. It was however felt that a publication of all contributions — if slightly revised and abridged — would be advantageous after all, thus demonstrating the very broad spectrum of views and differing perceptions of quality assurance among the participants.

RESUME
La plupart des rapports présentés dans ce chapitre ont été envoyés, avant le Workshop, par leurs auteurs aux participants. Il avait été prévu, à l'origine, de présenter ces contributions dans une forme très condensée pour éviter des répétitions. Eu égard au spectre extraordinairement large des points de vue exprimés, il a paru cependant juste de présenter ces contributions dans leur forme originale ou parfois légèrement abrégée et révisée.

ZUSAMMENFASSUNG
Die meisten der nachfolgenden Beiträge sind von den jeweiligen Autoren bereits vor dem Workshop an die Teilnehmer gesandt worden. Ursprünglich war vorgesehen, diese Beiträge hier nur überblicksweise zusammenzufassen, um unvermeidliche Wiederholungen zu umgehen. Es schien dann aber angesichts des ausserordentlich breiten Spektrums von Ansichten und Meinungen doch richtig, diese Beiträge, z.T. leicht gekürzt und überarbeitet, im vollen Wortlaut zu präsentieren.

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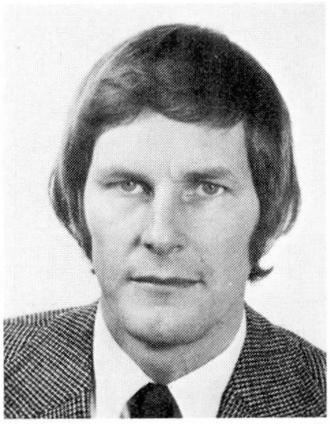
Quality Assurance of Prefabricated Products

Assurance de qualité d'éléments préfabriqués

Qualitätssicherung für vorgefertigte Produkte

Lennart ÅGÅRDH
Dr. Eng.
Swedish National Testing Inst.
Borås, Sweden



Lennart Ågårdh, born 1937, got his doctoral degree in Structural Mechanics at Chalmers University of Technology. Since 1976 he is head of the Division of Building Technology at the Swedish National Testing Institute, Borås, Sweden

SUMMARY
Quality assurance of prefabricated products used in buildings is discussed. Questions of Requirements, Responsibilities, Control Bodies, Test Houses and quality assurance-programs in factories are treated.

RESUME
L'article traite de l'assurance de qualité d'éléments préfabriqués dans l'industrie de la construction. Divers aspects sont traités: exigences, responsabilités, instances de contrôle, laboratoires d'essai et assurance de qualité en usine.

ZUSAMMENFASSUNG
Die Sicherung der Qualität vorgefertigter Bauprodukte wird diskutiert. Fragen bezüglich Anforderungen, Verantwortlichkeiten, Kontrollinstanzen, Versuchslaboratorien und Qualitätssicherungs-Programmen werden behandelt.

1. INTRODUCTION

1.1 Definitions

The framework for Quality Assurance (QA) of prefabricated products used in buildings is discussed. Quality means "fitness for use" regardless of price and time schedules, but the QA-concept must include even those aspects. Thus QA should be interpreted as "Planned and systematic actions taken in the production to achieve products with relevant quality at agreed time and cost".

The experience shows that requirements and specifications in contracts, even with penalty clauses, are not enough to assure the agreed quality in complicated and costly projects. Next step is to require a QA-program in the production as a condition for delivery. This may be done by prescribing the use of "type approved products", where production control and supervision are compulsary for the producer.

1.2 Scope

The requirements and specifications specified for a product are of vital importance for the outcome of quality. This paper is limited to QA for prefabricated products used at building sites. Key elements are requirements and the responsibility for their verification.

2. REQUIREMENTS

2.1 Classification

Building codes are based on law. They are restricted to considerations about safety, comfort and durability. (Requirements of 1 st order). Other requirements are described in standards (2 nd order) and finally there are specifications in individual contracts (3 rd order). The requirements can be classified according to the responsible party.

This division forms a basis for organizing quality control and supervision. If a property of a product is claimed to be important enough to be covered by the building codes the same importance should be applied to the supervision and verification of the quality of conformance. On the other hand if the property of a product is not under the restriction of codes, there is no authority responsible for the supervision. Then trade organisations, private institutes etc can organize external supervision of the conformance to requirements if requested. Finally the client is responsible for supervision of the conformance to requirements and agreements specific for his contract.

2.2 Type approvals

Many products used in buildings have a "type approval certificate" issued by the responsible authority. The approval of a production entitles the producer to mark his product with a quality mark, which simplifies the acceptance by local inspectors at the building site. In certain cases it also decreases the fee for the building permit and allows for more favourable design values. In most cases the approval implies production control at the factory, supervised by an authorized control body. Requirements are defined in the approval certificate and are based on the building codes. (1 st order requirements).

2.3 Official testing

"Official Testing" is a special notation in the Swedish legislation, covering inspecting and testing the conformance to 1 st order requirements when this is specified in codes. The legislation (issued 1975) states that "Official testing" has to be administrated by "National Test Centers" that fulfill certain requirements of competence and impartiality. The legislation is not yet adopted within the building codes but in one field, "Structural Timber and Wooden Materials", the Swedish National Testing Institute (SNTI) is pointed out as the "National Test Center".

3. SUPERVISORY

3.1 Control bodies

Traditionally control bodies develop from trade-organisations as a consequence of their needs to produce products of good quality. According to the development of regulations they become more "official" and include representatives from governmental authorities in their boards.

For supervision of requirements of 1 st order, independent bodies with technical competence and proper legal background should be pointed out. Based on increasing experience, quality control programs, compliance testing, external supervision etc may develop independently.

The competence required for a successful AQ-program within the factory lies with the producer and his people and may not be maintained outside the factory. The corresponding competence for successful supervision of the conformance to 1 st order requirements of the production, is knowledge of regulations, testing technics of the properties in question and statistical quality control concepts. This competence is best maintained by personal working in laboratory environments. Distributing the responsibilities between these parties may lead to a less effective result.

3.2 Test houses

Testing of products as part of the (external) supervision program should be made by authorized test houses. The authorization should involve tracable calibration of equipment and round-robin tests at least once a year. Very often the result of a test as a number of figures is not the only information that is necessary for the judgement of conformance. Thus there is a link between the judgement of conformity and the testing technics. This speaks for a close cooperation between inspectors and test houses.

4. PRODUCTION CONTROL AND INSPECTIONS

4.1 Works control

Before a permanent approval is given, the producer will propose a control program, choose control steps, testing methods, frequencies of testing, procedurs of documentation and internal supervision. In this work the producer and his personal generally show a great interest and positive attitudes to the program. The program often results in a remarkable increase in quality of the product.

4.2 Compliance testing

The judgement of conformance to requirements will be based on test records. Thus relevant test methods and testing frequencies have to be applied. In the production line the simplest possible methods should be applied with relatively high frequencies. Completion with more sofisticated methods may be needed at intervals. Test results are documented in journals. The laboratory equipment will be regularly calibrated and round-robin tests performed to assure the reproductability of test results.

4.3 Inspections

The inspections at the factory is part of the external supervision of the production. The main purpose is to verify that the quality of the products according to documented test results conforms to requirements. This may be done by compliance testing at external test-houses. If the documentations show that the product does not conform to requirements or if the compliance tests do not agree with the documented results the matter will be investigated and the approval may be put in question. At the time for inspection the QA-program will be discussed according to experienced results.

5. CONCLUSIONS

Better conformance to requirements of products can be achieved by introducing a QA-program in the production. This program consists of production control at the factory by the producer and his personnel and supervision by an external control body. This system are applied when "type approved products" are prescribed in contracts. By an increasing interest for type approved products the QA-concept may develop within the building industry as in other manufacturing industries.

Checklist for the Reliable Performance of Tasks

Liste de contrôle pour l'exécution correcte de missions

Checkliste für die zuverlässige Durchführung von Aufgaben

Hans BLAUT
Dr.-Ing.
Leonhard Moll GmbH & Co
Munich, Fed. Rep. of Germany

Hans Blaut, born 1924, got his civil engineering degree 1952 at the Technische Universität Munich. He was assistant with Professor Rüsch and was involved in Statistical Quality Control and Theory of Structural Reliability. In this field he took his doctor's degree, too. Since 1958 he works at construction site and prefab-plant. He is responsible for Quality Assurance for workforce, construction material and methods.

SUMMARY
The adaptable and weighted checklist for the reliable performance of tasks reflects the present experience. Especially the human factor was considered which plays an important role in the renewing and widening of knowledge, in the information and communication between the participants in a task and in the motivation of coworkers. The checklist is an open one, i.e. it must be adjusted in any case by the responsible manager to the actual situation. However it provides the necessary basic knowledge for everybody responsible for the performance of a task.

RESUME
La "liste de contrôle" de l'exécution correcte de différentes mesures à prendre pendant la construction, reflète les expériences actuelles. En particulier, le rôle essentiel de l'homme dans le processus de construction est considéré. L'importance de l'homme porte sur la mise à jour et la communication des connaissances, le transfert des informations et la motivation des collaborateurs. La liste de contrôle présentée, tout en restant ouverte, doit être adaptée aux conditions particulières de chaque situation particulière; elle fournit aux responsables d'une mission une aide précieuse dans la définition des activités appropriées pendant l'exécution d'un ouvrage.

ZUSAMMENFASSUNG
Die anpassbare und gewichtete Checkliste für die zuverlässige Durchführung von Aufgaben spiegelt die gegenwärtigen Erfahrungen wider. Besonders berücksichtigt wurde der Faktor Mensch, der bei der Auffrischung und Erweiterung von Kenntnissen, bei der Information und Kommunikation zwischen den an einer Aufgabe Beteiligten und bei der Motivation der Mitarbeiter eine wesentliche Rolle spielt. Die Checkliste ist offen, d.h. sie muss von dem Verantwortlichen in jedem Falle an die jeweilige Situation angepasst werden. Sie liefert jedoch dem für die Durchführung einer Aufgabe Verantwortlichen ein hilfreiches Basis-Wissen.

1. INTRODUCTION

According to the published results of Matousek, Schneider and other authors, Fig. 1 delineates the present situation in the concept of safety in the construction field [1]. In the weak element of the chain you will find terms all concerned with the human factor.

STATISTISCHE QUALITÄTS-KONTROLLE	STATISTICAL QUALITY CONTROL
PROBABILISTISCHE SICHERHEITSTHEORIE	THEORIE OF STRUCTURAL RELIABILITY
TEILSICHERHEITSBEIWERT	PARTIAL SAFETY FACTOR
LASTEN	LOADS
FESTIGKEIT	STRENGTH
VORHALTEMASS	SAFETY MARGIN
WISSEN	KNOWLEDGE
KÖNNEN	ABILITY
GE-WISSEN	CON-SCIENCE
KOMMUNIKATION	COMMUNICATION
ZUSAMMENARBEIT	COOPERATION
MOTIVATION	MOTIVATION
WEITERBILDUNG	CONTINUED EDUCATION
NETZDENKEN	NETWORK THINKING

Fig. 1 Present situation in the concept of structural safety.

What can we do with respect to the weak element of the chain?

The complex of questions of safety, of a general concept of safety, and of quality assurance does not only affect the building construction but the whole range of human activities (e.g. air-traffic, nuclear technique, off-shore-platforms, medicine, EDP-software a.s.o.). These questions can be attributed to the basic question for the reliable performance of tasks.

In many areas of human activity strategies and methods were developed to perform tasks in a reliable manner. Because tasks are always planned and performed by men the human being is in principle the most important factor in the reliable performance of tasks.

It is not sufficient to detect human gross errors but we have to avoid them by using all possible means, at least we have to reduce them.

The basis of any decision of a man is the most appropriate definition of the actual situation and the appraisal of the further development. The engineer uses his acquired logical thinking (in general that means: Linear thinking: Each cause produces one effect and vice versa).

Today more and more we become aware that logical thinking is absolutely necessary indeed but in no case a sufficient means to grasp the situation. Albert Einstein said: "Imagination is more important than the knowledge". We have to apply our imagination in order to think in networks and with their support we can more comprehend the situation (Network thinking,that means: Each cause produces many effects and vice versa). Of course also then remains a rest of uncertainty - but small - which cannot be excluded.

Making aware the basic elements for the reliable performance of tasks the engineer and manager shall be motivated and encouraged to rely not only on his knowledge but also on his conscience in solving reliable his tasks. F. Nietzsche says: "To make aware is already progess".

The following "Checklist for the reliable performance of tasks" is a so called "Open Checklist" (Fig. 2). It shall only inform the responsible man for the performance of a task by means of questions about the current knowledge of influencing factors and their weight in a clearly arranged form and with adaptable intensity. Then he himself has to decide how he will perform his task with this knowledge as a con-scienti-ous engineer or manager.

The form of a checklist was chosen because this checklist is adaptable in the best way to the individual knowledge, to the experience and to requirements of the reader by the intensity of its questions.

The very concise form of the Checklist will be introduced by some preliminary remarks and supplemented by some explanations.

2. PRELIMINARY REMAKRS TO THE CHECKLIST

The framed questions 1 through 6 of this Checklist show the essential influencing factors in the reliable performance of tasks. According to the situation and if the expenditure seems sensible also the respective sub-questions can be consulted resp. complemented or extended.

In case of a positive response to the respective questions by the responsible man for the performance he will become conscious by an iterative process of the essential influencing factors for the reliable performance of the task. By this fact the most important pre-requisite is given for a creative, to the situation adapted and therefore reliable solution of the task.

Certainly this Checklist cannot substitute the experienced expert or manager. But it can in the right moment provide helpful experiences in a clearly arranged form. It can sharpen the managers conscience.

Naturally the individual expenditure for the reliable performance of tasks will vary within wide limits: From the quickly only intuitive found solution to systematical well weighed work preparation. However experience teaches us that bigger tasks cannot be reliable performed without systematical preparation, especially because of the unavoidable division of labour.

Many of the possible solutions which are expressed in the questions seem at the first glance as obvious. But that does not mean that they are consciously and systematically applied.

The numbers in the circle ◯ refer to the explanations.

Adaptable[1] and weighted[2] Checklist[3] for the reliable performance of tasks

by Dr.-Ing. Hans Blaut, Munich, May 1983

$$T = m \times k^2 \times i^3 \times a^x$$

1.

Has the task resp. performance in the sense of a vision been clearly described and defined? [4]

Have there been made statements about the following details of the task...

1a about the aim?
1b about the scope?
1c about the structure?
1d about the requirements?
1e about the time span?
1f about the cost frame?
1g about the starting situation?
1h about the consequences to third parties? [8]

2.

Has there been found and compiled in a work plan for the solution of the task...

- **the required means?**
- **the required co-workers?**
- **the required measures (know-how)?** [5] [25]

Have hereby been...

2a evaluated own experiences?
2b evaluated outside experiences? [9]
2c conducted a Fault Tree Analysis? [10]
2d conducted an Event Tree Analysis? [11]
2e conducted a use analysis (Wertanalyse)? [12]
2f searched for creative solutions (e.g. by applying creativity techniques)? [13]

3.

Have there been supplied, with view to the aim and in due time, the required means and co-workers? [25]

3a Has there been worked out a network (CPM, PERT) for time and cost?

3b Has there been organized a Quality Assurance System and Quality Assurance Manual? [14]

4.

Have there been taken the required measures in view of the aim and in due time? [25]

4a Has there been worked out a network (CMP, PERT) for time and cost?

4b Has there been organized a Quality Assurance System and Quality Assurance Manual? [14]

5.

Is the necessary information and communication guaranteed between all participants involved in the task? [6]

5a Have all participants a clear, impressing description of the aim (vision)?

5b Had the participating persons the opportunity to get to know each other in their work and personally? [15]

5c Had the participating persons the opportunity to add their own ideas for solving the task? [16]

5d Were the various partial tasks and the appertaining competences assigned to the participating persons? [17]

5e Are there distributed frequently to the participants news about the situation of solving the task? [18]

5f Do the participants regularly receive a confirmation about their work and also, if necessary, constructive critics? [19]

5g Have all participants received a feed-back on the results achieved? [24]

6.

Were all participants in the task challenged by motivation in the ambition to perform the task in any case also in case of resistances? [7]

6a Were to co-workers selected according to talent, education and experience in view of the task? [20]

6b Were and will be the immediate and real needs of the participants observed? (Needs-pyramide of Maslow; Motivators and Maintenance factors of Herzberg) [21]

6c Are the co-workers led to events of success by their immediate superior? [22]

6d Gives the responsible man for the overall performance a good example for his co-workers? (possibly a fascinating example [23]

6e Has the responsible for the performance of the task made provision for his own that he is motivated again and again for the task, especially in critical situations?

Fig. 2

3. EXPLANATIONS TO THE CHECKLIST

(1) The contents of the Checklist can be adapted as the circumstances may require. However, the six framed questions represent the heart of the matter.

(2) The questions of this Checklist were weighted by the influencing factors which are summarized in a formula. This formula cannot be interpreted as a pure mathematic formula but shall only show the weights of the influencing factors in the language of the engineer.

(3) The form of the Checklist is especially appropriate to make conscious experiences in a concise and clearly arranged form. Furthermore, the questions produce associations and stimulate the creativity.

(4) The precise and impressive description of the task supports the concentration of all forces and stimulates the finding of solutions.

(5) The question about the means and about the know-how (measures) works like a wedge which divides the block of tasks in two essential parts. Since the know-how is more important than the material means, k-square was chosen; because the right know-how gives so much flexibility that one can find a good solution also with "unsure" means.

The engineer deals during his education and in his work mostly with influencing factors m and k^2 but less with the factors i^3 and a^x.

(6) The information and communication between all persons participating in the task were weighted symbolically with power cube because the factor "information and communication" and the herewith related organization plays a main role in the frame of the work division nowadays.

Many engineers do not always realize the importance of the influencing factor i^3.

(7) The factor a^x shows the ambition for the performance of the task. The exponent x can be both a positive or negative number. Thus it shall be expressed symbolically the decisive weight of this factor. A negative x would reduce much the factor a^x and therefore also the overall performance: Demotivation can block the contribution of other influencing factors for the performance.

On the other hand a positive x can compensate imperfections in other influencing factors.

(8) During the past years engineers experienced that the performance of their tasks (e.g. construction of a power station or of a incineration plant) was hampered resolutely by initiatives of citizens or even frustrated.

While defining the task the reaction of the affected persons has to be taken into consideration.

(9) There is no doubt that solutions of tasks are always newly invented with great efforts because the engineers do not find it worthwhile to search for already existing and published solutions and do not profit of them.

With the help of literature data files it could be solved very quickly.

(10) A Fault Tree Analysis points out qualitatively the net of possible reasons for a defined undesirable event (fault); refer to DIN 25424, part 1.

(11) An Event Tree Analysis points out qualitatively the net of all consequences of a defined undesirable event.

(12) The Use Analysis (Wertanalyse) is a method to improve the use. This method is characterized by the fact that by applying a systematic manner there will be achieved with great probability and without detours an optimal solution which meets the latest status of knowledge and the specific requirements. Reference is made to DIN 69 910, Wertanalyse - Begriffe, Methode. Berlin 1973 or VDI-Taschenbuch T 35: Wertanalyse: Idee, Methode, System. An introduction by the VDI-Gemeinschaftsausschuß "Wertanalyse", Düsseldorf 1975.

(13) The most known creativity techniques are Brainstorming, Brainwriting, Synectic, Morphological Box (Zwicky).

(14) Please refer to standards for quality assurance (e.g. DIN 55 355 or KTA 1401 or SN 029100).

(15) If co-workers are personally acquainted the cooperation is generally more fruitful.

(16) The personal engagement of the participating persons grows if they can add their own ideas.

(17) This item refers to a good organization.

(18) This information is very important for the personal engagement.

(19) Every man needs an acknowledgement from time to time that he is on the right way with his work, especially because of the always more complicated division of work nowadays.

(20) The selection of the right co-workers has to be rated very high. The co-worker should be in possession of the most important required attributes. A specific further development is possible but many times very time consuming and costly. Therefore, the own initiative for further development, arising from good motivation, gains importance.

(21) Today the findings of Maslow and Herzberg belong to the standard knowledge of leading staff.
Lit: Malsow, A.H.: Motivation and Personality, New York, 1970; Herberg, F.: Work and Nature of Man, Cleveland, USA, 1966.

(22) This is the most important task of a good superior. Only by the success of his co-workers the superior himself can be successful.

(23) The example of the superior is the best way to motivate a co-worker. That is more effective than many words.

(24) Because of the unavoidable division of labour it is very important that all participants personally take part of the success of the wohle task at least by information.

(25) Naturally the manager responsible for the reliable performance of task has to check all means and measures, not matter whether they are provided by the own organisation or by cooperating organisations.

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Ethics in the Building Process

Déontologie dans l'acte de construire

Ethik im Bauprozess

J. Ferry BORGES
Civil Engineer
LNEC
Lisbon, Portugal

Ferry Borges, born 1922, got his civil engineering degree at the Instituto Superior Técnico (IST), Lisbon. Researcher of LNEC, was successively Head of Structural Department, Deputy Director and Director of LNEC. Currently President of CEB and Professor at IST.

SUMMARY
Two problems in which the ethic component plays an important role are taken as an example of the importance of ethics in the building process. The first problem concerns intangibles in the decision process based on cost-benefit analysis. The second problem is related to the transfer of knowledge obtained from lessons gained by experience. Efficient information feed back systems should be implemented at international, national, regional and local levels. An important stimulus for this implementation should be gained through the recognition of the moral obligation related to it.

RESUME
L'importance de la déontologie dans l'acte de construire est mise en évidence dans deux groupes de problèmes. Le premier concerne les constantes dans le processus de décision basé sur une analyse de coût-bénéfice. Le second problème se rapporte au transfert des connaissances acquises par l'expérience. Un système de transfert d'information doit être établi aux niveaux international, national, régional et local. L'engagement moral de toutes les personnes concernées pourrait être un pas important dans cette direction.

ZUSAMMENFASSUNG
Anhand zweier Problemkreise wird die Wichtigkeit der Ethik im Bauprozess aufgezeigt. Das erste Problem betrifft den Einbau unfassbarer Werte in den auf Kosten-Nutzen-Analysen abgestützten Entscheidungsprozess. Das zweite bezieht sich auf den Austausch von aus Erfahrung gewonnenem Wissen. Funktionsfähige Austauschsysteme sollten auf internationaler, nationaler, regionaler und lokaler Ebene aufgebaut werden. Ein wichtiger Anstoss hierzu wäre die moralische Verpflichtung der Beteiligten.

1. INTRODUCTION

In every professional activity there is a moral component. Ethical aspects should be present when formulating technical problems and deciding on their solutions. This is the case in the building process and concerns all participants:owners,authorities,designers, builders, users, etc; all phases: planning, design, execution,use; and also activities related to the building process: research , guidance, information, control, etc.

Building problems are usually solved by considering technical aspects only, seldom complemented by economical and social con - straints.

This note calls attention to the need of further including ethical considerations in the decision process related to building.

2. ETHICS IN COST-BENEFIT ANALYSIS

Promoting and planning is the first phase of the building process. Cost-benefit analysis is an usual technique to inform decisions on planning. Several alternatives being considered, a simple economic rule to guide decisions consists in comparing costs and benefits and choosing the solution in which the ratio of costs and benefits is minimal.

The application of this rule brings us face to face with different types of difficulties.

Costs and benefits are distributed in time. In order to make them comparable they should be converted to values at a common time origin. This problem is usually solved by assuming a discount factor.

Costs and benefits are seldom deterministic: A probabilistic approach has to be used to represent them. Decision rules are thus usually based on the optimization of expected values.

In most cases the simple formulation in monetary terms is unsatis- factory. The concept of utility allows to rationalize decisions according to a scale of preferences.

However, the most important criticisms to basing decisions simply in cost-benefit analysis derives from the criteria usually adopted to compute costs and benefits, particularly due to the exclusion of ethical aspects often referred to as "intangibles" [1] .

The border between aspects that may be expressed in monetary terms and intangibles is undefined. The identification of intangibles is a first step to their consideration. However although being identified in most cases they are excluded from cost-benefit analysis.

Another difficulty in the comparison of costs and benefits derives from the fact that these usually refer to different groups of people [2] . Every undertaking benefits given groups in Society and increases risks to other groups. Thus equity problems in the distribution of benefits and risks have to be considered. Often this equitative distribution involves social, political and ethical problems.

In order to include in the design process the consideration of the interests of all people affected, Meseguer [3] introduces the concept of ambient-adequacy. It is suggested to modify present human requirements in building by considering that these should apply not only to direct but also indirect users (which are direct users of nearby construction) and the community.

This way of seeing the problem only gives partial satisfaction to our objectives. Adequate solutions have to be obtained by the explicit consideration of ethical principles.

Optimization techniques being used as a basis of decisions, the basic aspects of justice should be included from the very beginning in the formulation of both objective functions and constraint inequalities [4] .

3. LESSONS FROM EXPERIENCE

The need to feed back knowledge gained in building experience to guiding information related to design, execution, maintenance and repair is generally recognized. Even so the mechanisms necessary to this transfer are not satisfactorily established. This general statement applies to the different levels at which this feed back should be implemented: international, regional, national and local.

Conflicts of interests are one of the reasons why convenient transfer mechanisms are difficult to implement . An international code of ethics, dealing with collection, interpretation and diffusion of information gained from experience would be a useful tool to overcome present difficulties.

Information on errors usually affects the prestige of those who have committed them. What are the limits of the moral obligation to inform about errors and their consequences?

On the other hand, which are the limits to inform about a successful technique the dissemination of which would benefit mankind, but from which someone is taking direct profit?

In this context the code of ethics of the American Society of Civil Engineers [5] deserves being quoted.

Fundamental Canon 1 reads. "Engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties".

The guidelines to function under this canon are:

"a. Engineers shall recognize that the lives, safety, health and welfare of the general public are dependent upon engineering judgments, decisions and practices incorporated into structures , machines, products, processes and devices.

b. Engineers shall approve or seal only those design documents, reviewed or prepared by them, which are determined to be safe for public health and welfare in conformity with accepted engineering standards.

c. Engineers whose professional judgment is overruled under circumstances where the safety, health and welfare of the public are endangered, shall inform their clients or employers of the possible consequences.

d. Engineers who have knowledge or reason to believe that another person or firm may be in violation of any of the provisions of Canon 1 shall present such information to the proper authority in writing and shall cooperate with the proper authority, in furnishing such further information or assistance as may be required.

e. Engineers should seek opportunities to be of constructive service in civic affairs and work for the advancement of the safety, health and well-being of their communities".

The specific aims of this code of ethics may justify the mixing up of fundamental natural laws and natural rights with professional aspects of approval of drawings and conformity with standards.

An efficient feed back system of information is of fundamental importance to the progress of building. Those who cannot identify the errors of the past are going to repeat them in the future.

3. CONCLUSIONS

Two cases in which the consideration of ethical aspects would be of paramount importance for obtaining adequate solutions of general technical problems are presented.

It is advocated that the clarification of ethical rules should guide in many other aspects related to quality assurance.

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Loading Capacity and Quality Control of Precast Reinforced Concrete Structures

Charge ultime et contrôle de qualité d'éléments préfabriqués en béton armé

Traglast und Qualitätskontrolle von vorgefertigten Stahlbetonbauteilen

Alberto FONTANA
Prof. of Struct. Eng.
Politecnico of Milan
Milan, Italy

Alberto Fontana, born 1935, got his civil engineering degree at Politecnico of Milan. For some years he was involved in special structural problems connected with chemical process design and underwater pipelines. Now he is professor of structural engineering at the Politecnico of Milan.

Francesco SCIROCCO
Professor
University of Florence
Florence, Italy

Francesco Scirocco, born 1931, got his architectural degree at Politecnico of Milan. He is professor of structural engineering at University of Florence. He is consultant to quality control program at ICITE Laboratory of National Research.

SUMMARY
On the basis of a probabilistic structural analysis it is shown that it may be possible and convenient to avoid the production control of precast structural elements in reinforced concrete provided that the materials themselves have been submitted to a production control by means of control charts.

RESUME
Sur la base d'une méthode d'analyse probabilistique de la sécurité des structures, il est possible d'éviter le contrôle de la production des éléments préfabriqués en béton armé, à condition que soit effectué un contrôle complet de la production du béton et de l'armature au moyen de cartes de contrôle.

