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Construction and Inspection

Exécution et contrôle

Ausführung und Überwachung

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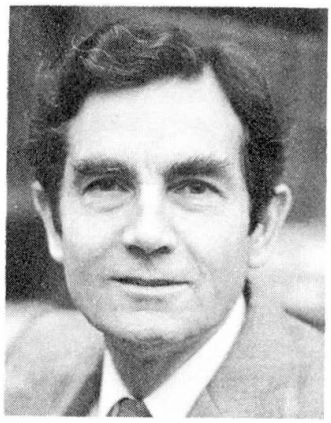

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SUMMARY

All parties to the construction contract seek assurance that the specified quality is being produced. It is emphasised that not only must the quality of the constructed project be assured but that it is no better than the specification which must be an assured interpretation of the client's requirements. Quality Assurance is of great benefit to the contractor as well as his client.

RÉSUMÉ

Toutes les parties prenantes du contrat de construction cherchent à ce que la qualité spécifiée soit effectivement obtenue. Il faut souligner que non seulement la qualité de la construction doit être garantie mais aussi que les spécifications doivent vraiment répondre aux exigences du client. L'assurance de la qualité est aussi bien à l'avantage de l'entrepreneur que du maître de l'ouvrage.

ZUSAMMENFASSUNG

Alle den Werkvertrag unterzeichnenden Parteien wollen erreichen, dass die spezifizierten Qualitätsmerkmale auch wirklich hergestellt werden. Es wird darauf hingewiesen, dass nicht nur die entsprechende Qualität des Bauwerks gesichert werden muss, sondern dass die Spezifikation auch wirklich eine gesicherte Interpretation der Wünsche des Bauherrn zu sein hat. Qualitätssicherung ist von grossem Nutzen für den Unternehmer und den Bauherrn.

The contributors to the project

The aspirations of a client, the concept and detailed design of his engineers come to fulfilment on the completion of the construction by the contractor and the satisfactory bringing into use of the engineering or building project. Each of the organisations involved have a critical part to play in the achievement of a satisfactory result. It is the user of the project following completion who is in the best position to determine both the utility of the constructed project and decide whether it is satisfactory for the intended purposes. The user may or may not have had the ability to influence the specification for the project in the first instance. There are, therefore, four parties, each with an important role to play in deciding whether the finished project is fit for purpose, is value for money and is of an appropriate quality. Quality is often defined as the totality of features and characteristics of a product or service which bear on its ability to satisfy a given need. The durability of the project and its ability to continually perform in a satisfactory manner is an important characteristic. For each of the parties, the definition of quality for the part they contribute to the finished product and its use, is likely to be very different. Since the project comes to reality in the hands of the contractor on the construction site or in the fabrication works, the contractor is concerned to meet the client's specification rather than the undefined requirements of the user. The client transmits a definition of the works to his engineers who, in turn, have satisfactorily to specify such requirements in a manner that enables the contractor to carry out his work in a foreseeable and controlled manner.

The welding together of these definitions and specifications without ambiguity is a crucial part of the process which leads to an assured quality for the end product providing a satisfactory outcome to each of the parties. Each party is subject to partisan interests. The client is interested in achieving his project at minimum cost and the highest quality for his stated definition of the project and usually wants it as soon as possible. The engineers hope to produce a structure or works which will impress their client, will provide maximum benefits for the available budget, and will demonstrate their prowess to the construction industry whilst ensuring that the contractor constructs in a safe and responsible manner. The contractor is committed by contract with the client to provide the specified works for a stated price and time scale and will be anxious to minimise his costs whilst meeting his commitments. The user awaits the end product before he can pass any judgement, and hopes that he can use it with minimal restraint.

The need for Quality Assurance (QA)

Few projects are really repetitive and even if the design and specification is identical for a second project on the same expected soil conditions, variations are likely in the weather, the contractor's staff and operatives, the sources of materials and their comparative costs. That is quite apart from political and legislative changes or reactions from local communities. Finally, of course, there is the unpredictability of human behaviour. The parties producing a construction project require assurance that quality will not only be controlled but can be reliably predicted.

