Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 51 (1986)

Rubrik: Session E: Human and organisational aspects

SESSION E

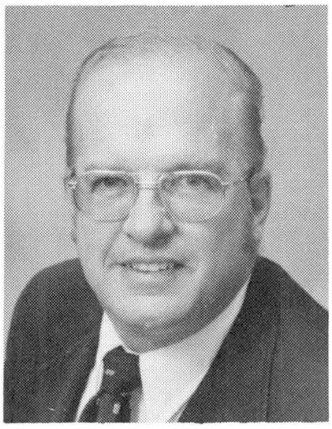
Human and Organisational Aspects

Quality Assurance in the USA and Japan: a Comparison

Assurance de la qualité aux Etats-Unis et au Japon: une comparaison

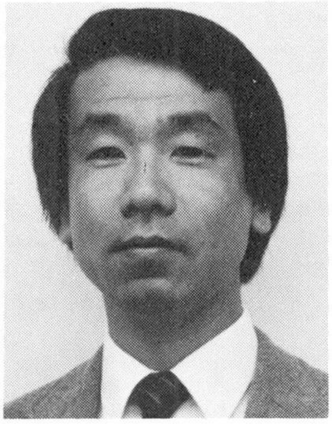
Qualitätssicherung im Bauwesen der USA und Japan: Ein Vergleich

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



Jack Willenbrock, born 1938, received a Ph.D. degree in Civil Engineering at the Pennsylvania State University (P.S.U.). He has taught there for 18 years, currently as Full Professor in charge of the Construction Engineering and Management area.

Takakazu KONISHI
Vice President
Shimizu America Corp.
Tigard, OR, USA



Takakazu Konishi, born 1951, received two degrees from Kyoto University in Japan. Employed by Shimizu Construction Co., Ltd., since 1975. He also obtained a Master of Civil Engineering degree from P.S.U. in 1984.

SUMMARY

This paper begins by defining some of the common concepts related to quality. It then points out the differences between the construction industry environment in the United States and Japan. Research results related to a «Case Study» building construction project illustrate how these differences would influence quality related practices if the same project were built in each country.

RÉSUMÉ

Cette présentation définit quelques concepts communs en rapport avec la qualité. Elle souligne les différences entre l'environnement industriel de la construction aux Etats-Unis et au Japon. Le résultat de ces recherches dans le cas précis d'un projet de construction de bâtiment montre les différences et l'influence des pratiques concernant la qualité, si le même projet devait être exécuté dans les deux pays.

ZUSAMMENFASSUNG

Der Beitrag definiert zunächst einige allgemeine Begriffe aus dem Bereich der Qualitätssicherung. Danach weist er auf die Unterschiede in den Existenzbedingungen der Bauindustrie in den USA und Japan hin. Die am Beispiel eines konkreten Bauobjekts gewonnenen Forschungsergebnisse zeigen, wie diese Unterschiede beim gleichen Bauobjekt die qualitätsorientierten Praktiken in den zwei Ländern beeinflussen würden.

1. INTRODUCTION

1.1 Differing Practices

Achieving and maintaining an owner's satisfaction with the quality of a building during the life cycle phases of design, construction and operation must be one of the primary goals of the construction industry in any country. The specific practices which are adopted to meet that goal will probably differ from country to country because practices are, to a certain extent, culturally dependent. Historical patterns which have developed as the engineering and construction communities have matured and owners have responded to that maturation set the boundaries for local present day practices.

1.2 Common Concepts

It should be recognized, however, that certain fundamental concepts related to quality transcede such constraints and have resulted in some universal commonality. Concepts such as those below are examples [5].

Quality - Fitness for Use - The extent to which the product successfully serves the purposes of the user, during usage, is called 'fitness for use'.

Quality of Design - Quality of design can be regarded as a composite of three separate steps: (1) identification of what constitutes fitness for use to the user, (2) choice of a product or service concept which is responsive to the identified needs of the user, and (3) translation of the chosen product concept into a detailed set of specifications and drawings.

Quality of Conformance - Once the quality of design has been specified, the quality of conformance is expressed as the extent to which the product conforms to the quality of design.

Quality Control - Quality control is defined as the regulatory process through which the actual quality performance is measured and compared with standards, and the resulting actions which are taken to correct the differences which are uncovered.

Quality Assurance - Quality assurance provides the evidence needed to establish confidence that the quality function is being performed adequately. Typically the producer not only produces the product but also prepares and makes available to the customer the proof that the product is fit for use.

Quality of Maintainability - Quality of maintainability consists of two aspects: (1) preventative or scheduled maintenance consisting of tests and checkouts to detect potential failures, and (2) unscheduled maintenance consisting of restoring service in the event of failure.

1.3 United States and Japan

An examination of the construction industries in the United States and Japan indicates remarkedly different environments. Research literature indicates that the construction industry in the United States is widely acknowledged to be dispute prone. In the traditional 3-party mode, the Owner, Architect/Engineer and General Contractor are brought together under fairly explicit contractual arrangements on a project by project basis. Each party often attempts to maximize its own short term goals at the expense of the other parties involved.

Under such a situation, when cost, schedule, quality and safety are among the multiple objectives, the one that can easily be sacrificed if special precautions are not taken is quality. Adding to the complexity of the situation is the orientation of the individual craftsmen on the construction project. Their loyalty, particularly in situations where the work is being performed in a "union" environment, is not with the contractor, it is with their local union hiring hall. They are often temporary employees of a particular contractor, who under the best of conditions, may only be employed by the contractor for the duration of the project. Long range training with regard to the contractor's quality philosophy and practices is difficult under these conditions.

The situation which exists in Japan appears to be markedly different. It has been characterized by parameters such as:

Life-time Employment - Japanese enterprises hire their employees directly after graduation from school and employment generally extends over the entire working life of the employee. They do not expect new employees to obtain special skills while they are students, rather they are willing to provide any training that is necessary for the specific jobs assigned to the employees throughout their employment.

Ranking by Seniority - It has been a tradition of the Japanese society to respect those who are older. It is generally agreed that ability (and contributions) in the company increase with length of service. Under seniority management, even a very able employee cannot be promoted without the adequate number of years of service required to achieve status in the organization.

Long-Range Company Strategy - Life-time employment and seniority are reflected in the long-range perspective of company strategy. Enterprises are judged in terms of long-range rather than short-range success factors. Therefore, firms spend a great deal of money for research.

High Group Spirit of the Work Force - Japanese workers tend to have high self-esteem. Job security is one reason and high group spirit is another. An emphasis on group activities while they are students teaches them to be sensitive to peers and restrain from personal egotism.

Contractual Relationships - It appears that in Japan, construction documents are not necessarily expected to contain nor exert requirements which constrain construction project practices and the interactions of the parties involved. What is most important in Japan is that the parties maintain an amicable relationship. The Japanese tend to settle their differences by negotiation rather than by litigation. In addition, although the legal relationship between an owner and the contractor appears to be equal, the owner traditionally assumes the dominant position. His satisfaction is often the key determining objective when project decisions are made.

2. CASE STUDY

2.1 Comparative Analysis Procedure

Given the above differences it was felt that a comparative analysis of the quality related practices in the two countries would be of interest. Ideally, such an analysis should be performed by individuals who had worked within the construction industry in one of the countries and were then given the opportunity to observe, for an extended period of time, the practices in the other country with an unbiased perspective. The opportunity to implement the beginning phases of such a research project design was created by the presence of Taka Konishi, an experienced construction engineer with the Shimizu Construction Company, in the graduate program in Construction Engineering and Management at The Pennsylvania State University. In order to provide fundamental data for the early stages of the research it was deemed appropriate to assign Mr. Konishi, who at the time, was totally unfamiliar with the construction practices in the United States, to only one project, a $3 million Academic Activities Building located on the University Campus. After his data was collected he was requested to also develop a hypothetical model of how the Shimizu Construction Company, one of Japan's major design/construction firms, would have approached the construction phase of a similar type building if it were built in Japan.

2.2 Case Study Description

Observations were made on the construction site during the period from June to September 1984. The project site consisted of approximately two acres, located on the northeastern portion of the campus. The approximate total area of the building is 50,000 square feet. The structure consists of concrete masonry unit bearing walls with open web steel joists spanned with a steel roof deck and poured floor slabs. The Owner retained an Architect/Engineer who first prepared the plans and specifications and then exercised some degree of inspection, monitoring and controlling during the construction phase. The Owner coordinated the work of separate lump-sum/fixed-price contracts for the (1) general, (2) plumbing, heating, ventilation and air-conditioning, (3) electrical and (4) library equipment work phases. Primary observations were related to the practices of the construction firm that held the general construction contract.

2.3 Case Study Observations

The case study revealed several areas of unsatisfactory performance. These can be summarized as follows:

2.3.1 Quality of Design

A number of mistakes were found on the drawings. This was probably caused by an inadequate formal review system during the design phase. Insufficient coordination of general, structural, mechanical and electrical design occurred because of a lack of specialized staff in these areas in the A/E firm. In addition, over specification occurred in a number of instances and there were difficulties associated with the A/E firm's interpretation of the specifications, perhaps because the structural, mechanical and electric consulting firms that had performed the designs did not have direct contact with either the Owner or the individual Contractors.

2.3.2 Quality of Conformance

The quality of conformance, relied, for the most part, on the abilities of the general contractor's superintendent. As far as the case study is concerned, the superintendent's responsibilities covered almost all items except the very specific technical ones associated with electrical or mechanical work. It is the opinion of the writers that the superintendent did not have sufficient support staff. He carried too much responsibility and was not, therefore, able to implement all of his duties satisfatorally. As a result, although the superintendent had extensive experience in field construction and a relatively good attitude towards the quality of construction, a number of deficient, corner cutting practices were observed. He often placed an uneven emphasis on the quality of the work.

The symptoms of this situation were:

- No updated schedule was used as a framework for controlling the project.
- Little effort was placed on the review of shop drawings. A structural shop drawing, which defined precise building dimensions, was not prepared.

- There was not enough attention paid to the protection of the installed project or stored material from damage.
- No formal quality related educational program to provide motivation of the worker was observed. No formal daily meetings to allow good communication among those involved on the project site were identified.

In addition, within the total project organization on the site, there was no formal procedure for establishing QC/QA tasks and functions and delegating QC/QA responsibility and authority. The respective responsibilities and authority among the A/E, the owner and the contractor were never satisfactorily clarified.

2.3.3 Feedback and Feed-Forward Information System
No satisfactory feedback and feed-forward information system was observed. This is because there was no incentive for each party to establish comprehensive visibility of his work for other parties and because each party tended to protect himself by performing only his work responsibilities, instead of cooperating and prompting open discussion of quality problems. As a result, no formal documentation system of inspection and daily supervision procedures were established. Also no formal feedback system to prevent recurring mistakes on future projects were initiated.

3. JAPANESE ALTERNATIVE

3.1 Total Quality Control Systems

Large Japanese construction firms such as the Shimizu Construction Company have introduced Total Quality Control (TQC) systems in order to improve the QC/QA procedures on building construction projects, as well as throughout the overall company organization. The main purpose of TQC is to secure the satisfactory quality of the project as well as accomplish company-wide cost effectiveness through the implementation of the work. The TQC system of the Shimizu Construction Company has the following four characteristics: (1) the TQC process begins by establishing both the social and individual market needs and ends with a final evaluation by the customers. (2) the TQC system is supported by well-organized documentation to allow each person to visualize his own work assignments and decision-making responsibilities; (3) the TQC is reinforced by quality training, QC circles and the standardization of manuals; and (4) the TQ system is supported by an informational system which utilizes a computerized system to deal with accumulating and developing the feedback information.

The Quality Assurance system, which forms the main framework of the TQC system, is divided into six components. (In the listing below, only a few of the components are defined in detail).

1. Development and Improvement of Technology
2. Design Phase
3. Construction Phase: For the purpose of integrating the overall capability of Shimizu, an "Overall Construction Plan" is developed which describes the entire construction phase and the utilization that will be made of other staff functions. During construction, Quality Control Process Charts, (which divide the work responsibilities and clarify and utilize job sequences) are executed. These activities are monitored and evaluated by pre-construction, intermediate, and construction review conferences, as well as through a final inspection.
4. Maintenance Phase

5. Resolution Activities for Important Quality Problems: In order to prevent the common quality failure in buildings, company-wide research studies and conferences are initiated. The findings from these activities are standardized and published in the supplementary specifications.

6. QC/QA Information System: For the purpose of supporting the development of new technology and preventing recurring mistakes or accidents, the SQIT (Shimizu Quality Information Table) system has been designed as a company-wide QC/QA informational system.

3.2 TQC Application to the Case Study

When the above TQC system requirements were overlayed on the Case Study project, by assuming that the Shimizu Construction Company would build a similar type of project in Japan, it was hypothesized that the following approaches would have been taken:

1. More site engineers would have been assigned (approximately 3 site engineers vs. one superintendent in the case-study) to the project in order to complete it in a shorter time period. In addition, the site office would have been supported by a special staff (mechanical and electrical installation, construction technology, estimation, procurement, cost control, safety and administrative departments) from the main office.

2. A review of the design drawings and documents would have been made by each special staff function, as well as by the project manager and the site engineers. The result of all of these reviews would have been compiled into a "proposal of improvement in design" which would have been submitted to the owner and architect/engineer. Such a proposal would represent the start of a feedback, feed-forward system of communication between all parties involved.

3. An "Overall Construction Plan" would have been prepared by the project manager based upon the design drawings and documents as well as upon upper management policies.

4. A "pre-construction conference" would have been held for all supporting staff as well as the project engineers', in order to verify the "overall construction plan" and to examine the information and know-how which each function possessed.

5. An overall construction schedule divided into quality control, cost control, schedule control and safety control would have been developed. This schedule would then be monitored by the project office and supporting staff who would also make periodic inspections. An "intermediate-construction conference" would also have been held to verify the execution of construction before beginning the work.

6. A "final inspection" and "construction review conference" which would summarize the results of feedback information and know-how in each function would have been held.

7. Daily site office meetings would have been established to assure that all site engineers and foremen involved with site construction received a consensus of the daily and weekly arrangements of work.

8. Morning assemblies would be held daily for all site staff and workers before daily work began.

9. More effort would be devoted to the earth and structural phases. Extensive effort would be expended by the site engineers towards developing shop drawings, related to structural and construction methods

in these phases. The structural shop drawings would become the basis for all other shop drawings.

10. "QC Circles" would be established in order to foster the improvement of the quality of both the end product as well as the process.

4. RECOMMENDATIONS

Although the above research effort only represents the beginning stages of a comparative analysis of contractor Quality Control/Quality Assurance procedures in building construction projects, several interesting recommendations can be made. The impact of these recommendations and the feasibility of implementing them in the United States will of course have to be studied in greater detail.

4.1 Increased Engineering Effort on Project Sites: It appears that more field engineers and support staff are assigned to projects in Japan. It is felt that construction projects in the United States could also benefit from such a staffing strategy. The development of shop drawings as well as construction planning and scheduling is essential for the successful completion of a construction project. Field engineers could assist in such efforts. They could, for instance, review the design to prevent the mistakes of the design phase from being executed by the work force. If field engineers do not assume that any preceding work (i.e., design) is done perfectly, there will be greater cost effectiveness in the whole construction process. It is felt that a single superintendent on a project is physically not able to carry out all of these tasks by himself.

4.2 Good Inter-relationships Between Parties: There seems to be compartmentalization between the Architect/Engineer and the Contractor. The contractor feels that the Arhitect/Engineer has built the structure on paper and it is his responsibility to build in the field. The contractor does not invite any "interference" from the A/E because he feels that the A/E is too theoretical and that he (the contractor) knows more about field related aspects. As a result, this tends to discourage the improvement of QC/QA procedures in construction. The cost effectiveness of cooperation in the construction process to all parties should be emphasized. A more inter-related organizational system must be maintained so that each party can review the other's work in order to prevent mistakes and promote improvement in the quality of construction.

4.3 Training and Motivation: The awareness of the people involved in the construction project in most significant. No matter how well established the QC/QA system is, it will not work if those involved do not know how to operate it. Therefore, educational systems which correspond to the various levels of people involved in the project should be established. It should be emphasized that the conventional misinterpretation of QC/QA procedures must be changed. QC/QA procedures in the construction industry in the United States have generally been limited to testing and inspection. There was little consideration given to the fact that "quality is produced through process". Rather, it was felt that good quality was obtained by rejecting bad results. However, this should not be the final objective of QC/QA procedures in building construction. This concept can be fostered by means of sufficient quality related training and motivation.

REFERENCES

1. ABDUN-NUR, E. A., Product Control and Incentives, Journal of the Construction Division, ASCE, Vol. 92, No. CO3, Sept. 1966.

2. AMERICAN INSTITUTE OF ARCHITECTS, AIA Document A201 General Conditions of the Contract for Construction, 1976.

3. BUSINESS ROUNDTABLE, Modern Management Systems, Report A-6, Construction Industry Cost Effectiveness Project, Nov. 1982.

4. FEIGENBAUM, A. V., Total Quality Control, McGraw-Hill, 1983.

5. JURAN, J. M., Quality Control Handbook, McGraw-Hill, 1974.

6. MIURA, T., Nippon no Kensetsu-Sangyo (Japanese Construction Industry), Shokokusha Publishing Co., Inc., 1977.

7. SHIMIZU CONSTRUCTION COMPANY, QC/QA Program Report, June 1983.

8. SHIMIZU CONSTRUCTION COMPANY, Total Quality Control of Shimizu Construction Company, 1979.

Quality Assurance and Safety in Highway Construction

Sécurité et assurance de la qualité dans la construction autoroutière

Sicherheit und Qualitätssicherung im Autobahnbau

Otto M. VOGLER
Consulting Engineer
Vienna, Austria

Otto M. Vogler, born 1940. Studied civil engineering at HTL-Vienna and the Technical University of Vienna. Received his diploma in 1964. Did scientific work for three years with Prof. F. Leonhardt at the TU Stuttgart. Worked for consulting engineering firms between 1967 and 1970. Has operated his own firm since 1971. Lectures on traffic engineering at the TU Vienna.

SUMMARY

The paper discusses the organisational and human aspects encountered in project management and on-site project supervision. Examples taken from five tunnel projects, with a total length of 6 km, and a highway-construction project (approximate length 30 km) demonstrate how continually changing geological and soil-mechanical conditions can be met in optimum form, in order to produce, with economies, safe and high-quality structures.

RÉSUMÉ

La contribution passe en revue les aspects humains et d'organisation pour la direction du projet et la direction du chantier. Il s'agit d'un tronçon d'autoroute de 30 km de longueur, avec 5 tunnels totalisant 6 km, dans des conditions géologiques et géotechniques diverses. Grâce à une organisation optimale, il a été possible de réaliser un projet sûr, économique et de qualité.

ZUSAMMENFASSUNG

Der Beitrag gibt einen Überblick über organisatorische und menschliche Aspekte der Projektsteuerung und örtlichen Bauaufsicht. Anhand von Beispielen über fünf Tunnel mit zusammen 6 km Länge und einem Autobahnbau von rund 30 km Länge wird gezeigt, wie auf die sich ständig ändernden geologischen und bodenmechanischen Bedingungen in optimaler Form eingegangen wird, um auf wirtschaftliche Weise ein sicheres und qualitativ einwandfreies Bauwerk erstellen zu können.

1. INTRODUCTION

As a rule, highways in Austria are planned and built by the Federal Road Administration. In May 1981, the National Council decided to establish "Autobahnen- und Schnellstrassen-Aktiengesellschaft" (ASAG) to accelerate the construction of priority road-construction projects. ASAG, a private corporation under Austrian law, has a small but highly efficient management staff. Consulting firms were commissioned with planning and supervising operations. ASAG extended a public invitation to interested consulting firms for the responsibilities of Project Management and On-Site Project Supervision (PRÖBA). 65 firms reacted to the invitation. My firm was put in charge of the following project components:

- Südautobahn A 2 across Wechsel Mountain
  total length of road 29.8 km, including more than 40 bridges, construction time 3 years

- Semmering Schnellstrasse S 6 from St. Marein to Oberaich
  total length of road 17 km, including several bridges and approximately 6000 m of tunnels in greatly varying geological conditions.

2. ORGANISATION

It must be borne in mind that extremely difficult geological conditions account for extremely complex terms of reference in project management and on-site project supervision, when including all bridges and tunnels and the structural facilities needed for the Federal Road Administration. It is recommended to resort to a matrix-like organisation, in addition to the linear organisation, just as there are staff and line functions in many industrial and military undertakings.

Project Supervision - Linear Structure		Staff Functions
Federal Minister for Public Works and Technology		professional support for
ASAG	supervisory board	earthworks
	managing board	soil mechanics
	technical management/commercial management	tunnel constructions
	departmental management	bridge constructions
		rock anchoring systems
		testing methods
PRÖBA	business management	concrete technology
	project supervision/ project management	bituminous materials
	project supervision of project sections	quality standards
	director	acceptance procedures
	registered engineer	transfer to maintenance
	engineer	
	engineer's assistant	

Technical support for the construction sites is one of the tasks of a staff function. It is just as necessary to participate in meetings with the owner and the contracting firms, as it is to obtain all required information and to compile and update all documents, regulations, standards and decrees, as well as all relevant literature.