ZUSAMMENFASSUNG
Es wird mittels einer wahrscheinlichkeitstheoretischen Erfassung der Tragwerksicherheit gezeigt, dass es möglich und nützlich ist, die Produktionskontrolle von Stahlbetonfertigteilen zu vermeiden, sofern die Produktionsprüfungen der Baustoffe mit "Kontrollkarten" durchgeführt werden.

INTRODUCTION

For some time now it has been accepted in construction practice that a probabilistic analysis is needed to assess structural safety, since the traditional deterministic method are too obviously limited [1]. This idea is gaining ground in Italy, too, as shown by its extension to the national Code in its periodic revision [2]. The CNR (National Research Council) also gives great importance to the probabilistic approach in its instructions on the design of reinforced concrete structures [3], [4].
Safety up to a given limit-state, which would be an indication that the structure was out of service, is worked out by comparing two randon variables (or stochastic processes) generally called "capacity" (strength) and "demand" (external actions). Generally speaking, demand can only be described in terms of statistics, since it is normally under the control of the designer.
On the other hand it certainly is possibe, at the design stage, to assign limits within which the capacity can vary (specified in the design), so as to make the most economic choices for a given safety level.
Recently, too, it has been shown that only through the application of probabilistics can the contrasting interests of structural safety and economic production be reconciled for precast elements [5]. In this case, with reference to the carrying capacity of a beam (shown by the ultimate load multiplier λ) the distribution function F (λ) is established.
Now, it can be shown [6] that the coefficients of variation for the geometrical imperfections are much smaller than for the strengths of the materials, so F (λ) depends above all on the probability density functions which describe the strengths of the steel and the concrete. So these functions can be taken as representing the "quality" of the materials (the r.v. being normal or gaussian) [7].
When the coefficients of variation for the geometrical imperfections are not negleagible the number of r.v. increases and the numerical processing is more burdensome (e.g. to work out the failure probability distribution function of a simply supported variable cross section r.c. beam using UNIVAC 1108, the CPU time is about 15 min.).
So for isostatic structures (widespread in prefabrication), and limited to the question of quality control, only capacity need be considered, and this can be done by examining the capacity of each individual member [8].
After working out the distribution function $F(\lambda)$ of the failure probability (which describes the quality of the product) the necessary data become available for setting up the quality control, which can be carried out through the two following steps:

- statistical control of the load-bearing capacity of the structural elements through the production control of the mechanical characteristics of the materials, so as to minimize the time and labour dedicated to the testing side of control work;
- acceptance tests on the various lots produced, carried out according to sampling plans and testing methods previoulsy agreed between producer and client.

Generally the producers of precast r.c. structures do not perform a complete control of the production neither on structural elements nor on component materials.
Acceptance tests of the materials call for the only control of the fraction of defectives which must comply with the expected characteristic values. These ones are conventionally associated with a proportion of defectives equal to 5%.
The only control of the fraction of defectives does not guarantee (in terms of probability) the reaching of a pre-established safety level of structures. Consequently it is necessary to put under control the whole distribution of the strengths of materials, taking care of concrete due to its greater coefficient of variation (from 15% to 30%).
Generally the strengths R_s and R_c of such materials have a normal law of distribution. Under this hypotesis and in view of finding the distribution function $F(\lambda)$ of the failure probability it is necessary and sufficient to perform the control of two parameters for each r.v. (e.g. the mean value η and the standard

deviation σ) instead of one only, as usually happens.
As it will be shown in what follows by working out a simple structural model, it is interesting to notice that loading capacity especially depends on the s.d. σ_c of concrete being pre-established its characteristic strength R_{ck} (fig. 1).

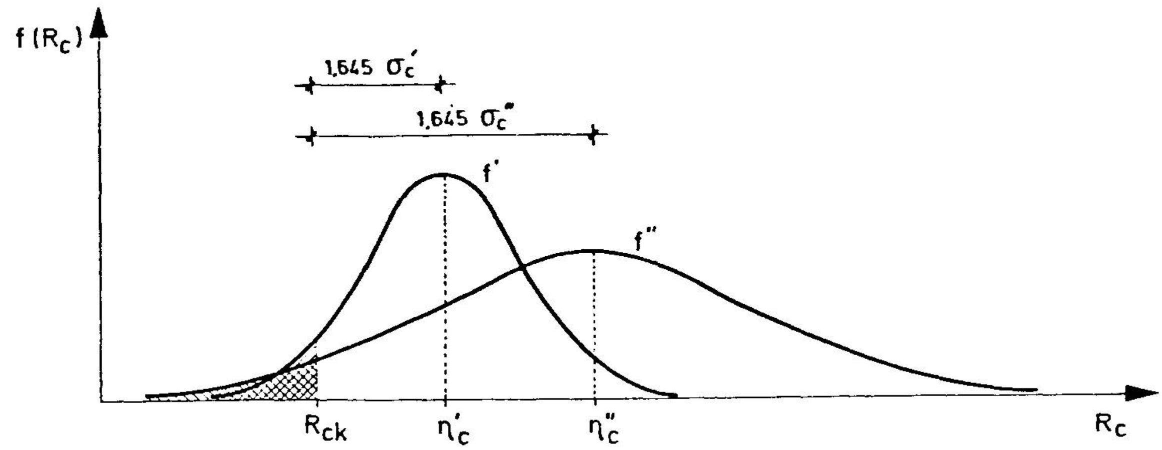

FIG. 1 Strength distributions of concrete

The randon variability of the geometrical imperfection of r.c. precast elements or structures and the one of the strength of materials are generally taken into account by proper design criteria partially or wholly based on the probabilistic methods of analysis.
By putting the production process under control the eventual changes of the law of distribution of randon variable may be avoided.
The control is exerted by means of two well-known statistical procedures based on the control charts (if reference is made to production control) and on the sampling planes (if reference is made to acceptance testing).
On the other hand if the systematic causes of deviation belong to the class of rare and temporary events (human errors, bad workmanship, unproper informations and so on) the inspection must be carried out on all r.c. precast elements or assembled structures.
Every event of the previous class can be represented throungh an impulsive function so that it is not influent on the law of distribution of r.v. which only refers to the stochastic variability of the production process of r.c. precast elements or structural assembling. Consequently such events do not modify the normal law of distribution of r.v. and therefore they are not taken into account in what follows.

THE MODEL

For sake of simplicity this research complies with a model of a particular frame (Fig. 2). This is made by rigid elements connected by two hinges and with three deformable cells quite similar to the Shanley's cell. Here two types of cells have been considered: the "beam" type and the "beam-column" type. The former is assumed to have a steel fiber (s) at the botton and a "composite" fiber (sc) at the top (made by a steel bar surrounded by concrete perfectly bonded).
The latter is assumed to have two composite fibers (sc); a proper choice of the e/l ratio succeeds in putting these fibers under compressive stresses so that cracking can be avoided.
Owing to the normal distribution of r.v. (R_c and R_s) the strength of the composite (sc) results a r.v. having the mean value and standard deviation respectively:

$$\eta_{sc} = \eta_c + \frac{1}{m}\eta_s \;; \quad \sigma_{sc} = \sqrt{\sigma_c^2 + \frac{1}{m^2}\sigma^2 s},$$

being $m = A_c/A_s$ the ratio between the concrete cross section (A_c) and the steel one (A_s).

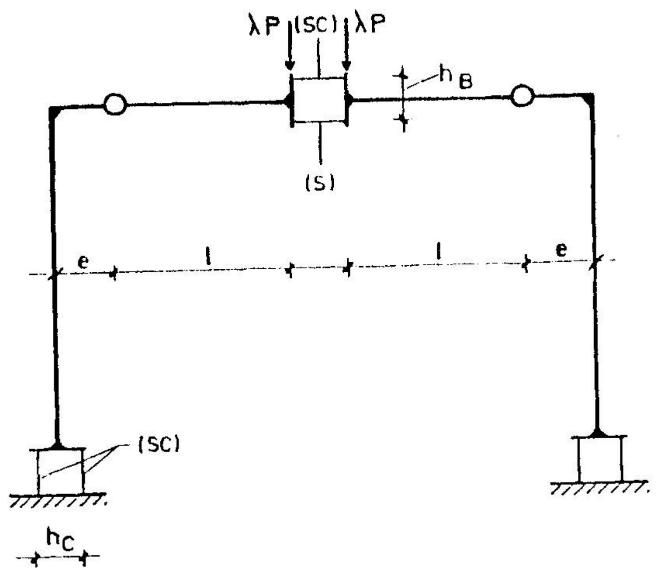

FIG. 2 The model of the frame

According to the model previously described and referring to the symbols of fig. 2, the failure probability Q_B of the beam is:

$$Q_B=1-P\{(N_{i(sc)}>N_{e(sc)})\cap(N_{i(s)}>N_{e(s)})\}=1-P\{(A_cR_c+\frac{A_c}{m}R_s)>\lambda\frac{Pl}{h_B}\}.P\{A_sR_s>\lambda\frac{Pl}{h_B}\}=$$

$$=1-[1-P\{(R_c+\frac{1}{m}R_s)\leqslant\lambda\frac{Pl}{A_ch_B}\}].[1-P\{R_s\leqslant\lambda\frac{Pl}{A_sh_B}\}]=1-[1-P\{\frac{R_{sc}-\eta_{sc}}{\sigma_{sc}}\leqslant\frac{\lambda\bar{s}_c-\eta_{sc}}{\sigma_{sc}}\}].$$

$$.[1-P\{\frac{R_s-\eta_s}{\sigma s}\leqslant\frac{\lambda\bar{s}_s-\eta_s}{\sigma_s}\}]$$

being $\bar{s}_c=\frac{Pl}{A_ch_B}$; $\bar{s}_s=\frac{Pl}{A_sh_B}$; $R_{sc}=R_c+\frac{1}{m}R_s$.

The failure probability Q_c of the column is:

$$Q_c=1-P\{(N_{iL}>N_{eL})\cap(N_{iR}>N_{eR})\}=1-P\{N_{il}>N_{eL}\}.P\{N_{iR}>N_{eR}\}=1-P\{(R_c+\frac{1}{m}R_s)>\lambda.$$

$$.(\frac{P}{2A_c}+\frac{Pe}{A_ch_c})\}.P\{(R_c+\frac{1}{m}R_s)>\lambda.(\frac{P}{2A_c}-\frac{Pe}{A_ch_c})\}=1-[1-P\{\frac{R_{sc}-\eta_{sc}}{\sigma_{sc}}\leqslant\frac{\lambda\bar{s}_c-\eta_{sc}}{\sigma_{sc}}\}].$$

$$.[1-P\{\frac{R_{sc}-\eta_{sc}}{\sigma_{sc}}\leqslant\frac{\alpha\lambda\bar{s}_c-\eta_{sc}}{\sigma_{sc}}\}],\text{ being } \bar{s}_c=\frac{P}{2A_c}+\frac{P.e}{A_ch_c}\text{ and }\alpha=1-2\frac{P.e}{\bar{s}_cA_ch_c}.$$

In the previous formulas indices i and e mean respectively "internal" and "external"; indices L and R respectively "left" and right".
The failure probability Q_T of the assembled structural elements is:

$$Q_T = 1 - (1 - Q_B) \cdot (1 - Q_C)^2 .$$

The results of the numerical analysis are worked out with the aid of the table of the values of the standardized normal distribution.
As an example a typical result is given in Table I.
It is interesting to note that the function Q_T (λ) for $\lambda \geqslant 2.5$ is virtually insensitive to variations in the s.d. values σ_c that may result in constructive practice (σ'_c = 4.25 MPa $\leqslant \sigma_c \leqslant \sigma''_c$ = 8.5 MPa).

TABLE I - Values of the failure probability.

λ	σ'_c = 4.25 MPa	σ''_c = 8.5 MPa	Q''_T/Q'_T	NOTE
	Q'_T	Q''_T		
1.	2.9×10^{-9}	3.2×10^{-5}	16000	R_{ck} = 25. MPa
1.5	3.2×10^{-5}	2.7×10^{-4}	8.5	$\bar{s}_c$ = 8.5 MPa
2.	2.2×10^{-2}	2.4×10^{-2}	1.1	R_{sk} = 320. MPa
2.5	50.1×10^{-2}	50.6×10^{-2}	≃ 1.	$\bar{s}_s$ = 160. MPa
3.	97.9×10^{-2}	97.9×10^{-2}	1.	σ_s = 40. MPa
$m \to \infty$ for the beam type cell ; $\alpha = 1$				

For our purposes the ratio Q''_T/Q'_T is significant.
For a given characteristic strength of the concrete (e.g. R_{ck} = 25 MPa and consequently $\eta_c = R_{ck} + 1{,}645\ \sigma_c$) varying the load multiplier within the interval $1.5 \geq \lambda \geq 1$ (the most interesting in the province of structural engineering) the failure probability increases with σ_c. Redoubling the s.d. value from $\sigma'_c = 4.25$ MPa (typical of production under control) to $\sigma''_c = 8.5$ MPa (typical of uncontrolled production) failure probability increases quite considerably even up to 16000 times.
Obviously the concrete having the s.d. equal to σ'_c allows a safer and less expensive technical solution (in fact $\eta'_c < \eta''_c$) than the one resulting from the use of concrete having the s.d. equal to σ''_c.
It is this which makes inseparable the problem of the structural safety (represented in probabilistic terms by $Q_T(\lambda)$) from the one of economic nature.
On the other hand the comparison within all the results so far obtained shows the inadequacy of the actual provisions of the national codes for the r.c. precast structures. Consequently it is necessary that codes improve the present instructions about the procedures of the production control of the materials compelling manifacturers to use control charts. So it is possible to get the probability distributions of the strength of component materials and the approach of structural production control suggested here (that is an indirect method to assess the "structural quality") becomes operating.

CONCLUSION

The results of a probabilistic analysis carried out on the loading capacity of the model of a simple precast r.c. frame show that is both possible and vantageous to replace direct with indirect production control of structures. Indirect quality control only checks the quality of the component materials and brings obvious advantages in terms of money and rapidity in dealing out of-services situations. Probabilistic analysis also offers design guide-lines for the best choice of the quality of the materials for a given safety level.
If the approach suggested here is adopted, the complete production control of the materials has to be peremptory exerted to get both the chosen safety level and highest economy.
Generally the production control of steel is carried out at steel plants. Therefore, referring to the production control of concrete, each manifacturer of precast r.c. structures takes up a position among those defined afterward.

- Concrete production control is not carried out; the mean value η_c of the r.v. R_c is reduced and the standard deviation σ_c increases. Therefore the probability of the structural failure is on the increase and overall costs bring down.

- Only the control of the fraction of defectives is carried out; both the probability of structural failure and the prime costs increase (being constant R_{ck}).
  The incomplete exertion of production control is doubly unfavourable.
- Production control is exerted through two parameters (usually the mean value η_c and the standard deviation σ_c). As a consequence of this position the probability distribution function of the ultimate load multiplier may be worked out and the assessment on the "structural quality" may be given by means of the indirect method of control, presented here. So it is possible to conciliate the problem of structural safety with the demand of cheap production control. The tendency (still widespread in Italy) to avoid any kind of control must inevitably be abandoned.

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Evaluation of Engineering Practice in Australia

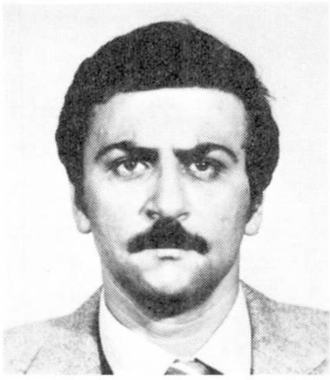
Evaluation de la pratique de l'ingénieur en Australie

Bewertung australischer Ingenieurpraxis

Owen INGLES
Assoc. Professor
University of NSW
Kensington, NSW, Australia

Owen Ingles, born 1923, graduated in Tasmania. His materials research is internationally recognised by many awards. His interests and consultancies are chiefly soil stabilisation, cost-benefit-risk, and failure analysis.

George NAWAR
Deputy Special
Housing Commission of NSW
Kensington, NSW, Australia



George Nawar, born 1949, graduated in N.S.W., 1977. He is responsible in the N.S.W. Housing Commission for investigating structural aspects of residential constructions.

SUMMARY
This note discusses the incidence of engineering failures in Australia, with special reference to the building industry. It relates observed occurrences in a large housing sample to the engineer's prior perception of, and tolerance for, risk exposure as determined by an Autralia-wide survey. Human error is seen to be the principal source of failure. Some feasible remedies are suggested.

RESUME
L'article se réfère à des cas de ruine de constructions, et plus particulièrement de bâtiments, en Australie. Les faiblesses découvertes dans un large échantillon de bâtiments d'habitation sont comparées au niveau de risque accepté, selon une enquête australienne. L'origine principale de ces défauts se résume à de lourdes fautes humaines. Des mesures pratiques sont proposées.

ZUSAMMENFASSUNG
Das Versagen von Ingenieurbauwerken wird diskutiert, insbesondere im Hinblick auf das Baugewerbe. Eine Beziehung wird hergestellt zwischen tatsächlichen Schadensfällen im Wohnungsbau und dem Ergebnis einer Umfrage, welche die Risikobereitschaft bzw. Risikotoleranz von Bauingenieuren in Australien feststellte. Menschliche Unzulänglichkeit wurde als die Hauptursache für die meisten Schadenfälle ermittelt. Einige mögliche Massnahmen zur Schadenverhütung werden aufgezeigt.

1. INTRODUCTION

The results of an extensive survey, made in June 1982 amongst 646 practising civil engineers distributed throughout all Australia, have recently begun to be published (1),(2). This survey sought to examine the attitude to risk amongst practising civil engineers, so that perceived risk levels could be compared with actual risk levels; also to identify more precisely the probable origins of, and countermeasures for, engineering risk.

A high level of response (>50%) and broad survey cover was achieved. This note examines hitherto unpublished aspects of the response, in conjunction with original data on actual risk levels in the building industry which provide a comparison with the measured perceptions. The human error rate is also deduced.

2. ORIGINS AND PREVENTION OF FAILURE

Though natural hazards are an important source of engineering failures (cf.(3)), they are increasingly well understood, and accumulated evidence now points overwhelmingly to human error as the major origin of failures (cf.(4)). Its components have been studied and discussed (cf.(5)), and include physical, psychological and philosophical aspects.

It has been concluded (2) that design checking does *not* provide a sufficient method for error reduction to the standards required; but that the best way to minimise risk is to optimise performance of the "human machine" by providing

(a) optimal mechanical - i.e. working - conditions
(b) optimal computing - i.e. *time to think* - conditions

Analyses of survey question 3 provided important complementary information on these matters. The question read:-

"Which of the following would you consider the best safeguard against failure?

(i) for the engineer	*(ii) for the overall work*
clear instructions	*extensive checking of designs*
numerical accuracy	*close supervision of construction*
length of experience	*operational simplicity*
severe penalties	*insurance*
	severe penalties

(check one only in each column)

Do you consider present legal penalties for failure:

Excessive   Adequate   Inadequate   (please circle which)."

The restriction on choice in the first part of this question was intended to force a clear and considered answer. The replies are shown in Table 1 both as a total response and - in brackets - the response of those who had specifically indicated elsewhere (Question 2) that they were structural engineers. Application of the Z statistic and confidence interval estimator confirmed the null hypothesis of no significant difference between the class of structural engineers and the class of all engineers, with the sole exception of the minority approach to penalties.

This latter difference, significant at the 5% level, seems to reflect the current situation, where the structural engineer is already achieving appreciably lower failure rates than his colleagues.

Table 1 shows the considerable emphasis placed on *experience* for the engineer, and the overwhelming emphasis placed on *supervision* for the work. The other major response of *"clear instructions"* is a condemnation of human error located in the communications sphere; which could be largely eliminated by computerisation, code formulation, and standardised specifications.

(*best safeguards are*)			
clear instructions	171 (45)	extensive checking of designs	72 (25)
numerical accuracy	20 (5)	close supervision of construction	182 (44)
length of experience	123 (41)	operational simplicity	54 (20)
severe penalties	3 (1)	insurance	1 (1)
		severe penalties	4 (1)
	Σ= 317 (92)		Σ= 313 (91)
(*present penalties are*)			
excessive 23 (13)	adequate 201 (56)	inadequate 46 (9)	Σ= 270 (78)

Table 1 Engineering opinion on safeguards and penalties for failure

Despite the importance attached to works supervision, and its low cost in the present Australian wage and salary structure, legal and social pressures appear to be forcing it into decline rather than growth.

Answers to question 3 overwhelmingly favour a legal "status quo", and penalties are not seen as a useful measure for failure reduction. Indeed, legal penalties *raise costs* rather than *reduce risks* (2), so that rulings which inhibit supervision by attaching increased responsibility to the engineer may prove counterproductive.

3. THE VALUE OF EXPERIENCE

If experience is measured by the number of years since graduation, then the survey showed it to be without influence on risk acceptance *except* where risks exceeding 1% were involved. (In which case, the more inexperienced the engineer, the more willing to accept the risk).

Nor did experience suggest any changed apprehension of risk, *except* insofar as the more experience the less the insurance deemed necessary. Length of experience correlated strongly (0.2% level) with breadth of experience,however.

These, and other survey results, were interpreted (2) as confirming that

(a) the engineer's *perception of risk exposure* is unaltered with age or experience: suggestive of a low level of failure incidence (realisation).
(b) younger engineers will *accept* higher risk than older engineers (thus the latter should have fewer failures).
(c) older engineers show greater confidence in their work. This does not conflict with (a), since to *perceive* a risk does not mean it will necessarily eventuate.

4. RISK TOLERANCE LEVELS

The survey was limited to measuring the risk tolerance levels of professional engineers. Although these are based on sound professional judgment and knowledge, they may well differ appreciably - due to a lack of public relations (communication) - from risk tolerance levels in the community-at-large. Some evidence exists which permits this difference to be assessed, at least to a first approximation.

Table 2 shows engineering risk tolerances computed from the survey. It is notable that risk tolerance is *one order higher* for public money as compared with one's own money. A more balanced view is taken in respect of injury.

Table 2 confirms the broad consensus in recent literature, which assigns a value of about 10^{-5} per person per annum for the level at which fatality risk is first *perceived*, and 10^{-4} per person per annum at which fatality risk reduction will be *demanded.* That these figures apply not just to engineers, but also to the community-at-large is shown by the relationship between traffic accidents and public demand for countermeasures (6).

Fatality	Money Loss, private	Injury, personal	Money Loss, public	Injury, impersonal	Injury, reputational
5×10^{-5}	2×10^{-3}	1×10^{-2}	2×10^{-2}	4×10^{-2}	$\cong 4 \times 10^{-2}$

Table 2 Risk Tolerances, per person (or structure) per annum, Australia 1982

The higher tolerance threshholds found for less severe forms of risk (injury, money, reputation) reach 10^{-2} per person (or event) per annum; and suggest strongly that human error always provides the upper tolerance bound to all engineering risk.

5. ACTUAL LEVELS OF REALISED RISK

5.1 General Incidence of Failure

The surveyed risk perceptions may be directly compared with actual **risk** realisations in Australia. It will be noted that these realisations are not greatly at variance with those reported elsewhere.

For pavements, actualised risk reaches 10^{-1} (1); for major bridges 3×10^{-3} (5); for earth dams 2×10^{-3} (5); for buildings 1×10^{-4} (7). Though such figures are overall averages, concealing some dependence on *locality* and *construction type*, it is clear nevertheless that actualised risk is only slightly below the tolerable risk level. This is a very efficient situation.

5.2 Failures in the Building Industry

A recent analysis of the records for 144,785 houses, flats, units and attached dwellings in New South Wales found 0.28% to have been defective. To be comparable with other data, it is necessary to reduce this fault occurrence to an annual basis. Using a preliminary estimate of the average age (10 years), the incidence of defective building per annum becomes 3×10^{-4}. This agrees very well with other sources (7), although the figure is probably still too low, because not all defects are reported (some being not noticed, or deliberately ignored for a variety of reasons).

As a result of this large sampling, it seems reasonable to assign a value of 0.5×10^{-3} per structure per annum for the incidence of building defects in Australia. This is very much better than achieved by dam or bridge builders, and the question must be asked, *why ?*

Probably this low failure rate stems from the use of clear codes and highly standardised specifications: since the sample population was wholly constructed by a single Authority, the Housing Commission of New South Wales.

Table 3 shows the incidence of building failures according to locality and structural type. χ^2 testing shows the defectives rate to be significantly higher in country areas (<0.1% level) and lower for the Wollongong district (5% level). Failures are also significantly lower for attached dwellings (<0.1% level) and higher for cottages (2½% level).

The higher incidence in country areas is thought to arise from relaxed standards of workmanship and material. The lower incidence in attached dwellings is thought due to the predominance of raft slab construction. Both these observations merit further investigation.

Type / Location	Cottages	Attached Dwellings	Flats	Units	Σ	Defectives
Sydney	56,509	6,909	13,988	7,263	84,699	211
Newcastle	5,469	527	936	802	7,734	15
Wollongong	9,351	613	846	554	11,364	20
Country	36,854	675	426	3,063	41,018	157
Σ	108,183	8,724	16,196	11,682	(144,785)	(403)
Defectives	340	5	35	23	(403)	

Table 3 Sound and defective buildings by location and type, New South Wales

The types of defect found are shown in Table 4, and the causes of these defects dissected both broadly and in detail in Table 5. In agreement with earlier observations (4), human error may be said to account for 87% of all defects. This sets a human error occurrence rate of at least $0.87 \times 0.28 \times 10^{-2} = 0.25\%$, and probably nearer to 0.4% for the reasons stated earlier (non-reporting).

Frame displacements caused by uneven foundation movement	82,0%
Failure of individual structural elements, e.g. brick growth, concrete shrinkage, rusted lintels, etc.	16.5%
Complete structural malfunction, requiring demolition	1.5%

Table 4 Types of defect found (New South Wales)

Human Error, 87.0%	differential volumetric instability in plastic clay foundations	41.5%
	consolidation of uncompacted foundations	22.5%
	poor site drainage and stormwater or sewer line leakages	11.0%
	material behaviour faults (design fault)	5.5%
	uneven bearing capacity on rock	1.0%
	construction mistakes due to human error	5.5%
Natural Hazards,13.0%	undermined footings	3.5%
	tree and vegetation growth	3.5%
	slope instability	2.0%
	floods	1.5%
	age	1.5%
	fire	1.0%

Table 5 Causes of building defects (New South Wales)

It is noteworthy that the percentage of building defects caused by differential foundation movement (see Table 5) corresponded closely to the percentage of dwellings founded on medium to highly expansive clays (48.5%): there is no statistical evidence therefore for a higher defect occurrence on reactive soils than on non-reactive soils. This suggests that, although expansive soils have a bad reputation, current design methods are largely capable of overcoming their disabilities.

6. CONCLUSIONS

This note has sought to quantify certain planning and performance aspects of civil engineering failures which have been recognised hitherto only as qualitative truths, lacking sufficient hard back-up data.

As will have been evident, a problem which needs definition is the concept of *failure* itself, without which no quantification can remain unchallenged. Between the most trifling, even visual, defect and the most catastrophic collapse involving loss of life, there is an unbroken continuum. Between maintenance and reconstruction needs (or costs) there is no clear borderline.

With the widest definition of failure, *defective construction*, we have found an incidence of 5×10^{-4} per structure per annum. With the narrowest definition of failure, *collapse/demolition*, the incidence falls to 5×10^{-6} (an order greater than suggested by Cowan (7) using the same definition).

Clearly some arbitrary but standard definition is required: preferably with international ratification. One possible basis might be the percentage loss of capital value (having due regard to insurance against damages claims also); but no doubt others can be advanced.

Even adopting the widest definition of failure, building construction in New South Wales as practised by the N.S.W. Housing Commission is seen to be unusually successful in achieving low-risk construction.

ACKNOWLEDGMENT

The authors wish to express their appreciation to the Housing Commission of New South Wales for permission to publish this data, and to the School of Civil Engineering, University of New South Wales, which supported the survey.

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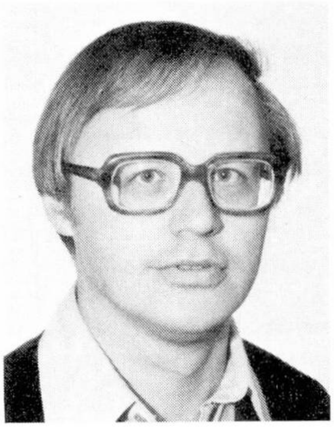
Strength and Structural Safety of Concrete Structures

Résistance et sécurité structurale des constructions en béton

Festigkeit und Sicherheit von Betonkonstruktionen

Hans INGVARSSON
Dr. Techn.
Swedish Natl. Road Adm.
Borlänge, Sweden



Hans Ingvarsson, born 1947, got his civil engineering degree in 1972 and his doctoral degree in 1978 at the Royal Institute of Technology, Stockholm, Sweden. Since 1979 he is working for the Swedish National Road Administration as Head of the Development Office within the Bridge Section.