Quality control, as generally practised, is the direction and inspection of activities as they are undertaken and the value of quality control is most

often demonstrated by tests on finished articles or sample pieces after the event. By the application of quality assurance procedures, a controlled environment is created in which the possibility of unacceptable mistakes or poor workmanship and materials is eliminated. To expect absolute abidance to instructions is not only unrealistic but usually expensive and the absolute should be confined to items which are critical. The possibilities for exceptions should be confined to circumstances where the consequences are acceptable. Quality assurance is defined as all the activities or functions concerned with the attainment of quality. QA procedures provide a control over working practices and the selection of materials to eliminate the foreseeable errors. These procedures necessarily require that appropriate records be compiled of the control checks made. In the context of QA, quality control is defined as the operational techniques and activities which sustain quality assurance. Thus QA should create a controlled working environment which applies from the definition by the client of his requirements through to the final commissioning of the works. QA requires responsible staff to think and to act logically and comprehensively and to demonstrate such actions. This is really no different to what has always been required of structural engineers but in the same way that the critical path network analysis disciplines the planning of construction operations, so does QA discipline the execution of these operations. The same basic questions which one asks, in order to write a critical path network, are asked when one sets up a QA procedure for a new project.

Emphasis has already been placed on the neeed for clear definition of requirements from one party to the next and in the contract specification to which the contractor is committed for construction. It is essential that each translation of the client's requirements is consistent, accurate and unambiguous if all the parties are ultimately to be satisfied and in accord. In any event the contractor will argue that he is only required to demonstrate that he has met the specification as defined to him in his contract. The records which result from his use of QA procedures will enable him to demonstrate this achievement. This may or may not satisfy the client, or indeed the user, who when dissatisfied, will seek to demonstrate to the engineers that they have misunderstood the requirements given to them. Every engineer has therefore to be particularly concerned that he correctly receives, interprets and records the instructions as to the client's requirements. Clients have to be educated and disciplined more than many of them are at present and many non-technical clients require help and guidance.

So far, the case has been made for clear specifications of the work to be carried out and the materials to be used for the benefit of all the parties to a contract. There are additional advantages to be obtained by the construction industry as a whole. The industry's clients will receive consistently better standards of workmanship and materials from competent contractors employing QA procedures. These contractors must organise their affairs to demonstrate assurance that they will achieve the specified quality of performance. Materials and workmanship will be defined or specified in terms of recognised national and/or international standards which are sufficiently precise for QA purposes. Manufacturers who regularly supply to the construction industry will be required to conform to national standards, Agrement Certificates or Third Party Certification Schemes in order that they can demonstrate the quality of their products and their assured ability to produce them. The standard of the materials and products in general use should rise and with the increased production runs, the prices of better products will become more competitive.

Increasing use is being made of new or improved materials and technology, and recognised methods for their assessment are required in order that a standard can be set and quality assurance procedures provided. With a new material or technique there is often inadequate background experience to predict the likely durability and performance of the component for more than a limited number of years. The construction industry, as much as any other industry, cannot afford to ignore the exciting possibilities offered by many of these new and developing ideas. It must adopt them in a controlled and realistic manner to take advantage of the economies and improved performance which is offered. New methods of design and construction need encouragement but should be related to ongoing research and development to provide support for the innovative nature of the new method. Assurance is needed that the method can be introduced in a controlled manner with identification of the action required in the event that adverse performance is obtained. Novel materials, techniques or methods presented to a contractor in the contract documents require evaluation by him as to the risks which they may present for which there is little precedence. Can the standards of performance required in using them be identified and are they realistic? Is the proposed application an appropriate one? Is the contractor able to protect himself from liability arising from any failure of the material or method to give satisfactory performance? Quality assurance may encourage such innovations providing the criteria of assessment are clearly defined.

Construction Risks and Opportunities

Whilst the designer of a structure will take into account the risks inherent in the construction of the project at its location and its exposure to the environmental conditions, his concern will be mainly directed to the long term performance of the project when completed. It is considered to be the province of the contractor to achieve construction of the specified works to the contract price and programme. When contractors are competing in situations of low risk there are not usually great opportunities to increase the expectations of profit. Areas of risk and uncertainty are attractive to competent contractors when they regard them as quantifiable and within their competence to influence. Political and financial uncertainties are separate subjects and not amenable to technical assessments. What then are the areas of risk and opportunity which contractors regard as a challenge to their skills and ingenuity?.

Usually these risks are associated with construction in poor and uncertain ground conditions, in hostile marine environments, novel forms of construction or the extrapolation of existing structural methods to longer spans or higher buildings. Although it is common practice to talk about the risks involved, what is really meant is the possibility of adverse circumstances occurring. When constructing a tunnel through ground which could not be adequately investigated there is the possibility that conditions may be so difficult that progress will be so slow and expensive as to defeat the cost effectiveness of the project. There is also a possibility that conditions may be much better than expected and the cost will be less than predicted. A balanced technical and experienced assessment is needed by the engineers acting for the client and then by the tendering contractors.