It may well be that one team member has both a staff and a line function, simply because team members vary in their qualifications, regarding specialized knowledge and acceptance from collaborators. When a team member is put in charge of duties that are of special interest to him, he may develop considerable motivating force. On account of his rural origin, an engineer's assistant, for example, who ranks at the bottom of the hierarchical structure, may be able to develop considerable professional knowledge on ecological engineering (e. g. using primarily such plants for landscaping purposes that have a water-draining and slope-stabilizing effect). When discussing the human aspects of organisational structures, we need to emphasize the fact that if a team member is capable of developing authority, regardless of the hierarchical constraints, and, thus, of making a valuable contribution to team performance, this will generate an overall positive impact.

Active Participants in the Construction Process

project control
- owner (client)
- design engineers

on-site project supervision
- contractors (working team consisting of several contracting firms)
- sub-contractors (specialized firms)

The following approach is recommended during construction performance, in particular when complex decisions must be reached under time pressure:

First of all, great care should be taken to involve all parties concerned in constructive cooperation. Each member of the team must have a sufficient understanding of the other members' problems, in order to select the technically meaningful option from a wealth of possible solutions. Good guidance through meetings is conducive to exploiting the potential technical resources of design engineers, consultants and the client's experts, but also of the contractor's staff, particularly of the specialized firms among the sub-contractors. At this stage, all contractual constraints should be disregarded.

Apart from, but in consideration of, the foregoing, all rights and commitments, time schedules, costs and responsibilities must be recorded in contracts. The contractual agreements require the written format and the preparation of all relevant drawings. It should be borne in mind, however, that irrespective of the efforts expended on the performance of a selected project, there is always scope for substituting the chosen approach by a better one.

3. QUALITY CRITERIA FOR ENGINEERING STRUCTURES

In the present context, quality means that a structure should be

a) functional
b) useful
c) safe.

Of course, a structure should also be commensurate with its environment and fit into the surrounding landscape.

In the planning of the structures which are discussed in this paper, it became apparent that they need not conflict with economy criteria. During performance it became evident that ecological engineering was required for many slope stabilizations and that careful re-cultivation of the landscape was indispensible, also for sound technical reasons.

One quality prerequisite consists in that the owner, i.e. the contract-awarding authority, not only specifies all requirements in a catalogue but also that he prepares a suitable in-depth project, where he can advance his opinion on quality in clear technical language. Any adjustment of the project to actual soil-mechanics and geological conditions must also meet a high standard - just like performance planning, since it is obvious that the building performance requires a high quality of planning.

The quality requirements for the building performance are laid down in the building contract and/or in the relevant standards, building regulations and statutes. Proper project supervision will make sure that the requirements are met. Suitability tests, tests during construction, and acceptance tests are the required means to this end. The same holds true for any documentation (of meaningful dimensions), since it helps to demonstrate performance according to contract and serves as reference basis for subsequent maintenance jobs. Unfortunately, the submitted price is the only competitive device used among contractors in most cases. As a result, a contractor's performance will not always come up to quality expectations, for reasons of economy. In doing so, he will incur the risk of price discounts for inadequate quality and contractual fines. In general, however, owners and, subsequently, maintenance authorities are affected more by inferior quality, than they benefit from a price discount for inadequate quality. Any responsible project supervision must therefore apply the necessary foresight in providing all prerequisites at the construction site which preclude such situations.

There are three aspects to safety:

a) The safety of tunnel driving crews and of workers below slopes exposed to slip hazards.

b) The safety of structural measures; this includes not only the prevention of failures of individual building components but also the hazard of above-ground collapses, or the impact of slope creepage or slippage, to which residents in the area are exposed.

c) Due evidence concerning the required safety of the finished structure.

Safety cannot be considered as an isolated quantity, it must always be viewed in the context of costs incurred thereby.

4. SAFETY IN TUNNEL CONSTRUCTIONS

The "New Austrian Tunneling Method" attributes special significance to safety in tunnel constructions. As is known, the resistance is reduced by incorporating the surrounding rock arch into the supporting structure. As a result, deformations are inevitable.

Nowadays road tunnels are built in areas which, a few years ago, would have been considered unsuitable for tunnel driving, on account of geological reasons. A wide range of technical decisions of great bearing, which also involve far-reaching financial implications, must be reached on site and with great expediency; as a rule, work continues 24 hours a day.

The "New Austrian Tunneling Method" is recognized today as being the leading technology in this field. Setbacks are usually suffered on account or bureaucratic obstacles. This means that, in many cases, the advantages of this construction method can be exploited only inadequately: there must be constant adjustment to actually encountered geological conditions, which cannot always be forecast fully, in spite of careful prospecting.

The author refers below to the southern tube of the Tanzenberg Tunnel (open for traffic since June 1985) and the two tubes of the Bruck/St. Ruprecht Tunnel, where construction work is nearing its completion.

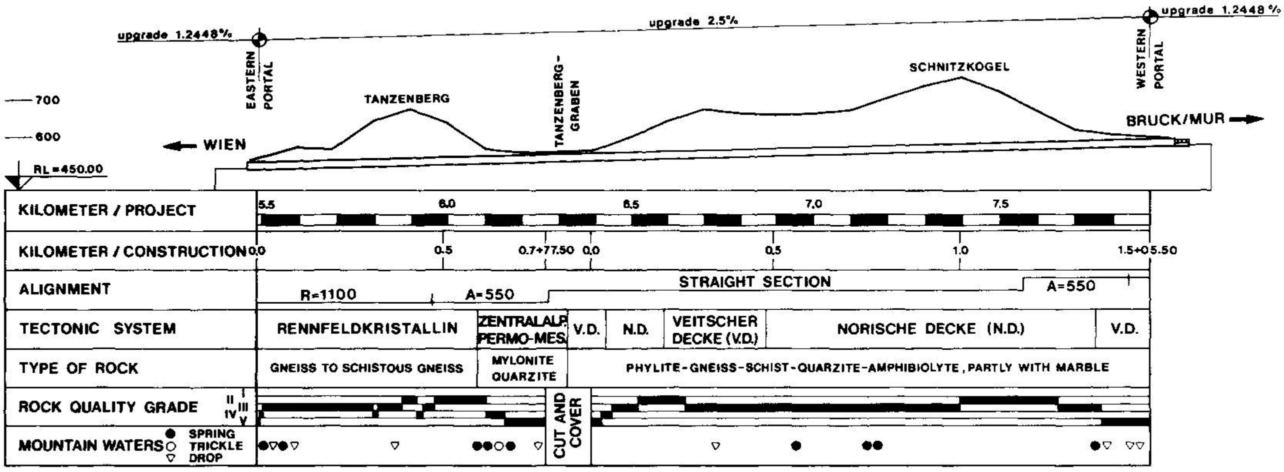


Fig. 1: Tanzenberg Tunnel, Southern Tube - Longitudinal Section

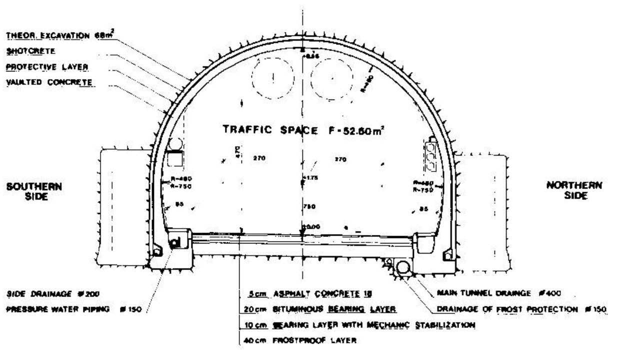


Fig. 2: Tanzenberg Tunnel, Southern Tube Standard Cross-Section with Bays

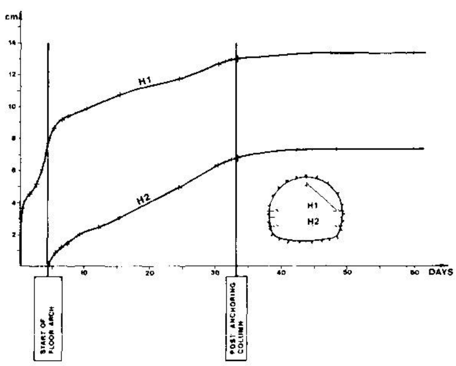


Fig. 3: Bruck Tunnel, Southern Tube Measuring Deformation at Station 750.0

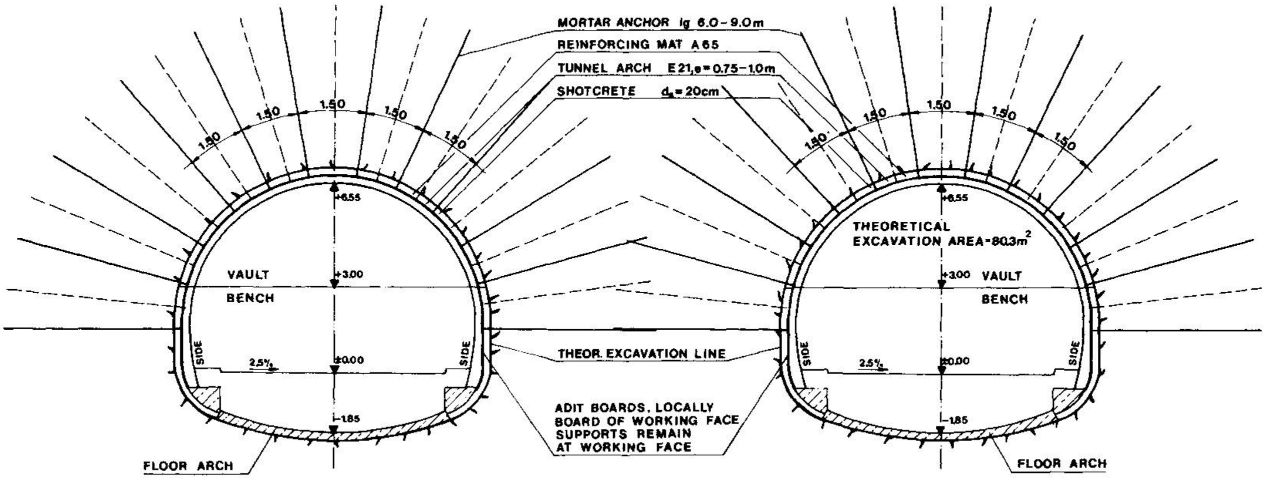


Fig. 4: Bruck Tunnel - Standard Supporting Means in Rock Quality Grade 5

The southern tube of the Tanzenberg Tunnel, driven at a distance of approximately 50 to 80 m from the previously existing northern tube of the Tanzenberg Tunnel, caused no major dificulties. Accordingly, the required rock resistance to finishing operations could be reduced, which, in turn, led to a reduction of costs for excavations and supporting means (shotcrete, reinforcing mats and anchors).

In the two tubes of the Bruck/St. Ruprecht Tunnel, which were advanced at a constant distance of 21.5 m, geological problems of considerable magnitude were encountered, since this tunnel is located close to the slope. The contractors tested deformations at intervals of 10 m, reporting the values continuously to the construction supervisor. Problems with the central column occurred first at station 300.0. Convergences H1 increased rapidly by 23 cm, the heads sank by 28 cm. This means that the central column (of graphite-like black phylite) could not absorb the forces. As a consquence, shotcrete thickness had to be increased to 30 cm, the anchors had to be reinforced with 9-meter pole anchors, and tube-excavation and floor-arch production had to be scheduled in optimum sequence. After consultation with the design engineer, anchors were also applied to the column, in order to increase the supporting effect, as in a girded column. When similar problems were encountered at station 700.0 - this time in heavily sheared black phylite - the same measures were taken. The convergence-value diagram clearly indicates the positive effect produced by the floor arch and the anchors of the central-column.

The following results were obtained at the Bruck Tunnel, regarding supporting means per tunnel meter in rock quality grade 5:

SUPPORTING MEANS	TENDERED VALUE	MEAN VALUE	EXTREME VALUE
shotcrete	4.28 m^3	4.34 m^3	6.46 m^3
reinforcing mat	67.7 kg	96.3 kg	192.7 kg
pole anchor	93.8 m	145.3 m	187.5 m

The two above examples indicate that expenditures have to be incurred in order to obtain the necessary safety standard. They also show that additional expenditures tend to stay within reasonable limits, although individual measures will produce major deviations.

rock quality grade	Tanzenberg Tunnel		Bruck Tunnel/St. Ruprecht Tunnel	
	tender	construction	tender	construction
2	495 m	558 m	0	0
3	1125 m	1318 m	1030 m	0
4	360 m	120 m	1684 m	388 m
5	293 m	287 m	716 m	3305 m
6	0	0	215 m	0
total length	2273 m	2283 m	3645 m	3693 m
costs for excavation and supporting means - mean value	AS 42,249/m	AS 37,883/m	AS 58,656/m	AS 72,787/m
	price basis July 1982		price basis April 1984	
deviation from contract sum	- 4.5 %		+ 7.4 %	

5. SLOPE STABILIZATION

Highway A 2 extends across Wechsel Mountain, which is supported by metamorphous rock series that were produced by physical and chemical transformation of a primary sediment. In an evolution of hundreds of millions of years, pressure, heat and hydro-thermal dissolution have led to the crystallization and scaling of minerals, which did not exist previously. These geological conditions give rise to a range of complex problems: the exposed rock structures could be worked with heavy equipment only; however, it became brittle and decomposed upon relief and access of atmospheric influences. Low-lying gliding layers caused large areas of instabilities in the slopes, which were cut up to levels of 130 m when constructing the highway. Tectonic-disturbance zones (mylonites) of greatly varying thickness can be found in all rock series. They mostly extend over longer stretches, causing a gliding effect in the slope locations. Apart from these natural gliding layers, it was our impression that over long stretches, the exposed rock material tended to revert the metamorphosis, i.e. to transform back into a primary sediment.

Accordingly, slope movement became apparent in many of the cuttings during excavation. In many locations, cracks (width: several decimeters) occurred at a distance of 200 m from the road. In other places, the movement could be detected only with the help of careful slope-indicator measurements. Slope indicators can also be used to determine the depth of the gliding layers and the speed of the gliding movement. In one location, 29,000 m^3 of material moved towards the road level, more or less suddenly, after the slopes had remained in balance for two months and after landscaping had begun.

Altogether, 50 slopes of cuttings were stabilized, 13 of which need continued observation after the construction has been completed, 5 of which at three-month intervals. In the case of one stabilization, it was decided to apply post anchoring.

Observations during cutting, and the measured values, served to produce project drafts, which were discussed at the construction site with all parties involved. The next phase was the implementation of the required extensive engineering projects for slope drainage and stabilization, which included wells, drainages, borings, piles, anchors, soil and rock nails, as well as rock and soil supporting structures.

For economic reasons, global slope-stabilization safety was increased by 5 % only, in most cases, since these measures entailed already considerable expenses. Localized stabilities, of course, were much higher. In particular, anchors (according to ÖNORM B 4455, class II/S2) and piles were built to produce the 1.7 safety factor, required by relevant standards. For technical reasons it would have been impossible to increase global slope stability to such a level!

Fig. 5: Loosened Rock Masses Gliding Off. Height of Slope: 50 m

Fig. 6: Crack Above Slope. Width of Crack: 20 cm, Distance to Road: 70 m

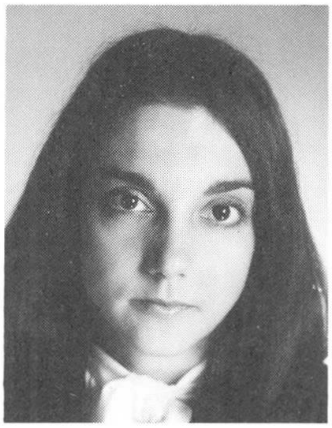
Figure 7 A Rock Mass of 29,000 m^3 Glides Off.

A Study of Construction Safety in Washington State, USA

Etude de la sécurité sur les chantiers dans l'Etat de Washington, Etats-Unis

Eine Studie zur Arbeitssicherheit im Bauwesen des Staates Washington, USA

D. A. REED
Assist. Prof. of Civil Eng.
University of Washington
Seattle, WA, USA



Dorothy Reed earned her Ph. D. degree from Princeton University in 1980. She was a Post-doctoral Research Associate at the National Bureau of Standards before joining the University of Washington in 1983.

Jimmie HINZE
Assoc. Prof. of Civil Eng.
University of Washington
Seattle, WA, USA

Jimmie Hinze received his Ph.D. from Standord University in 1976. For eight years he was associated with the construction program at the University of Missouri. He joined the University of Washington in 1984 as the Construction Engineering and Management Program Director.

SUMMARY
Results obtained from questionnaires received from seventy-five construction firms in Washington State were analyzed. The results of the business and labor survey show that injury-rate is a better measure of safety than experience modification rate and that safe companies are less geographically diverse in their operations, have a high supervisor to employee ratio, have few levels of management and have more work that is not obtained in a competitive environment. The questionnaire used is included in the appendix.

RÉSUMÉ
Les résultats d'une enquête réalisée à l'aide de questionnaires auprès de 75 entreprises de construction dans l'Etat de Washington sont étudiés. Les résultats du contrôle de l'exploitation et du personnel de chantier montre que le facteur «accident» est une meilleure mesure de sécurité que le facteur «modification suite à l'expérience». Les entreprises de construction considérées comme sûres, ont leurs activités moins dispersées du point de vue géographique, ont une proportion cadres-employés supérieure, ont un nombre limité de niveaux de conduite, et obtiennent plus de mandats directement que par appels d'offre. Le questionnaire utilisé est présenté en annexe.

ZUSAMMENFASSUNG
Ein von fünfundsiebzig Baufirmen des Staates Washington beantworteter Fragebogen wurde ausgewertet. Die Resultate der Betriebs- und Arbeitsüberwachung zeigen, dass das Verletzungs-Risiko ein besseres Sicherheitsmass ist als andere gebräuchliche Massstäbe. Die als sicherer zu bezeichnenden Baufirmen sind in ihren Aktivitäten räumlich auf kleinere Regionen beschränkt, haben ein grösseres Leiter-Angestellten-Verhältnis, operieren mit wenigen Führungs-Ebenen und haben mehr direkt erteilte, nicht im Konkurrenzkampf gewonnene Aufträge. Im Anhang befindet sich der verwendete Fragebogen.

Construction-related accidents frequently occur within major metropolitan areas which can clearly be attributed to human error (e.g., 1). It has been shown that the construction industry, which may employ five percent of the industrial workforce in the United States, accounts for approximately twenty percent of the total number of industrial fatalities. This situation has created concern within the industry. Although it has been shown through case studies that management style, the education and awareness of workers, foreman-worker relationships, organization size, etc., of a construction firm significantly affect its safety performance (e.g., 2-5), the degree to which these factors in relation to other factors beyond the control of the firm, such as the financial, social and political climate of the locality and country, contribute to the number, rate and severity of accidents is not known. In addition, the inherent risk-taking nature of the industry cannot be ignored. At the present time, the major strategy for reducing the number of accidents at a construction site is to implement a safety awareness program. The long-term goal of providing a uniform level of safety at construction sites is a much more difficult task.

It appears that major efforts may be required to reduce the number of injuries within the construction industry. Such efforts can be successful only if worker safety is better understood. Of the many factors mentioned above which affect injury occurrence, preliminary research suggests that the nature of the organization in which the workers are employed may be one of the most influential on safety performance. At the present time, however, a body of knowledge does not exist which describes the environment that a company should provide its workers for optimal safety performance. If such information were known, corporate changes might be made to reduce losses caused by job injuries.

Because of the high costs associated with construction injuries and the human suffering that invariably accompanies their occurrences, a study of construction safety has been undertaken at the University of Washington. The specific focus of the study is to develop a model profile of a construction firm with an outstanding safety record. Data have been obtained through questionnaires sent to firms located in the state of Washington. A copy of the questionnaire appears in the appendix. Of 200 firms contacted (obtained from the 1985 listing of the Associated General Contractors), 75 responses were received and analyzed. The average annual volume of the respondent firms ranged from $10,000 to $350 million.

As can be seen from the questionnaire, each firm was asked to provide information concerning organizational structure, volume of work undertaken, number of employees, levels of management, percentage of volume that is public construction, geographic dispersion of the firm's operations, percentage of work that is subcontracted, number of projects undertaken per year, employee turnover rates, employee benefit offerings, age of the firm, job injury history, etc.