SUMMARY
The structural safety of concrete structures, as far as the compressive and tensile strength is concerned, is partly depending on how the mixing of the concrete is performed and partly depending on how the concrete is handled with respect to compaction, curing etc. Thus the quality assurance just comprise both checking the concrete mix by testing standard cube specimens and checking if compaction, curing etc. have been performed satisfactorily by a final test of the concrete strength in the finished structure.

RESUME
La sécurité des structures en béton, en ce qui concerne la résistance à la compression et à la traction, dépend partiellement du malaxage correct et du maniement propre concernant le compactage, la cure etc. L'assurance de la qualité nécessite un prélèvement de béton aussi bien par essais sur des éprouvettes cubiques que le contrôle final du béton sur l'ouvrage.

ZUSAMMENFASSUNG
Die Sicherheit einer Betonkonstruktion, soweit sie auf die Druck- und Zugfestigkeit zurückzuführen ist, beruht zum Teil auf der korrekten Mischung des Betons und zum Teil auf der richtigen Verdichtung, Nachbehandlung usw. Die Qualitätssicherung muss folglich sowohl die Prüfung des Betons an genormten Prüfkörpern, als auch die Prüfung des Betons im Bauwerk betrachten, das letztere als Kontrolle, dass die Verdichtung, die Nachbehandlung usw., zufriedenstellend ausgeführt sind.

1. INTRODUCTION

An investigation has earlier been carried out by the Swedish National Road Administration in order to study the concrete strength of the slipformed piers of the Angered Bridge in Gothenburg. This investigation was presented by Ingvarsson[1] at the RILEM Symposium on Quality Control of Concrete Structures held in Stockholm 1979. In a more comprehensive manner this study was published as publication TB 133 [2] from the Swedish National Road Administration.

Investigations concerning the strength of concrete in finished structures have been carried out only in few cases at building sites with varying climatic conditions and so on. Beside those investigations by Lewandowski[3] and Petersons[4] the study carried out at the Angered Bridge is of special interest, since the mix proportions of the concrete were the same throughout the whole building period during which the piers were concreted. Furthermore, the same cement make and gravel-pits were used.

When slipform concreting the piers of the Angered Bridge 150 mm standard cube specimens were cast from the same concrete as the concreting layer, within which ø 100x100 mm cylinder specimens then were drilled out. Both the cylinders and the cube specimens were then tested so that a comparison could be made between the strength of the finished piers and the strength of the corresponding cube specimens. The observed ratios $t = f_{cc}/f_{ca}$ between the strength f_{cc} of the piers (drilled-out cylinders) and the strength f_{ca} of the corresponding standard cube specimens illustrate the effects of varying climatic conditions, compaction, curing and so on. The observed t-ratios at the Angered Bridge are shown in Fig.1. Based on the observed mean ratio, amounting to 0.80, and the corresponding standard deviation amounting to 0.10, the calculated normal probability density function is shown in Fig.1 in order to make a comparison possible. Apparently, the normal distribution seems adequate for the studied strength ratio $t = f_{cc}/f_{ca}$.

2. STRENGTH OF CONCRETE

If the ultimate compressive strength which can be utilized in a concrete structure is denoted f_{cu}, this can be expressed by the following equation

$$f_{cu} = \lambda \cdot f_{ca} \cdot t$$

where λ is a correlation coefficient between the compressive strength of the 150 mm standard cube specimens (f_{ca}) and the compressive strength of the corresponding ø 150x300 mm standard cylinder specimens. The latter strength is more accurate as far as the strength which can be utilized in compression is concerned. According to Swedish Standard (SS 13 72 07) the coefficient λ can be put to $1/1.35 = 0.74$.

The compressive strength f_{ca} of the standard cube specimens expresses the strength obtained at ideal curing conditions with respect to temperature and humidity. Therefore f_{ca}, so to speak, denotes a delivery check parameter concerning whether the actual grade of concrete is mixed in a proper manner or not. According to Bellander[5], for f_{ca} it can be stated that for each grade of concrete, the lower 10-percent fractile is 7 N/mm^2 lower than the average strength of the actual specified grade of concrete. The acceptance criteria of the former Swedish Concrete Code (B5-1973) were based on this fact. Thus for a grade K 40 concrete, a compressive strength of 47 N/mm^2 as an average was required. Considering the compressive strength as normal distributed, this requirement corresponds to an assumed standard deviation equal to $s(f_{ca}) = 7/1.28 = 5.5$ N/mm^2 which amounts to 12 % of the average compressive cube strength of a grade K 40 concrete, for which the mean value is equal to $m(f_{ca}) = 47$ N/mm^2.

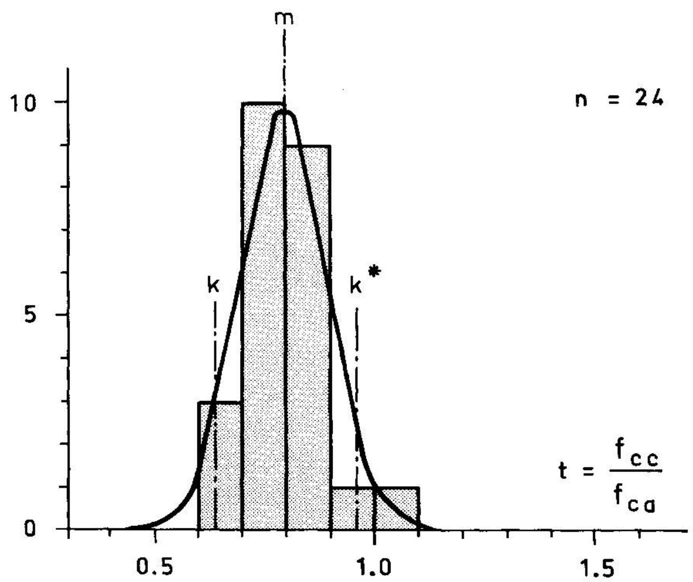


Fig.1 By Ingvarsson [1] and [2] observed ratio $t = f_{cc}/f_{ca}$ between strength in the finished structure (f_{cc}) and the strength of corresponding standard cube specimens (f_{ca}). n = number of observations. m = 0.80 (mean value). s = 0.10 (standard deviation). k = m - 1.65 s. k* = m + 1.65 s.

Except the compressive strength variation due to mixing etc., the actual ultimate compressive strength f_{cu} depends on a lot of site conditions, such as more or less skilful workmanship, compaction and curing as well as climatic conditions etc. These factors can be expressed by the ratio $t = f_{cc}/f_{ca}$ as stated above, which makes a statistical approach possible, based on the Angered Bridge investigation presented above. Assuming that the mean value for t being equal to $m(t) = 0.80$ and that the corresponding standard deviation being equal to $s(t) = 0.10$, which amounts to 12.5 % of the mean value, has a more general validity, makes a statistical approach to calculate the ultimate compressive strength f_{cu} in a finished concrete structure possible. Such an approach results in that the ultimate compressive strength $f_{cu} = 0.74 \cdot f_{ca} \cdot t$ in finished concrete structures can be calculated and expressed by the mean value $m(f_{cu}) = 27.8$ N/mm^2 and the corresponding standard deviation $s(f_{cu}) = 4.8$ N/mm^2 as far as Swedish Grade K 40 concrete is concerned. These parameters are shown in Fig.2 by the corresponding normal probability density function, together with the same function for the strength f_{ca} of the corresponding standard cube specimens ($m = 47$ N/mm^2, $s = 5.5$ N/mm^2).

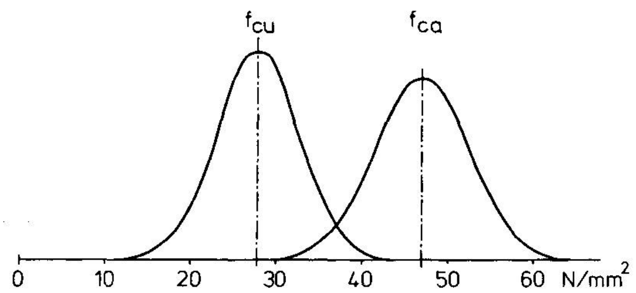


Fig.2 Compressive strength f_{cu} in a finished concrete structure of Swedish Grade K 40 concrete compared with the strength f_{ca} of the corresponding standard cube specimens.

3. STRUCTURAL SAFETY

In order to study the structural safety, the actual compressive strength f_{cd} used in design must be compared with the ultimate compressive strength f_{cu}. For Swedish Grade K 40 concrete, $f_{cd} = 19/\gamma$ N/mm^2, according to the new Swedish Concrete Code (BBK 79), where γ is a coefficient varying between 1.0 and 1.2 depending on the actual "safety class". This value of f_{cd} corresponds to the load factor equal to 1.0 for permanent loads and 1.3 for live loads. The actual structural safety can be expressed by the ratio S* defined as $S^* = f_{cu}/f_{cd}$. On basis of f_{cu} amounting to 27.8 N/mm^2 on an average, with a standard deviation of 4.8 N/mm^2, the structural safety corresponding to $m(S^*) = 1.46\gamma$ and $s(S^*) = 0.25\gamma$ can be observed to be valid for Swedish concrete structures, for which Grade K 40 concrete is specified. The normal probability density function for the structural safety S* when assuming $\gamma = 1.1$ is shown in Fig.3, from which it can be concluded that the probability for failure ($f_{cd} \geqslant f_{cu}$) is about 0.015.

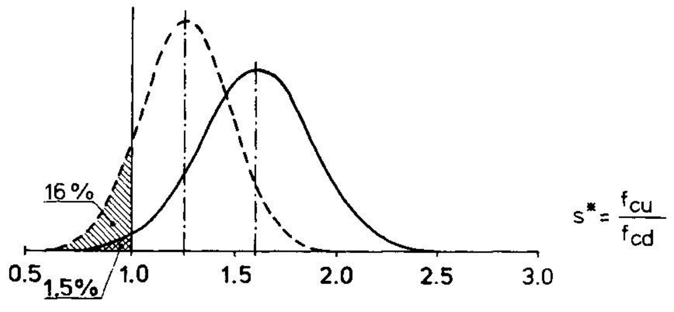


Fig.3 Structural safety $S^* = f_{cu}/f_{cd}$ when assuming $\gamma = 1.1$. The dashed curve shows the effect of delivering Grade K 30 concrete instead of specified Grade K 40 concrete.

4. CONCLUDING REMARKS

Regarding the risk for gross errors delivery of wrong grade of concrete seems predominant. If, for example, Grade K 30 concrete is delivered instead of Grade K 40 concrete, the ultimate compressive strength is reduced to 21.9 N/mm^2 instead of 27.8 N/mm^2 on an average. Thus the mean structural safety is reduced to 1.15γ from 1.46γ, which moves the probability density function to the left in Fig.3, so the probability for failure ($f_{cd} \geqslant f_{cu}$) is increased to about 0.16 from 0.015. In order to avoid such gross errors it seems adequate to take out and test standard cube specimens. However, these are not adequate for checking the strength of the finished structure as this depends on a lot more factors such as compaction, curing and climatic conditions. Therefore, it must moreover be recommended to carry out tests of the concrete strength in the finished structure, even though standard cube specimens are taken out and tested. For this purpose Bellander[6] has proposed acceptance criteria for concrete strength in finished structures, which have been adopted in the new Swedish Concrete Code (BBK 79).

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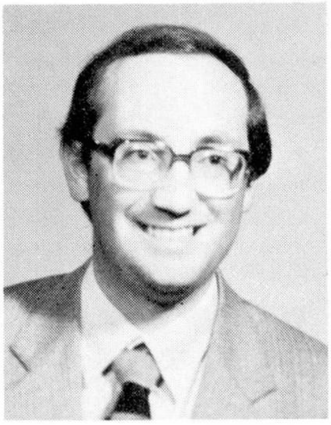
Quality Assurance of Construction Processes

Assurance de la qualité dans le processus de construction

Qualitätssicherung von Bauprozessen

Čeněk JARSKÝ
Dr. Eng.
Res. and Dev. Est. of struct. Eng. Trust
Praha, Czechoslovakia



Čeněk Jarský, born 1953, got his MSc degree in Civil Engineering and the PhD degree in Technology of Structures at Czech Technical University of Prague. For five years he worked in building process modeling. Now he is responsible for research in reduction of energy consumption and costs in construction processes.

SUMMARY
The necessity of evaluating the quality in the course of the construction process itself, not only according to the resulting product, is discussed. Quality parameters of the course of the construction process are stated and a proposed mathematical model of different construction processes, which enables finding the optimal means of production for the process is shortly described. The influence of failures of machines on the quality parameters of the process is verified by help of the model on earthmoving works at the Gabčíkovo waterwork on the river Danube.

RESUME
Il est nécessaire de juger la qualité au cours du processus de construction, et non seulement son produit final. Les paramètres de qualité du processus sont décidés et le modèle mathématique des différents processus de construction est décrit brièvement. Ce modèle applique la simulation stochastique et permet de trouver les meilleurs moyens de production. L'influence des pannes de machines sur les paramètres de qualité du processus est contrôlée à l'aide du modèle de chargement et transport de matériaux pierreux dans l'ouvrage hydraulique Gabčíkovo sur la Danube.

ZUSAMMENFASSUNG
Die Notwendigkeit, die Qualität des Bauprozesses nicht nur nach seinem endgültigen Produkt, sondern auch nach seinem Verlauf zu beurteilen, wird diskutiert. Weiter werden die qualitativen Parameter des Bauprozesses bestimmt und kurz das auf der stochastischen Simulation basierende mathematische Modell von verschiedenen Bauprozessen beschrieben. Dieses Modell ermöglicht die optimalen Erzeugungsmittel für den Bauprozess zu finden. Mit Hilfe des mathematischen Modelles wurde der Einfluss der Betriebsstörungen bei Baumaschinen auf die qualitativen Parameter der Erdarbeiten für das Wasserwerk Gabčíkovo an der Donau bewiesen.

1. INTRODUCTION

This article would like to respond especially to the papers /9/ and /1/ written in the Introductory Notes to the workshop. Let us introduce that by the term of a construction process we shall understand a certain type of activity done by a work gang on the building site using certain means of production (e. g. machines, tools etc.) with a certain distribution of labour within the work gang, e. g. earthmoving works, concrete laying works etc.

In /9/ a definition of the quality of a technical facility is given in the relation to its user. The definition of the quality stated in /1/ looks to be more complex as well as more abstract. In accordance to both definitions the quality of a building process is evaluated according to the quality of the resulting product (a building, a construction, a construction unit etc.) as it has been traditional since. One has to realize that a product of a high quality can be produced by a process of a very low quality of its course, that means with a low productivity of labour, with a high consumption of labour and costs and with a low utilization of means of production. On the other hand it is possible to produce a product of a poor quality to its user and to gain relatively good levels of economical indexes (low labour consumption, high utilization of machines, short time of construction etc.) what means a good quality of the course of the process.

In order to assure the quality in all phases of the building process it is necessary to judge its quality not only according to the quality of the resulting product but according to the course of the construction processes, too. Construction processes should therefore have a course of a good economical level with a high productivity of labour and high utilization of means of production and the resulting product should achieve the requested quality demands.

A mathematical model capable of simulation of different construction processes on a computer was created by the author in /5/ for the evaluation of the indicators of the quality of the course of construction processes. The indicators are stated further on. The proposed model enables to synthetize (simulate) and then analyze the actual course of different construction processes (e. g. earthmoving works, concrete laying works, assembly of pannels and others) on building sites inclusive random factors and influences (e. g. traffic conditions, failures of machinery, people factor etc.). Utility of use of the Monte Carlo method /2/ chosen for the modelling has been discuses in the survey /3/. This method enables to valuate the reality on the building site much better than classical deterministic methods of design of the means of production in a construction process or the queuing theory which is sometimes used too, see e. g. /8/.

The main purpose of the proposed model is the optimization of the quality parameters of the course of the construction process based on the choice of the best variant of machinery or work gangs that can be used in the process.

2. QUALITY PARAMETERS OF THE COURSE OF THE PROCESS

The evaluation and the choice of the best variant of the process is carried out according to 10 technological, technical and economical indicators, proposed in the report /4/, that formulate the requirements on the quality of the course of the process. One complex utility function for the evaluation was not used because usually only one parameter is crucial for the contractor in accordance to his resources and possibilities.

The technological parameters are as follows:
- total time of the process,
- output per time unit,

- utilization of machines,
- total labour consumption (machinetime),
- actual labour consumption (machinetime) per measure unit of the product.

The technical parameters are:
- total energy consumption in the process,
- energy consumption per measure unit of the product.

The economical parameters are:
- total costs,
- costs per measure unit of the product,
- productivity of labour.

All quantities that characterize the parameters stated are to be mathematically expressed and calculated in the analysis of the simulated variant of the building process.

3. A FEW FACTS ABOUT THE MODEL OF CONSTRUCTION PROCESSES

3.1 Fundamental assumptions and conditions of calculation

On building sites situations very often occur where one equipment (e. g. a loader) attends an another equipment (e. g. dumptrucks) and creates a so called mass operation process. It is intuitively clear that the design of both equipments has to be in harmony, that overdimensioning and then a small utilization of the serving equipment is connected with high costs and output losses in operation of such a system. Mass operation processes (sometimes named as queuing processes) can be characterized as flowing processes influenced by random interference. Because of this interference, sometimes queues may occur before the channels of service (e. g. loaders), sometimes channels of service may not work, because no units (e. g. dumptrucks) are available. There are more stages (phases) of service in such a process usually, sometimes more parallel channels of service in one phase are used. A circular (closed) system representing earthmoving works with 4 phases of service in line (1st phase - 2 parallel loaders, 2nd phase - road, 3rd phase - 2 parallel places of dumping, 4th phase - road back) is illustrated on fig. 1, an open system is on fig. 2. The stochastic simulation using Monte Carlo method was chosen for the evaluation and judgement of similar systems as it was stated previously.

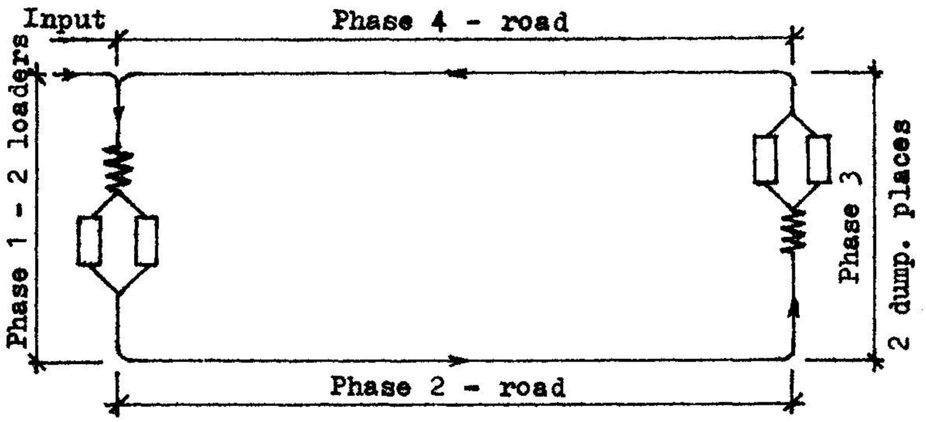


Fig. 1 Example of a closed mass operation system

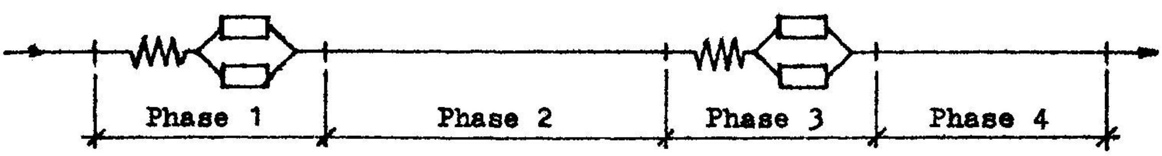


Fig. 2 Example of an open mass operation system

The mathematical model of a building process simulates a circular (fig. 1) or an open (fig. 2) system with which the construction process can be described. Multiple use of the model enables the simulation of more difficult systems, having a combination of a circular and an open system. The main part of the model is the time synthesis and the following analysis of the process. The random quantity is the actual service time in the channel (e. g. filling of a dumptruck by an excavator, time of driving through the road etc.), which is generated by a random number generator in the requested probability distribution.

If the channel of service is being repaired it cannot be used for attending the units, it is therefore blocked, units have to wait or use the other parallel channel if it exists. Repair of the unit does not block any channel of service.

Two sorts of phases of service are considered. The first sort are actual machines (e. g. excavators, loaders, concrete plants etc.) which are capable of serving only 1 unit during a certain time period. The other sort are roads where more units can be in during a certain time period.

The flowchart of the mathematical model was published e. g. in /4/ or /6/.

3.2 Simulation of failures and repairs of the machines

The proposed model simulates random failures of machinery (units and channels of service). The chance of failure or probability of a failure EPS is read by the computer in the data file for every machine (e. g. 0.01). In the failure control section of the program a random number XI with the rectangular distribution in the (0; 1) interval is generated. If the condition (1)

$$EPS \geq XI \tag{1}$$

is fulfilled a failure of machinery occurs and the time of repair is then generated, using the exponential probability distribution. The average time of repair is gained from the data file. The machine is blocked for use during the time of its repair. For units, the time of repair TRU(h, i, j) is added to the time arrival of the unit i into the phase j in the h-th round TINP(h, i, j) and the unit is marked that it was being repaired. In case of the channel of service repairs, the time of repair TR is added to the value TOUT1(j, k) which means the time when the channel k in the phase j will be free and prepared to attend the next unit. By this addition the channel is blocked for the time TR as well.

4. VERIFICATION OF THE INFLUENCE OF FAILURES OF THE MACHINES ON THE QUALITY PARAMETERS OF THE CONSTRUCTION PROCESS

The model was recently used for the optimization of loading and trasport of gravel for the embankments of the waterwork Gabčíkovo on the river Danube. The scheme of this process responds to fig. 1 with the exception of the 3rd phase where no queue was created. There were 3 different resources of gravel on site and 17 places of consumption - 17 sections of the embankments of the lenght 1 km each. Many different variants of the process were simulated on the computer using different sorts and numbers of machines. The optimum according to the costs and fuel consumption was to use the UNC-200 loaders and Tatra T 148 S1 dumptrucks of Czechoslovak production in certain numbers for different sections, quoted in table 1. In this table the basic characteristics (costs and fuel consumption per measure unit - m^3 of gravel) of the process are compared in case of the process with random failures of machinery and in case of the trouble-free course of the process. The chance of failure for the loaders was 0.01, for dumptrucks 0.02. The average quantities were calculated according to the ammount of gravel to be transported

Section km	Machinery used	Trouble-free course of the process		Course with failures of machines	
	number of loaders / number of trucks	costs Kčs/m^3	fuel consumption l/m^3	costs Kčs/m^3	fuel consumption l/m^3
1	1 / 10	3.46	0.80	10.44	1.72
4	1 / 6	2.28	0.45	2.26	0.44
6	1 / 8	2.95	0.64	3.82	0.64
7	2 / 8	2.25	0.39	2.91	0.41
9	2 / 16	3.17	0.69	5.54	0.86
11	2 / 30	4.15	1.00	6.72	1.52
12	2 / 42	5.33	1.35	8.54	1.98
15	2 / 28	3.80	0.90	4.95	1.04
17	2 / 14	2.61	0.53	6.09	0.49
Average		3.40	0.77	5.64	1.00
Increase %				65.88	29.87

Table 1 Characteristics of the process

from the resources to the sections of the waterwork.

It is to be seen that the influence of failures of the machines on the quality parameters of the process is surprisingly high, the costs being increased for 66 % and the energy consumption for 30 %. It is to be considered from that fact that it is worth to have at least 1 dumptruck on the site more which can be used in case of failure of a machine. Thus a trouble-free course of the process can be ensured with a minimum increase of cost and fuel consumption. Other examples were published in /6/ and /7/.

5. CONCLUSIONS

Mathematical stochastic models have gained more and more significance in the construction process research recently. From the results which have been obtained so far by use of the proposed model is to be seen that this model is suitable for simulation of many types of construction processes. The results gained by the model approaches the reality of the process more than if they were calculated by using the traditional deterministic way or the queuing theory. It is useful for calculating of quality parameters of different variants of the process for gaining the optimum. Those parameters should be judged extra of the quality parameters of the resulting product in order to assure the quality of all phases of the building process, the phase of production of the structure inclusive. The model is capable to research the influence of different factors on the quality indicators of the course of the process (e. g. failures of the machinery, number of means of production etc.).

Further research in this field will be directed to obtaining more reliable statistical data for the input for the model (chance of failure of machines, time monitoring of the behaviour of similar systems etc.) and the model itself is planned to be improved by capability to simulate construction processes which consist of more than one circular system with certain points of contact among them.

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Quality Assurance during the Construction Process

Assurance de qualité pendant la réalisation d'une construction

Qualitätssicherung während des Bauprozesses

Dieter JUNGWIRTH
Dr.-Ing.
Dyckerhoff & Widmann
Munich, Fed. Rep. of Germany

Dieter Jungwirth, born 1937, got his civil engineering diploma in 1960 from the Technical University of Munich as well as his Doctors degree in 1969. Since 1969 he is with the well known Contractor Dyckerhoff & Widmann AG, from 1981 on as a director. He was involved in the construction of many important structures and is active member of many national and international Commitees.

Gerd THIELEN
Dr.-Ing.
Dyckerhoff & Widmann
Munich, Fed. Rep. of Germany

Gerd Thielen, born 1942, got his civil engineering diploma in 1969 from the Technical University of Munich as well as his Doctors degree in 1975. He was NATO-Post-Doctorial Fellow at the University of California, Berkeley, Design engineer with the Contractor Dyckerhoff & Widmann and for three years Technical Director of CEB in Paris. Since 1982 he is involved with research and development at Dyckerhoff & Widmann again.

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.

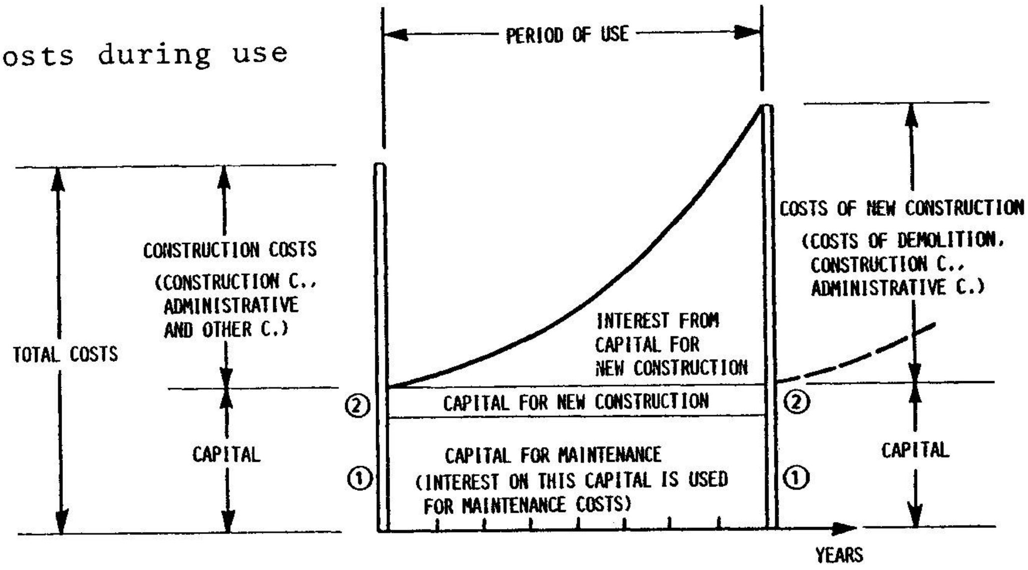
First some thoughts will be given to the cost-benefit situation at the construction market.