Contractors have varying success rates in tendering for projects but assuming a success rate of one project from eight tenders then they will be involved in the risk/opportunity assessment of some eight times their annual turnover of that type of construction. Large contractors therefore soon accumulate an

insight into the range of design solutions to different civil or structural engineering projects and observe how their successful competitors resolve the challenges on the seven tenders out of eight for which they were not successful. Their observations may or may not identify the real reasons which enabled the successful tenderer to be the low bidder. The annual accounts might highlight the reason!

Having secured his occasional project a contractor will set out to control the items at risk and identify where improvements can be obtained. He may initiate additional site investigations, construct and test models, or use research findings in a development programme. He will seek assurance of the adequacy of the information on which his construction method proposals are based. Failure to seek such assurance involves a gamble and he will wish to minimise it in order that the safety and success of his proposals are not jeopardised. It may well be that assurance is only obtained by applying large factors of safety but as in design work it is necessary to identify where and how such factors should be applied. The contractor has an absolute duty at law to provide for the safety of the construction works and those engaged upon or likely to be affected by them. That duty must not be jeopardised.

The greater the uncertainty the greater is the probable cost involved in adopting a safe and assured method of construction. The contractor is obliged to make such assessments for his tenders and when he is awarded the project will endeavour to reduce the provisions for uncertainty which accordingly enhance his potential profit. A client or engineer who has left all the uncertainties with the tendering contractors may feel aggrieved if all goes well and the contractor turns the risks into opportunities. It is more equitable for the client and his engineers to assess the nature of the uncertainties, provide all reasonable information for evaluation, and phrase the contract documents so that contractors may use their skills to solve the technical challenges. Provision can be made for the unknowns using provisional sums used at the engineer's direction. In this manner, the safety and quality of performance may be assured by careful specification from the engineer to the contractor.

Assured Safety and Quality Management

The principles governing safety and safe practices on construction sites are usually defined in statutory legislation such as the British "Health and Safety at Work Act" which refers to and is supported by regulations and Codes of Practice describing recognised good practices. Construction sites are hazardous workplaces and new measures are constantly being introduced to remove specific hazards, provide better working conditions and equipment, and improve working practices by education, mid career training and the adoption of guide documents. In the case of a number of site operations it is now customary to require registers indicating who is responsible for a particular operation, by whom it is inspected and when such inspections are undertaken. This discipline is notably successful in reducing bad or careless performances.

Whilst the contractor has been held fully responsible for the safe and proper execution of the construction it is not until recent years that similar control disciplines to those for safety have been introduced for temporary works. An international investigation identified that few countries had adequate design and construction guides available to direct and set standards for good practices in such operations as trenching, formwork, falsework and

cofferdams. Such guide documents are now more generally available and assured good practice is obtained by using Temporary Works Co-ordinators to ensure that the design, construction, use and dismantling of such works is undertaken in accordance with recognised standards. Responsibility is allocated on a formal basis and records are kept of operations and the inspections and approvals of them.

Quality management also requires the use of supervisory staff with appropriate experience and training to interpret the duties assigned to them and the quality plans defining how the work is to be undertaken. Codes and Guides have been prepared to make available advice and check lists for most aspects of construction so that site staff achieve consistently good, safe and economic standards of performance. As a support to quality plans, site pocket books are used which indicate the controls necessary for different types of construction, how and when to check specific aspects of workmanship, the reasons for the checks, the required accuracy and other criteria which govern acceptability, and recommend reference documents for more detailed information. Such pocket books establish the rules both for those directing and those checking construction and at the same time hopefully encourage younger staff to seek recommended explanations for any items they do not understand.

Quality management applies from the preparation of materials and components through their use in the construction to their performance in the completed project and governs the success of it.

The production of quality assured materials and components for use on site

A contractor, at the commencement of a new contract will schedule the materials and services required and programme the works in detail. This will establish dates by which firm information is required for the ordering of materials and services. The programme will indicate the dates for preliminary and final information related to the construction of the work on site. The contractor has to satisfy himself and be able to demonstrate that all his suppliers and fabricators carrying out work off-site are able to, and do, provide materials and components complying in all respects with the specification including the supporting drawings and other instructions. The contractor has to be assured that these off-site operations are carried out by suppliers of assessed capability subject to regular inspections. Such quality assurance assessments in Britain will be undertaken preferably by:

- A British Standards Institution (BSI) quality assurance assessment that manufacturers can produce materials under a quality management system as required by BSI Standard 5750: Quality Systems.