The data were analyzed by means of the Kendall Correlation Coefficient (6). This coefficient provides a general measure of correlation -either negative or positive- with an associated level of significance, p. A correlation for which the value of p is less than 5% is considered significant. In a preliminary study, correlations for which a value of p is less than 10% is considered important as they may be indicators of a trend or represent a tendency of significance. For the firms considered, two measures of safety were examined: injury-rate and the insurance experience modification rate (EMR). The EMR has been used extensively by the Stanford Construction Institute (e.g., 5). The process for calculating it is quite complicated and will not be examined. However, it is noted that it is used as a multiplier for manual insurance rates established at the state level for each work class or category. For example, an EMR of 55% would be used to multiply the manual insurance rate by 55% and effectively reduce the premium paid whereas an EMR of 105% would increase a company's premium above the manual rate by 5%. Although it would appear logical that injury rates and the EMR are related, the results of the present study do not show a statistically significant correlation between the injury-rate and the EMR. In fact, the results do not appear to even suggest a trend. In addition, while injury-rate was correlated with nineteen of the variables examined in the study, out of approximately thirty which were considered, the EMR was only correlated with two. These preliminary results suggest that the EMR is not an appropriate measure of safety. This result is not surprising when it is taken into consideration that EMRs are determined on the basis of three year averages and that a one year lag time exists before the newly-calculated EMR is used. In terms of the EMR, the effect of a current injury would not affect a contractor for two years. Since the EMR's of firms appear to be unreliable indicators of current safety performance, further analysis utilized only the injury rate information to represent safety performance.

The injury-rate was found to be negatively correlated with the following elements : percent of work within 50 miles of the firm's home office ($p < 0.001$) and supervisor to worker ratio ($p < 0.001$). The latter result would mean that firms with fewer workers per foreman have better safety performance. A positive correlation was found with the following elements: the number of average, peak and winter workers ($p < 0.001$ for all three); the number of W-2 forms filed ($p < 0.001$); the number layers of management ($p < 0.001$); the age of the firm ($p = 0.015$); the ratio of public to private work ($p < 0.02$); the number of WISHA (state administered OSHA program) fines successfully contested ($p < 0.06$); and the number of bidders on most projects ($p < 0.10$). Of these elements, previous results which are corroborated are : the correlation of injury-rate with the number of workers and work performed within 50 miles. In addition, Levitt (5) has shown that safer firms contest more fines and citations than do less safe firms. This result appears to be confirmed. It appears that injury-rates are higher for larger firms, as many of the aforementioned factors which were positively correlated with injury-rate are measures of size. Hinze has shown that the size of the firm in annual dollar volume is correlated with the injury-rate (3).

From these findings, several conclusions can be drawn. Indications are that the owner/designer can influence the safety performance in the construction stage. This could be done in the selection process by using an effective measure of safety performance. Research indicates that this measure should be the recent history of injury-rates as opposed to the EMR. In addition, negotiated contracts appear to result in fewer job injuries. Thus, negotiated contracts, which often result in lower pressure cost-plus arrangements, may have merit where worker safety is a particular concern.

Recommendations to increase worker safety for contractors include: (1) establish acceptable ratios of workers per supervisor; (2) maintain good project control exemplified by a shallow hierarchy in the company; and (3) avoid geographic dispersion. High incidences of injuries were noted in those firms that were larger and in those which were more geographically diverse in their operations. Indications are that the impact of these influences could be reduced by the firm. One possible means of accomplishing this may be by decentralization of company operations. This would be true for the large firms as well as for those firms that are geographically diverse in their operations.

REFERENCES

1. "Crane Falls 25 Floors," The Seattle Times-Post-Intelligence, April 21, 1985.

2. HINZE, J.W. and C. HARRISON, "Safety Programs in Large Construction," J. Construction Div., ASCE, vol. 107, No. CO3, Sept., 1981, pp. 455-467.

3. HINZE, J.W., "Characteristics of Utility Construction Firms and Their Relationship to Job Safety," The National Utility Contractor Magazine.

4. HINZE, J.W., "The Effect of Middle Management on Safety in Construction," Research Report, The construction Institute, Department of Civil Engineering, Stanford University, No. 209, June, 1976.

5. LEVITT, R.E., "The Effect of Top Management on Safety in Construction," Research Report, The Construction Institute, Dept. of Civil Engineering, Stanford University, No. 196, July, 1975.

6. GORDON, J., et al., Industrial Safety and Statistics: A Re-Examination, New York, Praeger Publishers, 1971.

APPENDIX: Questionnaire

CONSTRUCTION COMPANY
LABOR AND BUSINESS SURVEY

1. What is the general nature of type of work done by the company?

Check all that apply:

___ highway-heavy
___ utility construction
___ industrial construction
___ other:___________________
___ residential
___ small commercial
___ maintenance

2. What is the size of the company:

Average annual volume of work under contract? $_____________________

Number of salaried employees in the firm? _____________________

Number of hourly workers in the firm (average)? _____________________

Number of hourly workers at the season peak? _____________________

Number of W-2's completed by the firm per year? _____________________

Number of permanent field supervisory personnel in the firm? _________

3. What amount was spent on labor in the past year? _____________________

What percent of the contracted volume is consumed by the cost of labor? _____________%

Approximately how many man-hours were worked by company employees last year? _________________ man-hours

4. What percent of the company's work is subcontracted? _______________%

5. Which of the following best describes your firm? (Check all that apply)

___ union shop
___ general contractor
___ merit shop
___ specialty contractor

6. What percent of the company's work is done within 50 miles of the home office? ____________%

7. What percent of the company's work is competitively bid? ____%

8. What percent of the company's work is done for public owners (as opposed to private)? __________% is for public owners

9. How many layers of management are between the workers and the president of the company?

__0 __1 __2 __3 __4 __5 __6

10. Approximately how many different projects are completed each year?
__________ projects

11. What is the average length of time needed to complete a typical project?
_____ months or _____ weeks

12. How long has the firm been in business? _____ years

13. How many worker injuries requiring a doctor's attention occurred last year? ______

14. What is the average number of bidders on most jobs on which the company submits bids? ______

15. Does the company have a full-time labor-relations officer?
____ yes ____ no

16. Does the company have a full-time safety officer?
_____ yes ____ no

17. What percent of the field personnel have had some type of formalized training in first aid? ______%

18. If known, what is the insurance experience modification rating for the company? ________

19. In the last five years, how many WISHA jobsite inspections has the company had? ______

    Of these, how many resulted in fines? _______

    Has the company successfully contested any fines? _____ yes ____ no

ACKNOWLEDGEMENTS

The authors would like to thank David Maxwell, Graduate Research Assistant, for his assistance conducting the statistical analysis.

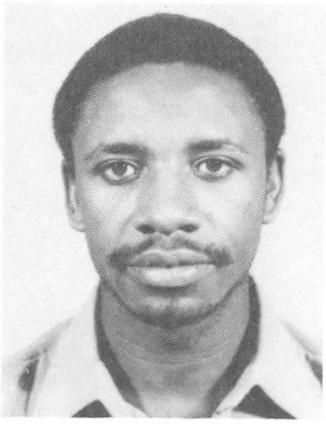
Problems of Safety and Quality Assurance in the Third World

Problèmes de sécurité et d'assurance de la qualité dans le tiers monde

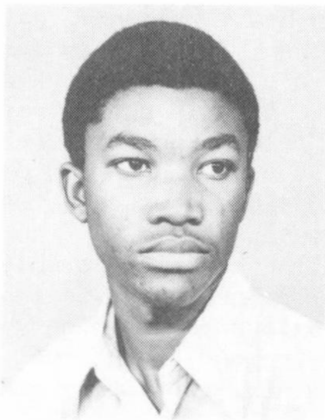
Sicherheits- und Qualitätssicherungs-Probleme in der dritten Welt

Primus V. MTENGA
Assist. Lecturer
University of Dar es Salaam
Dar es Salaam, Tanzania

Mohamed S. KASEKO
Assist. Lecturer
University of Dar es Salaam
Dar es Salaam, Tanzania



Primus Mtenga, born 1953, received his B.Sc. (Eng.) at the Univ. of Dar es Salaam and M.Sc. in civil engineering at the Univ. of Wisconsin Madison, USA. Besides teaching and research, Mr. Mtenga is involved in Consultancy activities including evaluation of structural performance and failures.



Mohamed Kaseko, born 1953, received his B.Sc. (Eng.) at the Univ. of Dar es Salaam and M.Sc. in civil engineering at Cornell Univ. Ithaca, NY, USA. Besides teaching and research Mr. Kaseko is involved in Consultancy activities in various civil engineering disciplines.

SUMMARY

Decisions and actions affecting the safety and quality of civil engineering structures depend highly on the skill, experience and attitudes of the individuals involved during design, construction and operation of the structures. This paper intends to look at how the level of development and organisation of the civil engineering profession in Third World countries influence these human and other organisational aspects which cause safety and quality assurance problems in these countries. Recommendations on how the situation could be improved are also put forward.

RÉSUMÉ

Les décisions et les actions qui ont une influence sur la sécurité des personnes et la qualité des ouvrages, dépendent pour une large mesure des capacités, de l'expérience et de l'attitude des personnes concernées lors du projet, de la construction et de l'exploitation des structures. La contribution présente le niveau de développement et l'organisation de la profession d'ingénieur civil dans les pays du tiers monde et l'influence de celle-ci sur les aspects humains et d'organisation, lesquels ont une influence directe sur la sécurité et l'assurance de la qualité dans ces pays. Des recommandations sont présentées sur les possibilités d'améliorer cette situation.

ZUSAMMENFASSUNG

Entscheidungen und Handlungen, welche die Sicherheit von Menschen und die Qualität von Bauwerken beeinflussen, hängen in hohem Masse von den Fähigkeiten, der Erfahrung und der Einstellung der beim Entwurf, bei der Ausführung und der Nutzung von Bauwerken beteiligten Fachleute ab. Im folgenden Bericht wird gezeigt, wie der Stand der Entwicklung und die Organisation des Bauwesens in Drittweltländern menschliche und organisatorische Aspekte beeinflusst, die ihrerseits Sicherheits- und Qualitätssicherungs-Probleme verursachen. Zuletzt werden Empfehlungen zur Verbesserung dieser Situation gegeben.

INTRODUCTION

The design, construction and maintenance of any civil engineering structure is normally closely guided by standards, generally referred to as "codes of practice" which, if adhered to,are supposed to safeguard agreed safety and quality levels for these structures at "reasonable" costs. Assuming that the standards adopted are optimal, any attempt to increase the safety and/or quality level of a structure would cost more than the additional benefits, while any attempt to reduce the cost of the structure would result in a disproportionately big reduction in the safety and/or quality levels of the structure. This trade-off between cost and safety and quality of a structure is dependent on not only the level of knowledge and experience of the individuals involved but also the environment they train in, practice in and live in which shapes their attitudes and professional conduct. This trade-off is done consiously or unconsiously at different stages in the conception, design and construction of the structure and by various individuals at various levels of organisation.

Thus, decisions that do affect the safety and quality of civil engineering (CE)structures have quite a heavy reliance on the human qualities (attitudes) and organisational aspects of the CE profession which in turn depend on the level of development of the industry in a given society. A study of structural failures in various parts of the world[2] have clearly shown that these human and organisational aspects play a very significant role in the failures. It is therefore,the objective of this paper to look at how the special human and organisational aspects existing in the Third World countries cause problems in safety and quality assurance of structures in the CE industry in these countries. In the paper, we will look at how the following factors do have an influence on the problem:

- shortage of well trained and experienced personnel at all levels;
- non-existent or existance of infant and inexperienced professional bodies for guidance of the development of the industry and profession;
- financial constraints, for capital and maintenance investment and for training of personnel;
- low level of development of the supporting industry, e.g. building materials industry, transportation, etc.

In the following chapters, we will first present a discuasion on the general level of development of the CE profession in a typical Third World country, and later on discuss on how the factors listed above interact to contribute to the problems of safety and quality assurance of CE structures in these countries.A few examples will be presented to illustrate these problems. But, it must be appreciated that such examples are going to have quite scanty details, since availability and access to information on structural failures in Third World countries is quite difficult due to the fact that such information is hardly kept and if available is normally highly confidential. The discussion and examples in the paper will be heavily biased towards the Tanzanian experience, which we strongly believe to be characteristic of a typical Third World country.

The paper will be concluded by presentation and discussion of our recommendations for possible improvement or rectification of the situation.

2. LEVEL OF DEVELOPMENT OF THE CE PROFESSION

In most parts of the Third World, engineering education, especially at college level is quite young and a fairly recent development. For example, in Africa, South of the Sahara (excluding South Africa), the first engineering school was started in 1938 at the University of Kumasi in Ghana. Most other countries established their schools or colleges after attaining political independence. Tanzania's only engineering school was established in 1973 at the University of Dar es Salaam with capacity to produce about only 60 graduate civil engineers per year. Thus, the CE industry in quite a number of these countries is largely dominated by foreigners and a few foreign-trained nationals.The situation is improving at a fairly slow rate. Tanzania,for example has an estimated 3000 engineers only, for all disciplines, for a country of more than 20 million people [6].

Besides this formal education, practical training, i.e. the period during which a graduate engineer works under close supervision of an experienced engineer ,is very important in the making of a competent engineer. But because of the scarcity of engineers, this aspect of training is skipped and it has been and still is to a lesser extent very common in Tanzania to find a fresh graduate being assigned to a top-most position in an organisation or a project straight after school. According to a survey conducted in Tanzania by the Institution of Engineers Tanzania [7] very few organisations or firms have training programs for fresh graduate engineers.This obviously causes problems, since you have a situation whereby inexperienced engineers are occupying critical decision making positions.

Yet another common feature in the CE profession in Third World countries is the adoption of foreign standards and codes of practice and lack of adequate building regulations. In Tanzania, for example, British standards are being used directly without proper modifications to account for the local prevailing conditions, like the differences in the levels of site supervision, workmanship as well as the level of quality control both on site and in industries producing the various building materials, let alone the different environment, culture and behaviour.

Worse still, professional bodies as well as building authorities which could act as watch-dogs and guide the development of the profession, both in performance and training, are either non-existent or are too young and still exist in a fairly ineffective form. In Tanzania, for example, the only professional engineering body,the Institution of Engineers Tanzania (IET), was established only in 1977, after the break of the East Africa Institution of Engineers.

Such is the level of development of the CE profession in a typical Third World country. Obviously, the attitudes and performance of all those involved in the CE profession in these countries are greatly influenced by these factors. Their effect on safety and quality assurance of CE structures will be discussed next.

3. DISCUSSION OF IMPORTANT ISSUES AND PROBLEMS

3.1 The role of Building Authorities

One of the key players in the enforcement of safety and quality standards for CE structures are the area building authorities who are normaly represented by city or town engineer(s). They are legally empowered to check and approve designs and construction of all CE structures. Third World cities are known to have very high gro-growth rates resulting in very high pressure on housing needs. This together with the fact that there is an ever increasing need for office accommodation and industrial facilities, puts very high pressure on the construction industry. The resulting construction activities by far outweigh the capacity of the poorly staffed and improperly organised building authorities. This leads to a situation where several civil engineering structures are being constructed without or with extremely poor follow up from the building authorities. Even building permits are issued without proper checking of all the aspects of the structure regarding land use, structural safety and health (sanitary) requirements fully analysed.

3.2 Quality Control

Another factor that greatly affects the quality and safety of civil engineering structures is quality control. In this respect reference is made to quality control of various building materials involved in these structures. One of the main problems in this area is the in-adequecy of testing facilities and qualified personnel to run them. In Tanzania, for example, there are only three known laboratories for testing various building materials. Moreover they are all located in Dar es Salaam! This makes testing for upcountry sites, some of them more than 1,000 km from Dar es

Salaam, and with poor transport facilities, very expensive and impractical as far as time is concerned. As such almost all upcountry constructions proceed without proper quality control.

It should be noted that this question of quality control is even more important in the Third World countries because even the quality of some inputs like cement, re-bars etc.,is quite unreliable. This means that to expect the desired quality and safety of a structure by simply adhering to what the code of practice says may be disastrous, unless the designer had taken the uncertainity factor in his/her design, say by deliberately overdesigning. In fact some consulting firms do overdesign in trying to compensate for the above problem.

Another problem as far as quality control is concerned is the fact that some decision makers at the sites do not fully appreciate the importance of quality control. In this aspect you find even the client or a representative of the client not very particular about it. As a result, you find even in major projects , some involving big international companies, the contractor may be free to choose whether or not to carry out specified quality control measures.This may set not very good examples to the growing local firms.

3.3 Non-adherence to Professional Ethics

Like in all other professions engineers and contractors are supposed to adhere to some code of conduct for the betterment of the profession. While the engineer is required to supervise the project during construction on behalf of and in best interest of the client, the contractor is supposed to adhere to the design specifications in order to uphold the safety and quality of the structure as per design. In some Third World cases these responsibilities are deliberately not adhered to either by the resident engineer,consultant or contractor or all may collude to cheat the client. For example in some public projects, the representative of the client, either for self-interest (economical or otherwise) or lack of commitment, may ignore recommendations put forward by the engineer and may tend to be working in the interest of the contractor e.g. keeping a blind eye when the contractor deviates from specifications without engineer's approval, at the expense of quality and/or safety of the structure.

Another problem in this aspect is contractor cheating by some unscrupulous contractors,who try to take advantage of the prevailing situation. They may, for example, violate specifications in order to save material. An example in this case is a situation where a contractor was discovered to have constructed a highly defective residential building by providing only 120 mm thick slab instead of 150 mm and 270 mm deep beams instead of 450 mm as specified in the design.

This behaviour together with the fact that there is no proper quality control leads to a serious problem. This is further complicated by the fact that there may exist no clear legal provisions specifically governing the conduct of engineers as is the case for Tanzania [4].

3.4 Incompetence

Shortage of well trained manpower, as well as lack of appropriate equipment and machinery are the main factors resulting in poor performance for both engineers and contractors. One interesting case in this regard is a recent event in Dar es Salaam in which a huge industrial building was saved from total collapse at the last minute. The building consisted of reinforced concrete portal frames to stand on pad footings three metres below floor level, and a boiler whose foundation was to be about twelve metres below floor level and within two metres of the outside walls. During construction, the contractor chose to start with the the erection of portal frames and when he later started excavating for the boiler foundation , he had reached a depth of about six metres below floor level when, as would be expected, the unprotected pit started to show signs of collapsing. If it were'nt for an experienced consultant who was called in urgently to recommend remedial measures, the entire structure would have collapsed. It should be pointed out that this project was the biggest for both the contractor and consultant,and apparently both firms did not have well qualified engineers.

Another case in point, is a bridge project in Tanzania. Here, the Tanzania Government had to expel the main contractor from the site allegely for "non-performance". At the time of expulsion, the contractor was almost 9 months behind schedule and had failed to carry-out recommended remedial measures after heavy floods had caused the collapse of 14 bridge poles and badly damaged two others [1]. This is certainly another case of an incompetent contractor.

One could go on and on giving these examples. The point is, there are many other projects being handled by incompetent contractors and/or engineers that go unnoticed but whose safety and quality leave much to be desired.

3.5 Safety on Site during construction

In most Third World countries construction work is mainly labour intensive with a minimum of the essential machinery. Hence the safety of workers on site is quite important. But, according to a survey conducted in Dar es Salaam [9] in 1984,safety conciousness among contractors, supervisors and workers on site is very low,and not much efforts have been made to safeguard the workers on construction sites. It appears that even the ministry responsible for industrial safety has no standard guidelines for safety measures on these sites [9]. Even basic items like crash-helmets, gloves and boots for the workers are often never supplied . In a number of cases you find casual labourers going around on site barefooted, carrying on their naked heads broken "karais" full of concrete and balancing them with bare hands!!. Even hot bitumen may be sprayed by workers who are bare-handed and without proper gum-boots.

Major site accidents reported in Dar es Salaam in the period 1980-84 are summarised in Table 1. In the table, traffic accidents include people injured or killed on their way to or from site on dump-trucks (not permitted to carry passengers).People falling from temporary structures included those falling from scafolds,working platforms and defective ladders. Most of these type of accidents could have been avoided if checking of the temporary structures by qualified people were performed.

Falling from permanent structures were mainly from areas designed to have hand rails or gates but at the particular stage of construction were not yet in place and no temporary fancing were provided. In other cases falling resulted from using poor quality or wrong tools. Falling of materials was found to be primarily due to overloading of cranes and lack of proper maintenance of machinery.

Table 1: Analysis of 212 Major Site Accidents [9]

	Traffic Accidents	Fall of persons		Fall of Materials	Nature of Injuries			
		From temporary structures	From permanent structures		hand/ arm	Legs/ feet	Head	Others
No of accidents	28	24	23	67	83	59	15	55
%-ge of total	13%	11%	11%	32%	39%	28%	7%	26%

Thus, a look at the table suggests that absence of safety equipment like helmets , gloves and boots is one of the major causes of lack of site safety. We can generally conclude that the major cause of site accidents is the ignorance, careless - ness and the contractors' attempt to cut costs at the expence of the safety of his workers.