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

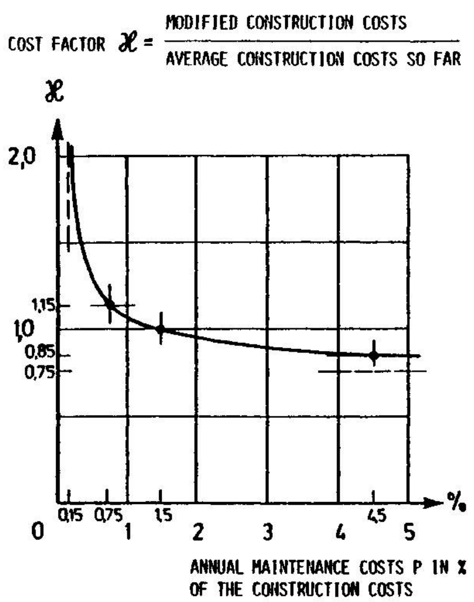


Fig.3:
Minimum of Total Costs

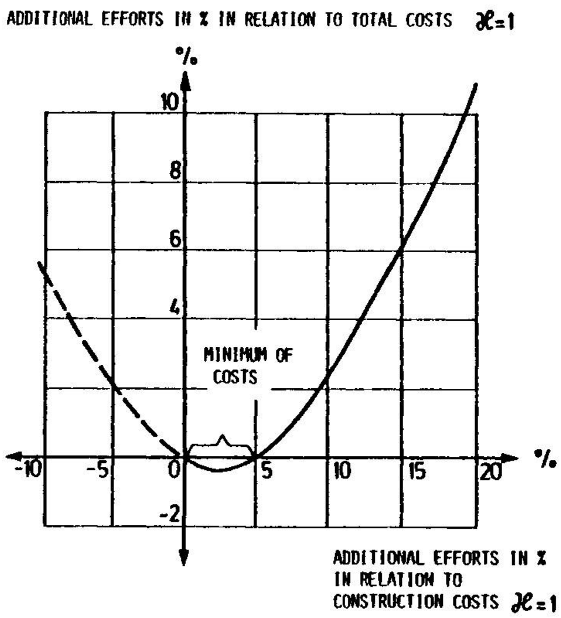


Fig. 3 summarizes these relations by showing how negative and positive increments in construction costs effect the total costs and how this relation allows to derive a minimum of total costs.

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 o291oo (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 ●

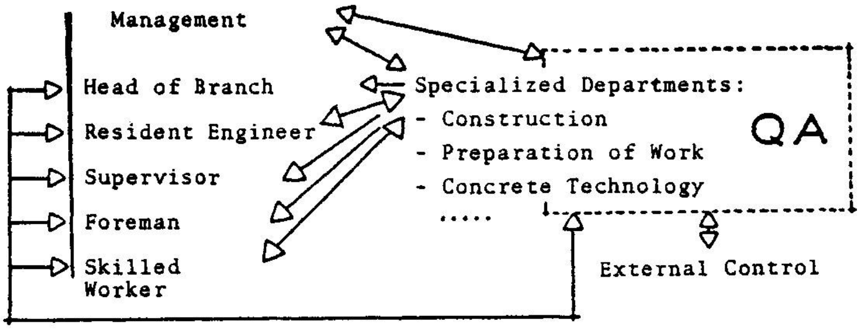
○ Reduced requirements against ◐

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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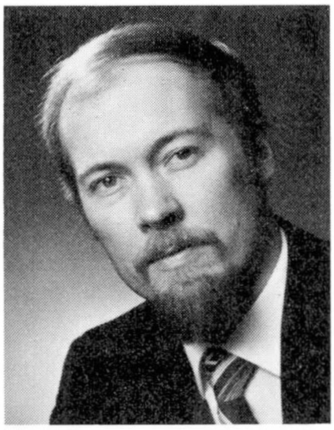
Software Quality Assurance

Assurance de qualité du logiciel

Qualitätssicherung in der Entwicklung von Software

Manfred KERSKEN
Electrical Engineer
Gesellschaft für Reaktorsicherheit
Garching, Fed. Rep. of Germany



Manfred Kersken, born 1944, got his Dipl. Ing. in Electrical Engineering from the Technical University of Berlin. He worked for the Lehrstuhl für Reaktordynamik und Reaktorsicherheit of the Technical University, München, afterwards he joined GRS, Garching. He is involved in the analysis and qualification of computer systems in safety related areas such as nuclear power plants and railway transportation systems.

SUMMARY
A short survey is given on the methods applied to avoid errors as far as possible during the construction of software. Likewise the fundamental analytical possibilities to remove remaining errors in programs are outlined.

RESUME
L'article présente les méthodes utilisées pour la prévention de fautes lors du développement du logiciel et sur les possibilités analytiques d'élimination de fautes restantes.

ZUSAMMENFASSUNG
Ein kurzer Überblick wird gegeben über Methoden, die verwendet werden, um Fehler während der Erstellung von Software weitgehend zu vermeiden sowie über die grundsätzlichen analytischen Möglichkeiten, um verbleibende Programmfehler zu entfernen.

1. NECESSITIY FOR QA IN SOFTWARE

The facts

- While the costs for hardware are decreasing, the costs for software are steadily increasing (Fig. 2).
- Up to 50 percent of the costs for software in its life cycle (Fig. 1) originate from verification and validation (V&V).
- In spite of V&V, a lot of errors which are implemented in all phases of software development, remain in the programs which are delivered to the customer.
- Specified properties of software, like reliability, effectiveness, maintainability, testability, readability, are insufficiently fulfilled.

The remedies

- Structuring the process of software development to prevent software errors (constructive approach).
- Structuring the process of software V&V to remove software errors (analytic approach) effectively.

2. CONSTRUCTIVE APPROACH

- Top-Down Development: The phases "Requirements", "Design" and "Coding" are developed from general towards specific aspects (Fig. 1), to avoid integration problems when developing a system bottom-up, from the component to system level.
- Levels of Refinement: Top-down development results in hierarchical levels within each of the development phases (Fig. 1). The steps between successive levels of refinement should be small to avoid errors in the transfer of a level to the next lower one. Each level of refinement must describe the whole system and must be fully documented.
- Development Tools: As far as possible computer assistance is involved in the development process. There are existing software systems which enforce a structured development of requirements-, design-, coding- and maintenance phase.
- Choice of Suitable Languages: Dependent on the problem to be solved, a suitable language is chosen, e.g. FORTRAN is good for numeric problems, ALGOL supports a good structure and the readability of programs, ATLAS has powerful features to implement test devices,...
- Restriction of Language Features: Theoretical work has shown that every problem (a computer can solve) can be solved with the three language constructs "Sequence", "Conditional Branch" and "Loop" (Fig. 3). With these constructs well structured programs can be written; however, every language contains additional constructs, some of which may contradict to the envisaged goal. E.g. a jump backward into a loop (see Fig. 3, dotted line) is a construct which is harmful for readability, reliability.

3. ANALYTICAL APPROACH

- Verification & Validation (V&V): The development of software is accompanied by V&V activities (Fig. 1). Verification is the process of demonstrating that all properties of a level of refinement have been translated in a correct manner to the next level of refinement. Validation comprises several levels of refinement, e.g. the coded software (a program written in a programming language) is compared against its specified requirements; it is shown whether the code fulfills the requirements or not.

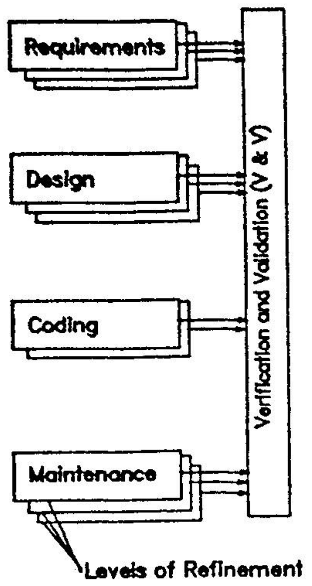


Fig. 1: Software Life Cycle

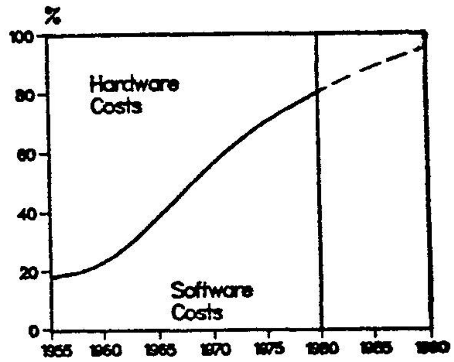


Fig. 2: Costs for Computer Systems

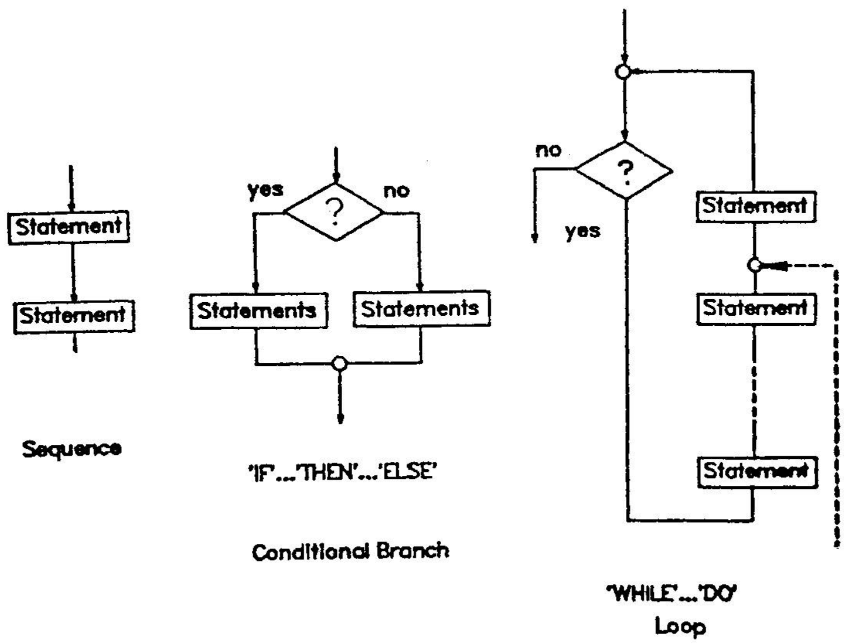


Fig. 3: Language Constructs

- Methods of V&V: These are static and dynamic analysis, testing, symbolic evaluation and proof of correctness.
- Proof of Correctness: Proving mathematical theorems about a program given its intended behaviour in the form of a set of assertions. These proofs are very difficult to realize, up to now no program of practical size could be proven with this method.
- Symbolic Execution: The program is executed as a sequence of symbolic formulas (with symbolic input data instead of numeric values). In the course of this method a set of symbolic expressions is produced, the solving of which may be very difficult - in a variety of situations even impossible.
- Program Analysis: The structure of a program is worked out, i.e. the control flow (all possible successions of statements which depend on jumps and branches) and the data flow within the program. With this knowledge the mappings of input data to output data by means of the program are demonstrated. All properties of the program are representable by these mappings.
- Testing: The program is executed with a predefined set of input data and it is observed whether the appropriate set of output data is produced. Difficulties arise in the determination of this set of output data; often it is determined from the requirements or by simulation. Testing is mostly preceded by program analysis to embed program structure in the tests.
- Verification Tools: As in development there exists a variety of software systems which are helpful in structuring the V&V procedure.
- Software Reliability Models: There are a variety of models which make the attempt to describe the activities of programming and removing of errors in a mathematical way and to give estimations on several figures of merit like "number of remaining errors after test" or "mean time to next error after test". As the above mentioned activities are very complex, the models can only be rather inaccurate as well as the resulting figures of merit.

4. CONCLUSIONS

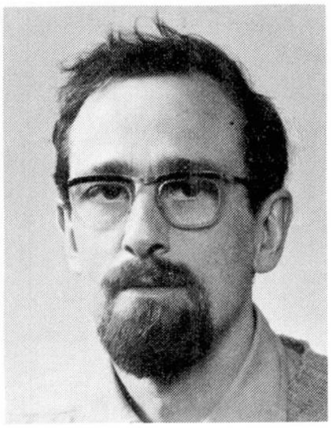
The proof that a piece of software is free of errors cannot be given by a single of the constructive and analytic methods. The only way to give a certain amount of confidence into the software is to apply a meaningful combination of methods which are "taylored" to the software to be examined.

Happy Balance in the Search for Quality

Juste milieu dans la poursuite de la qualité

Gleichgewicht im Streben nach Qualität

Franz KNOLL
Dr. sc. techn.
Nicolet, Chartrand, Knoll + Ass.
Montreal, PQ, Canada



Born 1937, in St. Gallen, Switzerland. Civil Engineer Diploma, ETH, Zurich 1960. Assistant at Institute for Geodesy and Photogrammetry ETH, Zurich, 1961 - 62. Research on Principles of Structural Safety, 1963 - 65. Doctorate 1966, ETH, Zurich. Design Engineer with M. Walt, dipl. ing., Zurich, 1966 - 67. Engineer and Partner with Nicolet & Associates, Montreal, since 1967.

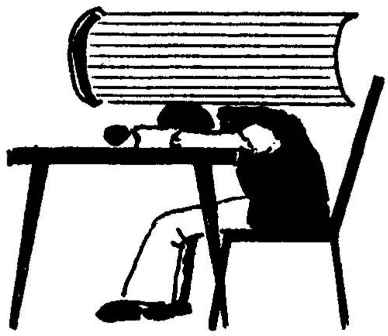
SUMMARY
The importance of a clarification of terms, and of an appropriate application of quality assurance measures is emphasized. A direction is suggested for research to take, comparable to methods used in medical science.

RESUME
L'article souligne l'importance d'une clarification de la terminologie dans la planification de la qualité et la nécessité d'appliquer les mesures de contrôle en fonction des cas particuliers. Une direction est suggérée pour la recherche, comparable aux méthodes employées en médecine.

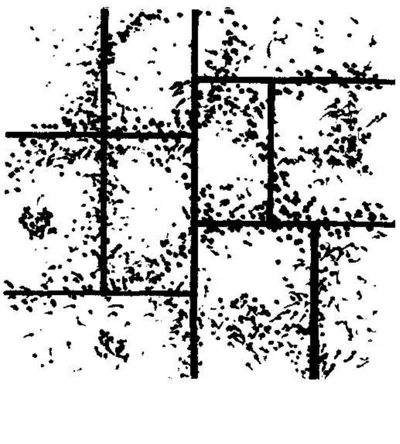
ZUSAMMENFASSUNG
Der Aufsatz erklärt, wie wichtig es ist, eine klare Terminologie für die Qualitätssicherung zu finden. Von ebenso grosser Wichtigkeit ist eine angemessene Anwendung der Qualitätssicherungsmethoden. Für die Forschung wird eine Methodik vorgeschlagen, die sich mit derjenigen der medizinischen Wissenschaft vergleichen lässt.

Much effort has been spent on clarifying the logical structure of the quality problem, using various methods. The common result of this has been that ways were found to formalize, in terms of a classification of ingredients, in the sense of a checklist, or in formalized logic. It would appear then that research is ready to commence on the basic structure of the quality problem as we all perceive it, more or less clearly, in order to come up with commonly accepted models and a rudimentary vocabulary on the subject which would then be used by everybody.

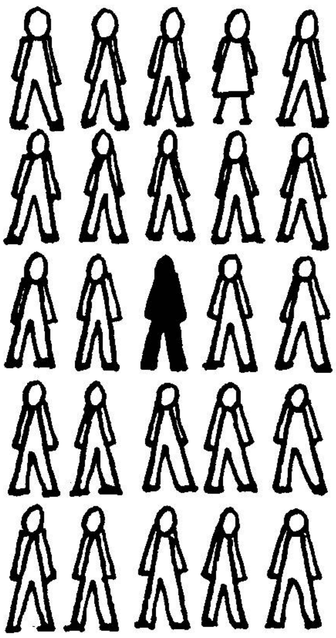
The quality problem of structures has received the highest degree of attention in the context of nuclear power plants because, and perhaps rightly so, the public is extremely apprehensive about the consequences of failures of any kind. In this context therefore, in every country producing such products, a special effort has spearheaded quality assurance programmes usually ending up in a great deal of regulations and procedures, sometimes to the degree of becoming counterproductive. My pet example for this is the drawing that I have seen going out of the design office, bearing 35 signatures of people somehow involved with the process of making, issuing and checking this drawing. I know - my own signature was one of them - that the thought must have taken root in the minds of these people because it did in mine, that nothing could go wrong after so many had apparently checked it. Something did go wrong just de same: there was so much reinforcing steel shown on the drawing that it was impossible to place it all, and somebody on the site had to make the decision by himself to do something else.



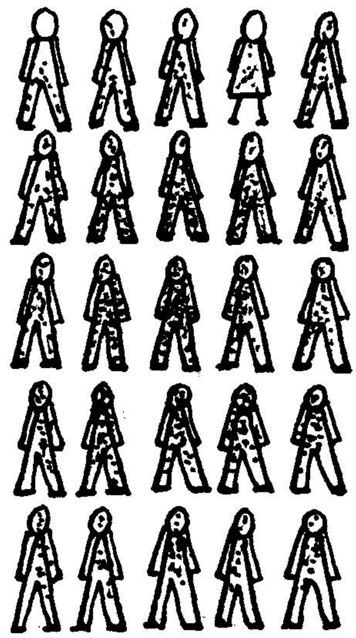
I also remember the rulebook about the quality assurance, it was a weighty document the production of which had cost a fortune, but which was not really read by the people doing the work, as procedures demanded were so cumbersome that they would have obstructed production. Shortcuts are of course the answer in any such case, which largely invalidate all the good effort which went into the quality assurance. As usual, the extreme is not the right place to look for the optimum, and those who burden themselves with too much weighty luggage of regulations and procedures may never reach their destination. The same line of thought has recently been brought up in the context of Codes and Standards which have become a nearly infinite jungle of prescriptions. I am sitting in two Code Committees and I have yet to see us make a Code shorther rather than longer everytime we touch it. I am also working as a practising engineer and I know what happens next: People are becoming confused and tend to ignore the Code, substituting it with their judgement or traditional "knowledge".



For the practising engineer who wants to stay in business, quality assurance is and has always been, a task to be performed on the basis of common sense, and within the limited resources of time, mind, energy and money he was able to put into it. The concepts we are discussing here such as hazard scenarios, weak points, checking, control etc. are all more or less consciously known and used in the everyday building process, and we have heard many suggestions that this is being done to a satisfactory or even surprizingly high degree of success. The difficulties start of course where we are trying to clearly define these concepts which are flexible and fuzzy by their nature, and to cast them into a system of sharply defined rules and methods. In order to demonstrate methods and relationships, we are invariably using the most simplified and trivial cases which makes it appear as though the methods were perfectly adequate to reflect all of reality. Living in that reality, I cannot escape the suspicion that we are in fact simplifying so much that a great deal of the essence is getting lost in the process.



One instance where this occurs is the typical model we are used to consider in our discussions where one single error or circumstance can be made responsible for the quality problem. In reality, this case is quite rare and our liking for the simple model clearly dates back to the days when we thought that to find the guilty man and to punish him, would solve the problem. Real circumstances are usually quite involved and I have often felt that every participant carries a piece of responsability when something goes wrong. After all, he could have recognized the fault and induced correction, had he only paid enough attention. Where is the error then ? The North American practice of sueing everybody for damages before even trying to determine who is at fault, presumably recognizes this basic uncertainty.



If it is true that reality is more complex than can be reflected by the models and formalized quality assurance procedures we have been able to produce so far, the conclusion appears to be quite clear: Known models and methods may have a great educational value but they cannot yet serve as exclusive replacements for the traditional commonsense approach. Portions only, or particular aspects of the reality of the building process and quality considerations can be rationalized presently and formal methods instituted to cover them. The overall quality assurance however, cannot yet be left to this approach, as it is necessarily incomplete. Especially when looking at gross errors and their characteristics, one is baffled by the great diversity of coordinates they can assume within the building process. Given the fact that the products of construction industry are essentially one of a kind, as opposed to the typically serial manufacturing processes of other industries, it appears quite futile to install detailed procedures for quality assurance with a "one size to fit all" idea in mind. Perhaps the best answer is presently to use formalized quality assurance methods with prudence and to set them up with as little detail and as much flexibility as possible. As always, true optimization results with the middle-of-the-road being recognized as best solution.

We must keep in mind that to replace thinking man with any sort of mechanism, however reliable and sophisticated it may be, will inevitably produce results in kind, i.e. predictable properties and quality - but for the gross errors which by their nature, are quite unpredictable. Mechanical or electronic devices, preplanned and regulated procedures, and even man himself when he operates within a rigidly preset functional frame, is much too inflexible to effectively deal with gross errors.

If used by themselves, without involvement of motivated and informed people, formalized methods will tend to spend much effort on trivial or unnecessary matters while missing the gross error, just because it happens not to fit any of the categories listed in the programme.

Similar thoughts apply to the use and state of the (partial) models available today for the analysis of quality. All are representing certain aspects of the building process, or of error history, like when one looks at a complex geometric body from different angles. Until the time, when a complete model becomes available if ever, integrating all aspects and correlations if ever, present day models can only be used in conjunction with informal experience and commonsense..

The analysis of data such as failure accounts may eventually have to proceed much along the extremely empirical methods commonly used for instance in medical science. In that field, complex scenarios including many ingredients which are not well known at all, are related to therapeutical measures which have been studied with heavy emphasis on the phenomenological aspects, because truly causal links are difficult to establish.

It was suggested earlier that the building process is quite comparable to a living organism, the final detailed analysis of which will forever escape us. This does not mean that we cannot find means even now to correct its ills and help it along, much like the doctor is doing when he persuades me to take these pink tablets so that my body will somehow receive the message that it should stop the particular ailment it bothered me with. It will, as we all know, in due course find another way to malfunction, sometimes quite related to the pink tablets which suggests that we might be well advised to use some caution when introducing miracle medication to the construction process, for example in the form of formalized control procedures which if overdone, may kill creative work.

Risk Assessment with Statistical Data

Estimation de risques au moyen de données statistiques

Risikoabschätzung mittels statistischer Daten

Gert KÖNIG
Prof. Dr.-Ing.
Technische Hochschule
Darmstadt, Fed. Rep. of Germany

Gert König (1934), professor of civil engineering at the Technische Hochschule Darmstadt, got his doctorate in 1966. Since 1971 he is a consultant in civil engineering and in 1972 he received the degree of a checking engineer.
Prof. König is mainly involved in design, checking of design, code development and safety analysis.

Bernd WITTKE
Dipl.-Ing.
König und Heunisch
Frankfurt a.M., FRG

Bernd Wittke, born 1950, received his civil engineering degree from the Technische Hochschule Darmstadt in 1976.
For five years he was involved in the construction of big bridges in a german contractor's planning department. He is now on the staff of Prof. König's engineering bureau in Frankfurt/Main.

SUMMARY
This report deals with recent results of a risk analysis in the field of civil engineering, with special consideration of bridges. In addition to a weak point analysis, some statements are made about the risk from damages of large prestressed concrete bridges in two federal states of the Federal Republic of Germany.

RESUME
Ce rapport traite de résultats récents d'une analyse de risque dans le domaine des constructions civiles à l'exemple des constructions des ponts. A partir d'une analyse des points faibles, il est possible de prédire le risque dû à des dommages causés aux grands ponts en béton précontraint, de deux provinces de la Rép. féd. d'Allemagne.

ZUSAMMENFASSUNG
Dieser Bericht befasst sich mit neueren Ergebnissen einer vom Bundesminister für Forschung und Technologie geförderten Risikostudie für das Bauwesen am Beispiel von Brückenbauten. Neben einer Schwachstellenanalyse gelingt eine Aussage über das Risiko aus Beschädigung von grossen Spannbetonbrücken in zwei Bundesländern der Bundesrepublik Deutschland.

1. INTRODUCTION

The analysis of structural damages or accidents which has been made by various authors [1] [2] [3] in the past, will also been carried out in a study of my office which deals with the condition and the corresponding damages of structures. The analysis is supported by the minister for r.a.t.. In contrast to the authors mentioned above the statistical empirical research is restricted to bridges which can approximately be combined to a parent population and for which data is available.

An arbitrary selection of great valley bridges in two German federal states has been taken as a sample for the analysis. In the first country prestressed concrete bridges with a total length greater than 200 m and in the second country bridges of a single highway-line were selected.

As a result from the global registration of damages, it will be attempted to find a relation to the parent population, to make assessments of the risk of defects in the period of use, and to give advice for risk reduction.

2. STRUCTURE AND COLLECTING OF DATA

The investigation is based on files of construction time, on correspondence, drawings, static calculations, expertises and the report of the periodic bridge examinations of the responsible departments.

A method which is based on a fixed definition of terms and which must simultaneously show high flexibility, is necessary because of the heterogenous structure and the great number of data. Starting from a terminological chain with the causality:

fault - shortcoming - defect - damage - consequential damage

the terms, based on [1] and [2], are defined as follows:

fault	Deviation between the results of human actions and the issue of the action
shortcoming	Negative deviation between an aimed condition and the obtained condition, if the deviation exceeds certain tolerable values
defect	Alteration of an object or human being in the aimed or natural turn of occurence in regard of form, structure or function
damage	Enchroachment on protected interests as a consequence of a defect

If one now wants to register the condition of structures which are seemingly without any damage, i.e. structures which did not cause any cost for reparation, one has to concentrate the collection of data on the defects which can also be understood as damage-indicators [4].

By means of several terms, subjective as well as objective ones, it is possible to register very different kinds of defects numerically, so that they can be compared with each other. To describe a case sufficiently, one has to give information about the following parameters:

- quantity
- state
- effect
- type of beginning
- type of defect
- place
- material
- extent

Fixed subterms can be provided for each term of the linguistic system "defect". By means of the subterms, the most different cases are defined as combinations of those terms. This method of splitting complex facts in previously defined subtermgroups is very well suited for data storage by electronic data processing. The necessary catalogues of the defined subterms are used for each case of defect, to steadily fill in the questionaire which has been developed for this reason. Apart from the specific data of defects, the basic data of the structural system, i.e. for example the cross-section of the superstructure, clear spans etc., are registered according the same scheme. In that case, the questionaire as well as the corresponding computer programmes only work on the basis of the given numerical codes.

3. EVALUATION

A total of 76 prestressed concrete bridges were examined and about 15.000 defects were registered. As a result, 12.500 different cases at diverse components of the system "bridge" can be separated. A component can be for example a cross-section of the main girder, a bearing or an expansion joint. Evaluating the results, one has to consider that the chosen bridges are built in a period of 20 years (1960 - 1980, see figure 1). The mean value of the observed service life is about 10 years, i.e. a total of 713 years of use were examined.

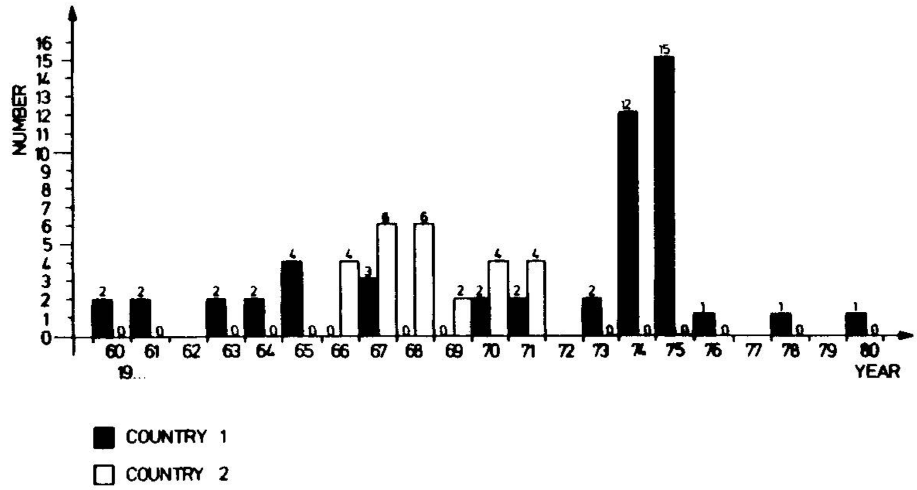
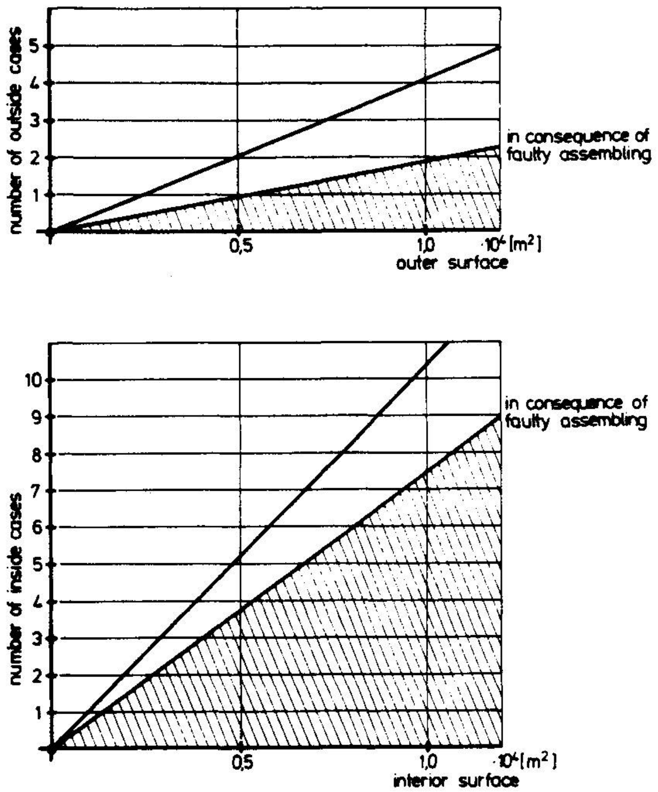


figure 1: Examined bridges - year of end of construction

Looking at the distribution of the effects of the defects in regard to the future condition of a component (figure 2), it appears that in the majority of all cases the durability of the building is endangered. Consequently, considerable costs arise from the maintenance of the bridges. Drawing a conclusion of this state of affairs, two main questions have to be asked:

- How many cases can be prevented directly and how much percent has to be added to the deviations of the resistances?
- How great is the real extent?

