Components of the quality assurance concept

In some cases experience obtained during one stage of the building process can be used for a later stage of the same project. For example, this is common for tunnel projects in rock where experience from the site is often a basis for the design.

The results of control activities can be regarded as experience that increases the knowledge (compare 5.1) about, for example, material and production processes.

The experience from building failures (severe or of minor importance) also form a valuable background for increasing the general level of knowledge. Thus code drafting and similar organizations should evaluate structural failures occurring during the execution of projects and the maintenance of structures.

2. COMPONENTS OF THE QUALITY ASSURANCE CONCEPT

2.1 Performance requirements

The performance requirements set out during the first phase of the building process concern the formulation of the specific requirements for the building and the requirements given in building regulations and codes.

See stage 2 in the flow chart shown in FIG 1.

These performance requirements have to be translated into technical terms for the loadbearing structure.

See stage 3 in the flow chart shown in FIG 1.

Thus, for example, stage 2 could be the specification of the intended use for the building and stage 3 the specification of the corresponding restrictions regarding deformations.

The performance requirements for a structure generally concern safety, serviceability and durability which, in this document, are defined in the following way

- Safety is the ability of a structure to sustain actions and other influences liable to occur during construction and use and to maintain sufficient structural integrity during and after accidents.
- Serviceability is the ability of a structure to perform adequately in normal use.

The requirements concerning safety and serviceability should apply throughout the anticipated time of use of each structure, which means that structures should be designed and maintained so that they have adequate durability.

> Requirements for safety should be obligatory, while requirements for serviceability may be just recommendations.

The requirements for safety imply that there shall be an acceptably small likelihood of structural failure causing damage to property and loss of human life.

> In every structure there are inherent hazards to life and property. The public at large, and those engaged in the construction industry in particular, expect that the danger caused by such hazards is restricted to an acceptable level. This is normally ensured by specifying safety requirements for structures.

In assessing the level of structural safety due consideration must be given to all circumstances that might lead to failure. These may be associated with

- an unfavourable combination of random variables such as actions, strengths, dimensions and others
- gross errors
- exceptional events
- lack of maintenance, etc.

The requirements for serviceability imply that there shall be an acceptably small likelihood of the structure becoming unfit for use. Thus the requirements concern restrictions against

- deformations which affect the efficient use of a structure or the appearance of structural or non-structural elements
- excessive vibrations producing discomfort or affecting non-structural elements or equipment (especially if resonance occurs)

- local damage (including cracking) which reduces the durability of a structure or affects the efficiency or appearance of structural or non-structural elements
- other special effects.

2.2 Consideration of utilisation scenarios and hazard scenarios

The measures to be taken to ensure safety, serviceability and durability of a structure are based on the relevant operational, environmental and boundary conditions. This involves the assessment of relevant utilisation scenarios and hazard scenarios.

Utilisation scenarios are descriptions of the foreseeable conditions associated with the normal use of structures. Each utilisation scenario defines a possible situation during which a particular set of operational and environmental conditions exist.

> A utilisation scenario can, for example, consist of a load combination, related to normal use, combined with the other conditions which are valid at the same time. Thus a large number of utilisation scenarios can be found. However, only a limited number of them are of interest in the context of quality assurance.

Hazard scenarios are descriptions of foreseeable conditions, dominated (in most cases) by one hazardous occurence, which alone or in combination with other normal conditions could cause the loadbearing function of a structure to be lost.

> The hazard could be related to occurrences outside the structure such as wind, impact, fire, but also to faults inside the structure, for example a very low strength in some component.

Section 3 of this document contains proposals for the description of utilisation scenarios and hazard scenarios and the corresponding measures to be taken.

2.3 Initial choice of structural system and material

With regard to safety, the choice of the structural system should be made so that important parts of it have the ability to maintain sufficient structural integrity during and after accidents. Specific hazard scenarios may involve actions or other influences, which the structure is not supposed to sustain without damage. However the structure should not be damaged to an extent disproportionate to the extent of the original accident.