- A British Board of Agrément (BBA) assessment as required by their certificate to demonstrate that the manufacturer will consistently produce to the same composition and workmanship standards.

- A Third Party Certification Scheme for the sector of industry which has been approved by a National Accreditation Council for Quality Assurance Organisations.

Alternatively, the QA procedures of the supplier must be inspected and found satisfactory by the contractor in the absence of any of the above. It should not be necessary for the contractor to conduct a capability assessment if the

supplier is already conforming to the satisfaction of one of these national organisations for the materials or components concerned, and this will minimise his own involvement off site. The assessment of the supplier's capability requires a demonstration that he has been consistently producing supplies of assured quality in the past which should include the majority, if not all, of his production being under such control thereby minimising the possibility of an error from the mixing of assured and non-assured supply items. The manufacturer or supplier needs to demonstrate under his quality assurance regime that his raw materials are controlled to an equal standard.

To take an example, there is in Britain, a Third Party Certification Scheme (CARES) for the certification of reinforcing steels. CARES is an independent authority, designed to be self-financing, and its membership represents all the principle organisations concerned with the specification, supply and use of reinforcing steels. CARES assesses the competence of steel makers and reinforcement manufacturers to supply products which consistently comply with the appropriate British Standards. To receive a CARES Certificate of Approval, an applicant is subject to an assessment of its quality management system in accordance with British Standard 5750: Quality Systems, and by independent product testing as well as past records of testing to demonstrate conpliance with the appropriate standards. CARES will, when satisfied, authorise the supplier to use the CARES registered mark and certificate number when delivering materials covered by the scheme. Following the initial approval, manufacturers and suppliers are subject to regular checking to ensure that no deviation from the inspected and accepted procedures has occurred. Failure to maintain standards will result in the withdrawal of the Certificate. Most suppliers to the British construction industry have joined the scheme and pay fees based on the initial assessment cost and at a price per tonne. The scheme is not limited to British producers. It is also possible for individual consignments of reinforcement from a non-certified source to be assessed by CARES when the supplier or contractor requires it. The adoption of the scheme by the many major specifiers who will only permit the use of reinforcing steel having CARES authorisation has helped this scheme to come into general use and for quality assured supplies to be the norm. The composition of the Board of Management of CARES balances the views of the interested parties. The author represents the Federation of Civil Engineering Contractors on that Board.

The development of similar schemes for most of the other important materials and components supplied to construction sites will ease the concern of the contractor to have quality assurance.

In the absence of such schemes the contractor will have to agree with a supplier or manufacturer how the qualities of the materials or components to be supplied to site can be demonstrated to be as specified so that they may be assuredly delivered to programme. The rejection of materials or a completed component due to poor quality, whether it is an item of structural steel, reinforced concrete or plant, must be avoided in order that the programme can be met. To obtain this needed assurance the contractor must consider whether to install inspectors at the works, apply frequent inspections by his own or independent inspection laboratories, or persuade the supplier to change to a continuing quality management operation and have it formally assessed by a nationally approved scheme.

The contractor, having ensured a regime off-site which provides only quality assured products, where these are necessary, should be presented with an appropriate record of manufacture of those products with identification references to each item except in the case of bulk supplies.

Performance on site

To establish quality assurance management the contractor needs to be more formal in his construction procedures and the records he keeps but in some respects his management concerns are reduced. It is necessary to examine the documentation of the contract to ensure that the requirements are accurately and unambiguously defined and have clear criteria for the assessment of the works as completed. When such clarity does not exist, early efforts are needed to resolve the potential difficulties from inadequate or conflicting specifications or details before they become problems. The receipt of quality assured supplies of materials and components should eliminate the rejection of any of these late in their preparation off-site or by subsequent testing on site, and arguments about their quality long after they have been used. Not all the work required on the contract justifies QA control but it is important if there are exceptions that QA is applied to all materials or workmanship of a particular type so that the introduction of dual standards is avoided.

A member of the contractor's site staff, a QA controller, should be appointed to be responsible for quality assurance, usually as an addition to other duties, e.g. he may be the senior site engineer. He will be required to operate in accordance with the contractor's Quality Assurance Manual which will detail the procedures to be adopted and the quality plans which will govern different activities on the site. From the construction programme, dates will be set for the receipt of the necessary information to enable enquiries to be made for materials and services and these enquiries will elaborate on the quotations obtained for estimating purposes which should therefore have been sought on a comparable basis. The QA controller will need to assess the current status of potential suppliers in respect of quality management and if in doubt will have to conduct, or organise, an audit of any proposed supplier's management systems. Before orders are placed, arrangements must be agreed as to the nature of the documentation to be supplied with deliveries and acceptable methods of loading, unloading and storage to be adopted off and on the site. The QA controller must ensure that these arrangements are formally instructed to the staff in charge of the stores so that covered areas and hardstandings can be prepared.