To answer the first question, weak-point-analyses are useful which are best carried out by correlations between the defects and the place of defects. As an example, the relationship between uncovered reinforcement and the surface of the superstructure will be presented. The analysis shows that the appearance of such a defect is no longer dependent on the type of the cross-section. Thus, the relation outlined in figure 3 can be deduced.



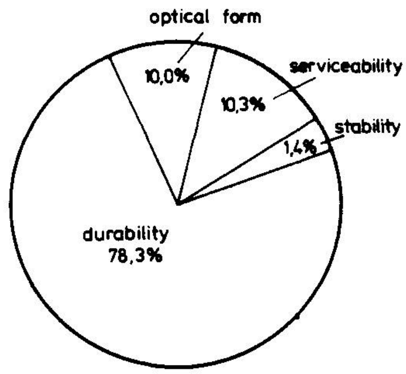


figure 2: Effect of the defects

figure 3: Uncovered reinforcement per surface (outside, inside respect.)

Corrosions of reinforcement were specially marked during the collecting of data, if the cause of damage could clearly be recognized, i.e. the shortcoming 'too low cover' in consequence of faulty assembling. Thus it is now possible to evaluate the influences separately. Figure 3 shows first of all, that there are more interior cases than outside ones. This effect is not due to different kinds of examination methods because all bridges have been checked inside as well as outside. As shown in the following, the cause of this is rather a shortcoming depending on the site method. Secondly, the part of those cases is almost constant, whose cause wasn't clearly recognizable, i.e. about $2.5 \cdot 10^{-4}$ cases per m^2-surface, inside as well as outside. This value sould be connected with the dispersion of the resistance. Moreover, one can see that a high percentage, outside $\approx$45%, inside even $\sim$70%, can be prevented by controlling the position of reinforcement. More developed analyses which consider the special place in the cross-section, i.e. deck slab, web, bottom chord, reveal other weak points.

Thus, bridges with bottom chord for example show the following measured values:

- In the webs, the number of interior uncovered reinforcement is more than double the size of outside cases. It seems, that the site method may be a factor because the interior formwork is assembled finally or 'blindly' as one might say.
- In the bottom chord, the number of outside cases is even five times as bis as the number of the interior ones. The cause may be tipping of spacers or simple deformation of the bottom reinforcement by the workers.

In bridges without bottom chord (e.g. T-beams), the high portion (85%) of the uncovered reinforcement in the webs can probably be explained by inexact reinforcement work in the narrow space of the web framework. In most cases the reinforcement is inserted from the top.

4. CLASSIFICATION

The second question about the real extent requires a graduation in accordance with the importance and size of the different cases. According to several publications [5] [6] [7] [8], it is possible to classify the cases into damage classes:

S1 - very small damage (no real financial loss)
S2 - small damage, with effect on serviceability
S3 - small damage, with effect on serviceabilty and durability
S4 - medium-sized damage (can be reconstructed at limited expense)

S5 - big damage (can be reconstructed at big expense)/ endangering of persons
S6 - very big damage (big financial loss)/ personal injury

A, B

A - measures for maintenance necessary in due time
B - counter-measures necessary immediately

A corresponding procedure of classification which rates the different parameters of the defect mentioned above, in accordance with their importance, results in frequencies of the damage classes which are shown in figure 4.

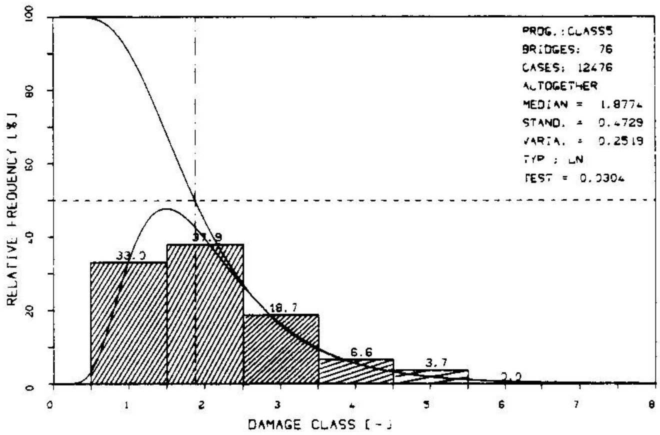


figure 4: Damage classes

On the supposition that the cases of defects are a sufficient random sample of a probabilistic model, one can derive a model of failure for the system "bridge" in form of a distribution of the damage classes. The density function refers to a constant damage rate λ [$1/a\cdot m^2$] which can be obtained satisfactorily by figure 5. This rate depends on different factors, such as type of cross-section, site method, method of bearing etc. By means of the model, the values of class S6, which were not measured in the observed service life, can theoretically be extrapolated to $7 \cdot 10^{-3}$.

To compare the damage classes with each other, a cost model is necessary. Such a model can be outlined on the following conditions:

- an annual rate of costs for maintenance of 2.5% (corresponding to the construction expenses for the superstructure) (see [8])
- an average damage rate λ [$1/a\cdot m^2$]
- an average factor of interest of 5% (German index from 1960 to 1980 [7], uniformly distributed beginning of defects in the time of use)
- frequencies from figure 4

$$C_i = p^{S_i}$$

S_i = damage class
C_i = costs per class [DM]

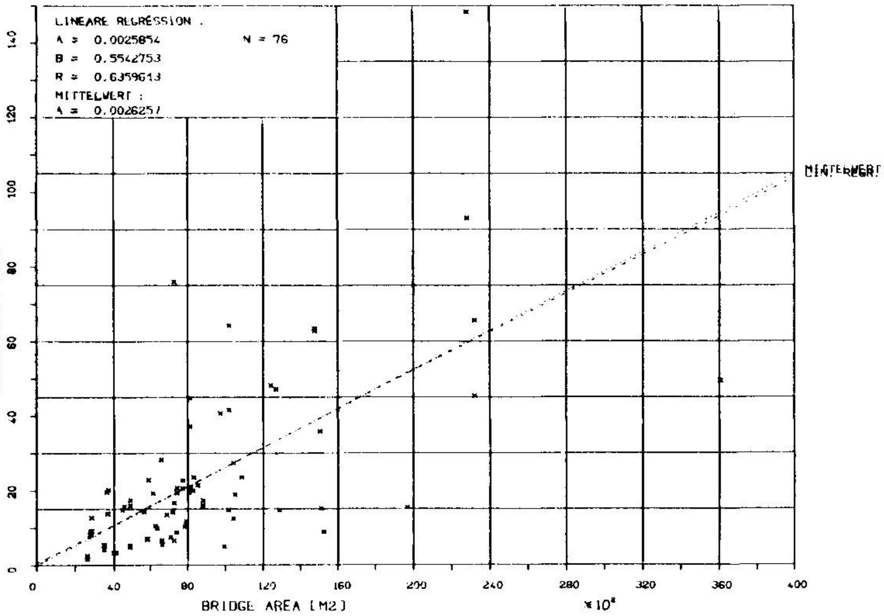


figure 5: Damage rate

Taking the average over all examined bridges, one computes the basis to

$p = 9.8 \approx 10$ (exactly valid for 1980)

$C_i = 10^{S_i}$ [DM]

Assuming this model and comparing group S1 to S4 with S5 + S6, it is obvious that the contribution of the many small damages to the estimation of the critical risk of total failure can be neglected.

5. CONCLUSION

The statistical empirical method which has been introduced makes it possible to give statements about weak points in a structural system and to draw conclusions about the risks of defects. This method is practicable for every other structural system with suitable classification and calibration.

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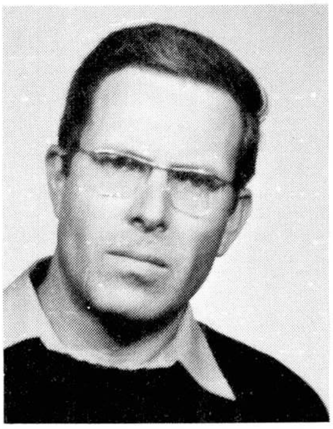
Quality of Buildings — Quality of Engineers

Qualité des constructions — qualité des ingénieurs

Qualität von Bauwerken — Qualität von Ingenieuren

Bèla KOVÀCS
Sen. Lecturer
Technical University
Budapest, Hungary



Bèla Kovàcs, born 1942, graduated from Budapest Technical University 1965. After having a 4 year practice as contractor and designer he is now lecturer at his former university. He deals with problems of dimensioning and checking in complex cases. Dr. techn. degree in 1979.

SUMMARY
Assuming causality to exist between abilities and qualification level of structural engineers and the quality of buildings, some relevant problems of higher education are considered. Education has its responsibility to develop human and professional abilities, and to impart material knowledge directly affecting the quality of engineering work; still conception and methods expect to be improved.

RESUME
En supposant qu'il existe un lien de causalité entre les aptitudes, le niveau de qualification des ingénieurs de structures et la qualité des constructions, quelques problèmes de formation des ingénieurs sont traités. L'éducation des ingénieurs de structures a pour objectif de développer les aptitudes humaines et professionnelles et de donner les éléments de la connaissance qui influencent directement la qualité de l'activité d'ingénieur. Néanmoins la conception et les méthodes doivent être encore perfectionnées.

ZUSAMMENFASSUNG
Davon ausgehend, dass eine Kausalität besteht zwischen dem Qualifikationsniveau des Bauingenieurs und der Qualität der Bauwerke, werden einige relevante Probleme der Ingenieurausbildung geprüft. Die Ausbildung von Bauingenieuren hat die Förderung von humanen und fachlichen Fähigkeiten zum Ziele und bezweckt die Vermittlung von Fachkenntnissen, die die Qualität der Ingenieurarbeit unmittelbar beeinflussen; Konzepte und Methoden müssen jedoch weiterentwickelt werden.

1. INTRODUCTION

Authors of the Introductory Notes are nearly unanimous in enhancing the relation between the human factor and the building quality. Let me quote:

- "due to the ... barely progressing or even decreasing qualification of personnel involved, errors give rise to increasing trouble among builders and clients alike."(p. 1, Mrs Kersken-Bradley)
- "Most failures can be shown to occur because of gross human errors..."(p. 13, Mr Melchers)
- "...a tendency for a diminishing qualification is apparent." (p. 38, Mr Hillemeier)
- "In most cases collapses and other failures of load bearing structures seem to be caused by some kind of gross error." (p. 60, Mr Essunger)([1]).

These statements are duly supported by statistics, and are coincident with observations in Hungary.

Taking as granted that among the mentioned human mistakes those due to engineers prevail, let us have a deeper insight into the relation between errors leading to building deficiencies, and human-professional qualities of structural engineers, in order to find possibilities and responsibilities of higher education in improving the human factor. Our comments -certainly intuitive- rely on over a decade of exprience in lecturing on reinforced concrete structures, and on being well acquainted with views on the side of industry.

Beyond questions of quality assurance in the building industry, professionals are deeply interested internationally in problems of moral appreciation, performance, responsibility and qualification of structural engineers ([2],[3]).

2. HUMAN FACTOR AND HIGHER EDUCATION

As concerns the relation of quality assurance to the human factor, the statement seems to lie at hand that positive properties enabling one to high-niveau, low-error performance are partly inherent moral and mental features, partly professional abilities and knowledge. The former include:

- intelligence,
- responsibility,
- self-control,
- consistency,
- aesthetic exactingness etc.

These characteristics essential both for individual performance (designer) and for teamwork (constructor) may override material knowledge in importance. They have mostly developed before university studies and subsquently cannot be generated but furthered, developed, by methods belonging to the area of general education.

Among professional abilities

- creativity,
- general realistic attitude (sense to mathematics and mechanics)
- visuality,
- organizational sense

may be stressed, the development of which is largely expected from university education. At last, there are material knowledge, rules, experience concerning buiding quality, to be acquired partly as subject matters, but mainly through practice.

In final account, higher education is expected to be a priming for the human factor in building quality. As a matter of fact, fulfilment of this task has to overcome ever more obstacles. Let's consider some of them.

3. PROBLEMS OF FURTHERING ABILITIES

The first obstacle is to select those fit to the structural engineering from among a decreasing number of applicants. Secondary-school curricula do not tend to, teenagers' minds are not grasped by, the science of structural engineering, resulting in a blurred scanty image of the profession before the public. "In general the outlook of engineers has been too narrow" ([2]).

As concerns fundamental mental abilities, working ability and mental fitness of the present age-group are inadequate, a strong drawback in this profession. Though temporarily out of mind, it is rather a commonplace that in any profession, a high standard can only be achieved with endurance and diligence.

Opinions about role and importance of mathematics and structural are fairly divergent. Higher education is often reproached for focusing on analysis rather than to enhance constructivity. From the aspect of quality assurance alone, theoretical knowledge and numerical calculation ability needed for structural analysis are in fact insufficient but indispensable. Danger lies only in the unquestioning faith in numbers; not in mathematics itself but in starting assumptions. Apart from certain inspired architects, a good sense of constructivity develops from experience gathered in course of great many analyses. An engineer inexperienced in computation is unable to quick assessments, in delicate situations this is a hindrance to correct decisions, maybe a source of errors.

The use of a computer requires clear problem setting, survey of the process, safe handling of input and output data. An important percentage of time saving from mechanical computation work is spent on the minutious interpretation of outcomes, including e.g. correct use of sign rules. All these are creative activities, demand efforts, and observations show that students in engineering unwillingly assume them.

Visuality, ability of spatial seeing, precondition of constructivity is unfortunately in shortage among future engineers. This is closely related to deficiencies of imaging and general drawing abilities, which may partly raise coarse design errors, exemplified by concrete cases, and partly, induce general depreciacion of engineering achievements, projected on the final product if not as "gross error" then as "negligence", or simply as lack of good taste.

4. PROBLEMS OF TEACHING QUALITY

How professional knowledge in "quality assurance" can be instructed? Beyond possibilities of developing abilities, and of professional training, higher education has facilities to impart positive knowledge. However, two considerations prevail:

-In this field, empirical knowledge is much more efficient than is encyclopaedical knowledge. Site visits, inspections may be rather impressioning while a dead text of even the most spectacular case study leaves little imprint in students.

-Most essential knowledge matter on quality assurance is at a low level within the curriculum hierarchy. For instance,the almost internationally codified subject matter of reinforced concrete structures relies on the principles of safety to local failure, tradition, and fitness to be imparted. Problems of serviceability are relegated to the background by being unclear and difficult; so are global stability problems and those of interaction with the soil by being too complex. On the other hand, seemingly obvious problems are therefore held to be of secondary importance, e.g. lifting problems in prefabrication. Beyond meeting safety and serviceability requirements, whether a structure is covered or exposed is no criterion though it should be.

5. CONCLUSIONS

Assuming causality to exist between qualification niveau of structural engineers and the quality of buildings, some relevant problems have been considered. In spite of difficulties, partly reducible to causes outside the profession, higher education of structural engineers has its possibilities and responsibility to develop human and professional disposition, and impart material knowledge directly affecting the quality of engineering work, still conception and methods expect to be improved.

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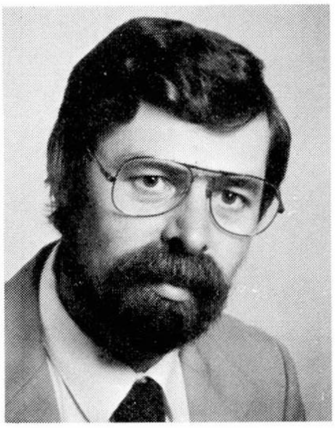
Remarks on the Quality Assurance of Steel for General Structural Purposes

Remarques sur l'assurance de la qualité des aciers de construction

Anmerkungen zur Qualitätssicherung allgemeiner Baustähle

Wolfgang MAIER
Civil Engineer
Technical University Braunschweig
Braunschweig, Fed. Rep. of Germany



Born 1941, in Marienbad, CSSR. Steel Structural Engineer Polytechnikum, Munich 1958 - 1962. Design Engineer with Kustermann Stahlbau, Munich 1962 - 1965. Civil Engineer Diploma TU Munich 1969. Assistant at Institut for Constructions, TU Munich, Research of Structural Safety, 1969 - 1976. Doctorate 1978. Laboratory director, Institut for Steel Constructions, TU Braunschweig, since 1977.

SUMMARY

The quality assurance of structural steel takes place almost exclusively outside the constructional engineering part of the building process. There are some indications that the scope and the nature of present quality assurance measures are not satisfying the requirements of steel structures, especially with regard to the increasing importance of plastic design. A systematic research is necessary.

RESUME

Les examens visant à assurer le niveau de qualité défini pour les aciers de construction ont lieu à peu près exclusivement en dehors du génie civil. Certaines indications montrent que le mode et l'ampleur des contrôles actuels sur la qualité ne satisfont pas aux exigences de la construction métallique, en particulier si l'on considère les calculs à la charge ultime qui prennent de plus en plus d'importance. Il est nécessaire d'effectuer une recherche systématique.

ZUSAMMENFASSUNG

Für die allgemeinen Baustähle findet die Qualitätssicherung fast ausschliesslich ausserhalb des Bauwesens statt. Es gibt Hinweise, dass Art und Umfang der derzeitigen Qualitätssicherung nicht zufriedenstellend für die Erfordernisse des Stahlbaues sind, insbesondere im Hinblick auf die zunehmend bedeutend werdenden Traglastberechnungen. Eine systematische Erforschung ist notwendig.

1. GENERAL REMARKS AND PRESENT STATE

The following remarks are restricted to common steel structures covered by structural standards. Welding problems are not considered.

Certified steel assortments and quality classes are completely listed in the structural steel standards.

The quality control, however, is not regulated in structural standards, but in quality standards - irrespective of the intended application.

Quality standards specify the following properties:
- deoxydation method
- chemical composition
- properties in the tensile test: minimum tensile strength, upper yield strain and strain to failure
- properties in the folding test and notch shock test.

The steel producer is almost free in the choise of number and nature of quality assurance measures. With respect to the material, certificates of material tests issued by the producer are the only measure of quality assurance within the building process. According to the certificate, some or all guaranteed properties listed above are testified.

It may be pointed out that some technological properties can be significantly altered during the construction process (e.g. by heat treatment).

2. EXCHANGED MATERIAL CERTIFICATES BY MISTAKE

There is a danger that material certificates may be exchanged by mistake. This happend, e.g. with the metal sheets ordered for the cable anchoring of a 360 m high guyed mast. In consequence of a damage during erection it was revealed that brittle material had been used because of exchanged material certificates.

3. UPPER LIMIT OF THE YIELD STRESS

Ultimate load analyses using plasticity theories are gaining more and more importance in structural analysis. According to a plastic design, internal forces of one structural member can depend on the yield stress of other members. An example is given in Fig. 2. A plate girder is supported by a central column. According to elastic theory the girder behaves like a continous two-span beam. Once the yield stress of the girder is reached at the support, a plastic hinge develops an the structural system changes to that of two simply supported beams. Therefore the normal force in the column depends on the yield stress of the overlying plate girder. Higher yield stresses give rise to higher column loads. Consequently, actual yield stresses which significantly exceed the guaranteed minimum values may not always lead to a safe overall structure.

Tensile tests in connection with experimental investigations often show yield stresses which are much higher than the guaranteed minimum values.

It may be supposed that - in some cases - steel, originally produced as St 52, which does not comply with all quality standards of that class, is later sold as St 37. The resulting overqualification with respect to the required properties of steel class St 37 is not always specified in the producer's certificate.

Since more quality may be less quality with regard to the overall safety of a structure, upper as well as lower limits should be specified.

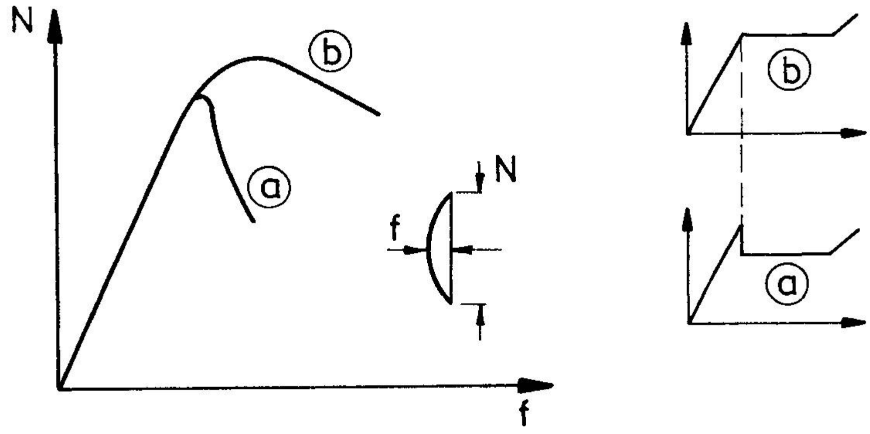


Fig. 1 Load-Deformation-Diagram of an eccentrically loaded column and its correlation with the Stress-Strain-Diagram

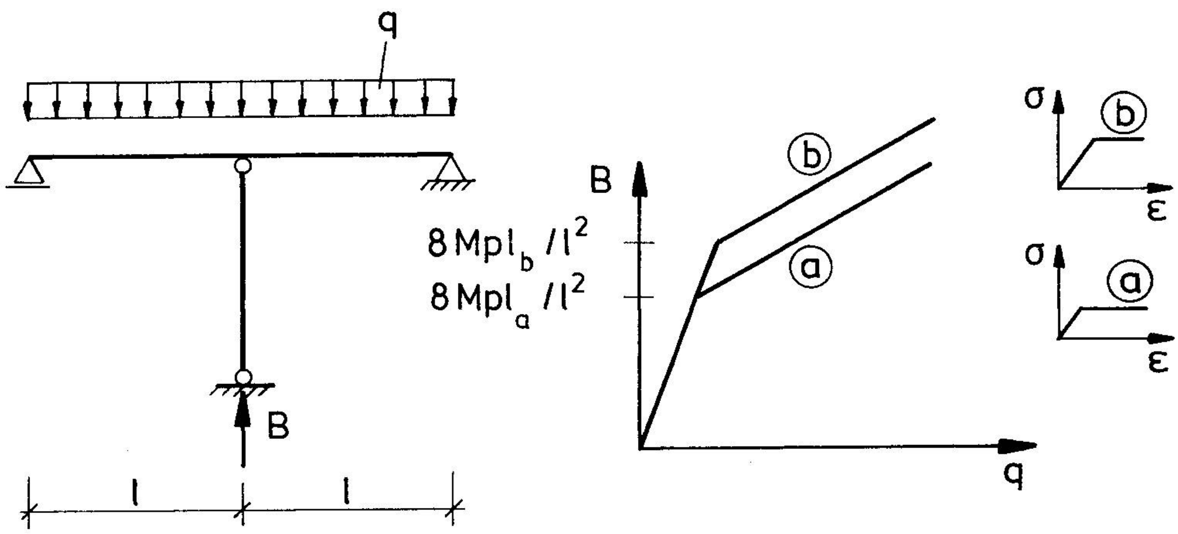


Fig. 2 Column load as a function of the plastic bending moment of the overlying girder

4. STRESS-STRAIN-DIAGRAM

The behaviour of a structure or structural element close to the plastic limit load does not only depend on the yield strength but also on the shape of the stress-strain-diagram.

Structural steel of the same type and quality class may show a more or less distinct upper yield stress level. The lower (static) yield point may deviate up to 40% from the upper yield point, and the strain corresponding to the start of the hardening part of the stress-strain curve shows large scatter. Fig. 1 illustrates that the load capacity of some structures (especially those which are susceptible to stability failure) can be markedly affected by the shape of the stress-strain-diagram.

However, only lower limits of the upper yield stress are specified in the quality standards.

5. CONCLUSION

There are distinct indications that it is possible to modify scope and nature of quality assurance measures in such a way that reliability and economy of steel structures can be improved. The present measures of quality assurance employed by the producers do not satisfy the requirements of steel structures.

Particularly with regard to plastic limit design research should be encouraged in the following fields:

- Which properties of structural steel affect the reliability of steel structures?
- What is the range of scatter of these properties within one type and quality class of steel, and what correlations exist between them?
- What is the present state-of-the-art concerning quality assurance?
- Which modifications of quality assurance measures are possible, and what are the consequences with respect to reliability and economy of steel structures?

Quality of Designs

Qualité des projets

Qualitätseigenschaften von Projekten

Henry MATHIEU
Insp. Gén. des Ponts et Chaussées
S.E.T.R.A.
Bagneux, France

Henri Mathieu, born 1925, got his diploms in Ecole Polytechnique and Ecole Nationale des Ponts et Chaussée in Paris. For 13 years he was chief of central bridge division in France. Besides general inspection tasks for bridge activities, he chairs now several national and international Commissions, most of them devoted to problems associated with structural reliability.

SUMMARY
Desirable qualities of designs are numerous and various; they cannot be measured and they are highly subjective. In spite of these difficulties, a proposal is presented to define synthetically different degrees of quality. How to obtain the required qualities is also discussed in general terms.

RESUME
Les qualités désirables des projets sont nombreuses et variées, non mesurables et largement subjectives. Malgré ces difficultés, une proposition est présentée pour définir de façon synthétique différents degrés de qualité. Comment obtenir ces qualités est discuté en termes généraux.

ZUSAMMENFASSUNG
Die wünschbaren Qualitätseigenschaften von Projekten sind zahlreich und verschieden; sie können nicht gemessen werden und sind zudem stark abhängig von subjektiven Werten. Trotz dieser Schwierigkeiten wird hier ein Vorschlag beschrieben, um auf eine synthetische Weise verschiedene Qualitätsstufen zu definieren. Wie diese Eigenschaften erreicht werden können, wird auf einer allgemeinen Ebene diskutiert.

PRELIMINARY REMARK

This short contribution has been taken out from the draft of a paper under discussion in IABSE Commission I, devoted to the techniques of checking designs. More details will be found in the final document or can, in the between-time, be obtained from the author (in a French version).

1. SCOPE

For many activities (among them the design) the quality cannot be measured, and quality assurance is up to now limited to very general rules. To improve this situation a first step is to define quality and quality degrees (or levels) for these activities.

2. ELEMENTS OF A DESIGN PROCEDURE

2.1 A design is recorded by drawings, written specifications and calculations.

Drawings and specifications are the "final product"; calculations are only auxiliary. However all these elements are important for quality.

2.2 In a design three successive conception stages are commonly distinguished :

- primary conception, which is functional (location, some requirements, constraints, program ...)
- 2nd stage conception, which includes the choice of the structural type and of some basic dimensions; few and simple calculations are usually done at this stage
- 3rd stage conception, which includes final dimensioning and detailing; sufficiently complete and final calculations are then necessary.

3. DESIRABLE QUALITIES OF DESIGNS.

3.1 These qualities depend on the conception stage under consideration (see above).

Desirable qualities are also not the same for the client, for the staff working on site, and for a checker of the design. For people working on site the information to be provided by the design documents depends on their intellectual level and on the possible cooperation with the designer.

3.2 Desirable qualities (aspects of quality) may be related to :

a - the quality of the proposed solution, i.e. :

- functional requirements,
- aesthetics,
- mechanical requirements (ULS, SLS, robustness, durability ...)
- inspection and maintenance,
- cost,
- delays,
- etc ...

b - the quality of the description of this solution,

c - the quality of the justification of this solution (notably calculations).

Mechanical requirements are mainly considered in the 3rd stage conception.