Thus the existence of a particular hazard scenario may influence the choice of structural system, since if the structural system is changed some of the relevant hazard scenarios may also be changed. There is clearly an interaction between the choice of structural system and the assessment of the relevant hazard scenarios.

The activity between the stages 4 - 5 in the flow-chart in FIG 1 consists of preliminary design made in order to obtain a basis for the choice of structural system and general arrangement. Often a number of alternative designs have to be studied at this stage.

2.4 Analysis and design

A structure shall be designed so that it fulfills the specified requirements for safety, serviceability and durability.

Principles for analysis and design are given in the JCSS-document "General principles on reliability for structural design".

The design should, where possible, be such that it facilitates quality assurance activities and other activities within the building process.

Thus during the design, due regard should be paid to the feasibility of carrying out the control as well as to the feasibility of maintenance and repair.

2.5 Measures against human errors

The frequency of occurrence of human errors can be reduced considerably by taking suitable measures. These include

- improving professional education
- selection of qualified staff
- improving working procedures
- precautionary measures against unintentional or deliberate human errors and negligence
- additional precautions in the case of new design or construction methods for which there is little prior experience.

Working procedures may be improved, for example, by improving communications between persons and between organizations and by protecting persons from disturbing influences. These could be physical in nature (e.g. noise, bad weather) or of a psychological character (e.g. stress, shortage of time).

Even if good working conditions can be achieved and the work proceeds smoothly it will be found impossible to avoid errors completely. Suitable control measures should be instituted to check each stage of the planning and execution for the presence of errors.

Thus the construction work should be planned so that important parts will be accessible for inspection during the work.

Recommendations for suitable preventive measures against human errors should be provided wherever appropriate.

2.6 Responsibilities

It is of the utmost importance that the responsibilities of persons involved in the planning, design, construction, control and use of structures are clearly defined.

Many cases of structural failures and poor serviceability can be traced back to human errors (in its broadest sense) arising in those situations where responsibilities are not clear.

Section 4 of this document contains proposals for the allocation of responsibilities to those involved in the building process. These proposals may be elaborated with due regard to national legislation.

2.7 Control

All steps in planning, design, construction and use of a structure should be controlled to an extent related to the consequences of possible deviations from the intentions (including the result of human errors), the cost of control, etc. Ideally an optimal amount of control should be aimed at.

> Many cases of structural failures and poor serviceability of structures are caused by errors which remain undetected by those engaged in the building process.

Control should also include the introduction, execution and supervision of measures required in the event of disagreement between the results aimed at and the results obtained.

Sections 5 and 6 of this document contain suggestions towards the principles and methods of the required control. The detail and manner in which these suggestions are presented in a code depend on national legislation.

2.8 Project documentation

Important project documents should be stored throughout the entire life of the building, updated and made available to authorised specialists when required.

> This is already done in some countries. However, in most countries storage of documents is not generally required.
>
> The important documents may for example be:
>
> - drawings and other descriptions
> - the utilisation plan (see section 3)
> - the safety plan (see section 3)
> - working documents produced by the specialists which are relevant to structural safety (e.g. structural calculations, technical reports, control reports).
> - use and maintenance instructions.

- list of names of responsible persons connected with the work and of firms involved with the construction.

3. UTILISATION SCENARIOS AND HAZARD SCENARIOS

3.1 Utilisation scenarios

In order to ensure the serviceability and durability of a structure all relevant utilisation scenarios should be considered which may result, for example, in the following

- agreed actions during service phases, including a description of static and dynamic components
- actions during erection phases, in so far as it may influence the serviceability of the completed structure
- temperature effects arising out of use.

In addition, the accompanying influences under which the serviceability of the structure has to be ensured should be selected, as for example

- from climatic environment which may exist at the site of the structure, such as wind, water, snow, ice, temperature and combinations of them.
- tectonic and geotechnical influences, including the influence of the construction on the surroundings and viceversa.
- effects of ground water, water-bearing ground strata, running water and surface water.

For the purposes of analysis and design, utilisation scenarios have to be modelled and quantified.

It is often convenient to give the utilisation scenario models and the corresponding measures taken to ensure serviceability and durability in the form of a utilisation plan.