3.6 Inadequate Maintenance

Another major cause of problems of safety and quality assurance of CE structures in the Third World countries is poor or absence of maintenance. In Tanzania, for example, pot-holes are a common feature on highways. Even relatively cheap maintenance activities like ditch and culvert clearing are often never done. As a result an increasing number of highways are becoming very unsafe due to the sometimes half-hazard manner in which traffic has to move to dodge potholes and other defects on the roads. Why is all this happening despite the existance of special maintenance departments in various organisations ? The following factors may help highlight some of the causes of these problems.

3.6.1 Lack of maintenance awareness.

Quite a good number of decision makers, especially those responsible for allocation of funds, are not technically trained and/or do not seem to appreciate the importance and magnitude of the maintenance problem. They are more willing to issue funds for new projects rather than for maintenance of existing structures, i.e. they much more readily respond to the need for "increased quantity" as opposed to maintenance of "existing quality". Budgetary allocation of funds for developmental and recurrent projects clearly display this phenomenon [8].

3.6.2 Lack of well qualified maintenance personnel.

There seems to be a general attitude among young engineering graduates and even some top decision makers in the Third World countries that an engineer's job is to design and/or construct only. Maintenance is looked upon as a job for the less technically qualified people since, they claim, it is not "technically challenging". As a result, many well qualified people are not keen to join maintenance departments and the few who are already there are generally not enthusiastic with their jobs. This could be partly due to university curricular, which does not generally stress on the importance and techniques of good maintenance management, but mainly due to the general shortage of qualified personnel. The situation is made worse by lack of incentives which would reward for good maintenance work done and punish for poor maintenance work.

3.6.3 Influence of Foreign designs.

Quite often, foreign consultants have come up with designs for structures, which, after construction, have posed a lot of maintenance, and hence, operational problems due to heavy reliance on imported machinery, equipment, spare parts and sometimes even personnel!

Many examples do exist in this category. One of them, in Tanzania, is an infamous railway level crossing, between a 3-track rail-line and a major 4-lane highway in the capital city. The crossing was designed to operate with an automatic alarm system in combination with traffic lights, but just a year after openning the automatic alarm system went out of order and the crossing has since claimed a lot accidents, causing loss of lives and property. The authorities have failed to repair the system apparently for lack of spare parts which have to be imported. A look at other automatic alarm systems in the city had already indicated the unreliability of these systems in Dar es Salaam. A strong metal-gate operated manually (since the train frequency is fairly low) to block the way could have been a better solution at may be the same cost.

This clearly spells out the need for foreign designers to study in their projects maintenance feasibility of the designed structures.

4. RECOMMENDATIONS

4.1 Manpower Training

- While at college the engineer to be must be thoroughly educated on the importance of keeping to professional ethics as well as the importance of maintenance.
- Practical training for graduate engineers should be given more emphasis. Efforts to establish training procedures, as is currently been tried in Tanzania [7] , should be encouraged with machinery to enforce its implementation.

4.2 Monitoring of Performance.

- Professional bodies should be strengthened to provide a more effective media for sharing experiences and as a body to advise governments on how to improve the performance of the profession.
- The authorities concerned with the development of the construction industry should try their best to acquire more testing facilities and locate them in a geographically balanced manner.
- Supporting industries should try to have better quality control during the production of the inputs to the construction industry.
- Clients must be educated on the importance of making sure that contractors , do follow existing building regulations and quality control procedures.
- There should be incentives that reward for good performance while costly mistakes which are proved to be deliberate actions are heavily punished by say the withdrawal of registration.
- There should be a thorough check, by competent bodies, on both credentials and ability of engineers reported to be working for any engineering company just before its registration, and from time to time on the availability of those engineers to that particular company.
- Analysis of structural failures and site accidents should be well documented and made available to the profession to do away with possible repetitions of mistakes.

4.3 Maintenance.

- Efforts should be made to quantify the benefits aquired from the maintenance of civil engineering structures. This will place maintenance activities at a competitive footing with new projects when it comes to the allocation of funds.
- To improve efficiency governments could employ private contractors to avoid current inefficiencies known to exist in the in-house maintenance crews.
- To check on the suitability of projects designed by foreign firms, there should be a machinery for ensuring, among other things, the maintenability of the structure under prevailing Third World conditions.

4.4 Others

- The government ministry responsible for industrial safety should set safety regulations on site and establish procedures and machinery to enforce them.
- Before the use of any foreign code in a Third World country, a critical review should be made to ensure that it complies with the prevailing level of development of the CE industry.

REFERENCES

1. Barozi, F., Gamba, A.R.M., Mariki, D.J., and Urio, H.G. "Kirumi Bridge Project - a Case Study". Presented at Annual Seminar of the Institution of Engineers Tanzania held at Arusha on Feb. 17 - 18, 1986.

2. Blockley, D.I. "The nature of Structural Design and Safety". Published by Ellis Horwood Ltd., 1980.

3. Jones, S.H. "Dar es Salaam Sewarage and Sanitation Project" Presented at the Annual Seminar of the Institution of Engineers Tanzania held at Arusha on Feb. 11 - 12, 1985.

4. Kimambo, I.N., "The Need for Consulting Engineering Policies in Tanzania". Presented at a (Tanzania) National Construction Council Seminar held at Arusha on Aug. 22 - 24, 1983.

5. Kimambo, I. N., Ndiwaita, L., and Munyagi, M.B., "Dar es Salaam International Airport Project - a Case Study". Presented at the Annual Seminar of the Institution of Engineers Tanzania held at Arusha on Feb.17-18, 1986.

6. Mawenya, A.S., "Some Programmes for Enhencing the Professional Development and Effective Utilization of Engineers" Presented at the African Regional Seminar on the Role of Scientific and Engineering Societies in Development Abijan, Ivory Coast, Dec. 10 - 14, 1984.

7. Mbwette, T.S., and Mtenga, P.V., "Practical Training Directory for Graduate Civil Engineers" Unpublished document prepared for the Institution of Engineers Tanzania, 1985.

8. Ministry of Communications and Works. Public Expenditure and Development Budget 1970/71 - 1983/84. Unpublished Report.

9. Ministry of Labour and Manpower Development - Factory Inspectorate Section. "Safety and Health Conditions at Construction Sites in Tanzania". Unpublished working paper, 1985.

Improvement of Quality Evolution System for Inground Storage Tanks

Amélioration du système de développement de la qualité pour des réservoirs sous terre

Verbesserung eines Qualitäts-Entwicklungs-Systems für Erdbehälter

Akira NAKAZAWA
Civil Engineer
Shimizu Construction Co.
Tokyo, Japan

Akira Nakazawa, born 1940, received his Civil Eng. degree from Waseda University, Tokyo, Japan. Licenced Consulting Engineer and for more than 10 years has been involved in the design of inground storage tanks.

Takashi NAKAJIMA
Civil Engineer
Shimizu Construction Co.
Tokyo, Japan

Takashi Nakajima, born 1945, received his Civil Eng. degree from Tokyo Institute of Technology, Tokyo, Japan. Licenced Consulting Engineer and for more than 10 years has been involved in the design of inground storage tanks.

SUMMARY

In 1979 Total Quality Control was adopted in our company and it was our great honor to receive the Demming Prize in 1983. Through quality control activities, the role of the authors' department has always been examined from the viewpoint of quality assurance. It was then that the quality evolution system was adopted and has been improved since that time as a measure for quality assurance. The improvement process of the «Quality Evolution System» and various other activities using it are described in this paper.

RÉSUMÉ

En 1979 un système de contrôle de la qualité très développé a été introduit dans notre société et nous sommes fiers d'avoir obtenu le prix Demming en 1983. Notre attention a toujours été dirigée vers une assurance de la qualité globale, laquelle peut être mesurée à l'aide d'un système de développement de la qualité. Ce système a été introduit ces dernières années et est en permanente amélioration. L'article présente ce processus.

ZUSAMMENFASSUNG

1979 wurde ein umfassendes Qualitäts-Kontroll-System in unserer Firma eingeführt, und wir sind stolz darauf, dafür 1983 den Demming Preis erhalten zu haben. Unsere Aufmerksamkeit war dabei jedoch immer auf eine umfassende Qualitätssicherung gerichtet, in der als Massnahme ein Qualitäts-Entwicklungs-System figuriert, das in den letzten Jahren eingeführt und laufend verbessert wurde. Dieser Prozess wird dargestellt.

1. PREFACE

Inground storage tanks are facilities for storing energy resources i.e. LNG, LPG and crude oil etc., safely inground, in volumes ranging from 60,000 KL to 130,000 KL. Up to now approximately 50 inground tanks are either already in operation or are under construction in Japan.
The inground storage tank is mainly composed of an outer concrete structure, an insulation layer, a stainless steel membrane and a steel roof. The insulation layer and the membrane are attached to the outer concrete structure.
In the actual construction of the tanks, high tecnology is utilized in the design and construction techniques which take into account the necessity of maintaining stafety standards. The construction period itself is usually up to 3-4 years.

2. QUALILTY EVOLUTION SYSTEM (QES)

In our company TQC was first introduced in 1979. In the beginning, however, only classification regarding the design documents, which are the main work of our dept., was carried out, because it was believed the QA of our dept. should assure the design documents, but this was unclear.
Incidently, that the the most important stage of our QC activities was to assure the functions of the tank that is a result of our design and construction technologies was appreciated. So the design action itself comes under QA.
Therefore the consistency of customer requirements as to parts of the tanks was considered very important and in the process of this consistency, QA of the tank, QA of the design and in addition the QA of the construction had to be taken into account. The inter-relationship of these three was also taken into account.
So, customer requirements (Q), the substitutive characteristics of the tanks (HA), QA items at the design stage (SA), QA items at the construction stage (PA) and parts evolution (L) were separated clearly into respective divisions and organized in the manner of a matrix in order to correspond and relate to each other. This organized form is hereafter referred to as the quality evolution system (QES).
After the QEC was formed and started to function, the constitution of tank parts was made clearer by rearranging the parts sequence and by a comparison of construction methods and a more cost efficient method was discovered. Furthermore, an approach for a greater reliability was also uncovered.
Once it came to this stage the quality of various items being classified clearly became themselves vast in number. Furthermore, the volume of corresponding data got to be enormous and it also bacame apparent that the large amount of paperwork used in QEC was necessary.
So as a countermeasure computerization was introduced and a paper conservation compaign was adopted and promoted. The computer was used and a speed up regarding the searching, correcting and delating of items was accomplished.

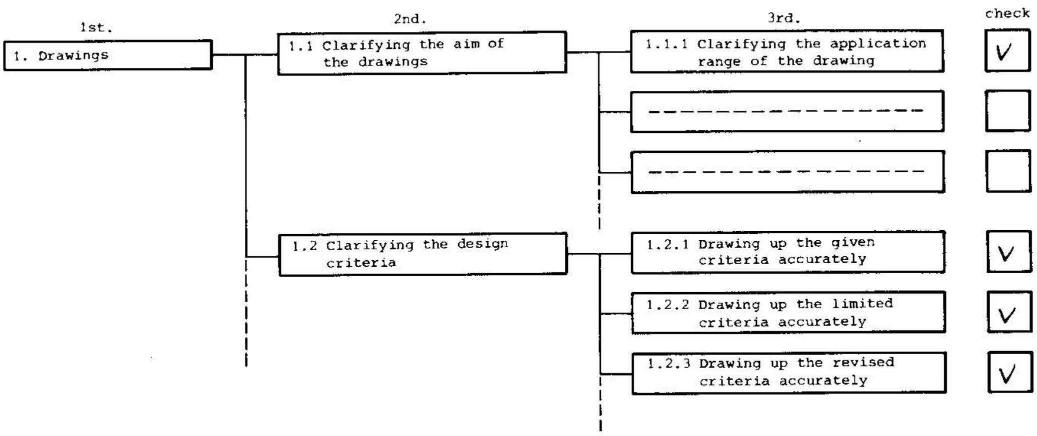


Fig. 1 One Dimensional Table

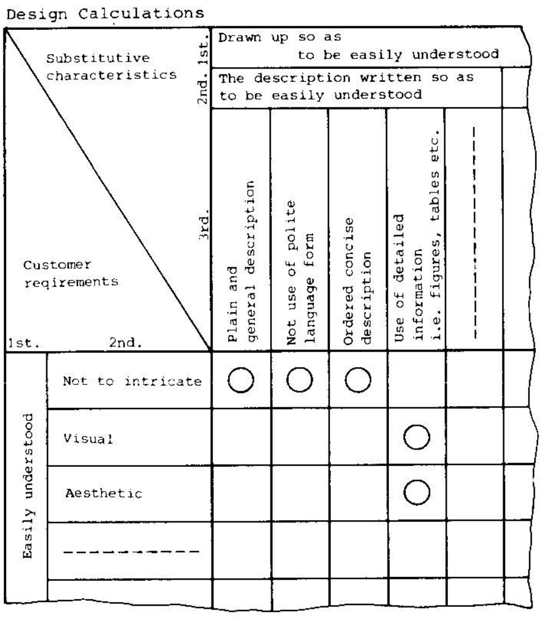


Fig. 2 Two Dimensional Table

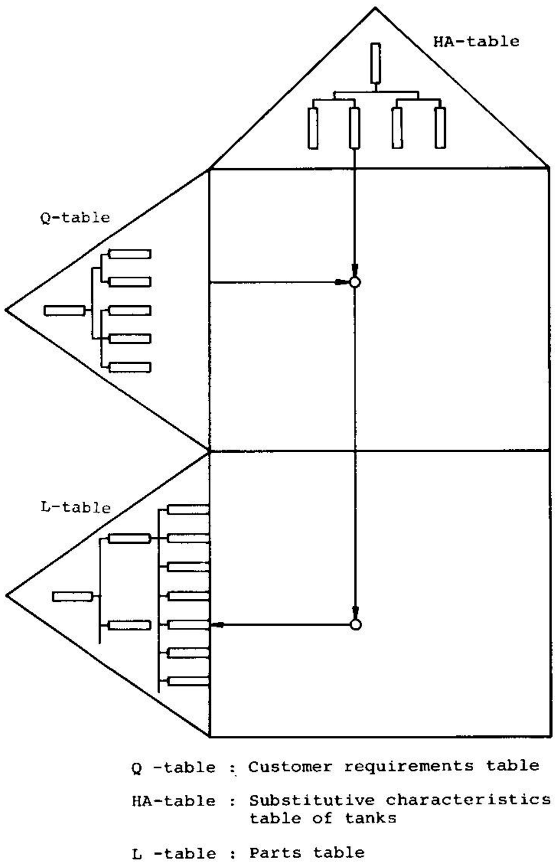


Fig. 3 Three Dimensional Table

3. DETAILS OF ACTIVITIES (The road to improvement)

3.1 The One Dimensional Table Period ('80 Oct.-'81 Feb.)

First the process of our dept. action was broken down into 21 minute processes and a one dimensional table of each process was drawn up, taking into account that QA would be clarified by means of the evolution of the quality characteristics produced in each process. (Ref. Fig. 1)
This one dimensional table was drawn up for every major design document (i.e. Calculations and Drawings) and it was used as a checksheet in order to ascertain whether these documents possessed the required characteristics.
But in the table, the customer requirements, substitutive characteristics and the characteristics of products were evolved in some confusion and each of the items was ambiguous.
That is, there was some confusion as to what should be done in order to satisfy the customer requirements.

3.2 The Two Dimensional Table Period ('81 Dec.-'82 Apr.)

On the basis of a review of activities in using a one dimensional table, a separation, reclassification and a reassesment of the inter-relationship of the customer requirements, the action of our dept. and the characteristics of our products was considered necessary.
Thus a two dimensional table composed of the customer requirements and substitutive characteristics was drawn up. (Ref. Fig. 2) This then allowed the customer requirements and substitutive characteristics to correspond with each other.
But this table was mainly drawn up for design documents, so it didn't have a positive role in QA of the completed tanks.
Furthermore it was then thought that in substitutive characteristics a certain value should be specified and this value would be transferred and correspond to the actual part of the tank. If water pressure resistance is set, as a substitutive characteristic, at a value of 2 kg/cm , the substitutive characteristic would be transferred the actual part of the tank in the form of a cutoff wall of 1 m in thickness.

3.3 The Three Dimensional Table Period ('82 May-'82 Jul.)

Here a three dimensional table composed of a two dimensional table and a parts evolution table was completed. (Ref. Fig. 3)
However, even when the table was completed, the items regarding design documents and actual tanks were still not clearly visible in both the customer requirements part of the table and the substitutive characteristics evolution part. The opinion at the time of the review in this period was that the important thing about our dept. QC activities was to assure the quality of the functions of the tanks as a storage tank and not to assure the quality of the design documents.
Therefore it seemed juistified to order the customer requirements from the structural construction viewpoint and then transfer them to structural characteristics which correspond to parts of the tank. Thus the QA of documents was thought to be positioned in the total process of the QA for tanks.

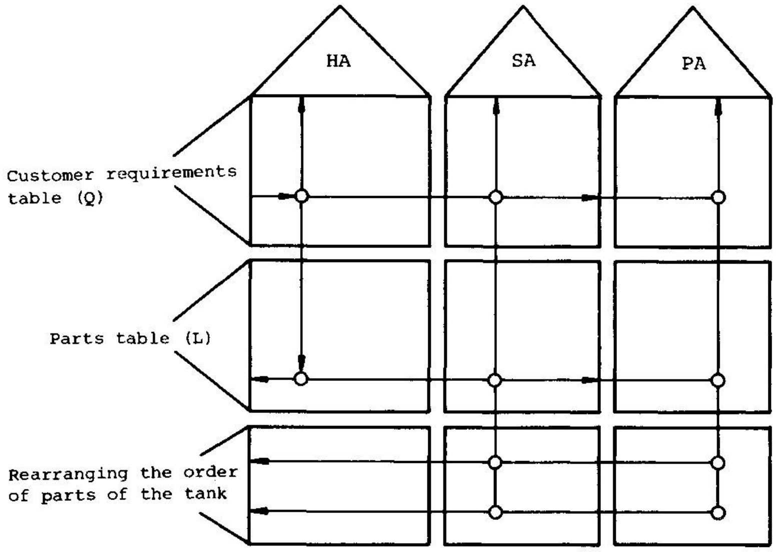


Fig. 4 The Concept of the Quality Evolution System

Project Name ______________________ Type of Tank ______________________

Design Dept. → Construction Dept.

Design Quality Information Sheet

GM	DM	SM	P	GM	DM	SM	P
Design Dept.				Construction Dept.			

Design Quality (Written by Design Dept.)								(Written by Construction Dept.)					
No	Customer Requirements (Q)	Substitutive Characteristics of Tanks (HA)	Standard Value or Specifications			Date	Remarks	Construction Process Capability Index	Construction Process Capability			Date	Remarks
			Components	Parts	Standard Value, Specifications				Controled Point	$\bar{x}$	s		

GM : General Manager DM : Deputy Manager
SM : Section Manager P : Personnel

Fig. 5 Design Quality Information Sheet

3.4 Quality Evolution System ('82 Aug.-The present)

After QC activities for 2 years, it gradually became clear that the aim of QC activities of our dept. was to transfer the customer requirements to substitutive characteristics in the design stage and to transmit those characteristics to the ones of the tanks precisely by promoting consistency in quality.

Thus the present QES now in operation at our company was arrived at.

The details of the present QES are as follows. (Ref. Fig. 4)

1) A three dimensional table is the main framework, in which the customer requirements (Q) are transferred to the substitutive characteristics (HA) and to the parts of the tank (L).
2) The elements of design technology are corresponded to the quality characteristics which should be guaranteed at the design stage and are called SA. These are added to the three dimensional table.
3) The manufacturing technologies at the construction stage are defined in relation to the construction substitutive characteristics and are called PA. This PA is also added to the three dimensional table.
4) As a result of their corresponding to each other, a mutual relation between HA, SA and PA is made clear and when the level of HA is once determined, it is to be related to SA and PA.
5) Another table of parts of the tank is added in order to compare the tank types by rearranging the order of the parts of the tank.

4. EXAMPLES OF QES ACTIVITIES

4.1 Examples of QES Activities

The actual activities described below were carried out in the process of setting up the quality evolution system and its improvement.

* The Review of the Customer Requirements (Q-table)

At this time the customer requirements table (Q-table) was drawn up by us on behalf of the users. A review activity was then carried out to make sure that customer requirements were reflected in the Q-table which was then drawn up. A number of people from relivant departments, from major client companies, were interviewed to obtain authentic customer requirements. And new Q-table was compiled by grouping the data thus obtained from these interviews.

* Cost-Planning Activities

The users' planned tank cost is set and the activity of keeping our price close to the users' planned cost is carried out by rearranging the order of parts of the tank. In this activity QES is used in order to get an idea of the influence on the customer requirements and the substitutive characteristics when the order of parts is changed. Actually 'The revised price sheet', in which the change of price after the rearrangement and the influence on the Q-table and HA-table are recorded accurately, is used.

* Approach for Reliability
This QES being completed, the order of the parts and components became clearer. The reliability of the tank as a total system is enhanced as the reliability of individual parts and components is increased.
In our present QC activities the FMEA and FTA methods are utilized and reliability tests are carried out if necessary for the parts and components.