4. QUALITY DEGREES OF DESIGNS

4.1 No common measurement unit can be found for all the aspects of quality. Some aspects cannot be assessed but in a subjective manner (e. g. aesthetics). Even the quality of calculations (editorial aspects excluded) cannot be considered as represented by the numerical precision of the results, because the necessary precision depends considerably on the structure and the structural element under consideration.

4.2 Although the aspects of quality hereover mentioned are almost mutually independant, a tentative synthetic classification of quality degrees, derived from practice, is proposed hereafter for the 3rd stage conception*.

Level Q_o

Calculations are theoretically consistent with existing Codes, but they are very incomplete and cannot be easily read (if even they can be presented); many data and symbols are not defined.

With regard to the drawings :

- they are not systematically in a right scale,
- dimensions etc ... can generally be found in one place,
- they are unclear and cannot be used without interpreting the content; instead of representing details ambiguous foot-notes refer to other more or less analogous details,
- individual dimensions of reinforcing bars are not given,
- any ducts for prestressing are only represented by a line in longitudinal section,
- no or almost no internal checking by an engineer has been done.

Level Q_1

Calculations are really consistent with existing codes.

Calculations and drawings are graphically correct.

Technical choices have been derived from the most common practice; no time has been given to investigate better solutions.

Level Q_2

Calculations are made with due regard to existing Codes, but also to physics, material properties, external and internal equilibria and synthetic view on the details. They are not highly sophisticated.

All important drawings defining reinforcement and prestressing are done before the final calculation which takes them into account. All details are represented at a big scale.

An engineer cares about all important and/or tricky details (beam ends, anchorage areas ...). All aspects which may affect the final structural quality are closely examined. The whole design is supervised by a senior engineer. The designer visits the works on site during the main phases and writes down possible improvements for future studies.

* Such a classification has been proposed by M. TONNELLO in his introductory report to the Journées of March 1983 of the Association Française des Ponts et Charpentes (A.F.P.C).

Level Q_3

Design is done as in Q_2, but it is supplemented by a continuous cooperation of the designer with the execution. Economical as well as technical consequences of the design are considered in order to reconsider and improve it when useful. All possible incidents are submitted to the designer for interpretation.

Design is no more a supply, it has become a part of the fulfilment.

5. HOW TO ACHIEVE THE DESIRED QUALITY OF DESIGNS.

5.1 Because of the numerous aspects of quality and the variety of structures, no more than very general rules can be proposed hereafter.

5.2 The general principles for q. a. are applicable, that is : a logical and relevant organization must be established; it includes controls, but does not consist only of controls.

5.3 This organization is not necessarily completely defined in advance.

Hence it may be judicious that the checker takes some initiative in order to prevent possible defects of the design.

5.4 Many aspects of the quality of designs can be ensured mainly by organizational preventive measures and may be checked very easily before calculations (or most of the calculations) and detailing are done. Checking these aspects as soon as possible is desirable for efficiency and economical reasons.

These are the reasons why the three conception stages defined in 2.2 are usually distinguished and why "preliminary designs" (avant-projets-Vorentwürfe) having predefined contents are commonly required for acceptance.

6. CONCLUSION

Quality of design has many aspects and can be defined only when the objectives in the particular case under consideration have been identified.

Refering to Codes is unsufficient for defining this quality. Quality of design cannot be assured without requirements about intellectual means and methods to be used for the design.

The difficulties which are met for defining this quality can be overcome. For example, since 1975 the French Administration has been specifying, for the design of scaffoldings of bridges, means and methods close to the level Q_2, and since this time practically no collapse of such scaffolding happened (instead of about 2 per year - for 1000 bridges before).

On the other hand, not defining this quality may be harmful. Not having defined it might be one of the reasons why so many damages occur in buildings in France, with obvious consequences on economy and cost of insurances.

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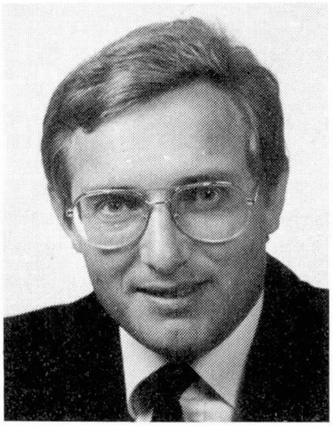
Control Measures and their Application

Description et application de mesures de contrôles

Kontrollmassnahmen und ihre Anwendung

Miroslav MATOUSEK
Dr. sc. techn.
O.Wenaweser +
Dr. R. Wolfensberger AG
Zürich, Switzerland



Miroslav Matousek, born 1945, got his civil engineering degree at the Technical University of Prague. For 5 years he was with Phillipp Holzmann AG, Frankfurt, Fed.Rep. of Germany. Afterwards he was working on the safety of buildings at the ETH Zürich, where he got his doctoral degree. Since 1983 he has been head of the Department of Safety and Quality Assurance in a consulting firm.

SUMMARY

This paper refers to measures against human errors in the building process more specifically to data control. It shows the necessity of systematic planning and realization of controls. Four principles are formulated. The important measures for planning and realization of controls are described and their application is discussed.

RESUME

Cet article traite de l'élimination des fautes lors des phases de la construction, et plus spécialement du contrôle de l'information. Il est nécessaire d'introduire une planification et une réalisation systématiques des contrôles. Quatre principes sont formulés. Les mesures importantes à prendre pour la planification et la réalisation des contrôles sont discutées en vue de leur application.

ZUSAMMENFASSUNG

Dieser Beitrag behandelt Massnahmen gegen Fehler im Bauprozess und insbesondere mit Datenkontrolle, Überwachung und Überprüfung. Es wird auf die Notwendigkeit einer systematischen Planung und Durchführung von Kontrollen eingegangen. Vier Kontrollprinzipien werden formuliert. Die massgebenden Massnahmen für die Planung und Durchführung von Kontrollen werden beschrieben und deren Anwendung wird diskutiert.

1. INTRODUCTION

Controls are usually effective as well as economical. Therefore, they occupy an important place in the field of quality assurance. Controls are applied in the building process to supervise accepted risks and to detect errors in time. More serious consequences or damage can thereby be avoided. This fact is also shown from analyses of damage. According to one analysis of structural damage [3], for example, 85% of cases with property losses and 90% of cases with personal injury could have been avoided through timely controls followed by corrective measures.

Controls were and are applied extensively in the building process, but often not at the most sensitive points. The controls are often not carried out in a systematic way, considering only some phases of the building process, e.g. testing of materials, checking of drawings, etc. As the analyses of damage show, such unsystematic use of controls is insufficient. What we need therefore, is a systematic introduction of controls. This introduction should be divided into two stages:
- planning of controls at the sensitive points in the building process ('control stops' [2]) and their documentation in the form of control plans, control instructions and checklists;
- realization of controls by using check and correction notes, control records and reports, and corrective measures.

2. CONTROL ACTIVITIES

In a general sense, controls involve four activities:
- identifying actual conditions
- comparing actual with assumed conditions
- assessing any detected discrepancies
- application of corrective measures.

The identification of actual conditions is carried out at a specific time, and is limited to a few important characteristics that can be measured. Therefore, controls are useful only if discrepancies can be easily identified using a few characteristics at the right time, and if these can be overcome with minimum effort.

Once the point of time and the characteristics of the control are established, it is necessary to determine people or bodies responsible for carrying out the controls. The following controls should be distinguished:
- self-control
- internal control
- control by people involved in the building process
- external control by other bodies.

In this connection, the control by people involved in the building process occupies a distinct place. The analysis of structural damage [3] shows, that many of the errors which slipped through the self-controls or the internal controls could have been detected without additional controls, provided the people involved in the building process had remained alert and followed the proper procedures according to their position in the hierarchy, from architects to engineers to contractors, etc.

3. CONTROL PRINCIPLES

The detection of discrepancies is based on four principles formulated with respect to the possible errors. Such errors occur if procedures or their results are:

- missing
- wrong
- insufficient.

The following principles should be used in the planning and the realization of controls:

1st principle: Actual conditions should be checked for completenes ('completeness principle').
The purpose of these control procedures is to identify any missing items without checking the circumstances in detail.

2nd principle: Actual conditions should be checked for correctness ('correctness principle').
These control procedures are detailed, and they determine whether the circumstances to be checked are reliable and correct on the basis of the available documents.

3rd principle: Actual conditions should be verified entirely and independently of any previous controls ('principle of independent overall check').
If the circumstances have been checked for completeness and correctness they are known in detail. A final, independent overall check allows possible 'gaps' and 'weak points' to be detected.

4th principle: The feedback from actual conditions should be assessed in terms of the building process ('feedback principle').
The integration of the actual conditions within the building process might result in errors at the various interfaces. Therefore, it is necessary to check the interface situation, and to assess any impact on the technical procedures of the building process, on the areas of responsibility and duties, on the flow of information, on the cooperation and on the people involved.

4. PLANNING OF CONTROL

Suitable aids including control plans, control instructions and checklists should be used to ensure a systematic planning of control.

A control plan provides full details of the proposed controls. It indicates what controls will be carried out by whom, how, and when. There are control plans for the building process as a whole, as well as for individual phases and activities. Control plans normally contain only the most important information. Details are often laid down in existing standards, guidelines, etc. If such is not the case, control instructions and checklists must be used.

Control instructions provide a detailed description of the relevant procedure. Depending on the type of controls and their importance, the instructions can be given verbally or in writing. The various steps in the control procedure should be set out in the form of a checklist.

Checklists describe individual control procedures, step by step, using key-words, short phrases and questions. Checklists should generally be based on the control principles. There are two types of checklists in terms of content:
- closed checklists which deal with a distinct, clearly defined content, e.g. checking of building components or individual steps of a procedure;
- open checklists which deal with less clearly defined circumstances, using questions to ensure personal thinking and judgement.

5. REALIZATION OF CONTROL

The systematic realization of control must be ensured by using control and correction notes, control records and reports and corrective measures.

The various control steps require that all errors be properly noted, along with any planned measures, so that nothing will subsequently be forgotten.

The results of control procedures which affect further operations and have some impact on the quality of the structure should be written down in records and reports. If several people are involved in control procedures, as it is in the case of acceptance checking, the records are prepared jointly. In other cases, the control results can be included in a report.

If detected discrepancies exceed the given tolerances, corrective measures must be used. The corrections can often be made directly within the procedure. In other cases, the corrective measures must be planned, realized and documented.

6. APPLICATION OF CONTROL

Controls are generally used to detect and to correct errors in time as well as to supervise the accepted risks taken in the building process.

Within the individual phases of the building process, documents are prepared, materials are ordered and put to use, structural components are built, etc. In such activities, errors can occur. To prevent any errors in one phase from being carried over to the next, controls must be planned and realized at the important interfaces in the building process, that is at the so-called 'control stops' [2].

The quality of buildings and structures is governed not only by the actual errors that occur, but also by the accepted risks taken in the construction and utililzation phases. Therefore, it is necessary to supervise the individual risk indicators such as deformations, smoke, ground movement, etc. A potential occurrence of damage can then be detected in time and measures applied to prevent or reduce the possible damage.

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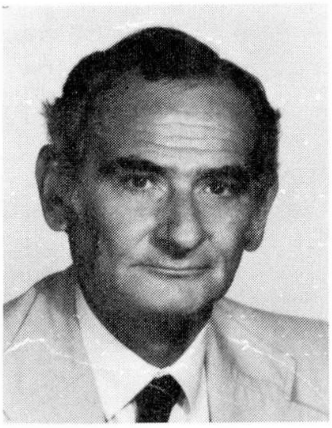
Ambient-adequacy, a Missing Requirement

"Compatibilité avec l'environnement": une exigence manquante

Umwelt-Verträglichkeit, eine fehlende Anforderung

Alvaro G. MESEGUER
Prof. Dr.
Instituto Torroja, CSIC
Madrid, Spain



A.G.Meseguer, born 1934, is an active member in CEB and chairs the Section for the Construction Industry within EOQC (European Organisation for Quality Control).

SUMMARY
The ambient-adequacy concept is presented and proposed for introduction into Codes. It leads to refer the requirements of safety and serviceability not to the structures but to the persons (users) and to make a distinction between direct and indirect users as well as between direct and indirect hazards. It also points out the importance of the very early stages in the construction process and the need of dealing with such stages in current Codes.

RESUME
Le concept de la "compatibilité avec l'environnement" est présenté. L'auteur en recommande son introduction dans les normes. Selon ce concept, les exigences de sécurité et de serviciabilité ne sont pas posées aux constructions mais à ses utilisateurs. Il fait une distinction entre utilisateurs directs et indirects, de même qu'entre danger direct et indirect. Le concept souligne également l'importance des premières phases dans le processus de construction, ce dont il faudrait tenir compte dans les normes actuelles.

ZUSAMMENFASSUNG
Das Umwelt-Verträglichkeits-Konzept wird vorgestellt und zur Einführung in Normen empfohlen. Das Konzept soll dazu führen, dass die Anforderungen für Sicherheit und Gebrauchstüchtigkeit nicht für Bauwerke, sondern für den Menschen aufgestellt werden, und dass zwischen direkten und indirekten Benützern als auch zwischen direkten und indirekten Gefahren unterschieden werden soll. Das Konzept betont ebenfalls die Wichtigkeit der allerersten Phasen innerhalb des Bauprozesses und Notwendigkeit, diese in Normen adäquat zu behandeln.

1. INTRODUCTION

Codes will be written increasingly in form of performance criteria. The concept of performance demands a clear definition of the requirements a building is expected to meet. In the structural field, basic requirements traditionally considered are Safety, Serviceability and Durability. At another level, Economy and Aesthetics are sometimes added.

Three simple examples will show that an important basic requirement is missing.

1.1 Example 1

A new highway is constructed, just fulfilling all requirements in present Codes. Years afterward, an extraordinary flow of water coming from unusual raining is deviated by the embankement of the highway. As a consequence, inundations occur in a village where never such a problem arised before, with the corresponding losses in lives and goods. Safety failed.

1.2 Example 2

A new tall building is erected, just fulfilling all requirements in present Codes. As a consequence, wind regime is modified in the neighborhood, this producing a disturbing vibration in existing tall buildings of the area. Serviceability failed.

1.3 Example 3

A new construction provokes a derivation of underground stream of agressive water, this producing a decrease of Durability in another existing structure.

It is evident that new constructions must not interfere negatively the existing constructions nor the ambient. This is a basic requirement that, up to now, has not been explicitely introduced in Codes. In the following, the wording ambient-adequacy will be used to cover the idea. Several considerations are to be made around this concept.

2. DEFINITION OF AMBIENT-ADEQUACY

To define ambient-adequacy is not easy. Obviously, the definition must cover the idea of not producing a significant decrease of safety, serviceability and durability in existing constructions. But two problems immediately arise, the first one concerning quantification, the second one concerning extension.

2.1 Quantification

What is the meaning of "significant decrease"? How much decrease are we prepared to accept? It is evident that asking for a zero decrease is not reasonable. Can the decrease be quantified?

2.2 Extension

When defining ambient-adequacy, the condition of "not interfere the existing constructions" is only a first approach. In a wider sense, ambient-adequacy must also cover negative influences in the zone. In other words, the quality of life in the area should not be decreased by the new construction. How far

Codes must go in the description of possible damages and where to establish the border line are both difficult points.

2.3 Examples

Again some examples can illustrate the difficulties:

A tall building is constructed near an airport. Air traffic can be affected. //. A quiet zone in a small village is used by people to rest and chat in sunny days. A building is constructed, just shadowing the zone. //. Tall buildings at the sea-side usually disturb the quality of life of inhabitants. //. Are nuclear power plants degradating quality of life? . //. Should ambient-adequacy cover ecology?

3. HOW TO INTRODUCE AMBIENT-ADEQUACY IN CODES

A first possibility in order to cover it in Codes is to introduce a new limit state for structures. Codes could then say that:

"Structures must be designed in such a way that they fulfill the requirements of safety, serviceability, durability and ambient-adequacy".

This is not a perfect solution for two reasons. First, the condition of ambient--adequacy refers to safety, serviceability and durability at the same time (see examples in item 1) and therefore can not be placed at its same level. Secondly, ambient-adequacy has to be taken into account from the very beginning of the building process (promoting-planning), the design stage being often too late to avoid disturbances.

A convenient solution is to refer the present requirements (or limit states) not to the structure as present Codes do but to the users and to clarify that there are two kinds of users:

- Direct users, who directly benefit of the building; and
- Indirect users, who are direct users of sourroundings constructions and even the community, which can be affected by the building.

In a correlative way, a differentiation must be made, when analyzing hazards, between direct hazards (which mean hazards for the structure and relate mainly to direct users) and indirect hazards (which mean hazards because the structure and relate to indirect users).

This solution leads to include in Structural Codes a clause with the following (or alike) wording:

> "The aim of the building process is to safisfy a human need, expressed by means of basic requirements. To fulfill the basic requirements, structures must ensure an appropriate degree of safety and an adequate performance in normal use, during a reasonable period of time, to all users, not only direct users (who directly benefit of the building) but also indirect users (who are direct users of sourrounding constructions) and the community. To fulfill the structural requirements, adequate decisions have to be taken at each stage of the construction process: promoting, design, materials choice, execution and use".

4. THE IMPORTANCE OF QUALITY ASSURANCE (QA)

Hazard analysis and, in particular, indirect hazard analysis, is of paramount importance at the promoting stage. This points out the concern of QA concepts, as they permit to deal with all stages of the construction process in an integrated way. As said in item 1.3 of (1), until now engineers have been confined in the three intermediate stages of the process, design, materials and execution. As a matter of fact, most of Codes are divided in three main chapters dealing with these three activities. But it is evident that quality depends not only on these phases but also on the other two, promoting and use. In particular, the promoting stage is of utmost importance as in it a great deal of main decisions are taken with a direct influence in the final quality. This is illustrated in Fig. 1 taken from (2).

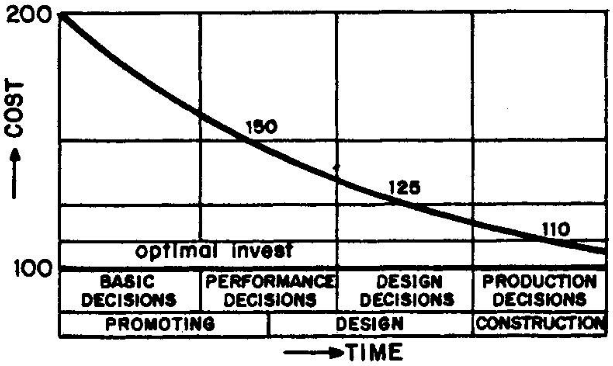


Fig. 1 Cost of wrong decisions

Ambient-adequacy has to be taken into account when adopting basic, performance and design decisions. Therefore, ambient-adequacy affects not only the promoter (owner, client) but also the structural designer.

On the other hand, QA approach emphasizes the figure of the user, which is the only one giving a sense to the construction process. The user will perform an increasing relevant role in the technical literature. This has been already recognized when introducing the performance concepts in new Codes, as performances are no other thing than translation of a human need into a technical language.

The fact that the term user covers also indirect users must be emphasized everywhere in the future. We all are users of all constructions (we look at them, we live with them). The ugliness of most of our cities is probably due to the fact that, up to now, the term user has been considered as synonimous of direct user, just forgetting indirect users and the community.

The ambient-adequacy requirement permits to open the door of the technical field to social values of growing concern -such as ambient impact and ecology- and aggrandizes the social dimension of our profession.

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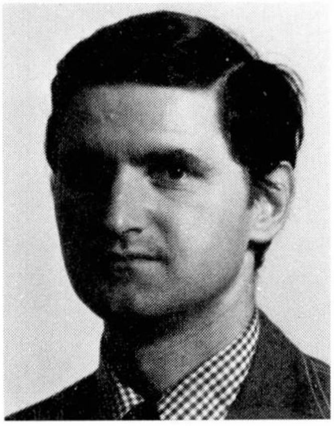
Strategies for Control of Human Errors

Stratégie pour le contrôle d'erreurs humaines

Strategien zur Reduktion menschlicher Fehler

Andrzej S. NOWAK
Assist. Prof.
University of Michigan
Ann Arbor, MI, USA



Andrzej S. Nowak received his masters and doctoral degrees from the Warsaw Technical University in Warsaw, Poland. His research interests include safety of structures, optimization of building codes, modelling human errors, and design of bridges.

SUMMARY
An approach to control the effect of human errors is considered. Possible consequences are identified and sensitivity analysis is performed to optimize the control of error causes. A brief numerical example is included.

RESUME
L'article propose une méthode de contrôle d'erreurs humaines. Les conséquences possibles sont évaluées et une analyse de sensibilité permet d'optimaliser le contrôle des causes d'erreurs. Un exemple numérique est présenté.

ZUSAMMENFASSUNG
Ein Vorgehen zur Erfassung der durch den Menschen verursachten Fehler wird behandelt. Mögliche Konsequenzen werden beschrieben und Sensitivitätsanalysen durchgeführt, um die Ursachen von Fehlern in den Griff zu bekommen. Ein kurzes, numerisches Beispiel ist angefügt.

1. INTRODUCTION

Human errors are the major cause of structural failures. This has been indicated by the surveys in Europe and in America. The errors include ommisions, misplacements, misinterpretations, numerical mistakes, poor inspection, etc., in planning, design, detailing, fabrication, construction, and use.

Control of errors is the principal factor determining structural safety.

The basic flowchart is as shown below:

CAUSES ---------→ ERRORS ---------→ CONSEQUENCES

Errors can be controlled through control of causes or consequences (or both). The proposed approach is to identify possible consequences, perform sensitivity analysis, and then optimize the control of causes.

2. CAUSES OF ERRORS

Observations show that errors are an inevitable part of human performance. They are made by planners, designers, manufacturers of materials, contractors, users and occupants. Each phase of the building process may be involved.

Frequency and magnitude of errors may very depending on: motivation, qualification and psychological or physiological conditions.

Most of the errors are detected within the process, in particular by self-checking. The rate of detection depends on checking and inspection systems. Cost of control is related to this rate by the economical efficiency function.

Structural safety, depends on the number and magnitude of undetected errors.

3. CONSEQUENCES OF ERRORS

Errors can be put into categories depending on the answer to the question "What goes/went wrong?". Wrong may be the whole idea (planning), design (overall or some details), construction procedure, quality of material, use or occupancy. The error may affect the structure directly or indirectly.

As in case of causes, there is an infinite number of erroneous ways to realize a structure. However, based on past experience and using engineering judgement the important error consequences can be identified. For example, in a bridge slab cast on steel girders, the possible consequences of error(s) may be deviations from intended strength of concrete, effective depth, amount and grade of reinforcing steel, thickness of concrete cover, or spacing between girders.

The relationship between consequences and structural safety is established by sensitivity functions.

4. APPROACH TO ERRORS

The suggested approach is based on the sensitivity analysis.

Let $Z = g(x_1,\ldots,X_n)$ be the limit state function, and $X_1,\ldots,X_n$ are the state variables (e.g. loads and resistance). $X_1,\ldots,X_n$ are random variables and their distributions are usually obtained from the test data, measurements, or by engineering judgement. For given distributions the structural safety can be evaluated using available methods (reliability index, upcrossing rate, Monte Carlo simulations).

Errors may change the distributions of X_i's. Changed distributions may result in changed structural safety level. In many practical cases the relationships between the safety level and distributions of X_i's can be established.

The sensitivity functions may point to the "sensitive areas" requiring a special error control effort. This, together with the cost analysis, can be used to optimize the whole control system.

The proposed procedure includes the following steps:

1. Develop a model of the considered structure (or its part). Identify the limit state function(s) and state variables.
2. Establish the distribution and correlation functions for the variables.
3. Identify the range of possible variation for the distribution and correlation functions.
4. Develop sensitivity functions relating these distributions and correlations to structural safety.
5. Develop economical efficiency functions relating these distributions and correlations to cost of error control.
6. Distribute the error control effort using sensitivity functions and economical efficiency functions.

5. NUMERICAL EXAMPLE

Sensitivity analysis is demonstrated on a very simple case. Consider a noncomposite steel girder bridge (Fig. 1).

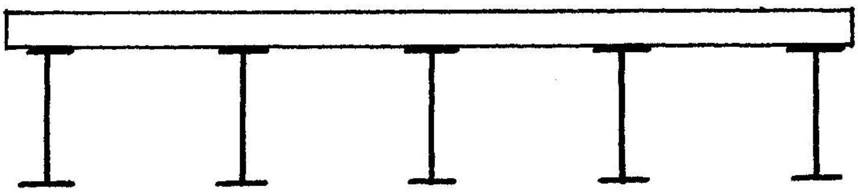


Fig. 1 Cross Section of the Considered Bridge

Girders are designed using Ontario Highway Bridge Design Code with the design equation

$$0.9R = 1.2D + 1.4\,(L + I)$$

where R = moment carrying capacity, D, L, I = moments due to dead load, live load and impact.

The distributions of these variables are given by the ratios of mean-to-nominal and the coefficients of variation, as follows:

	R	D	L	I
mean-to-nominal ratio	1.16	1.05	1.15	.74
coeff. of variation	.10	.08	.11	.45

Assume D $\div$ L = 1 $\div$ 1 and I = .25 L.

Safety is calculated in terms of a reliability index, β,

$$\beta = \frac{\bar{R} - \bar{D} - \bar{L} - \bar{I}}{\sqrt{\sigma_R^2 + \sigma_D^2 + \sigma_L^2 + \sigma_I^2}}$$

where $\bar{R}$, $\bar{D}$, $\bar{L}$, $\bar{I}$ are the means and σ's are the standard deviations.

Sensitivity functions were calculated for R, D, and L. The results are plotted in Fig. 2.

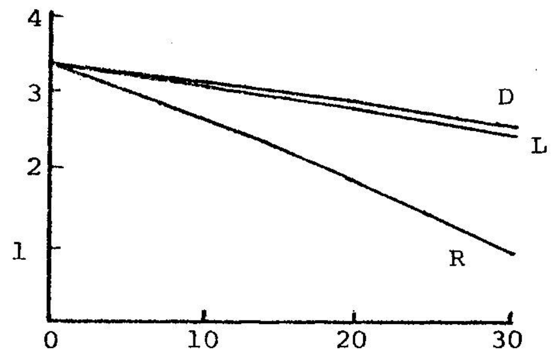


Fig. 2 Sensitivity Functions

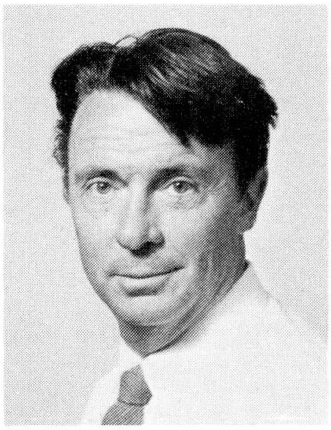
Safety is sensitive to errors in R, however not so much to errors in live load. This also means that accuracy in transverse distribution of live load is less important than a correct R.

Role of Standards in Quality Assurance

Rôle des normes pour l'assurance de qualité

Beiträge der Normung zur Qualitätssicherung

Caspar REINHART
Civil Engineer
SIA
Zurich, Switzerland



Caspar Reinhart, born 1931, got his civil engineering degree at the Swiss Federal Institute of Technology in Zurich. Since 1972, he heads the Technical Department of the Swiss Society of Engineers and Architects SIA which is in charge of Building Standards of Switzerland.

SUMMARY
Standards play an important role in Quality Assurance. They are existing "tools" well known to professionals. The paper describes how they can contribute efficiently and in many ways to the different systems conceived to define and assure quality.

RESUME
Les normes jouent un rôle important pour l'assurance de qualité. Ce sont des "outils" existants, bien connus des professionnels. L'article décrit leur contribution à la définition et l'assurance de qualité.

ZUSAMMENFASSUNG
Normen bilden eine wichtige Grundlage für die Qualitätssicherung. Sie sind bestehende und dem Fachmann bekannte "Werkzeuge". Der Artikel beschreibt deren Beitrag zur Definition und Sicherung der Qualität.

1. PHILOSOPHY

Man himself with his qualities is crucial for the attainment of qualities desired in any manmade product. Standards can be valuable tools in helping to assure quality.

2. STANDARDS AS TOOLS FOR QUALITY ASSURANCE

There are many ways in which the existing national and international building standards can be used for QA.

They can:

- standardize the information flow

  We can minimize errors in the information flow by using standardized terminology. Chances are better that each partner understands what the other wants to communicate.