The quality plans describe the controls to ensure that the defined specification of workmanship and accuracy are achieved and will indicate the records which should be kept to describe the circumstances of construction, the sources and references of the materials used, and the nature of any checks and tests. The circumstances of construction will record the drawings and instructions which defined the work, the person responsible for quality, the person responsible for checking, the date and weather conditions, and any interruptions or delays which occurred which might have influenced the operations.

The QA controller will receive the records and will inspect the procedures as they are practised. Large numbers of records will be produced and a data handling system is needed to produce documentation indicating how the quality of the completed works has been assured.

The quality management systems on site should be periodically audited to ensure the adequacy of the measures being taken and their conformity to the quality manual and plans. Such audits will generally be undertaken by a senior member of the contractor's Head Office technical staff with that appointed responsibility. The client may also require to carry out random audits to inspect the adequacy of the quality management.

The intention of some clients is that quality assurance no longer requires detailed inspection and approval of the construction as it proceeds by staff of their own or staff provided by the engineer. It is sufficient that the engineers be represented on site to observe general behaviour and the use by the contractor of his QA procedures whilst dealing with queries about information, issuing necessary variation orders and dealing with third parties. Other clients consider it necessary to audit the system by carrying out inspections of their own or by using appointed inspectors.

Following construction

After the project has been constructed it may have to be commissioned by performance testing before formal acceptance by the client. When quality assurance has been applied these handing-over procedures should be short and purposeful and will be accompanied by a comprehensive construction record. The project should, whether or not it contains operational plant, be accompanied by a manual for use. This manual should describe the operating performance for which the project has been designed and proposals for its operation or use, the timing and nature of inspections, the maintenance of the works and the renewal of components which can be foreseen as necessary during the design life of the project. The benefits which are obtained by quality assurance of the design and construction could soon be lost by any failings in the way the project is operated or by ill-considered alterations to it.

The user of the project, who is the ultimate provider of the funds with which it was constructed, only usually becomes involved following completion or at commissioning and may not agree with the the original specification produced by the client who defined and ordered the contract. His use of the project determines the performance and continued life of it. Any abuse must either be quickly identified and prevented or the specification and the constructed project amended to assure the use to which it is put. The availability of a quality assurance record enables responsibility to be identified as specification rather than workmanship and provides a basis for introducing amendments which will be equally assured. When, as so often happens, the project needs changes to meet a new use many years later, the detailed records enable the alterations to be carried out with confidence and quality assurance extended to those alterations.

Overview

Quality assurance requires demonstrably adequate supervision by contractors using materials of continually assessed capability. Competition between contractors therefore becomes a function of their ability to perform to good recognised standards. Contractors welcome the disciplines which quality assurance requires from specifications and the clarification of their position in respect of their performance. Clients seek greater assurance that their projects will meet their requirements. With quality assurance a client will generally not find a project more expensive than a similar one with good quality control but better value for money than projects without formalised

disciplines. The engineers undertaking the design discover that their ability to establish a clear brief from a client and express this in clear equivalent terms as a specification and drawings is all important. This may give greater encouragement to design and construct contracts between clients and contractors where the engineers are commissioned by the contractor and not the client. It may alternatively encourage the engineers commissioned by a client to only provide designs, general arrangement drawings and performance specifications whereby the contractor has then to allow for the production of detailed drawings and specifications. Working practices in such matters already differ considerably around the world and would benefit from the exchange of views and experiences.

Since we are now experiencing the impact of microprocessor technology on the construction industry further encouragement is perhaps being given to the employment of robot machines which offer strict control of repetitive and individual operations. The guiding computerised instructions might be an ultimate in quality assurance!

The Tokyo Symposium is an encouragement and opportunity to debate these philosophies to improve our practices for safe and good quality construction on site. Accidents and failures can be costly in human and material terms and provide sensational journalism which is damaging to the public image of our industry. The answer is not to increase factors of safety and be more cautious but to improve our working arrangements and develop better materials, construction techniques, and design concepts which enable continuous and assured progress. We thereby provide benefits to our clients and benefit ourselves.