4.2 Transferring the Design Quality to the Construction Side
The design quality was transferred to the construction side one-sidedly in the form of drawings, that didn't take into account the construction process capability. As a result unfortunately there were quite a few cases where the difficulty of the construction and the cost were unnecessarily increased due to the design.
Then the Design Quality Information Sheet (Ref. Fig. 5) was drawn up and information transfer between our dept. and the construction dept. was set up to overcome communication difficulties. The details of this information transfer are as follows.
First our dept. completed the design quality sheet in the form of standard values or specifications and sent this sheet to the construction dept. The latter fills in the construction capability range on this sheet and the projected construction process capability. If the capability is less than expected, the sheet is returned to our dept. and a review of the design quality is carried out. After the review, if the construction process capability index increases, the difficulty of construction is lessened and the construction period shortened and cost efficiency is achieved without overlooking the substitutive characteristics.
This sheet is used actively in order to transfer quality from our dept. to the construction dept. and to improve the construction process. So far having an idea of the construction process capability is the main activity when parts are assembled, but the results of this activity are considered a prototype for the next scheduled inground tank.

Leere Seite
Blank page
Page vide

Comments on Quality Assurance drawn from Building Collapses

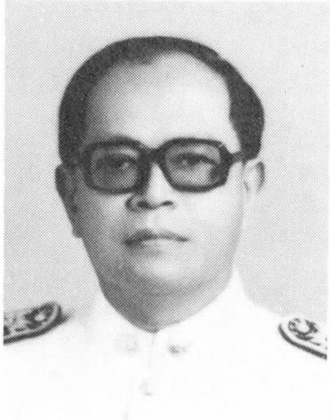
Commentaires sur l'assurance de la qualité basés sur l'écroulement de bâtiments

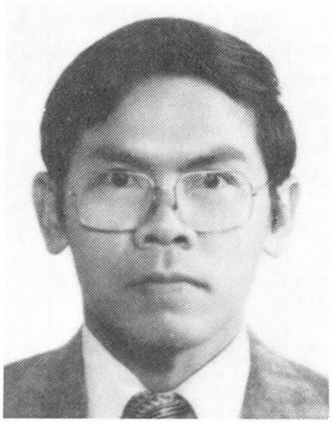
Bemerkungen zur Qualitätssicherung anhand von Bauwerks-Einstürzen

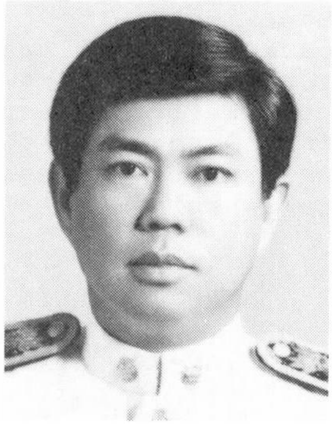
Prasop KRASAESINDHU
Dir., Techn. & Training Div.
Public Work Department
Bangkok, Thailand

Ekasit LIMSUWAN
Associate Professor
Chulalongkorn University
Bangkok, Thailand

Choochart SITTIPAN
Dir., Fuel Storage Contr. Div.
Public Work Department
Bangkok, Thailand







SUMMARY

Structural performance in strength and serviceability can be guaranteed only when quality assurance measures have been implemented by the process of analysis, design, construction, operation and maintenance. Some comments were drawn from several cases of collapse in Thailand where structural investigation had been conducted to find major causes of failure. Quality assurance can be improved by means of analysis, experience and control by engineers, contractors, inspectors and owners upon their responsibility.

RÉSUMÉ

La durabilité et la serviciabilité ne peuvent être garanties que sur la base de mesures appropriées d'assurance de la qualité, lors de l'étude du projet, de sa construction, de son exploitation et de son entretien. Plusieurs bâtiments se sont écroulés en Thailande et des études ont été entreprises pour déterminer les causes majeures de ces accidents de structures. L'assurance de la qualité peut être améliorée par l'application et le contrôle de règles et procédés par l'ingénieur, l'entrepreneur, l'inspecteur et le propriétaire.

ZUSAMMENFASSUNG

Tragsicherheit und Gebrauchstauglichkeit von Bauwerken können nur gewährleistet werden durch Massnahmen der Qualitätssicherung im ganzen Prozess von Berechung und Bemessung, Erstellung, Nutzung und Instandhaltung von Bauwerken. Die Untersuchung verschiedener Bauwerks-Einstürze in Thailand gibt Anlass zu einigen Bemerkungen über Qualitätssicherung, die durch Ingenieure, Unternehmer, Kontrollinstanzen und Eigentümer in ihrem jeweiligen Verantwortungsbereich verbessert werden kann.

1. INTRODUCTION

Many buildings collapsed or defected and needed repair due to structural failure. Quality assurance of the structures will lead to excellent performance in strength and serviceability, in short terms and long terms. Sound structures can be obtained only when quality assurance measures have been implemented along the process of analysis, design, construction, operation and maintenance. Comments drawn in this paper are from various structural investigation of collapse cases in Thailand. The investigation was conducted mostly after the collapse had taken place partially or completely. The investigation is to figure out the causes of structural failure by means of physical observation, and analytical solution. Most common causes of damage for sub-structures and super-structures are illustrated corresponding to the failure cases.

Some comments on quality assurance are drawn from cases where causes of failure are identified. The comments are critic on academics, practices and regulation through engineers, contractors, inspectors and owners. The very nature of progress itself requires the excercise of control, whenever the quality assurance is lack, then it could result in problems and lead to collapse.

2. STRUCTURAL INVESTIGATION

The investigation of structural failure especially after its collapse is quite complicated. Methods and procedures may vary by cases due to severity of the collapse, left over symtoms, available information and its mode of failure. The major task of the investigation is to find out primary causes of failure. In some cases, secondary and tertiory causes may be also found.

The process will concern data collection, physical examination, structural analysis and loaded tests. The data collection and physical examination must be done first, then several possible alternatives are assumed and the actual causes can be confirmed by means of analyses and tests.

3. MOST COMMON CAUSES OF FAILURE

From various cases of structural investigation of building collapse, several causes can be grouped for sub-structures and super-structures as shown in Fig. 1 and 2, respectively.

For sub-structures, most common causes of failure are due to insufficient soil data, soil subsidence, differential settlement, off-center pile, excavation, slope stability and soil distrubance.

Collapse cases in super-structures are primarily concerned with un-equilibrium of forces, reliability of computer software, insufficient structural detailing, formwork failure, over loads during construction, poor control of material quality, tolerance and workmanship, misuse of the structures, and un-foreseen problems.

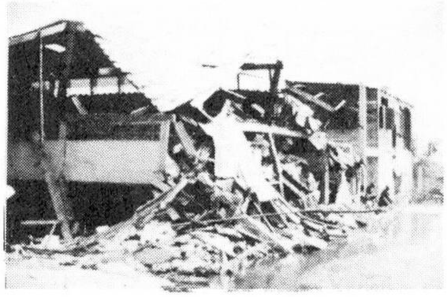
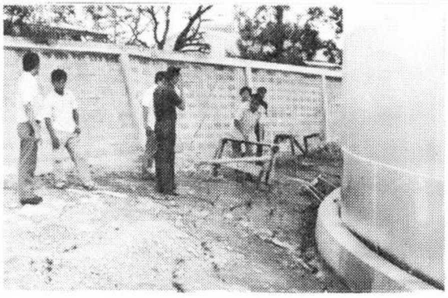
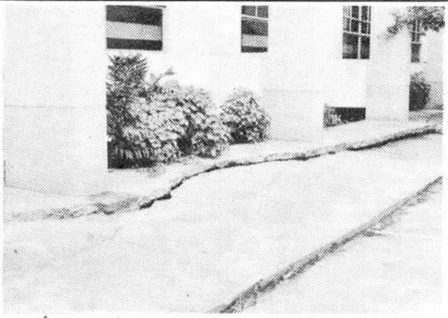
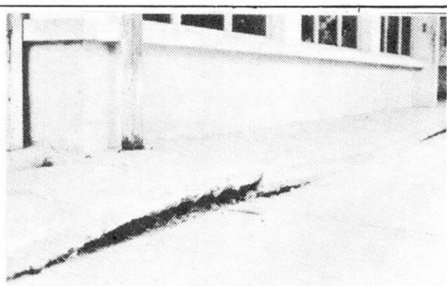
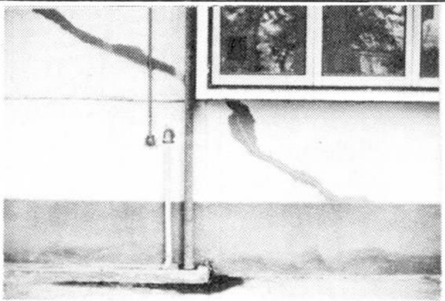
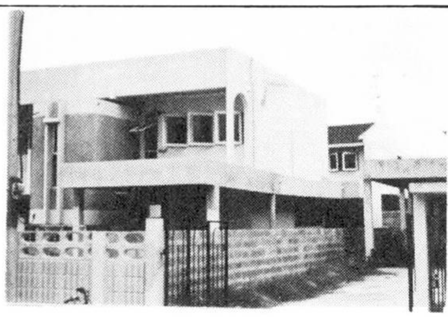
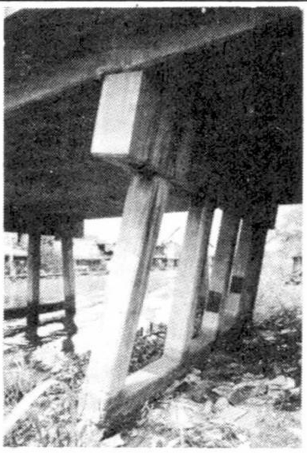
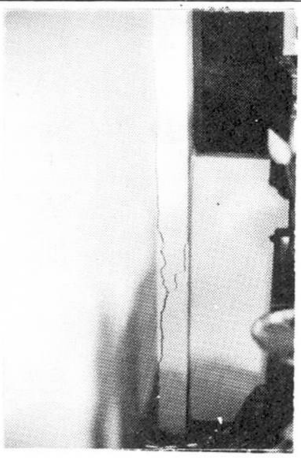
Cause of failure	Example of failure cases	
Insufficient soil data	 No soil investigation	 Mis-interpretation of soil data
Ground subsidence	 Collapse at building edge	 Wave form up hold on on the foundation
Differential settlement	 Different pile length	 Different loads
Off-center piling	 Effect on column	 Effect on wall

Fig. 1 Collapse cases of sub-structures

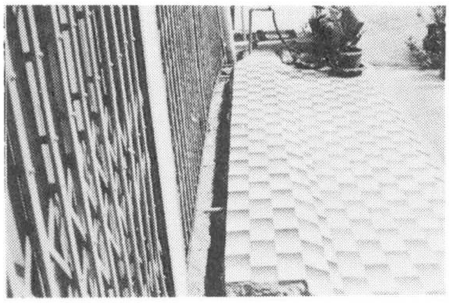
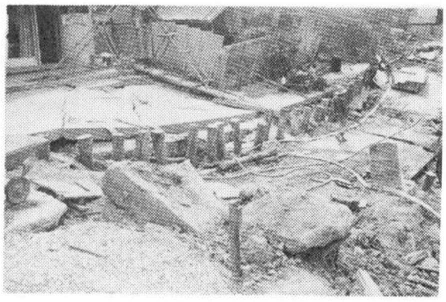
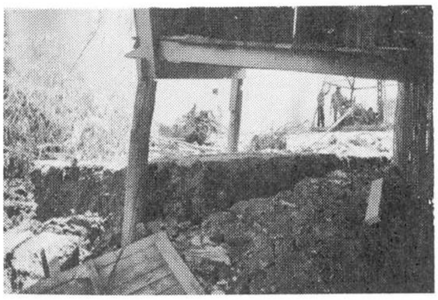
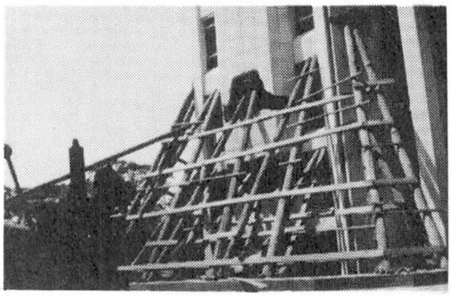
Cause of failure	Example of failure cases	
Excavation	 Movement due to excavation	 Slope failure due to excavation
Slope Stability		Fail of slope
Soil disturbance	 Disturbed from water table	 Disturbed from equipment

Fig. 1 (Cont.) Collapse cases of sub-structures

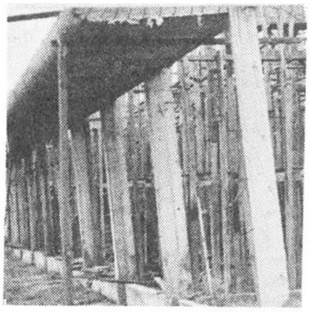
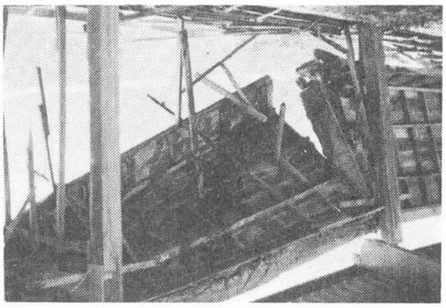
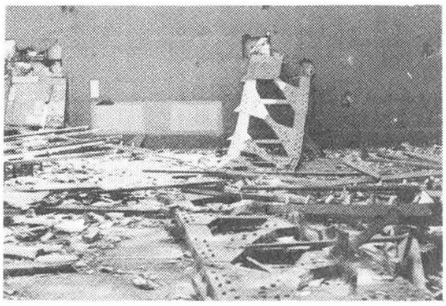
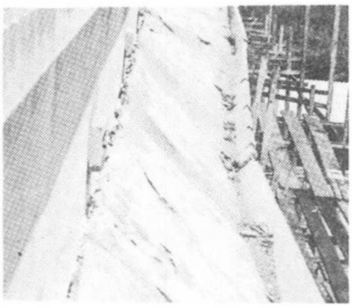
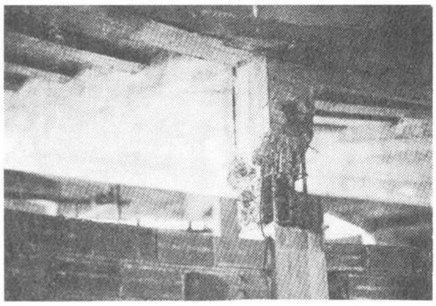
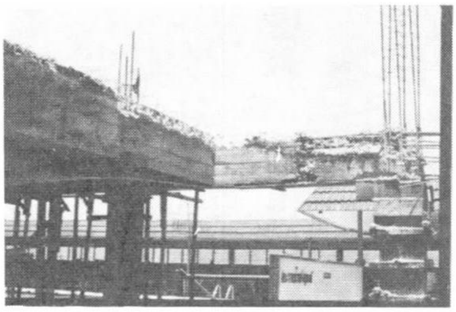
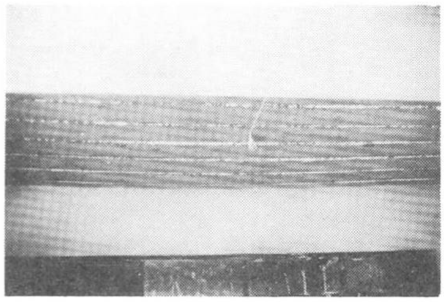
Cause of failure	Example of collapse cases	
Un-equilibrium of forces	 Contilevered slab at intermediate floor	 Summation of moments is not-zero
Reliability of computer program		No stability checking
Insufficient of structural details	 Rebar at bottom for cantilevered slab	 Beam/column joint
Formwork failure	 Collapse during pouring	 Excessive deformation

Fig. 2 Collapse case of super-structures

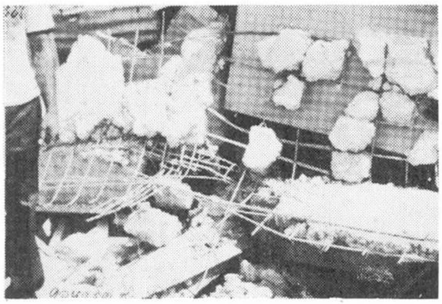
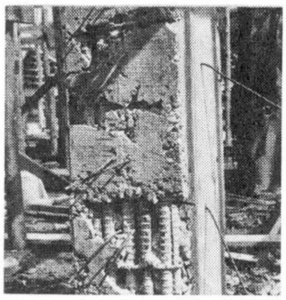
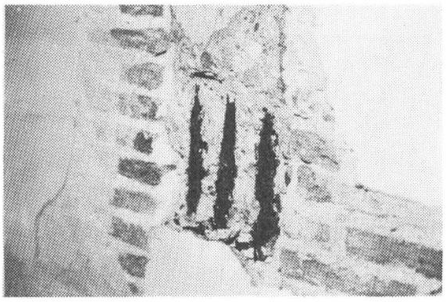
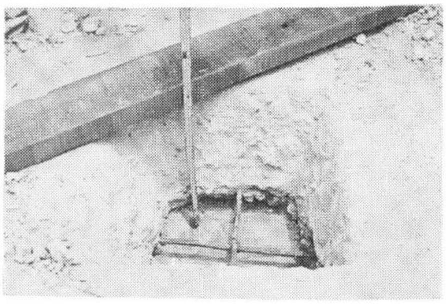
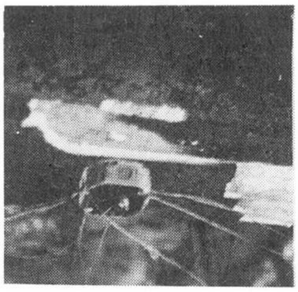
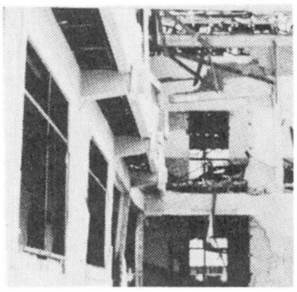
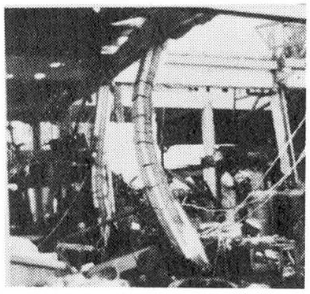
Cause of failure	Example of collapse cases		
Poor centrol of materials	 Low strength concrete	 Honeycomb	
Workmanship and it tolerance	 Less covering	 Slab is thicker than requirement	
Mis-use of the structures		Over-loaded uses	
Un-foreseen problem	 Fire	 Bomb	 Gas explosion

Fig. 2 (Cont.) Collapse case of super-structures

Such causes of failure can occur not only during the phases of design, and construction but also during operation and maintenance. Various parties such as engineers, architects contractors, owners and users are always involved.

4. COMMENTS ON QUALITY ASSURANCE

According to various causes of damages as illustrated in this paper, several measures of quality assurance must be implemented at all stages of project development as the critical comments below:

4.1 By-Law

Building regulation in Thailand is covered only the urban areas, many sophisticated buildings in the rural area are not governed by the law. However, this act should be implemented for all buildings and structures, but the degree of control can be vary due to their necessity. Law should provide better relationship amoung parties involved in the structures such as owners, engineers, contractors and users. Responsibility of each party must be clarified for easy implementation

4.2 Codes and Standards

Revision of codes and standards should be done more frequently to up-date design information and some specific values with the progress in theoretical development, advanced technology and new materials. Design codes on the basis of probabilistic approach which loads and resistances at various limit states of structural performance are considered. Then both quality assurance and probability to failure should be in the same basis.

4.3 Analysis Control

Development of modern computers and software for structural analysis have been over-emphasis on their capability rather than the reliability. Each computer program for complicated analysis requires some checking to prove the reliability prior to its uses.

Idealization of the structures for analyses is very necessary to obtain most precise behavior. Simplification of analysis models must represent the real condition within the limitation of error. Equilibrium of forces at any joints or connections must be checked. Many failure cases are due to unbalanced forces at a joint since the forces are distributed to un-assigned members.

4.4 Design Control

Preliminary data, associated with design data, such as materials, soil exploration, and soil invesigation must be on hand prior to the design process. Structural details must be sufficient for construction work.

Each element must be equilibrium by a set of forces. Sophisticated structural responses under soil pressure, dynamic, vibration and long term effects should be monitored to check the performance, and to collect data for further study and development.

4.5 Construction Control

Materials used in construction site must be fully controlled. Emphasis should be made on concrete production and fabrication. Strength evaluation must be frequently checked and adjusted. Statistic approach can offered reasonable quaility assurance for this purpose.

Economic views of formwork design and construction have overshadowed on importance of structural quality. Formwork management should fit quality assurance and rate of construction conformed to the techniques and sequences.