- define the standardized frames of reference

  With the standards we can define frames of reference, the SI "international system of units" being an example. With standardized performance levels - together with standardized testing methods - it is easier to define the quality required in practice and to check the result of the operation.

- define standardized operations

  In addition to the standardized terminology and performance levels we can standardize whole operations. The object is to commit fewer errors by using them, since these operations have been tested in advance as to their possible susceptibility to errors, since these operations will be used automatically and since results can be compared with empirical data.

  In technical regulations: we can standardize dimensioning methods, measuring methods (e.g. heat transfer or acoustical measuring) and testing methods.

  In organizational regulations: we can standardize conditions of contract such as the specification of services, contract documents, measuring and warranty regulations. We can allocate tasks for the standardized operations.

- define standardized rules of conduct

  Standardized rules of conduct can contribute to assure quality. The definition of for example a level of safety (which does not necessarily describe the actual safety) prevents dangerous decisions from being made during the design phase in order to obtain economic advantages.

3. REQUIREMENTS

In order that standards serve their purpose and can be used for QA, the following requirements have to be met:

- Clear distinction between technical and organizational regulations [3]

  Technical standards regulate what is to be done in which manner in order to be technically and ethically correct. They are binding by virtue of their factual correctness even when they are not mentioned in the contract.

  Organizational standards regulate competence, duties and mode of operation. They are only valid if they are part of the contract.

- Standards shall not restrain inadequately

  Standards shall restrain neither creativity nor progress. They shall not prevent that everyone carries the responsability for his actions by himself. The blind belief in standards and affidavits is a source of numerous errors and the negative side of standardization.

  To avoid this negative side two proven measures can be taken: a) An exception clause should be included in every technical standard which allows for substantiated deviations from the fixed regulations and b) it should be avoided that standards are declared compulsory by the Government.

- Limitation of standards

  Using standards one should never forget that they are but tools and no substitute for professional know-how, dialogue with the partner and thinking.

4. OPEN QUESTIONS

I have not yet found answers to the following questions:

- Should standards sensitize the user to particular problems?
- Should standards give reasons and explain contexts?

  or should this information be left to professional teaching and training?

The information mentioned above would contribute considerably to greater Quality Assurance since it is conducive to "the right thought at the right moment". This is why I as a pragmatician would advocate the judicious inclusion of these references in standards.

5. SYNOPSIS

The following Synopsis shows for which tasks standards can be used in the different systems conceived to assure quality:

Technical rules	Organizational rules	Rules of conduct
Standardized information flow Terminology Symbols .... Standardized frames of reference Performance levels Standardized operations Dimensioning methods Testing methods	Standard conditions of contract Services Fees and payments Contract documents Measuring regulations Accounting Warranty Allocation of tasks for standard operations	Standardized level of security

4. BIBLIOGRAPHY

[1] M. Portmann: "Normen: Regeln der Baukunde, Mittel der Vertragsgestaltung und des Abbaues von Handelshemmnissen", Schweizer Ingenieur und Architekt, 101(1983) No 7

The paper describes the bases and structure of the technical and organizational standards of SIA (Swiss Society of Engineers and Architects) and cites past experience which lead to today's standards.

[2] Weisung SIA 260: "Sicherheit und Gebrauchsfähigkeit von Tragwerken", bereinigte Fassung vom September 1982

Basic document for the coordination of SIA standards for safety and serviceability of structures

[3] M. Lendi: "SIA-Normen - Struktur und Geltung", Schweizer Ingenieur und Architekt, 101(1983) No 7

Contains an analysis of SIA standards from the legal point of view: Structuring, validity, liabilities and responsabilities

[4] SN 029100: "Anforderungen an Qualitätssicherungs-Systeme", aufgestellt aufgrund der Arbeit der Schweizerischen Arbeitsgemeinschaft für Qualitätsförderung

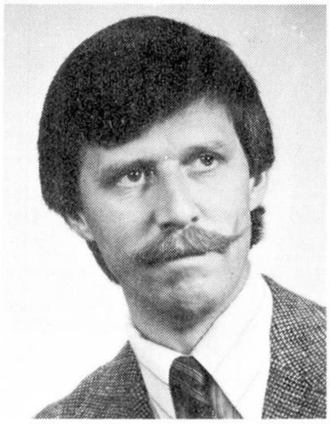
Describes the requirements for Quality Assurance Systems and proposes three different levels. It is coordinated with the work of EOQC, the European Organization for Quality Control.

Supervisory Control and Suggestions on Quality Improvement

Contrôles de fabrication et idées pour une amélioration de qualité

Überwachung der Produktion und Anregungen zur Qualitätsverbesserung

Klas TORBERGER
Civil Eng.
A-Betong
Stockholm, Sweden



Klas Torberger, born 1941, got his degree in civil engineering at the Royal Institute of Technology, Stockholm, Sweden. For seven years he was involved in the design of bridges and industrial buildings followed by four years of marketing of prefabricated concrete structures. He is now responsible for the design of prefabricated concrete structures.

SUMMARY
This paper gives a brief description of the organization of the supervisory control of concrete element prefabrication. It presents some results from the control, as well as dealing with some ideas on how to improve the quality of production.

RESUME
Cette communication donne une brève description de l'organisation des contrôles exercés lors de la préfabrication d'éléments en béton. Quelques résultats de ces contrôles sont présentés ainsi que quelques idées concernant l'amélioration de la qualité des produits fabriqués.

ZUSAMMENFASSUNG
Der Vortrag enthält eine kurze Beschreibung der Organisation für Güteüberwachung in der Produktion von Betonfertigteilen. Es werden auch einige Resultate dieser Überwachung nachgewiesen sowie Hinweise gegeben, wie sich die Qualität der Produkte verbessern lässt.

The manufacturing of concrete elements as well as most concrete products in Sweden is subject to supervisory control by a control organization. This organization is formed and managed jointly by state and municipal authorities, state and private customers (contractors) and by the manufacturers of concrete elements. The aim of the organization is to carry out a control based on specific competence, thus limiting the need for control by each customer or by each municipal authority. Their right of control is not, however, restricted hereby.

The supervisory control is executed on randomly chosen visits to the factories. No prior warning of the visits is given. The number of visits made to the factory depends on the scope of the production.

During the supervisory visits the main functions subject to checking are shown below together with the results for four consecutive years. [1-4].

	Function	1979	1980	1981	1982
-	drawings	152	167	138	178
-	basic materials	19	8	16	13
-	personnel	48	69	69	36
-	equipment for control and production	21	14	17	11
-	labeling	109	79	98	111
-	execution of the products	355	444	382	408
-	handling	10	14	6	5
-	completed products	38	19	17	20
-	internal control	197	207	187	207
-	basic materials, testing reports	8	26	20	12
-	pre-tensioning	13	8	13	5
TOTAL		970	1055	963	1006
Number of control visits		458	507	534	528

Each function comprises different checking points. On checking, each notation is documented. The seriousness of the error is then judged and given a grade of 1, 2 or 10, where 1 stands for minor errors and 10 for very serious errors. To assess the capability of the factory a weighted sum of the reported errors is used.

During the four years the notations given the grade of 1 vary between 79 and 85%, the grade of 2 between 13 and 19% and the grade of 10 between 1.7 and 2.5%. The volume of production has increased yearly by 5 to 10%.

High proportions of errors are shown for the functions, drawings, labeling, execution and internal control. Drawings are in most cases subject to checking by authorities before distribution to the factory.

Execution and internal control have also high proportions of notations.

What conclusions can be drawn from these figures and what steps can be taken to provide better quality? Can it be possible that the control is so effective that the ultimate level of quality has been reached? An affirmative answer to the last question means that no further knowledge and improvement can be obtained from the results.

The relatively high level of notations with regard to drawings is astonishing. The reason may be that municipal authorities in many cases are without specific competence. They trust the designers - some kind of unofficial authorization. Type approval of design and products is one method of improvement. Another way way might be authorization. To improve the competence of the municipal authorities would be a third way but this seems to be a bit costly.

The proportion of notations is high for the execution and internal control of the functions. This leads one to believe that the comment in the Introductory Notes, page 59, "someone else will look at this work and will find out if anything goes wrong so therefore I can leave it as it is" is valid.

It would not be correct to assume that the best possible level of quality has been reached. Rather, I think, that the goal of a better quality cannot be achieved by applying the present system.

One solution could be to strengthen confidence in the ability of the producer and to reinforce his responsibility. This could be attained by setting up a supervisory organization that would impose the following requirements on the producer:

1. An organization plan with clear allocation of responsibilities.

2. A plan for control that puts the responsibility for the internal control on the manufacturing units.

3. A control unit that can handle the control equipment. Their responsibility is to serve the producing units.

4. A control programme for each production unit that describes the necessary checking points and how often checking has to be done (differs depending on the seriousness of a mistake).

The task for the supervisory organization should primarily be to check that the organization works according to the plan for control, secondly to check that the control programme has been implemented, and thirdly to execute its own spot checks. The number of supervisory checks by each producer should be related to the results of the checks. Bad performance could lead to extra visits involving much higher costs.

By integrating control and manufacturing it will be possible to learn from mistakes and it will also contribute to the development of better methods of production. The consciousness of quality will penetrate the whole organization. Costs may appear to increase, but this will be compensated for by fewer errors, i.e. lower costs.

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Causes of Some Steel Structure Failures

Origine de la ruine de quelques constructions métalliques

Ursachen des Versagens einiger Stahlkonstruktionen

Franjo TURČIĆ
Senior Lecturer
University of Zagreb
Zagreb, Yugoslavia

Franjo Turčić, born 1939, got his civil engineering and M.Sc. degrees at the University of Zagreb, Yugoslavia. For twenty years he has been involved in different phases of the building process: design and calculation, construction, quality assurance, now doing research and teaching at Zagreb University.

SUMMARY
This paper contains some short reports about several steel structure failures that happened on the territory of Croatia in Yugoslavia between 1967 and 1982. These failures are considered from the quality assurance's standpoint. Also, some personal opinions about the role of quality assurance within the building process are given.

RESUME
L'article traite de quelques cas de ruine de constructions métalliques qui ont eu lieu entre 1967 et 1982 sur le territoire de la Croatie, en Yougoslavie. Ces écroulements ont été analysés au point de vue de l'assurance de la qualité. L'exposé est suivi de quelques considérations de l'auteur sur le rôle de l'assurance de la qualité dans le processus de la construction.

ZUSAMMENFASSUNG
Dieser Artikel enthält knappe Berichte über das Versagen einiger Stahlkonstruktionen, die in Kroatien (Jugoslawien) von 1967 bis 1982 vorgekommen sind. Diese Versagensfälle werden hier vom Standpunkt der Qualitätssicherung analysiert. Einige Überlegungen über die Bedeutung der Qualitätssicherung im Bauwesen werden angefügt.

1. CAUSES OF SOME STEEL STRUCTURE FAILURES

Series No.	Structure discription	Failure	Place	Year	Load in moment of failure
1.	Sugar Silo D-45 m, H-30 m	Collapse during erection, H-22 m	Vrbas	1979	Wind cca 30 m/sec.

Insufficent stability of the cylindrical shell without wind girder and any erection assurance, with a big unstiffened opening on mantle (6x18 m) on the wind-side.

Series No.	Structure discription	Failure	Place	Year	Load in moment of failure
2.	Corn Silo D-8,28 m, H-32 m (6 cells)	Collapse of one cell in use during lateral unloading (after 3 years of limited use)	Daruvar	1980	Cell filled with wheat

The cause of the failure was not officially determined, but there were three obvious defects of structure: insufficent stability of cylindrical shell, increased initial geometrical imperfections, shortage of loadbearing capacity of longitudinal bolted connections (The hole diameter greater than bolt diameter by 2 mm, thread length equal to bolt length).

Series No.	Structure discription	Failure	Place	Year	Load in moment of failure
3.	Cement Silo (Capacity 10 MN)	Collapse in use (after 2 years of use)	Split	1981	Silo filled (70%)

The official report says that there were several different design defects and also possibility of a "shake down" effect in the place where the shell is supported.

Series No.	Structure discription	Failure	Place	Year	Load in moment of failure
4.	Water tank, 2200 m^3 (on a water-tower above a restaurant). The tank was designed as two ventricle inside two concentric cylindrical shells, with free upper edge.	Collapse of inner empty cylinder in use	Vukovar	1970	The inner ventricle was empty, and the outer was full of water

Insufficent stability of cylindrical shell under outside pressure because of: increased initial geometrical imperfections, residual welding stresses and poor design (inadequate edge conditions).

Series No.	Structure discription	Failure	Place	Year	Load in moment of failure
5.	Corn Silo (capacity 100 MN)	Collapse of one cell in use	Podravska Slatina	-	Cell was filled

Insufficent stability of cylindrical shell because of: inadequate appreciation of loading conditions, inadequate appreciation of edge conditions of vertical stiffeners, poor design of stiffener splices without continuity on the level of horizontal shell splices.

Series No.	Structure discription	Failure	Place	Year	Load in moment of failure
6.	Tanks D-32 m H- 8 m	Collapse of 5 tanks during erection	Obrovac	1974	Strong wind

Insufficent assurance during erection.

7.	Single story industrial building with steel roof trusses. Area 840 m^2, Span 20 m.	Collapse in use	Gerovo	1972	Snow 2-3 kN/m^2
	Poor workmanship of butt welds in a lower chord tension member.				
8.	Single story industrial building with steel roof trusses. Area 2000 m^2, Span 24 m.				
	Poor workmanskip of butt welds in lower chord tension member.				
9.	Single story industrial building with steel roof trusses Area 2000 m^2, Span 20 m.	Collapse in use	Virovitica	-	Snow cca 1.8 kN/m^2
	Load above the standard (0.75 kN/m^2). Also inadequate treatment of supposed statical system.				
10.	Single story warehouse with steel roof trusses. Area 600 m^2, Span 10 m.	Collapse in use	Skradin	1976	Snow cca 1.0 kN/m^2
	Serious mistake in erection. The tie rods of main roof girders were connected with bolts M12 instead of M14, as it was designed. The bolt holes were made by burning.				
11.	Roadway bridge with trusses above floor	Collapse in use	Karlovac	1981	Special transport
	Special cargo hitched on a truss member. Precaution measures were not strict enough.				
12.	Roadway bridge with trusses above floor and lateral bracing between upper chords	Collapse in use after a special cargo hitched on a member of bracing.	Ličko Lešće	1980	Special transport
	Precaution measures were not strict enough.				
13.	Lamp posts	Collapse in use	Zagreb	-	Wind
	Underestimation of wind effects. Neglected influence of the dynamics. Difference between workshop drawings and original drawings.				
14.	Steam generator for nuclear power plant (NPP)	Overturned in transport	Between Zagreb and Rijeka	-	-
	Transportation procedure was not prepared professionally enough.				
15.	Stator of turbine for NPP	Overturned during transport	Krško	-	-
	Underestimation of influence. Precaution measures were not strict enough.				

16. River dam (water suply for NPP)	Collapse of all seven gates	Krško	-	High water wave

Grossly inadequate execution of operational procedure, and poor design.

17. Steam generator (NPP)	Excessive vibrations of U-tubes	Krško	-	Prestarting operations

Inadequate appreciation of real behaviour of structure.

18. Reactor make up water storage tank (NPP)	Rupture during filling	Krško	-	Pressure too high

Inadequage execution of filling procedure.

19. Auxiliary feedwater system (NPP)	Deformation of pipes	Krško	-	Pre-starting operations

Poor design.

20. Condensate pump (NPP)	Erosion on rotor and stator	Krško	-	Pre-starting operations

Poor workmanship.

Note:

Failures described under 14 to 20 happened either durign building phase or prestarting operations, between 1977 to 1982. During all that time quality assurance was implemented against USA Model of QA for NPP.

2. QUALITY ASSURANCE WITHIN THE BUILDING PROCESS

2.1. Experience gained from the failures described

Most of the described failures occured also because of gross human errors, that happened in different phases of building process. Most of them could have been discovered with a little additional checking, or in some cases without any additional checking, if there exised a more efficient QA system. Referred are only the cases of collapses or failures that have caused unforeseen costs and delays (e.g. the causes in NPP Krško), but not very many causes where gross errors have been noticed on time, either in planning phase or in construction phase, after wich corrective actions have been taken.

Phase	Design	Construction	Design and constructi-on	Use	Design and use	Total
Description case No.	3,5,13,17, 19	1,6,7,8,10,14 12,2o	2,4	11,12,18	10,16	
Number of cases	5	8	2	3	2	20
%	25	40	10	15	10	

Table 1 Phase of building process in which gross error has occured

	Possibilities of discovery	Case	%
a)	Discovery probable with additional checking		
	in phase of:		
	Planning:	3,5,9,13,14,15,16,17,19	45
	Construction	4,8,10,20	20
	Use	11,12	10
b)	Discovery probable without any additional checking	1,2,6,7,17	25

Table 2 Possibilities of Error Discovery

Described cases of failures refer to the structures that could be classified as "middle or low level of technology".

Gross human errors occured because jobs were entrusted to the people with insuficient knowledge or negligent attitude to the job. That was possible because of absence of effective QA.

Most countries already have some kind of a more or less effective "classical" QA system within the industry and within the building process. The question is, are there good reasons for some changes, particularly in construction? I think the answer is yes, both in technicaly developed countries as well in those which are not.
It would be a mistake if a country, through its technical regulations, implemented a QA system completely against Appendix B to 10CFR 50 /USA/ in the construction field, because this system as a whole, as a society game, is necessary and tolerable for the components of highest technology, e.g. nuclear industry, but the same system would be an unadequate and unnecessary handicap in civil engineering. Within the building process, a QA system against a new concept would be useful and necessary, in the form of regulations and guidances, but this should be an appropriate and simplified level of QA programme. However, in the internal policy, rules and organization of a construction firm, it is reasonable and useful to implement and accept all the principles and concepts of the 18 criteria, Appendix B, which has already been done by many world known firms and manufacturers outside nuclear industry, for competition and economic reasons.

However, everyone should be aware that efficiency of the QA system would essentially oscillate in different countries depending on their national system of contract and legal liability, motivation and technical level. The danger in implementation of QA lies in formalism and bureaucracy of the process. It could be expected that in some countries firms taking part in building process will accept QA principles and establish quite perfect QA manuals, procedures and organization,but only formally. Actually they will not implement it truly against known principles, and for example quality assurance will not have sufficient authority and will not be independent from production, etc.

IABSE, because of its international respectability should prepare a document on QA. This document could be a model for a national standard on QA. It shall contain only principles and aims. Good examples are standards: BS 5750 Part 1,2 and 3 CSA Z 299.1 to Z 299.4. These are standards for general industrial use, with three or four basic levels of quality programs, including guidelines for selection of appropriate level of quality program in each individual case.

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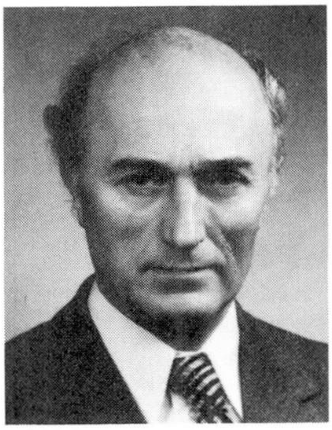
Collapse of the Bridge at Pulle

Effondrement du pont de Pulle

Einsturz der Brücke von Pulle

Daniël VANDEPITTE
Professor
Ghent University
Ghent, Belgium



Daniël Vandepitte, born 1922, got his civil engineering, master's and doctor's degrees at Ghent University and at Yale University (USA). He designed many bridges and supervised bridge construction, during 10 years as a civil servant in the Ministry of Public Works. He teaches structural analysis at Ghent University.

SUMMARY
The bridge at Pulle and its sudden failure after 8 years of service are described. The mechanism of the collapse is explained. As the investigation showed, the failure was due to the organizational set-up. The lessons that can be learnt from the collapse of the bridge at Pulle are not strikingly novel.

RESUME
Cette contribution contient une description du pont de Pulle. Le pont s'est soudain effondré après 8 ans de service. Le méchanisme de l'effondrement est expliqué. En dernière analyse le désastre était dû au mode de gestion de la réalisation et de l'entretien de la construction et de ses abords.

ZUSAMMENFASSUNG
Der Beitrag gibt eine kurze Beschreibung des Einsturzes der Brücke in Pulle. Acht Jahre nach ihrer Inbetriebnahme stürzte die Brücke plötzlich zusammen. Der Mechanismus des Einsturzes wird erklärt. Letztlich ist die Zerstörung der Brücke in Pulle auf die Art der Organisation der Erstellung und der Instandhaltung der Brücke und ihrer Umgebung zurückzuführen.

DESCRIPTION OF THE BRIDGE

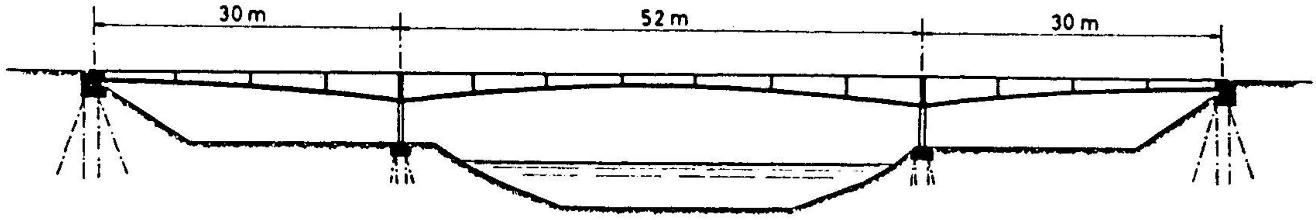


Fig. 1

The bridge at Pulle carried the Antwerp-Liège motorway across the Nete canal. Its spans were 30 m, 52 m and 30 m long (fig. 1). The concrete superstructure had 11 continuous prestressed longitudinal girders. The abutments and the piers were small concrete bodies supported by concrete piles. An unusual feature was the shortness of the piles under the piers : those under the east pier were only about 2.5 m long. This was due to the fact that a layer of sand was come upon which was so dense that the contractor was unable to drive the piles through it. The bridge at Pulle and 19 other bridges had been designed and built simultaneously under pressure of time in order to enable a section of the Antwerp-Liège motorway to be opened for traffic before a certain date. If the geotechnical report had reached the designers in good time they would probably have designed the piers with spread footings resting directly on the soil.

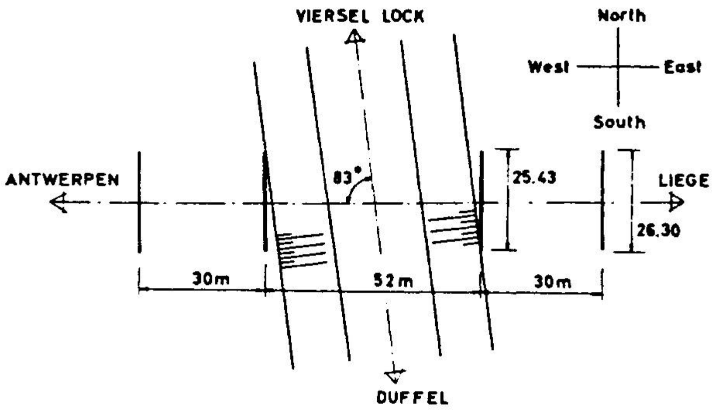


Fig. 2

The angle between the centre-line of the bridge and that of the canal was 83° (fig. 2). The centre of the east pier coincided at its southern end with the crest of the theoretical talus profile. Figure 3 is a vertical cross-section showing the relative position of the southern end of the east pier and the bank of the canal, drawn with its theoretical shape. The side slopes of the cutting were not protected by a lining of any kind. The newly completed bridge at Pulle was subjected to loading tests in September 1958. Its behaviour under a live load almost equivalent to the full (unfactored) design live load was entirely satisfactory.

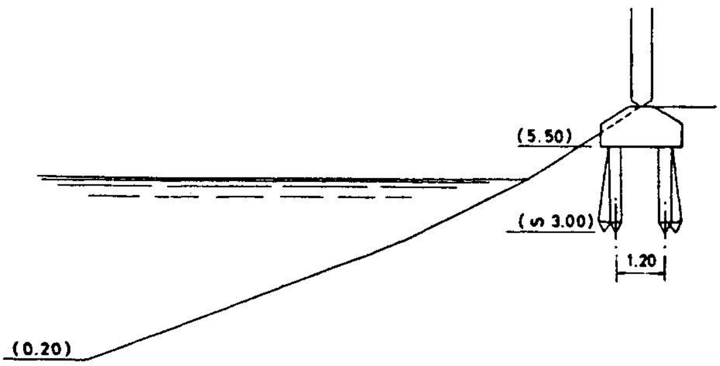


Fig. 3

the

THE COLLAPSE AND ITS CAUSE

Eight years later, on 12 November 1966, the bridge collapsed without warning in ~~het~~ middle of the night while no vehicles were passing over it. An investigation showed that the bridge had been well designed and built, that the concrete was of excellent quality, that the prestressing steel possessed the necessary strength and that it had not been weakened by corrosion. Measurements revealed that the east pier had moved considerably towards the canal, settled and tilted. This is visible in figure 4, which consists of 3 cross-

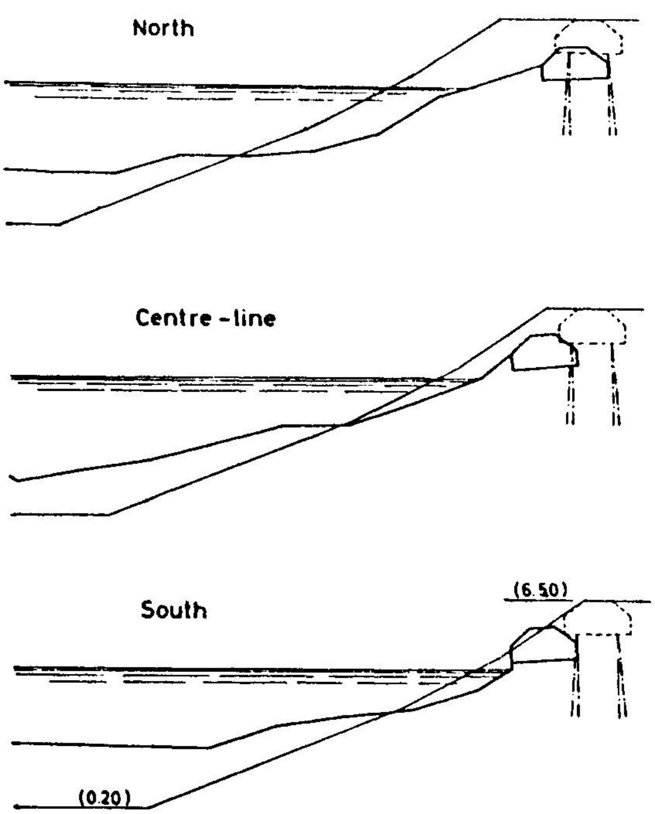


Fig. 4

sections and which shows the theoretical and the actual profiles of the canal, and the initial and the actual positions of the east pier. The amplitude of the displacement of the east pier was the greatest at its southern end.

The east talus of the canal was in very bad shape over the width of the bridge and also immediately to the south of it. The severe local scour which the east bank had undergone was mainly due to the proximity, just to the north of the bridge, of the Viersel navigation lock in the Nete canal. Barges awaiting their turn to lock through halted under the bridge or just to the south of the bridge, alongside of the east bank. When their turn came they started off and it is easy to imagine that the stir caused by their propellers a few metres from the bank slowly eroded the unprotected talus.

The scour gradually removed the soil near the points of the left hand piles in figure 3 . As a consequence the carrying capacity of those piles decreased. Figure 5b shows the configuration of the piles, the east pier and the concrete rocker bearing corresponding with an assumed 12 cm settlement of the piles on the canal side. The resulting inclination of the rocker increases the load acting on the left hand piles, thus accelerating the subsidence and the whole displacement of the body of the pier. Hence, once the settlement of the piles and the movement of the pier had begun, its horizontal displacement increased so rapidly that the foot of the rockers soon slid off the pier and that the main girders came crashing down.