Construction loading must always be checked to avoid over-loads on any components. Design live loads and date of concrete casting should be recorded and used to prevent over-loading on the structures.

4.6 Operation and Maintenance

Live loads should be kept to the design basis. Routine checking on durability items must be implemented as general practice by in-house personal for periodic maintenance.

Monitoring for special behavior such as settlement, vibration or drifting should be commenced to determine the stuctural performance.

5. CONCLUSION

Several causes of building collapse summerized in this report should be similar to several places in the world. Quality assurance of the sructures can be concluded as

1. Law and regulation must provide roles for safety and quaility assurance in terms of building regulation, qualified engineers and contractors.
2. Codes and standards should be frequently modified from advanced information and technology. Probabilistic approach for loads and resistances at various state limits should be compatible with local materials and workmenships.
3. Reliability of computer software for structural analysis must be considered on the basic concepts in idealization of the structures and equilibrium.
4. In design control, all design data must include soil investigation and sufficient structural details. Structural responses should be monitored to assure the performance under soil pressure, dynamic, vibration and long term effects.
5. For quality control of materials in construction, attention must be paid on concrete construction, formwork management, and construction techniques.
6. Functions of building must be controlled by resisting strength and durability in both short term and long term serviceability.

REFERENCES

1. Krasaesindhu, P. "Building Collapse Cases in Kae-Lai, Nakorn Sawan and Patum-thani" paper presented to Civil Engineering Seminar on Building Collapse, Chulalongkorn University, Bangkok, 23-24 April, 1984

2. Suttipan, C. "Building Collapse from NPG Explosion" paper presented to Civil Engineering Seminar on Building Collapse, Chulalongkorn University, Bangkok, 23-24 April, 1984

3. Limsuwan, E. "Structural Investigation of Building Failure" paper presented to Civil Engineering Conference on Remedal Measures for Building Failure", Chulalongkron University, 1980

4. Chaiseree, A. "Building Failure; Causes and Problem Solving", Engineering Institute of Thailand, EIT-Bangkok, 1982

5. Lin, T. Y. "Progress and Problem - Today and Tomorrow" IABSE-Congress Final Report, International Association for Bridge and Structural Engineering, Vanconver, 1984

6. Nishino, F. "Critical comments on the Recent Trends of design Code changes to load Factor Design" Proceeding of Japan-Thai Civil Engineering Conference on the Recent Advances in Structural Engineering , Chulalongkorn University and Engineering Institute of Thailand, March 1985.

Leere Seite
Blank page
Page vide

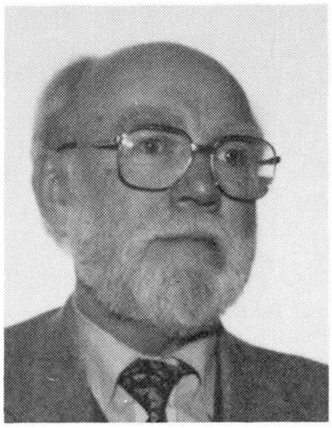
Quality Assurance in a Major Consulting Engineering Company

Assurance de la qualité au sein d'une société importante d'ingénieurs-conseils

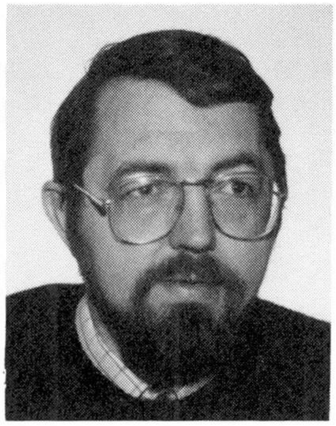
Qualitätssicherung in einer grossen Ingenieur-Unternehmung

Aksel G. FRANDSEN
Technical Director
Cowiconsult
Copenhagen, Denmark

Tonny JENSEN
Chief Engineer
Cowiconsult
Copenhagen, Denmark



Aksel G. Frandsen, born 1924, received his M.SC.C.E. degree at the Technical University of Denmark. With Cowiconsult since 1949, the last 15 years in technical management. Since 1985 Technical Director.



Tonny Jensen, born 1948, received his M.SC.C.E. degree at the Technical University of Denmark in 1973. With Cowiconsult from 1973 and since 1981 Quality Assurance Engineer on a major civil engineering project. Since 1985 Chief Engineer, Quality Assurance in Cowiconsult.

SUMMARY

This paper outlines how the concept of quality assurance has been adopted and interpreted in a consulting engineering company. Selected elements of the quality assurance system, such as organization, document control, and audits are described in detail.

RÉSUMÉ

Le présent document décrit la manière dont la conception de l'assurance de la qualité a été adoptée et interprétée au sein d'une société d'ingénieurs-conseils. Des éléments du système de l'assurance de la qualité tels que l'organisation, la vérification et la révision des documents, sont décrits en détail.

ZUSAMMENFASSUNG

Der vorliegende Beitrag beschreibt die Formulierung und Interpretation eines Qualitätssicherungs-Konzepts in einer Ingenieur-Unternehmung. Ausgewählte Elemente dieses Systems zur Qualitätssicherung, wie Organisation, Dokumentation und Qualitäts-Audit, werden im Detail dargelegt.

1. INTRODUCTION

Cowiconsult, Consulting Engineers and Planners, is an independent Danish company founded in 1930.

The company operates on a worldwide basis with planning, design, supervision and management of projects within all major engineering fields. Among others also civil and structural engineering.

Cowiconsult has a total permanent staff of more than 900 people, of whom some 600 are graduates from universities, and the company have rendered consulting services in more than 60 countries, mainly in Europe, Africa, the Middle East, and East Asia.

The paper outlines the means utilized to ensure the quality of the projects undertaken. The methods used in the past are described, and it is discussed in detail how the modern concept of quality assurance is interpreted, introduced and implemented.

It is and has always been a main objective of Cowiconsult to render engineering services of high technical standard and the company has therefore aimed at adapting its quality assurance system to the changing demands.

2. QUALITY ASSURANCE IN THE PAST

Certain means have always been established to assure the quality of the projects, and they will continue to form a fundamental part of any quality assurance system.

The management has always recognized that the professional qualification of the employees are of fundamental importance to quality. Comprehensive training and postgraduate programs are carried out, and close contact with colleagues, other companies and research institutes all over the world have been established to keep the employees and the company up-to-date with the technical development.

Instructions, manuals and guidelines have been established to define the engineering practice to be adhered to by the engineers and planners. Emphasis has been placed on checking activities to ensure that the documents prepared actually fulfull the design basis and meet the company's engineering practice.

3. WHY CHANGE THE QA SYSTEM

The means described in Section 2 are sufficient for smaller companies covering only a few disciplines, and where one person is able to conduct and understand all activities involved in a project.

Often this is not the situation anymore.

Gradually it has become evident that the concept adopted to assure the quality should be re-evaluated due to the following:

- The number of disciplines undertaken have increased rapidly in the last 10 years, which has required changes in the traditional organizational structure.
- Generally, the projects are becoming more and more complex, encompassing - among other things - oil and gas facilities both onshore and offshore.
- The consequences, both economic and safety-wise of possible omissions or negligence, are increasing with the complexity and size of the projects.
- Experience has shown that mere checking of documents does not always lead to the expected results.

- It is more and more common that clients, especially within the oil and gas industry, require a documented quality assurance system in accordance with quality assurance standards recognized, implemented by their consultants and contractors.

It should be realized that it is not possible to check quality into a design document. Quality has to be introduced, primarily through the original design process, into it. Consequently, a certain number of parameters must create and influence the quality. If we are able to identify and control these parameters, we should be able to design the project to the required standard, the right quality. This is exactly what the modern concept of quality assurance is aimed at.

Basically, this means that some resources are moved from the "back end" of the engineering process, where one only registers what has actually been done to the "front end", where one can plan, monitor, and influence the activities to be performed. The resources are changed from being passive to being active in the engineering process.

Generally the major decisions in a project are taken at an early stage, and the resources spent in the concept and planning phase to identify the basis and the expected outcome and to plan the project implementation are of utmost importance to the success of a project.

4. HOW TO ESTABLISH THE QA SYSTEM

The first problem is to define the quality policy.

What do we actually mean by quality in relation to the services rendered by a consulting engineering company? We have to ask ourselves questions such as:

- Is a six-lane motorway in Denmark of a higher quality than a dirt road in Africa?
- Is a detailed design of a higher quality than a basic design?

We ended up with the following quality policy of the company:

> "Every project undertaken must be carried out in such a way that:
>
> - it meets the client's needs,
> - the technical quality of the project is acceptable,
> - the contract is fulfilled, and
> - account is taken of social and environmental considerations."

With this definition, it is evident that the dirt road in Africa may have a higher quality than the motorway in Denmark - it depends on the needs.

All four statements have to be fulfilled as a prerequisite for the success of a project.

Having reached this fundamental definition, the phases for establishing the quality assurance system are as follows:

1. Identification of the parameters influencing the quality of the services to be rendered.
2. Definition of the overall requirements of the parameters, "the means", in a quality assurance manual.
3. Acceptance of the commitments in the manual by the management.
4. Definition of procedures necessary to fulfil these commitments.
5. Identification and review of existing procedures.
6. Preparation of missing procedures.

7. Information and training of employees in the quality assurance concept.

In Cowiconsult's process of introducing the QA-system the first five phases are completed and the last two phases are expected to be fully implemented by the end of the year.

5. DESCRIPTION OF THE SYSTEM

The quality assurance manual describes the means employed in the company to fulfil the quality policy. The list of contents is as follows:

Preface

0. Quality Basis

1. Basic Organization

2. Project Organizations

3. Activity Planning

4. Aim and Criteria of Projects

5. Planning and Execution of Projects

6. Document Control

7. Changes in Projects

8. Corrective Actions in the Event of Errors/Faults

9. Quality Audit.

The obligations given in the manual are further elaborated in procedures related to the means mentioned. Procedures are detailed to such an extent that different persons with sufficient qualifications will reach the same correct result when using these procedures. This will leave the engineer more time for the more essential engineering activities: to reach appropriate solutions to technical problems.

Generally, a procedure consists of instruction sections giving rules that must be complied with at all times, and guideline sections describing good engineering practices.

As can be seen in Fig. 1, there are two forms of procedures: general procedures not related to specific projects and project-oriented procedures.

General procedures are established to cover the majority of the projects undertaken.

A project-oriented procedure will only be established if no general procedure fits the project.

In case a client has specific requirements, the project-oriented procedures shall fulfil both the quality assurance manual and the client's requirements.

All general procedures are registered in a database, and employees are able to call this register on-line to see which procedures are available.

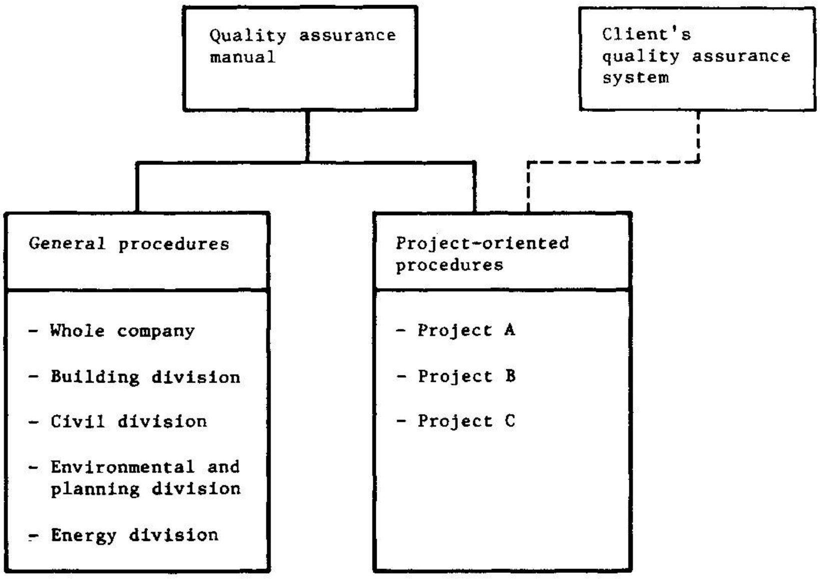


Fig. 1 Quality Assurance System

6. SELECTED ELEMENTS

Three of the parameters identified to contribute to the quality of the projects are described in detail.

6.1 Organization

The organizational structure of the company can be viewed in two ways: it can either focus on the project organization, which solves actual tasks, or focus on the basic organization, which supplies the engineering and administrative resources to the project organization.

6.1.1 Basic Organization

The basic organization is structured in four individual divisions with a common management and common technical and administrative functions.

For the whole company, a Technical Director is appointed and a Chief Engineer, Quality Assurance, reporting to the Technical Director. In each division, Assistant Technical Directors are appointed to cover the disciplines undertaken, and a Quality Assurance Engineer.

These functions are established to ensure that a high technical standard is developed and maintained, and that the quality policy is attained. Lines of information and coordination between the Assistant Technical Directors and the Technical Director are established independently of the administrative reporting lines.

6.2.2 Project Organizations

For each project, a project organization is established with a clear definition of tasks and responsibilities, as well as effective internal and external communication lines.

A project organization is, in principle, shown in Fig. 2.

Head of departments are responsible for the technical standard and the project manager for the execution of the project. Head of departments have the authority to delay a project until the technical standard is sufficient. This separation of responsibility is considered important, as the project manager will be challenged by qualified opponents in each project, and an adequate balanced between the technical aspects and the project management is obtained.

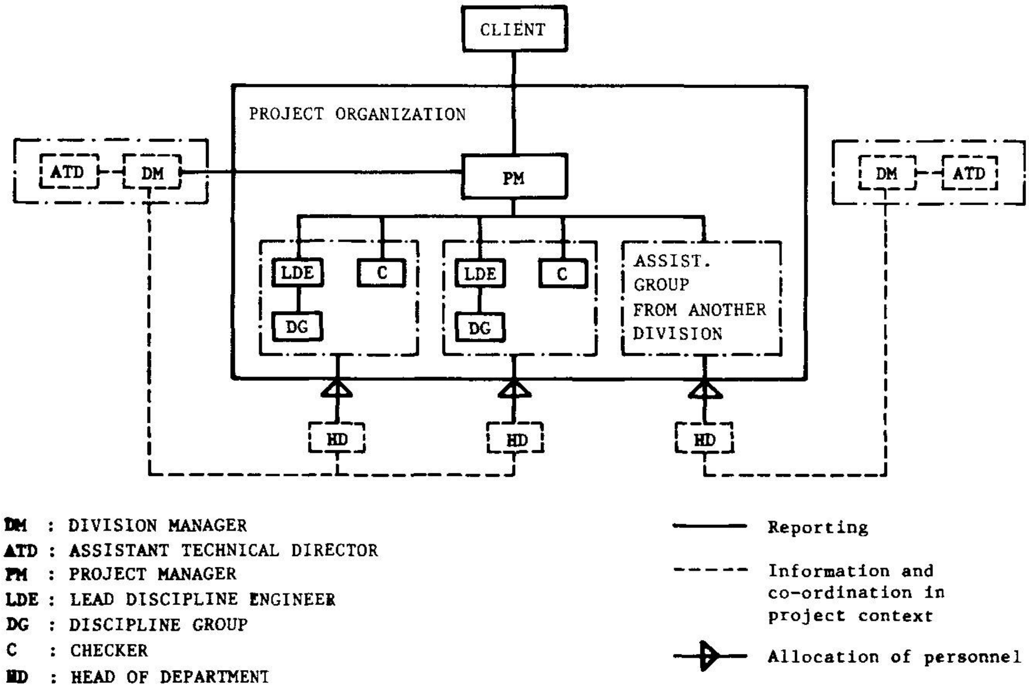


Fig. 2 Project Organization, in principle

6.2 Document Control

A consulting engineer produces documents (drawings, conditions, specifications, reports, etc.), and it is of the utmost importance to have an effective document control system to ensure that documents are issued for the purpose intended by authorized personnel, and that the documents are available at the right places at the right time.

All documents are provided with a document title, a job number, a serial number, an issue number, a date, and signatures for preparation, checking, and approval. Revised documents are given a new issue number and provided with signatures for preparation, checking, and approval of the revised document. Index lists are maintained showing the issue number of all documents prepared. Distribution lists are prepared for each document or each type of document, both for internal and external distribution.

The meaning of each signature in a document is defined.

For instance, signing for approval shall be done by the lead discipline engineer in charge. The signature means that the document has been prepared by a qualified person, that the document has been checked by a person not involved in the preparation of the document, and that the document is released to be used outside the discipline group.

6.3 Audits

To identify and control the parameters influencing the quality is a complex task and the effectiveness of the system should be constantly evaluated, and if necessary, adjusted. Furthermore, it should be verified that the intentions laid down in the quality assurance manual are implemented.

Audits are an effective tool for this purpose.

Two kinds of audits are performed:

- System audits
- Product audits.

System audits are performed with the purpose of:

- Verifying that applicable procedures are adhered to
- Evaluating the effectiveness of the procedures
- Identifying areas where improvement is needed.

Product audits are performed with the purpose of evaluating management and the technical standard of a specific project.

Audits performed are reported to the division management and to the person responsible for the area audited for corrective action if any deficiencies are identified.

The audit function is in the process of being implemented, but it may in certain cases be met with resistance and is generally considered as one more bureaucratic obstacle.

If audits are performed in a constructive atmosphere, highlighting topics essential for project success, it is our experience that audits will be considered as an effective management tool by project managers and head of departments.

7. FINAL REMARKS

The aim has been to establish a flexible system which defines "what to do" and not "how to do it" and "to what extent". These decisions will remain with the project responsible. However, it is ensured that these decisions will be taken at the right time during the project execution.

The authors are well aware of the difficulties by implementing the quality assurance system described. However, it is believed that this concept on a long term basis will contribute to maintain and improve the quality of the services rendered in a cost effective way. To reach this target it is a condition that the system is considered by the employees as an effective tool in the daily work and not as one more bureaucratic exercise. To obtain this is a real challenge.

It the authors' hope that other colleagues, who are in a similar situation, can find some help and inspiration in this paper.

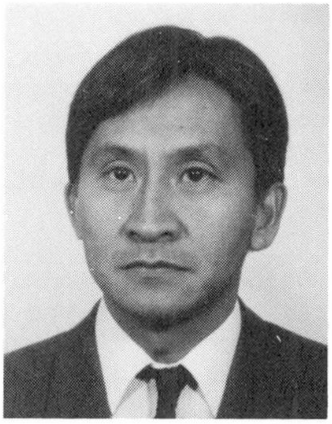
Leere Seite
Blank page
Page vide

Quality Assurance as a Management Tool for Large Projects

Assurance de la qualité comme moyen de gestion d'un grand projet

Qualitätssicherung als Führungsinstrument für grosse Projekte

Lac VU HONG
Quality Assurance Manager
SPIE Batignolles
Puteaux, France



Lac Vu Hong, born in 1944, received his engineering degree from Ecole Centrale de Paris. Since 1979, he is the QA Manager for Spie Batignolles, responsible for Quality Assurance policies and standards and for large project management auditing. Lac Vu Hong is also certified Quality Engineer and member of ASQC.

SUMMARY

The setting up of a Quality Assurance programme should not generate unnecessary formal procedures and excessive paperwork which may discourage the personnel whose efforts are wasted on the «trivial many» and not concentrated in the «vital few». The key solution is to adjust the QA requirements according to the importance and complexity of the activity. Moreover, QA principles should be extended to the management of all aspects of a project: quality, programme and cost. With theses principles, management by objective technique (MBO) can be used as appropriate means to motivate the personnel to peak performance.

RÉSUMÉ

La mise en place d'un programme d'assurance de la qualité ne devrait pas entraîner un excès de documentation et de formalisme qui peut démotiver les intervenants dont l'effort est gaspillé par «le grand nombre d'événements sans importance» et non concentré sur «les quelques uns qui comptent». La solution clé est de moduler les exigences AQ en fonction de l'importance et de la complexité de l'activité. D'autre part, les principes AQ devraient être étendus au management de tous les aspects d'un projet: qualité, délais et coûts. En combinaison avec ces principes, on peut aussi utiliser la technique de Direction par objectif (DPO) comme moyen de motivation du personnel afin d'obtenir une performance maximale.

ZUSAMMENFASSUNG

Bei der Einführung eines Qualitätssicherungs-Programms sollten eine allzugrosse Dokumentation und übertriebener Formalismus vermieden werden. Sie entmutigen das Personal durch grossen Zeitaufwand für Unnötiges, anstatt auf das Wichtigste aufmerksam zu machen. Das Programm sollte dem Ausmass und der Vielfalt des Unternehmens angepasst werden: Ausserdem sollten die Prinzipien des Programms alle Gebiete des Managements umfassen, das sind Qualität, Termine und Kosten. In Verbindung mit diesen Prinzipien kann auch «Management durch Ziele» als Mittel zur Motivation der Mitarbeiter zu Spitzenleistungen angesehen werden.

1. SAFETY AND QUALITY ASSURANCE OF CIVIL ENGINEERING STRUCTURES

Safety and quality assurance requirements are not normally applied to civil engineering work in the same way that they are to other parts of a nuclear power station.

In a nuclear power station the safety-related components and systems are classified according to the contributions they make to the overall safety of the plant. The classification determines the design and construction rules that need to be applied to individual components and systems to ensure that they meet the appropriate requirements for structural integrity and quality.

But while the various ASME codes and the American National Nuclear Standards provide safety classifications for pressure boundary components and electrical, instrumentation and control equipement components and systems, and sometimes for their supports, they rarely cover the embedded items (which serve as the link between these supports and the concrete structure), the concrete structure itself, and the foundations of the building inside which the equipement will be installed.

Because it is not practicable to "nuclear classify" a civil engineering structure in the way that electrical and mechanical components and systems are classified, the current practice is for the structural requirements of a nuclear power station to be developped and specified by qualified and experienced structural engineers according to the best engineering practice. However, civil structures are, like electro-mechanical systems, classified according to their ability to meet the effects of seismic disturbances, and in particular to remain functional if a safe shutdown earthquake (SSE) occurs. Thus according to the US NRC Regulatory Guide 1.29 "Seismic design Classification", the main portion of the nuclear island (nuclear buildings, electrical building, diesel generator buildings, essential water pumping station and tunnels) is classified Seismic category 1, and therefore these structures have to be designed to withstand the effects of the SSE and the associated load combinations.

In contrast, quality assurance (QA) requirements are not subject to classification according to the safety importance of the item covered, but are applied universally. In addition, the majority of QA standards are still directed towards the manufacture of electro-mechanical components because this is where the safety stress lies. For example, the concrete containment is included in the ASME code (which concentrates on the QA systems for pressure boundary components) not as a building structure but as pressure retaining barrier that retains or controls the release of radioactive or hazardous effluents.

In practice, QA programmes in compliance with ANSI N. 45.2. or its equivalent must be applied to the design and construction of the reactor containment. For other parts of the nuclear power plant, the degree to wich QA programmes are implemented depends on agreement between the owner and the contractor. Generally the situation is one of all or nothing : either the QA programme required for the containment is applied to the whole plant, or no QA programme is required except for the containment.

The first approach may generate unnecessary formal procedures and excessive paperwork that damages the motivation of those involved because their efforts are wasted on the "trivial many" and not concentrated on the "vital few".

In the second approach, the absence of a formal QA programme means that the minimal documentation to demonstrate quality is incomplete or non-existent, and the management of quality is subjected to numerous organizational conflicts and conflicting requirements between the design and construction phases.

2. A RATIONAL APPROACH TO CIVIL QA

In 1976, SPIE BATIGNOLLES set up quality assurance programmes for the civil works of several nuclear power plants in compliance with ANSI N.45.2.

Then in 1979, the Company took advantage of what had been learned and started to elaborate its own quality assurance standard in collaboration with MOTOR COLUMBUS and SOCOTEC. The standard has since been developed and improved based on the experience gained on large construction projects by the three parties.

The published standard (1) outlines the basic concept of the system. The quality management requirements are presented in separate chapters of the standard, covering design, manufacturing and construction for each of three quality assurance levels. Each chapter repeats the same pattern of basic and specific QA requirements adapted to the activity and graded to suit each level of quality assurance. This is done to establish the optimum way of performing an activity, in the environment where it has to be done, and to achieve the required results at a given price.

The standard aims to structure the QA requirements in such a way that they remain compatible with existing QA standards and codes (ANSI.N. 45.2, IAEA Code of practice 50 CQA, BS 5750, CSA Z 299, AFNOR NFX 50.110.) and at the same time allow them to be implemented realistically.

The special features of the quality management standard are thus that :

1. It is specific to civil works.
2. Its requirements are adapted specifically to each of the project activities : design, manufacturing and construction.
3. These requirements are adjusted or "modulated" into different levels of QA or quality management according to their importance and complexity.

It is important to note that the technical requirements for quality may be the same for each level and only the methodology for the management of this quality is graded from level 1 to 3. Therefore, quality assurance level 1 provides the most systematic, formalized, time consuming and costly methodology. Level 2 combines the reasonably desirable with the practically feasible. Level 3 constitutes what is considered as good normal practice.

In principle, each QA level contains fewer or less stringent requirements than the one immediately above. This does not mean that the good practices resulting from meeting the requirements of the higher level should be abandoned when producing an item to the lower level. It means that at the lower level, lesser assurance is required in the form of documentary evidence of the implementation and effectiveness of theses practices.

For example in the area of quality records (construction activity), QA level 1 (C1) requires the maintenance of records to demonstrate that each portion of the QA programme has been established and effectively implemented. These records include as appropriate :

1. QA manual, QA procedures and quality plan.

(1) "Quality Management for Civil Works", Macmillan Press, London, 1984

2. Technical records such as specifications, drawings, calculation notes and inspection and test procedures.
3. Records of qualification of special processes (procedures and personnel).
4. Records of calibration of measuring and test equipement.
5. Procurement records
6. Corrective action records
7. Audit records
8. Final performance records such as : as built records, materials test reports or certificates, NDE reports, inspection and test reports, non conformance reports, concrete batch plant print out etc...

QA level 2 (C2) requires only maintenace of those records relating to items 1,2,3 and 8. At QA level 3 (C3) only specifications, drawings, calculation notes and inspection and test reports are required to be maintained.

In establishing a methodology for adjusting or modulating the QA requirements to these different levels it was recognized that a complete and complex civil engineering structure is composed of simple parts and that theses simple parts can be verified to be acceptable by utilizing simple quality assurance programme.

The setting up of a quality management system for civil works starts with a detailed classification in which each structure or part of the building is considered in order to obtain a consistent system. For such classification, the following factors must be taken into account :

- the complexity of design, manufacturing and construction activities involved in the building, structure and its parts ;
- the maturity of the technology, and
- the importance of malfunction (this factor includes the safety aspect and safe operation during seismic disturbances).

In this manner, according to the following structure of the standard :

		Design (D)	Manufacturing (M)	Construction (C)
	1	D1	M1	C1
Quality Assurance Levels	2	D2	M2A	C2
			M2B	
	3	D3	M3	C3

D1 to D3, M1 to M3 and C1 to C3 designate the different sections of the standard at the different levels of quality assurance.

The classification for the reactor building of a 900 MW PWR plant shall be as follows :

	Design	Manufacturing	Construction
Raft	D 1		C 1
Containment :			
- structure	D 1		C 1
- liner	D 1		C 1
Internal structure	D 1		C 1
Handling gantries	D 2		C 2
Aggregates		M 2 B	
Cement		M 2 A	
Concrete		M 2 A	
Rebars		M 2 A	
Prestressing materials :			
- ducts		M 2 B	
- strands and anchorage		M 1	
Liners steel :			
- liner base		M 3	
- liner, liner anchors, penetration, sleeves, equipement hatch, personnel air locks		M 1	
- polar crane corbels		M 2 A	
Primary steel work (handling gantries)		M 2 B	
Decontaminable paint		M 2 A	

The quality management standard provides then the different organizations participating in the design, manufacturing and construction of these items and structures with a readily available set of QA requirements that enable them to set up their corresponding QA programmes.

The same procedure shall be done for the rest of the plant including the conventional parts (turbine building and others).

It is important to note that the quality management standard could be applied to non nuclear projects.

Thus, for a building with a relatively simple design but a complex construction method, the quality management system could be set up according to the following classification :

DESIGN	MANUFACTURING	CONSTRUCTION
D2	M 2 B Reinforcing Structural steel cement Aggregates	C1 Structural works C3 Painting Drainage Waterproofing

The quality management standard allows the implementation of clean and efficient QA requirements that provide assurance of quality commensurate with the relative importance and complexity assigned to each structure or item. It provides a rational and realistic solution for quality management of civil works.

However the success of such a system depends on the strict enforcement of the standard at all levels within the participating organizations. Modulation must not be interpreted as laxity : it must be a consistent decision supported by detailed analysis and extensive experience in order to determine the most legitimate QA requirements taking into account the particularities of a given activity or item, the most appropriate level consistent with the obligation to observe all specified requirements that have been judged indispensible.

In other words, the following well-known quality management principle is applied to increase the probability of better quality and therefore better safety, cost and schedule : requirements must be realistically set and rigidly enforced.

3. QA AS MANAGEMENT TOOL

A QA programme requires always the use of formal procedures which may deteriorate human relationship. The creation of an independent QA department responsible for the establishment of manual and procedures, their implementation and verification thereof may lead to the dilution of responsibility of personnel performing project activities. These latters may consider that from now on, quality is under the sole responsibility of the QA department.

On the other hand, the absence of a formal QA programme leads to the situation that we have already mentionned at the end of the first paragraph of this paper.

Based on these reflections, SPIE BATIGNOLLES has developed a management system which covers all aspects of a project : quality, cost and programme.
This management system combines QA principles with personnel motivation factors.

Thus, the following QA principles are retained :

- The clear definition of organisation and responsibility of each participant to the project.
- The planning and preparation of project activities (by means of project plans and procedures).
- The use of independent review performed by experts inside or outside the project team.
- The documentation of activities and results.
- The verification of the implementation of the management system by audits.

On the other hand, it must be noted that :

- There is no independent QA department.
- Management of quality is the responsibility of personnel who performs the project activities.
- The responsibility for the implementation of the management system is assumed by the Project Manager who establishes himself (with his team) the project procedures.
- Only the audit function is independent from the project management team.

Moreover, the organization of the project is based on two key principles which affect the efficiency and reaction capacity of the system :

- A temporary and autonomous project team structure.
- The decentralization of responsibilities and management of objectives (MBO) through :
  - the appointment of a Project Manager who receives a large and clear delegation of responsibilities and authorities.
  - the division of the project into sub-project each of which the management of technique, programme, quality, costs and contracts is placed under the responsibility of one person.
    The Sub-Project Managers receive delegation of authorities from the Project Manager.
  - project objectives and sub-project objectives are clearly defined by consensus and followed up.

All these principles are recorded in a DIRECTIVE FOR MANAGEMENT OF MAJOR PROJECTS approved by General Management and issued to all persons involved for implementation.

At the start up of a project, the Project Manager establishes and submits to General Management for approval :

- a project manual defining organizational rules, responsibilities and tasks of each participant. These rules comply with the principle of project division mentionned above.
- a project plan proposing the objectives (quality, costs, programme) for the project and for each sub-project.

During the execution of the project, the project activities are subject to project procedures established by the Project Manager and his team.

In the area of quality (of design, manufacturing and construction) the project procedures are established in accordance with the requirements of the quality management standard.

The implementation of the project management system, from the start-up, through the execution and upto the completion of the project, is subject to periodical audits to assure its compliance with the rules of the DIRECTIVE.

The audit department reports directly to General Management but performs as expert adviser and the audit reports are issued directly to the Project Manager for action. The General Management is called in as ultimate recourse only when important disagreement appears between the Project Manager and the audit team.

Accident Analysis and Safety Assessment for Tunnelling Works

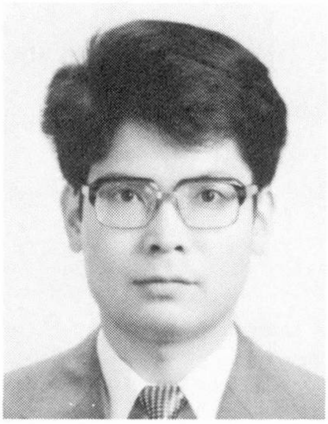
Analyse des accidents et sécurité dans la construction de tunnels

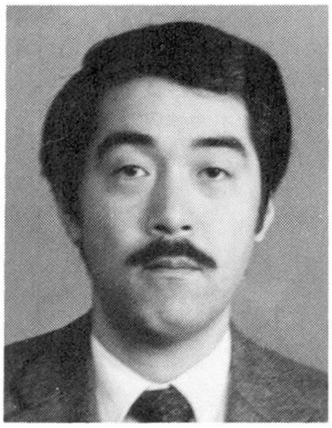
Unfall-Analyse und Sicherheits-Beurteilung im Tunnelbau

Shigeo HANAYASU
Senior Res. Officer
Res. Inst. of Ind. Safety
Tokyo, Japan

Yoshimi SUZUKI
Senior Res. Officer
Res. Inst. of Ind. Safety
Tokyo, Japan

Ikuo MAE
Director General
Res. Inst. of Ind. Safety
Tokyo, Japan





SUMMARY

This paper presents labour accident analyses of large construction projects for the purpose of clarifying a basic understanding of accident situations on construction sites. A guideline of the safety assessment for tunnelling work is proposed to set up precautions at the stage of execution planning, prior to the initiation of the work, in order to prevent accidents during the construction stage.

RÉSUMÉ

Le rapport présente l'analyse d'accidents dans de grands chantiers de construction afin de mieux comprendre cette situation fondamentale des accidents du travail. Les grandes lignes d'une méthode d'évaluation de la sécurité pour la construction de tunnels sont présentées dans un but de prévention des accidents du travail, déjà lors de l'élaboration du projet.

ZUSAMMENFASSUNG

Der Beitrag beschreibt zunächst die Untersuchung von Arbeitsunfällen auf grossen Baustellen, um die Verhältnisse klarzulegen. Dann werden Richtlinien für die Sicherheits-Beurteilung im Tunnelbau gegeben, damit schon im Entwurfsstadium Arbeitsunfälle verhindert werden können.

1. INTRODUCTION

Every year a lot of casualties take place in the construction industry. Recently labour accidents associated with construction work account for about one third of all occupational accidents and represent nearly a half of the number of deaths for all industry in Japan. Labour accidents also constitute a major cause that downgrades the construction production with direct and indirect financial losses. Therefore, prevention of labour accidents is one of the important issues in safety and quality assurance in the area of construction work.

This paper presents 1) labour accident analyses of large construction projects for the purpose of clarifying a basic understanding of accident situations in construction sites, and 2) A guideline of the safety assessment for tunnelling work, to set up precautions at the stage of execution planning, prior to the initiation of the work, in order to prevent future accidents during the construction stage.

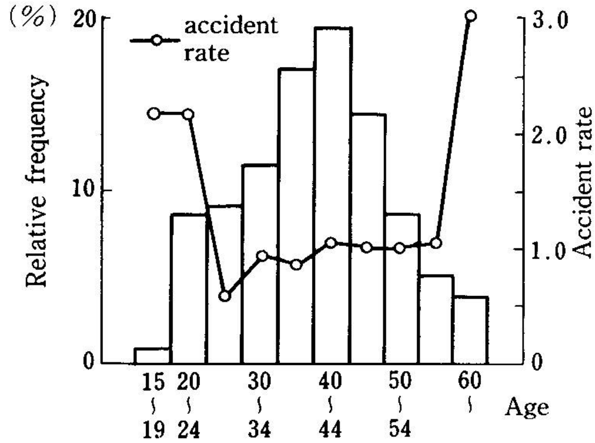
2. ANALYSIS OF OCCUPATIONAL ACCIDENTS IN CONSTRUCTION WORK

Two large bullet train construction projects were selected for the analysis in this study. 1) The New Sanyo Rapid Trunk Line (from Okayama to Hakata ; 444km length ; construction period 1967–1975), and 2) The New Joetsu Rapid Trunk Line (from Omiya to Niigata ; 304km length ; 1972–1982). These two projects cover various types of structure construction work, such as tunnels, bridges, etc. .

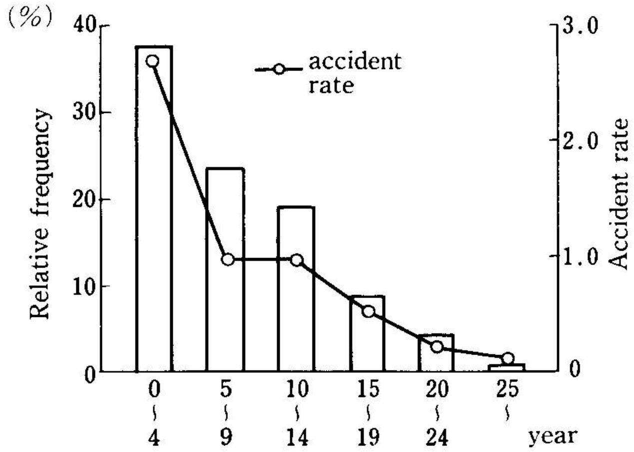
Available accident data (Industrial accident reports) were collected from prefectural labour standard offices involved. These data totaled in number 1868 injuries, including 55 deaths in the New Sanyo Line construction work, and 2055 casualties including 84 fatalities in the New Joetsu Line construction work.

2. 1 Accident situation of personnel [1]

To throw light on the nature of labour accidents in construction sites, various statistical analyses were carried out. Here, an analysis on the accident situations of personnel is presented. Fig.1 and Fig.2 show the distribution of accidents in the New Sanyo construction work, analyzed by age and years of exprience of the injured personnel. Both figures also contain the relative accident frequency rate (ratio of the proportion of accidents to the proportion of workers in each cell). As illustrated in these figures, accidents are concentrated in the middle age groups and inexperienced personnel. From the relative accident frequency rate, accidnts are more liable to occur in young and elderly personnel, which is 2 or 3 times higher than the average rate. As shown in Fig.2, accidents are less likely to happen in accordance with the increase in work experience. This statistical tendency could also be found in the anaysis of the New Joetsu construction work accidents. A notable difference between the accidents of the two projects is that the average age and the experience years of injured personnel in the Joetsu project (41.0 old, 10.4 years) were higher and longer than those of the Sanyo's (39.9 old, 7.1 years), which reflects the fact of the aging of work population in this industry.



Fig・1 Distribution of age of personnel



Fig・2 Distribution of years of experience

2. 2 Multivariate analysis of accidents in tunnelling work [1]

Various multivariate analysis methods were applied to the study of the basic relation between labour accidents and tunnel construction site characteristics. The tunnels under investigation in this analysis are those in the New Sanyo construction project belonging to Hiroshima and Yamaguchi prefectures, which were 75 sites in number. Depending upon the construction project record compiled by Japan National Railway, the available data on site's characteristics involved in the analysis were collected, viz: 13 kinds of numerical variables (eg. tunnel length, construction periods, rock grade index, total excavation hours consumed, etc.), including the number of accidents, and 3 kinds of categorical data such as method of excavation, transportation system, and of types of entrance approach.

After compiling these data for all the sites, 12 numerical variates in each site were divided by the tunnel length to make these variables comparative between each site. In order to find outliers in these normalized data, the 3rd moment (skewness) and 4th moment (kurtosis) of these variables were used. This detecting resulted in 6 sites that had some discordant values with respect to the construction variables. Therefore, for the purpose of assuring homogeneity of the data structure, variables in these 6 sites were excluded from the data set, so that the final number of construction sites for the analysis was 69.

The main results obtained in this analysis are pointed out as follows :

1) From the correlation analysis, there is a strong correlation between total number of accidents and the total volume of construction materials consumed. However, the accident frequency rate (the number of accidents per 1 km) has no positive relation to the volume of the construction variables concerned. In contrast to the overall accident frequency rate, the fatal accident frequency rate decreases in accordance with the increase of the volume of construction variables. This rate also depends upon the individual geological characteristics of the strata of the particular construction site.

2) According to the principal component analysis, many selected numerical variables can be explained by a few factors such as the size of construction work, the geological factors of tunnel, and the labour accident factors. (See Table 1) Since accidents constitute a major component in the analysis, statistical evaluation between work sites with reference to accident can be achieved by making use of the accident frequency rate. The Poisson distribution also could be employed for the statistical analysis of the number of occurrences of accidents in a site.

3) A discriminant function was developed to distinguish with high accuracy whether or not a work place may have fatal accidents during its construction periods. From this analysis, fatal accidents are more likely to occur in a workplace where the geological conditions are relatively better, and the execution of the construction work was accomplished within a short period of time. Interpretation of the variables employed in the proposed discriminant function were explained similar to the ones given in the correlation and the principal component analyses.

4) Also a multiple regression equation was proposed to predict the number of occurrences of accidents in a construction site with a relatively high multiple correlation coefficient. Total volume of steel arches erected, method of excavation, and index of rock grade have played an important role for establishing the regression equations. These explanatory variables could also give the same implications of the accident situation as revealed in the preceding analysis.