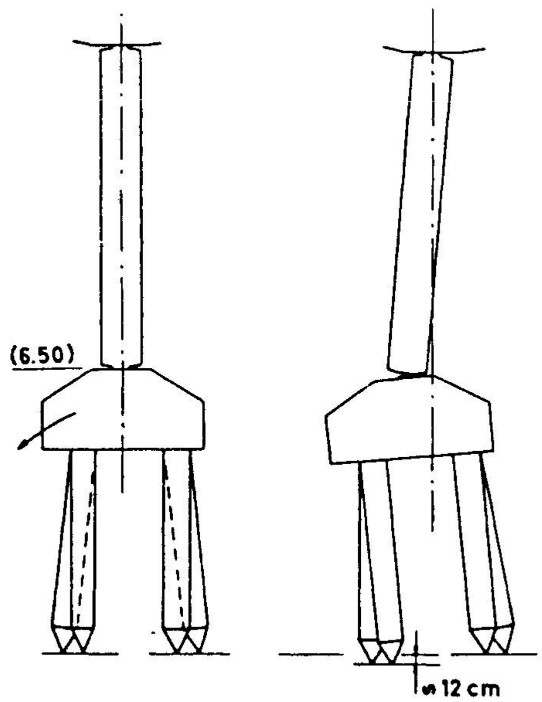


Fig. 5

So the cause of the collapse was erosion of the east bank of the canal in the immediate vicinity of the points of the canalside piles under the east pier. The bridge would not have failed if *either one* of the following situations had obtained :

1) Piles long enough to extend a few metres below the theoretical level of the bottom of the canal.
2) Canal banks efficiently protected against scour under the bridge and on either side of the bridge.

ORGANIZATIONAL SET-UP - RESPONSIBILITY FOR THE COLLAPSE

The engineer who was responsible for supervising the construction of the bridge and who was a civil servant in the Roads Division of the Ministry of Public Works was indicted. He was acquitted by the court. In the opinion of the writer acquittal was the proper verdict because the bridge possessed the required carrying capacity when it was built and because its foundations, in particular, did not constitute weak points at that time, in spite of the unorthodox shortness of the piles under both piers. The Nete canal and its banks, whose gradual deterioration had eventually caused the failure of the foundation of one of the four supports of the bridge, were the responsibility of another agency, the Navigable Waterways Division, of the Ministry of Public Works. Apparently the Roads Division did not know that the Navigable Waterways Division did not plan to protect the canal banks against scour, and the latter agency presumably did not suspect that the tips of the piles under both piers were situated close to the slopes and several metres above the level of the bottom of the canal.

The files pertaining to the bridge contained design drawings showing pier foundation piles having the originally intended length, i.e. piles much longer than the actual ones. After the failure no drawing was found similar to figures 1 and 3 and showing the real position of the tips of the piles with respect to the theoretical profile of the canal. The mere existence of such a drawing might have been sufficient to make someone realize the potential danger and induce him to ward it off. In the last analysis the collapse was due to fragmentation of responsibility and of the power of initiative and decision. Far too many different parties were in some way connected with the project : the contractor, an independent civil engineering design office, and no fewer than 4 agencies of the Ministry of Public Works : the Soil Mechanics Laboratory, the Bridge Design Bureau, the Roads Division and the Navigable Waterways Division. It was, more specifically, the poorness of communication between the two latter agencies which turned out to be fatal.

CONCLUSIONS

The lessons to be learnt from this failure are not strikingly novel. They can be phrased as follows :

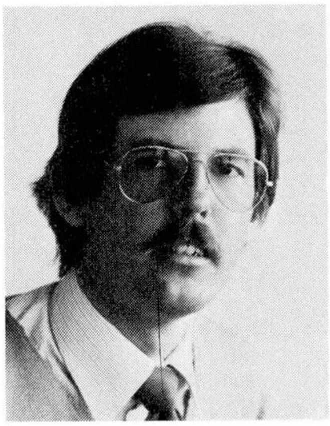
1) mainly, the danger inherent in dispersion of responsibilities,
2) the imperative need of effective communication between all the parties involved, if responsibility for the creation and for the upkeep of a structure cannot be concentrated in a single spot for whatever insuperable legal or organizational or other reason,
3) the necessity for scale-drawings showing, without distortion, the configuration and the proportions of the whole real structure and of its parts,
4) and the vital importance of maintenance extended to the environment of the structure proper.

Quality and Quality Assurance in Tender Documents

Qualité et assurance de qualité dans des documents d'appels d'offres

Qualität und Qualitätssicherung in Ausschreibungsunterlagen

Walter H.A. WEISS
Dipl. -Ing. (Architecture)
Weidleplan Consulting
Stuttgart, Fed. Rep. of Germany



Walter Weiss, born 1948, received his degree in architecture at the University of Stuttgart. He specialized in Building Economics and Contract Law and was responsible for a number of research projects in these fields. At Weidleplan, Walter Weiss is Head of the Department for Preparation of Tender Documents and Building Economics.

SUMMARY
This report gives some indications of the definition of quality and quality assurance in tender documents and outlines the different approaches towards this problem in the United Kingdom, Fed. Rep. of Germany and in international tenders.

RESUME
Ce rapport donne un aperçu de la définition de la qualité et de l'assurance de qualité des documents d'appels d'offres et montre les différentes approches en Angleterre, Rep. féd. d'Allemagne et lors d'appels d'offres internationaux.

ZUSAMMENFASSUNG
Dieser Beitrag gibt einen Einblick in die Definition von Qualität und Qualitätssicherung in Ausschreibungsunterlagen und stellt die unterschiedlichen Ansätze in dieser Hinsicht für England, Bundesrep. Deutschland und in internationalen Ausschreibungen dar.

The definition of Quality and Quality Assurance in the construction process is traditionally the professional field of the Architect/designer/Engineer and the Contractor. A well established division of design and construction responsibility therefore results.

Legally, the duties of the Architect and the Contractor with regard to definition of Quality and Quality Assurance are defined in their Contracts and are governed by the relevant system of laws and standards.

1. Contract for Design and Supervision

The Contract between the Owner and the Architect is usually divided into the Design Contract and the Supervision Contract. In the Design Contract, "Quality" is mainly defined by forcing the Architect to prepare his design in accordance with the laws and regulations and to apply the latest codes and standards available.

As laws, regulations and standards only define minimum Quality requirements, it is the Owner's responsibility, in conjunction with the Architect, to establish the actual quality requirements. Quality during the design phase is assured by the Architect's professionalism and a close dialogue between the Owner and the Architect.

In the Supervision Contract, the Architect's/Engineer's role is defined as being the guarantor of a defined quality level and his responsibilities in this respect are usually described in the relevant fee regulations or listed in the Contract.

2. Construction Contracts

The legal document for the construction and erection of a building consists of the tender documents. The tender documents are legally binding for the Contractor with regard to Quality requirements and Quality Assurance.

Tender documents consist of the following:

- Conditions of Contract, which describe the contractual relationships between the Owner and the Contractor, define the role of the Engineer and regulate all administrative matters, such as duties of the various parties, certificates, and payments etc.

- Specifications, which describe all technical aspects of the work and specifically define materials and workmanship.

- Bills of Quantities, which indicate the quantities of the various items required for the proper completion of the work.

- Drawings, which define the visual requirements and indicate layout and appearance.

The following analysis examines the conditions of contract as they are adopted from local authorities in Germany and England, and the internationally applied FIDIC Conditions, with regard to the definition of Quality and Quality Assurance.

2.1 Germany

The standard form of building contract as applied to public works in West-Germany, does not refer to the word "quality" at all, but is limited to the statement "... The general conditions for the execution of Construction Work are

- DIW 1961 - VOB/B, the general technical regulations.
- ATV - VOB/C and any further DIN-standards as referred to in the tender documents, in their latest edition ...."

Also, Part B/VOB defines Quality only in very general terms:
" ... The Contractor has to execute the work under his own responsibility in accordance with the Contract. He has to ollow the recognized rules of technique and note the laws and regulations as issued by the Government and the public authorities."

Even Part C/VOB provides no direct definition of Quality, but lists all those DIN-standards, which describe Qualities.

As an example, DIN 1833 for concrete and reinforced concrete work, refers to 21 further DIN's, which describe Quality Requirements and Quality Assurance procedures. These DIN's refer to further DIN's etc.

As the DIN-standards are a provision of the construction contract, the actual specification writing can concentrate on the specific requirements of the actual job and those requirements which exceed the DIN-standards.

In case of contradictions between the various parts of the tender documents, Specifications in the Bill (Leistungsbeschreibung) will take precedence over Special Conditions of Contract, Technical Instructions for Construction Work and General Conditions of Contract for the execution of Building Work.

The tests which the Contractor has to perform, are again described in the relevant DIN-standards and the Engineer may issue instructions with regard to the removal from the site of any work, material or goods, which are not in accordance with the Contract.

2.2 England

The I.C.T. Standard Form of Building Contract, 1980 Edition, for Local Authorities for Contracts with approximate quantities, generally states in para. 2: "The Contractor shall upon and subject to the conditions, carry out and complete the work as set out in the Contract documents in compliance therewith, using materials and workmanship of the quality and standards therein specified ...." Clause 8 of above Contract then specifies:

"8.1 Materials, goods and workmanship shall so far as procurable, be of the respective kinds and standards described in the Contract Bill".

Contrary to the quoted German conditions, reference is made to the specifications and Bills for Quality and Quality Assurance, and it is the responsibility of the specification writer to properly define the Quality and describe the Quality Assurance procedures.

He will most certainly refer to the relevant B.S. wherever possible, but it shall be noted that there is no automatic link in the Conditions of Contract to standards as under the German system."

The Guarantor for the Quality described is the Architect/Supervising Engineer.

Clause 2.1 states "... provided that where and to the extent that approval of the Quality of materials or of the standards of workmanship is a matter for the opinion of the Architect/Supervising Officer, such Quality and standards shall be to the reasonable satisfaction of the Architect/Supervising Officer. He may, according to Clause 8.4., "issue instructions in regard to the removal from the site of any work, materials or goods, which are not in accordance with this Contract" and, if the Contractor refuses or persistently neglects to comply with the written notice from the Architect/Supervising Officer, require him to remove the defective work or improper materials or goods and by such refusal or neglect, the work is materially affected - thus the work may be terminated by the Employer.

The most significant difference between the German and the English conditions is the precedence of documents in the case of ambiguities: Under the English system, the Articles of Agreement, the Conditions or the Appendix overide all other documents. All other documents are mutually explanatory.

2.3 International

For International Contracts FIDIC (Federation International des Ingenieurs - Conseils), Conditions of Contract for work of Engineering Construction are commonly applied.

It is according to Article 8.1 of these conditions, a general obligation of the Contractor"... subject to the provisions of the Contract and with due care and diligence, execute and maintain the works ...." He "shall take full responsibility for the adequacy, stability and safety of all site operations and methods of construction...," and, described in more detail in Article 36 is "All materials and workmanship shall be of the respective kinds described in the Contract and in accordance with the Engineer's instructions and shall be subject, from time to time, to such tests as the Engineer may direct ...."

Again, as under the English system, no reference is made to a specific system of codes and standards, but it is the responsibility of the specification writer to define the Quality requirements and Quality

Assurance procedures in the specifications. However, FIDIC provides for the Engineer a wider margin for interpretation than forseen in National contracts, whereby, similar to the English contracts, the provisions of the Conditions of Contract Parts I and II shall prevail over those of any other document forming part of the Contract and, subject to the foregoing, the documents forming the Contract are to be taken as mutually explanatory of one another; but in case of ambiguities or discrepancies, the same shall be explained and adjusted by the Engineer".

FIDIC is mainly applied to countries without a tradition in construction work and without specific laws, regulations and standards to cover the construction aspect. Emphasis is therefore placed on the professional role of the Engineer as a guarantor of "Quality." The Engineer's powers in respect to Quality Assurance under FIDIC are much broader than under national conditions of contract, as they are not defined and limited by a well defined legal system, but consequently, this enlarges his professional responsibilities to act as a fair and independent arbitrator between the Owner and the Contractor. He has the power to reject material and order the removal and proper re-execution of any work, which in respect to materials and workmanship is not, in the opinion of the Engineer, in accordance with the Contract.

3. Specification Writing

As Conditions of Contract refer to Quality and Quality Assurance only in very vague terms, it is left up to the specification writer to establish quality levels and specify the materials and methods which shall be used to achieve these levels.

A well defined set of procedures of Specification writing is typically not developed for building construction projects. This matter is left to the discretion of the Architect/Engineer and although he may be guided by industry codes and standards, it is mainly his own judgement and experience which governs the process of specification writing.

In Germany, specification writing is commonly the professional field of the designing Architect, which to some extent guarantees that the intentions with regard to Quality and Quality Assurance are properly described in the specifications, but on the other hand this creates administrative problems as the Architect is sometimes unfamiliar with the legal background routine procedures of specification writing.

In England and America, specification writing is commonly assigned to specialists (Quantity Surveyors/specification writers) with a special training in specification writing, but here the information transfer between the Architect and the specification writer creates problems which often result in incomplete specifications.

To make the process of specification writing more objective, standard phraseologies have been developed both in England and Germany and in Germany it is mandatory to apply them to all public authority construction work. However, due to the nature of building construction work, still a vast number of items still have to be worded on an individual basis.

4. Industry Codes and Standards

Industry codes and standards play an important role for the definition of the desired quality levels. However, industry codes and standards have developed on the basis of the traditional approaches to building construction in the various countries. These approaches have been affected by climatic conditions and availability of local materials. Certain items have no equivalent (e.g. Trass cement is unknown in England). Certain laws and regulations have developed differently (e.g. fire regulations in Germany and the States).

Since the preparation of standards has generally been undertaken by National committees which represent all interested bodies including manufacturers and suppliers, standards generally reflect the current status within a particular section of the industry, and only comparatively recently have attempts been made for the Standards Committees to normalize accepted standards on a European basis.

Thus, standards for basic materials such as cement and steel reflect local manufacturing practice. For instance, comparison of weldable structural steels under DIN 17100 and BS 4360 indicate that of the 14 qualities noted in the DIN and 21 (excluding weathering steels) in the BS, only 5 are directly comparable via the Euronorm 25 Standard.

In the field of fabricated products, the possible diversification is vastly increased. Many BS products are only now being standardized in SI units, and the necessity for repair and maintenance as well as usage, means that imperial or near imperial measure continues to be used.

In structural steel sections for example, a much larger range of sections is listed in the DIN standard and only a very small number of near exact BS equivalents exist.

In principle, the designers work to either DIN, BS, American or other Standards, depending on nationality or training. The use of Codes of Practice relates directly via other National standards to various dimensional, manufacturing and material standards. There is at present, no exact relationship or point of interchangeability. The end result may be very similar, but the component parts will vary in a number of major and minor ways.

Thus, to design to DIN and specify to BS or vice versa, is extremely difficult and may be dangerous because of the interrelationship between the design methods adopted and the standard of material and construction technique employed in the structure.

Obviously, most of the differences are minor and will have little effect on overall structural stability or durability. Nevertheless, they should be taken into account in areas of high stress.

Their major effect is in complicating the construction supervision - both for the Engineer and the Contractor. Overseas sites rarely have extensive libraries of both DIN and BS standards, and there is therefore always a risk that the designer's intentions are misinterpreted on site when mixing the two systems in design and construction.

5. Summary

Conditions of Contract refer to Quality and Quality Assurance only in a minor way and in vague terms. The German conditions automatically link the Contract to the relevant DIN system and thereby guarantee a certain minimum degree of Quality and Quality Assurance. The English conditions with regard to Quality and Quality Assurance refer to the remaining Contract documents and it becomes the responsibility of the specification writer to refer to established industry codes and standards in order to define the desired quality levels. As most of the industrial countries have well defined codes and standards, it is relatively easy to establish such a reference system. Furthermore, the general system of laws and regulations in such countries guarantees a certain quality level - even without such references.

However the existence of Standards by no means guarantees a similar understanding of Quality and Quality Assurance within different European Countries.

FIDIC for International Contracts again refers to the remaining Contract documents for Quality and Quality Assurance. However, most of the countries in which FIDIC is applied have no developed system of regulations of standards. Thus, it is one of the most essential functions of the specifications, to establish a well defined network of descriptions in order to ensure the desired quality levels and procedures of Quality Assurance. If reference is made to codes and standards, these references should be limited to only one system of codes and standards: e.g. DIN <u>or</u> BS <u>or</u> ASTM etc, in order to avoid contradictions and ambiguities.

Both National and International specifications are the primary documents specifying the materials and methods which shall be used to achieve the required quality levels. However, the traditional approach of specification writing relies very much on the individual specification writer's inspection rather than on formal processes for the definition of Quality and Quality control programs.

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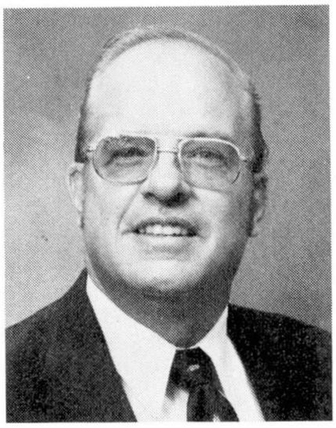
Construction Quality Assurance and Control Practices in the USA

Assurance et conrôle de la qualité dans la construction aux USA

Qualitätssicherung und -Kontrolle in der Baupraxis der USA

Jack H. WILLENBROCK
Prof. of Civil Engineering
Pennsylvania State Univ.
University Park, PA, USA



SUMMARY
An analysis of the construction industry in the United States which compares the Quality Assurance/ Quality Control systems adopted in the Highway, Nuclear Power Plant and U.S.Navy construction areas with the "traditional" quality control approach used in Building Construction is presented in this paper. Each sector of the industry is examined with regard to Background, Planning, Procedures and Organization and Management. This consolidation of existing concepts and practices should provide a direction for establishing an improved conceptual approach to quality assurance.

RESUME
L'industrie conventionnelle de la construction aux Etats-Unis est comparée du point de vue de l'assurance de la qualité et du contrôle de la qualité, avec les domaines de la construction des routes, des centrales nucléaires, et de la marine américaine. Chaque domaine est étudié de façon systématique: base, planification, procédure, relatives à l'assurance et au contrôle de la qualité. L'amélioration des concepts et des méthodes actuels aidera à trouver une meilleure base en vue d'améliorer l'assurance de la qualité.

ZUSAMMENFASSUNG
Die konventionelle Bauindustrie der USA wird in bezug auf Qualitätssicherung und Qualitätskontrolle verglichen mit den Bereichen Autobahnbau, Kernkraftwerkbau und Schiffsbau. Jeder Bereich wird dabei untersucht nach Hintergrund, Planung von Qualitätssicherung und -Kontrolle, Verfahren und Organisation und Management. Die Darstellung bestehender Konzepte und Verfahren soll helfen, einen grundsätzlich besseren Ansatzpunkt für Qualitätssicherung zu finden.

1. QA/QC IN HIGHWAY CONSTRUCTION

1.1 Background

In the early 1970's, a new "statistically based quality assurance/quality control" approach began to emerge on highway construction projects. The variability, as well as the central tendency, of material characteristics were considered. In addition: (1) the contractor or material supplier had to submit a "Process Control Plan" for approval prior to the start of the project, (2) the highway agency was held responsible for Monitoring the contractor's activity and the Final Acceptance of the material and (3) The highway agency was also held responsible for "Quality Assurance" auditing to ensure that the total quality system operated satisfactorily [1].

1.2 QA/QC Planning

State highway agencies carried out extensive testing programs on construction projects to collect sufficient statistical data about selected material properties. A variance analysis (to establish the sources of variability) was performed prior to establishing the tolerances that appear in the highway agency's "Acceptance Plans" and that govern the contractor's "Process Control" activities. Data from these testing programs also influenced the development of the "Adjustment of Bid Price Schedules" which were included in the Acceptance Plans [2].

1.3 QA/QC Procedures

With regard to process control, many contractors graphically document their measurements and test results in a "Statistical Control Chart" format. With regard to the acceptance function, the Acceptance Plan becomes the basis for a decision to accept the inspected "LOT" of material at full price, to accept it at a reduced price, or to reject it.

1.4 QA/QC Organization and Management

The organization and management of highway construction QA/QC is best portrayed as a combined effort. This effort, although managed by the state highway agency, allows the highway contractor complete managerial and organizational flexibility as long as the specification requirements and the process control plan commitments are met.

2. QA/QC IN NUCLEAR CONSTRUCTION [3],[4],[5]

2.1 Background

Public concern for nuclear safety has made quality more important than cost and schedule on nuclear projects. Failure to meet the QA/QC requirements established by the U.S. Nuclear Regulatory Commission (NRC) can result in either very large financial penalties or the denial of an operating license. Quality Assurance on nuclear power plant construction had its formal beginnings with the publication of the 18 Criteria of Appendix B of 10 CFR 50 (CFR = Code of Federal Regulations) in 1969. These criteria, together with the numerous interpretive documents and standards which have since been published, constitute a highly restrictive set of regulatory requirements which govern all quality activities related to a nuclear project. The NRC holds the owner (i.e., the electric utility) responsible for all QA/QC activities. As a result, the owner must develop an extensive QA/QC program for each project. Each firm involved in the project must also develop its own written QA/QC program.

2.2 QA/QC Planning

QA/QC planning in nuclear construction is an activity that occurs throughout the life of a project. The establishment of required quality levels for the various construction materials is not considered to be a QA function, it is viewed as an engineering design responsibility. There is generally no attempt made to perform an extensive testing program to set particular tolerances beyond those which are promulgated in the accepted industry codes and standards of practice.

2.3 QA/QC Procedures

Virtually every aspect of construction must be supported by documentation. Construction Procedures (CP's) prepared by the contractor's construction group represent the first level of documentation. They specify in great detail how a particular construction operation will be performed. The next level of documentation is typically generated by the contractor's QC group in the form of Quality Control Procedures (QCP's). These procedures are based on the commitments defined in the above mentioned Construction Procedures (CP's) and are written to provide the QC inspectors with a guide for judging the acceptability of the construction activities. A third level of documentation is represented by the Quality Assurance Procedures (QAP's). The owner and each contractor maintain their own Quality Assurance organizations. The contractor's QA group is primarily involved in an"auditing" role. The owner's QA group has essentially the same role with the additional responsibilities of overseeing the constructor's QA group and serving as the primary point of contact with the NRC. At any time the NRC may perform random unannounced inspections and audits to verify the total quality system. The extreme influence of a governmental agency such as the NRC has no parallel in other types of construction. Although the NRC does not have a direct contractual relationship with either the owner or the contractor it "controls" the QA/QC phase of each project.

2.4 QA/QC Organization and Management

The concept of organizational freedom for QA/QC personnel is an important aspect of the nuclear programs. On a nuclear project it is required that the QA and QC engineers report directly to their counterparts in the home office, not to the job site construction manager or project manager. This allows the QA/QC personnel to accomplish their tasks without undue cost and schedule pressure from the construction or project manager.

3. QA/QC IN U.S. NAVY CONSTRUCTION

3.1 Background

The U.S. Naval Facilities Engineering Command (NAVFAC) administers all construction work which support Navy ship and shore facilities. Nearly all work is accomplished by civilian contractors. A Navy Contractor Quality Control (CQC) Program was adopted in 1970 because many people felt that contractors were relying too heavily on Navy inspectors for control of quality and workmanship. The basic premise of CQC is that the individual contractor is completely responsible for the quality of his work.

3.2 QA/QC Planning

Contractor Quality Control (CQC) planning in Navy construction begins during the design phase and continues through the bidding and preconstruction phases.

The most significant contractor planning occurs between the time of contract award and the commencement of work. In this period of time the contractor must establish a quality control organization, develop procedures for processing submittals, provide an inspection and testing schedule, and develop documentation procedures. Each of these items, as a minimum, must be included in the mandatory CQC Plan, which must be approved by the Navy prior to commencement of construction. The contractor must designate a CQC representative in his firm who will insure that the CQC plan commitments are properly implemented.

3.3 QA/QC Procedures

QA/QC procedures in the CQC program can be divided into contractor related procedures and government related procedures. A major objective of both is the prevention of defects rather than the discovery of them after they occur. The contractor is responsible for testing and usually hires an independent testing agency that is satisfactory to the Navy. Documentation requirements in the contract stipulate that a daily report be prepared by the contractor. The report documents all quality control activities. Navy procedures govern enforcement, inspection and surveillance. Enforcement involves steps to correct a contractor's problems and deficiencies in carrying out his CQC tasks. Navy Inspection is an independent examination of construction for the purpose of insuring that all work complies with the plans and specifications. Surveillance is defined as "a close watch or observation kept over a contractor's inspection system to ensure that it is functioning properly..." It is accomplished by the assigned Navy inspector. It differs from nuclear QA in that it is not accomplished according to formal procedures. It is highly judgmental, and conducted at the discretion of the inspector.

3.4 QA/QC Organization and Management

The most important member of the contractor's QC organization is the CQC representative on the construction project. It is his duty to execute the "CQC Plan." The requirements state that the CQC representative must not be subordinate to the project superintendent, but rather must report directly to an officer of the firm. This parallels the concept of organizational freedom which is so important to nuclear QA. In addition to authority and organizational freedom, the contract requires that the CQC representative's duties be limited to those which involve quality control. This ensures that this individual gives adequate attention to his QC responsibility.

4. QA/QC IN BULDING CONSTRUCTION

4.1 Background

Building construction is accomplished in the United States for both private as well as public owners under many different types of contractual relationships. The "traditional" QA/QC framework is often established by American Institute of Architect's (AIA) documents. During the preliminary design phase the owner, in conjunction with the architect, establishes the quality, budgeting and time constraints which will govern the project. The attitude of the owner at this point in the process is crucial. If he insists that "time is of the essence" or if the competively bid contract approach is used in order to achieve a minimum cost situation then these factors, rather than QA/QC, will naturally receive the highest priority. The drawings and specifications which the architect develops typically reference industry codes and standards in order to define the desired quality levels of the various phases of the project. The contractor is very rarely required to submit a quality control plan for approval by the architect or owner, perhaps because such a requirement would tend to increase the apparent cost of construction.

4.2 QA/QC Planning

The plans and specifications prepared by the architect, in addition to establishing quality levels and specifying the material and methods which should be used to achieve these levels are the primary planning documents of the QA/QC programs. This traditional approach to QC planning has been criticized because unreasonable, unrealistic, and poorly worded specifications are often used as the frame of reference.

4.3 QA/QC Procedures

A well defined set of procedures for building construction field inspection or quality control are typically not developed for building construction projects. Contracts between Owners and A/E's may specify the frequency of inspections (periodic or continuous), but they usually do not tell the inspector how or what to inspect. These matters are left to the discretion of the inspector, and although he may be guided by industry inspection codes and standards, his own judgment and experience often dictate his procedures.

4.4 QA/QC Organization and Management

Formal QA/QC programs, such as the Highway, Nuclear and Navy examples, do not exist on most Building Construction projects. As a rule, building contractors do not have a separate quality control staff in their project or home office organizations. The project manager and superintendent for a particular job is typically assigned the responsibility for all aspects of project control (cost, schedule, and quality, etc). Also they usually do not establish formal ongoing quality control programs. Project manuals, which provide field personnel with job control procedures covering timekeeping rules,administration of subcontractors, etc., are frequently prepared without ever mentioning anything about QA/QC procedures.

5. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are considered to be of particular importance to the building construction industry:

1. A formal QA/QC system approach holds the greatest promise of achieving the goal of high quality construction because it encompasses an active quality effort over all phases of a project, and it requires the direct involvement of all participating organizations.

2. Implementation of a QA/QC system requires <u>owner commitment</u> prior to the selection of the architect and the construction firm. The owner cannot assume that these organizations will automatically preform QA/QC functions, particularly if each is under pressure to reduce costs and construction time. Specific requirements emphasizing QA/QC responsibilities must be included in the contractual documents.

3. The contractor should be required to develop some type of a "Quality Control Plan" which describes his inspection, testing, documentation and management procedures. The plan should be approved by the owner prior to job site mobilization and should be monitored by the owner during the construction phase.

4. Within their organizations, the contractor or the architect should maintain a <u>Quality Control</u>, and in addition, perhaps a <u>Quality Assurance</u>

group. These groups should have the necessary authority and organizational freedom to effectively perform their responsibilities.

5. The architect should be committed to writing clear and realistic specifications. To be realistic, quality levels should include tolerances based on the natural variability of the material characteristics being considered. The building construction industry should seriously consider the adoption of statistically based price adjustment schedules where appropriate. Such schedules, fairly applied, may provide the proper incentive for a greater QA/QC emphasis.
6. The architect should include in the specifications a description of the quality control and acceptance criteria for each work item. It is essential in a QA/QC system that each participating organization understand, in advance, the responsibilities and activities of all parties.
7. The QA/QC system which is adopted should be consistent with the type of project being built. It is totally inappropriate to directly transfer the QA/QC complexity required on a nuclear power plant project to a more conventional type of building project. Selective adoption of aspects of the system cited above, should, however, improve the level of quality which is currently being achieved.

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