Table 1 Principal Component Anaysis of Tunnel Construction Work

Principal component	1	2	3	Accumlated contri-bution
Eigen value	8.4313	2.2968	0.5980	
Contribution	0.6486	0.8252	0.8712	
Number of accidents	0.7741	0.0818	0.5073	0.8632
No.of fatal accidents	0.7110	−0.1620	−0.1666	0.5595
Tunnel length	0.9719	−0.0896	−0.1308	0.9697
Construction period	0.7891	−0.0228	−0.1486	0.6453
Construction cost	0.9762	0.0658	−0.0658	0.9617
Excavation time	0.9644	0.0664	−0.1654	0.9619
Rock grade index	0.5072	−0.7503	0.2051	0.8623
Number of arches	0.9707	0.1057	−0.0896	0.9615
Volume of arches	0.8800	0.3389	−0.0558	0.8924
Volume of concrete	0.9763	0.0412	−0.1470	0.9764
Volume of invert	0.2848	0.8918	0.1190	0.8905
Invert proportion	−0.4369	0.8649	−0.0343	0.9401
Electricity	0.8228	0.1119	0.3897	0.8414
Notice	Scale	Geology	Accident	

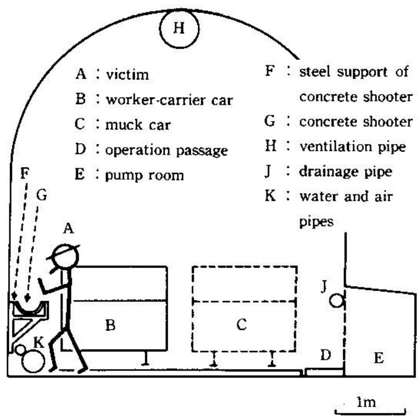
2. 3 Causal Tree Analysis of accidents in construction work

Understanding in total, the tendency of labour accident which occurred in two bullet train construction works, it is also necessary to study about each labour accident as individual cases. It is commonly recognized that there are many factors which contribute to the occurrence of labour accidents, and that these factors constitute various combinations and concatenations in the process of the occurrence of each labour accident. Therefore in order to establish the effective safety measures, it is necessary to examine in detail the process leading to each labour accident.

For the purpose of analyzing the process of the occurrence of labour accidents, 234 labour accidents that occurred in the constructin work of the New Joetsu rapid trunk line were selected. The selected samples of labour accidents were examined by means of adapting the C.T.A.method [3~5] . This is an a-posteriori method of analysis of accidents taking the passage of time into consideration. This method is regarded as a useful approach to predicate clearly and facilely the process of occurrence of an accident ; particularly concerning the relationships between various contributive factors to the accident.

In this section, in order to describe the process leading to an accident graphically, the C.T.diagrams for each accident were drawn out. The C.T.diagrams are made up by indicating events which contributed the occurrence of an accident, and by connecting these events in three kinds of connection types : sequence type, disjunction type, and conjunction type. As an example, one of these C.T.diagrams is exhibited in Fig.3. Then the linkages of events in the C.T.diagrams were investigated, one by one, each diagram with reference to the factors which might contribute to the occurrence of the accident. These contributive factors were identified and classified into five categories shown below :

- —I (human, individual) factor ; factors relating with persons concerned (ex. unskillfulness, fatigue)
- —T (task) factor ; factors relating with work/task concerned (ex. operation at a high elevated place)
- —M (material) factor ; factors relating with machinery/equipment/tool (ex. breakdown, dangerous tool)
- —Ep (physical environment) factor ; factors relating with working place/environment (ex. climate)
- —Es (social environment) factor ; factors relating with organization/management (ex. control, planning)



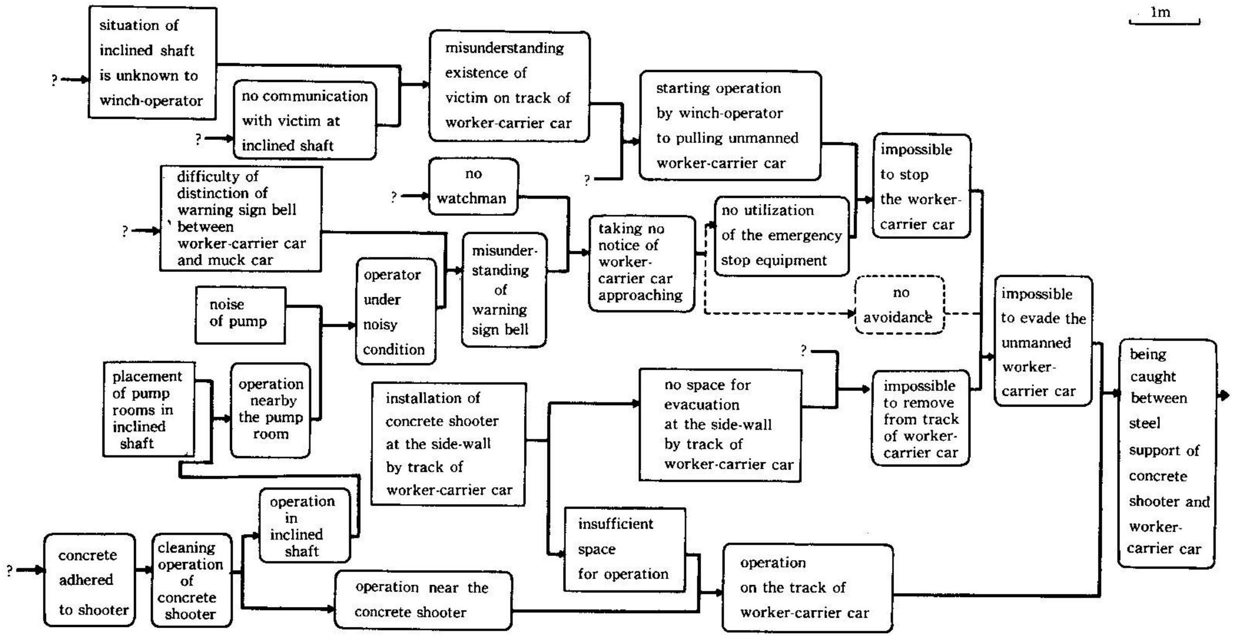


Fig. 3 C.T. diagram of an accident

Table 2 Typical interrelationshipes between contributive factors to accidents in construction works

Previous factor	Subsequent factor: I	T	M	Ep	Es
I	difficulty of communication between individuals (ex. default sign) etc	operation disturbance by improper behavior (ex. unskilled worker) etc	improper use of machinery/tools etc	influence for working condition by behavior of individual etc	disturbance in organization
T	dangerous works (ex. operation at a high elevated place) etc	inadequate adjustment between concurrent operation etc	improper task assigned to machinery/equipment etc	influence on working condition by inadequate operation mode etc	confusion of working crew due to changing operation mode etc
M	insufficient protection of worker from machinery etc	disturbance in operation by using improper tool/equipment etc	mismatching use of machinery and material etc	influence on working place by using machinery (ex. vibration) etc	confusion of working crew by using new-machinery etc
Ep	un-hygienic working place etc	disturbance in operation by working condition (ex. inadequate lighting) etc	environmental effect on machinery/equipments (ex. humidity, heat) etc	environmental effect on working place(ex. decrease stability of sloop by rain) etc	delay the work due to climate condition etc
Es	Inadequate management system in communication etc	Allowing inadequate work mode etc	absence of person in charge of examining machinery etc	work areas left in a disorderly fashion etc	disorganization due to inadequate adjustment between working crews etc

In accordance with the definition of classification of these five contributive factors, the frequencies of the factors leading to labour accidents, and the relationships between the factors were investigated. The description of the relationships between the five contributive factors were arranged and illustrated in a table (Table 2). One of the purposes of this arrangement is to consider dynamically the characterization of the factors; for instance, the factor generally called "human-factor" has varied significance. So it is necessary to treat the effect of the human-factor on other factors, and the influences of other factors to the human-factors. Though this table seems unable to indicate exactly the facts which bring the risks to the construction field, it is very helpful in obtaining a new understanding of the malfunctions inherent to a certain situation of the construction field, and very useful for considering specific prevention measures against labour accidents in the future.

By making use of the results of C.T.A., the process leading to accidents which occurred in the New Joetsu construction work was compared with accidents in another type of work (cutting works of road-constructing), and was examined from the point of the differences of the five structures constructed (tunnel, bridge, overhead railway, rail installation, and others), of the four types of accidents (falling, flying objects, machinery, and cave-in), and of the nine supervisory contractors ; symbolized A~H and J in this study. The results of examination are presented as "the distributions of the frequency of contributive factors to accidents" and as "the influential transition matrices" which means the situations of reciprocal actions between five contributive factors to accident.

The distributions of frequency of contributive factors to accident are shown in Table 3. From this table, it can be seen that T (task) and M(material) factors were the predominant factors to accidents in the New Joetsu construction work. When compared with another type of construction work, the New Joetsu construction work did not have the same proportion of frequency of the five factors. Particularly, M (material) and Ep (physical environment) factors were different in the two types of work. So far as the types of accident concerned, the distributions of the frequency of the contributive factors were slightly different each other.

Concerning the relationships between contributive factors, a total result of examinations of 234 accidents which occurred in the New Joetsu construction work is shown in an influential matrix (Table 4). Other matrices were also obtained in accordance to various points of difference ; types of work, types of accident, surpervisory contractors, and types of the structure constructed. (Tables are

Table 3 The distribution of the frequency of contributive factors to accident

Item			Sample number	contributive factors to accident: I	T	M	Ep	Es
New Joetsu construction work	Total		234	14 %	41 %	33 %	9 %	2 %
	types of accident	falling	14 •	27	38	25	9	2
		flying object	14 •	21	50	17	8	4
		machinery	20 •	11	42	40	5	2
		cave-in	5 •	13	47	13	20	7
	supervisory contractors	A	37	12	44	27	16	1
		B	24	16	36	38	8	1
		C	21	11	41	37	10	1
		D	19	13	43	34	8	2
		E	27	20	42	29	6	3
		F	22	16	35	34	13	2
		G	15	21	42	30	6	1
		H	35	16	38	31	14	1
		J	34	16	30	46	6	2
	structures constructed	Tunnel	159	13	37	37	12	2
		Bridge	16	20	45	29	6	0
		Overhead railway	41	22	41	30	6	2
		Rail installation	9	22	37	32	5	3
		Others	9	22	40	32	5	2
Cutting works of road-constructing	Total		82	7	38	13	34	9
	types of accident	sloop-failure	50	2	43	5	41	9
		machinery	32	15	28	29	20	7

(• selected only representative samples) omitted for want of space.) The similarities between these matrices were examined numerically by the chi-square test and cluster analysis, these results are shown in Table 5. A similarity could not be found between the four matrices according to the different types of accidents. When comparing the nine different supervisory contractors, the similarity between matrices could not be verified. When making a comparison between the five matrices according to different structures constructed, the existence of the similarity was confirmed. As contrasted with another type of work (cutting-works of road-constructing), the influential transition matrix of the New Joetsu construction work is clearly different.

These results suggest the necessity of speific measures taking care of each different type of labour accident concerning to its own projects.

Table 4 The influential transition matrix (Total results of 234 samples of the New Joetsu construction work)

		Subsequent Factor				
		I	T	M	Ep	Es
Previous Factor	I	0.60	0.09	0.26	0.01	0.04
	T	0.19	0.53	0.24	0.04	0.0
	M	0.14	0.18	0.63	0.04	0.0
	Ep	0.25	0.15	0.36	0.24	0.0
	Es	0.17	0.57	0.17	0.09	0.0

Table 5 The similarity between influential transition matrices

Matrices considered	Number of matrices compared		Result of similarity
Classified by works	2	New Joetsu construction work, Cutting works of road-constructing	different
Classified by types of accident	4	New Joetsu construction work; falling, flying object, machiney, cave-in	different
	2	Cutting works of road-constructing sloop-failure, machinery	different
Classified by supervisory contractors	9	New Joetsu construction work; supervisory cotractors symbolized A～J	not specified
Classified by structures constructed	5	New Joetsu construction work; tunnel, bridge, overhead railway, rail installation, others	similar

3. SAFETY ASSESSMENT FOR TUNNELLING WORKS

According to the analysis of causes of the accidents in tunuel construction work, there exists some cases where safety precautions at the stage of work planning seem to have been inadequate. Therefore, in order to assure safe execution of work, a comprehensive checking system for setting up the precautions at the stage of work planning prior to the initiation of work, which we will call here "safety assessment" would play an important role for prevention of future accidents in the construction stage. The basic concept of the "safety assessment" is very close to the one that emerged from system safety engineering where the emphasis is placed upon the "before the fact" concept, identify/analyse/prevent, rather than the traditional "after the fact", accident/investigation/fix concept. [6]

With this thinking in mind, development of the safety assessment procedure was carried out. The developed system here is a process to check the necessary safety measures against all anticipated accidents by predicting the potential risk inherent to the tunnel construction site's characteristics. The developed procedure of safety assessment is described as follws :

1) Collection of basic data (lst step)

At this step, basic materials and data necessary to perform the safety assessment of tunnel construction are collected and compiled. Typical of these are the following groups : a) geolgical and geographical maps, survey

Table 6 Safety measures for basic matters

Basic matter	Details of assessment
(1) Work control organization	
1) Chief engineer on supervisory engineer	○ Assign a chief engineer or a supervisory engineer with sufficient experience and knowledge in tunnel construction to the construction site.
2) Management organization (regulations)	○ Prepare control organization regulations specificaiiy prescribing duties for all members including subcontractors.
3) Selection of subcontractors	○ When selecting subcontractors, consider past work results and safety results.
(2) Safety and health management	
1) Safety and health management system	○ Appoint the following:

Controller	Worksite covered
General safety and health supervisor	Worksite employing not less than 100 workers usually
Safety supervisor	Worksite employing not less than 50 workers usually
Health supervisor	〃
Industrial physician	〃
Overall safety and health controller	prime contractor's worksite where 30 or more workers including subcontract workers work at the same place
Master safety and health supervisor	Worksite requiring appointment of a general safety and health controller
Safety and health controller	Contractor for other than worksite requiring appointment of a general safety and health controller

results of environment and climate of the working site. b) documents of design, schedule, working plan, temporary work, equipments. c) work record of similar type tunnel construction or other structures constructed nearby. d) safety and health law and other related laws and ordinances, various safety technical guides and practice.

2) Check the basic matters (2nd step)
At this step, examine as to whether appropriate safety countermeasures are already in force or are going to be taken with respect to the basic matters indispensable to the safe execution of tunnel construction.

For this purpose, a comprehensive check list was prepared, which includes more than 80 items as necessary requirements to ensure safe execution of tunnel work. Each item has a detailed guideline to help assess whether or not the corresponding safety measure in the execution plan is adequate. A study should also be made as to when and how the proposed safety measures are to be implemented. Table 6 illustrates a portion of the list items of basic matters with a detailed explanation for the assessment, in which work control organization requirements are presented. Many of these items listed as the basic matters, were selected from the articles related to tunnel construction work in the Safety and Health Law established in 1972, and other authorized engineering specifications.

Table 7 Potential risk evaluation of gas explosion

Element	Condition	Raw Score
Geology (G)	a. The tunnel is in an area with gas generation. The preliminary survey indicates that the geology has a possibility of great gas generation for the entire length.	3
	b. Part of the tunnel is either in or near an area of gas generation. The preliminary survey indicates that part of the geology involves an amount of gas generation.	2
	c. There is no gas generation	0
Length (L)	a. Long. (1,000m or more)	3
	b. Medium. (300m to less than 1,000m)	2
	c. Short. (less than 300m)	1
Cross section (A)	a. Small cross section (excavation cross section: less than $10m^2$). or uses a bottom heading and a sidewall heading.	3
	b. Medium cross section (excavation cross section : $10m^2$ to less than $50m^2$).	2
	c. Large cross section (excavation cross section: more than $50m^2$).	1
Type of tunnel approach (S)	a. Vertical shaft	3
	b. Inclined shaft	2
	c. Regular tunnel or adit.	1

R (risk for gas explosion) = $G \times (L+A+S)$

Table 8 Rank classification of potential risk of each anticipated accident

Rank	Gas explosion	Flooding	Fire	Transportation	Cave-in
I (High)	11 or more	13 or more	8 or more	8 or more	10 or more
II (Middle)	7−10	9−12	5−7	5−7	7−9
III (Low)	1− 6	1− 8	1−4	1−4	4−6
IV(Improbable)	0	0	—	—	—

Upon conducting the evaluation of the basic matters, corrective action including modification of the execution plan should be taken if necessary. These safety measure assessment tables for the basic matters prepared here is not only useful at the stage of work planning for assessment, but also can be effectively used as a check list during the execution stage as well.

3) Ranking of the potential risk of the anticipated accidents (3rd step)
After confirming the basic safety requirements for tunnel construction work in the preceding step, quantitative evaluation of the chances of occurrence of several serious accidents inherent to tunnelling work is achieved by taking the construction site's characteristics into consideration. Then in accordance with the scores obtained from numerical evaluation, assign the rank of degree of potential risk of the anticipated accidents to the specified construction site concerned.

Table 9 A portion of the list of items to be checked for each accident

Gas explosion	Excessive flooding	Fire	Transportation	Cave-in
(1) Preliminary survey 1) Boring survey 2) Collection of data 3) Survey tunnel	(1) Preliminary survey 1) Boring survey 2) Collection of data	(1) Fire control 1) Storage and handling of combustibles 2) Gas welding and cutting 3) Electric equipment 4) Smoking places, etc.	(1) Hauling methods	(1) Preliminary survey 1) Geological and other surveys 2) Collection of data
(2) Measurement of gas 1) Measuring instrument 2) Measuring method	(2) Excavation work 1) Horizontal boring 2) Drain tunnel 3) Concrete shot 4) Injection	(2) Making tunnel equipment	(2) Tunnel hauling equipment 1) Operation control regulations 2) provision of track bed 3) Inspection of signals and markings 4) Use of pushcars	(2) Excavation work 1) Excavating method 2) Check for loose stones 3) Arrangement of

Table 10 Safety measures against gas explosion

Item of study	Rank I	Rank II	Rank III
(1) Preliminary survey 1) Boring survey	Carry out a boring survey and measure the amount of gas inside the whole tunnel from the entrance. Analyze the boring core and make a precise survey on gas composition, content, etc.	Make a boring survey and measure the amount of gas. Also study and analyze the boring core.	Same as left.
2) Collection of data	Survey on generation of gas in past tunnel and under-ground works in the vicinity.	Same as left.	Same as left.
3) Survey tunnel	Excavate a survey tunnel, if necessary, and check for the output, pressure and composition of gas.	Study to excavate a test tunnel.	
(2) Measurement of gas 1) Measuring instruments	Use portable instrument for local measurement and stationary measuring instruments for permanent measurement where gas is likely to stagnate.	Provide portable measuring instruments.	Same as left.
	Set standards for the inspection and maintenance of measuring instruments.	Same as left.	Same as left.

From the result of accidents investigation in recent tunnelling work, it was recognized that major accidents that resulted in either many workers being injured or large amount of damage to work performance were identified as gas-explosion, fire, flood, cave-in, and accidents in transportation work. [2] In order to evaluate the potential risk of these anticipated serious accidents numerically for a specific tunnelling work, four primary elements of construction site' s condition were considered. Geological condition, length of tunnel, cross section of tunnel, and type of entrance approach, were employed for the analysis. To assess the conditions of the elements in conjunction with the potential risk of hazards, descriptive criteria about the conditions of elements and assigned raw scores were prepared for all anticipated accidents. Table 7 gives a detailed description of the element condition as well as the corresponding raw scores for the occurrence of gas explosion. The numerical potential risk assessment point could be analyzed by substituting the identified raw score into a pre-determined equation for each anticipated accident. This assessment point is then set into rank classification from I (high) to III (low) or IV (improbable). Table 8 illustrates the relation between rank classfication and assessment points for all anticipated accidents.

4) Check the safety measures against inherent accidents (4th step)
As the final stage of safety assessment, check to see if proper safety measures against anticipated inherent hazards are already undertaken in compliance with the grade of the potential risk which was evaluated in step 3.

Table 9 illustrates a portion of lists of necessary items to be checked for each inherent hazard. Table 10 demonstrates a portion of proposed safety measure guidelines to the items in accordance with the degree of potential risk, for gas explosion accidents. Similar tables of guidelines for other inherent accidents have also prepared. After thorough checking is accomplished, similar to step 2, additional necessary safety measures should be taken if the proposed safety measures in the execution planning are judged inadequate.

The Ministry of Labour has approved this assessment system and recommends to the contractors, who have full responsibility for the safety of workers, to employ it to evaluate the working schedule before they start the work.

REFERENCES

1. MAE. I, HANAYASU. S, SUZUKI. Y, Accidents Analysis in Tunnel Construction Work I ~IV, (in Japanese), Research Report of RIIS, 1976, 77, 78, 86
2. MAE. I, HANAYASU. S, Accidents Analysis in Tunnelling Work, Proceedings of the International Symposium on the Safety of Underground Works of I.T.A., 1980
3. MERIC. M, MONTEAU. M, SZEKELY. J, Technique de gestion de la sécurité, I.N.R.S. n° 243/RE, 1976
4. DARMON. M, MONTEAU. M, QUINOT. E, ROHR.D, SZEKELY. J, Les facteurs potentiels d' accidents, I.N.R.S. n° 200/RE, 1975
5. SUZUKI. Y, The Method of Analysis on Industrial Accidents by Causal Tree Analysis, (in Japanese), Research Report of RIIS, TN-83-5, 1985
6. RODGERS. P. W., Introduction to System Safety Engineering, John Wiley, 1971