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Quality Assurance in the Eastern Scheldt Project

Assurance de la qualité dans le Projet de l'Escaut oriental

Qualitätssicherung beim Bau der Osterschelde-Sturmflutsperre

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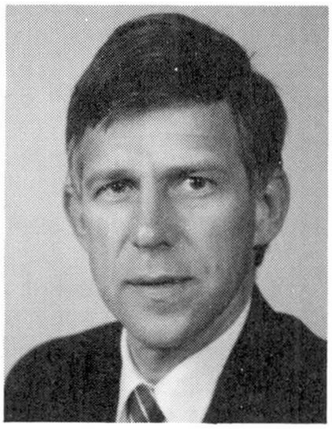


Wim Colenbrander, born 1942, received his civil engineering degree at the University of Technology Delft, The Netherlands. Since 1976 he has been involved in the Project Management Team of the Eastern Scheldt Storm Surge Barrier Construction.

SUMMARY

Quality Assurance in a multi-million project like the Eastern Scheldt Storm Surge Barrier is a necessity and covers the total building process: planning, design, construction and operation/ maintenance. In the project no particular quality-assurance system has been introduced but the principles of the feedback loop have been followed. In general, quality-assurance has functioned satisfactory, especially the establishment of audit-days and Sections for Quality Control in the different areas of the project.

RÉSUMÉ

L'assurance de la qualité est indispensable dans un projet gigantesque, tel que celui de la protection côtière à l'embouchure de l'Escaut oriental. Elle concerne tout le processus de la construction: conception, projet, construction, exploitation et entretien. Aucun système réel d'assurance de la qualité n'a été introduit dans le projet mais les principes d'itérations successives ont été respectés. En général, le système appliqué a fonctionné de manière satisfaisante, en particulier par l'établissement de journées d'auditions et de sections de contrôle de qualité dans les différentes parties du projet.

ZUSAMMENFASSUNG

Bei so gewaltigen Projekten wie beispielsweise der Osterschelde-Sturmflutsperre ist Qualitätssicherung eine Notwendigkeit. Sie umfasst den ganzen Bauprozess von der Planung über Projektierung und Ausführung bis zu Nutzung und Instandhaltung. Im vorliegenden Fall wurde kein eigentliches Qualitätssicherungssystem eingeführt, jedoch war jeder Projektleiter in seinem Bereich für die Qualitätssicherung verantwortlich. Es zeigte sich, dass das Rückmeldeprinzip gut funktionierte. Vorteilhaft wirkten sich die Einführung von Audit-Tagen und von unabhängigen Sektionen für die Qualitätskontrolle in den verschiedenen Projektbereichen aus.

1. INTRODUCTION.

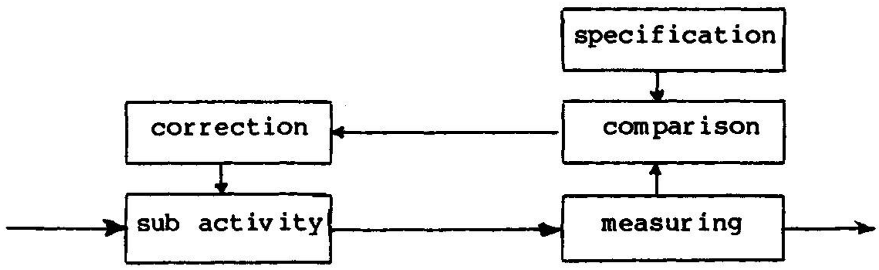
After the floods of 1953, which engulfed large areas of the Dutch delta, claiming 1835 lives, it was decided to the closure of the main tidal estuaries and inlets in the southwestern part of the Netherlands.
The various parts of this challenging project, called the Delta Project, were undertaken, one after the other, without delay.
The final part of the Delta Project was to be the closure of the Eastern Scheldt, which is the widest and deepest estuary in the area.
Due to environmental reasons, the Eastern Scheldt estuary was to be kept open in normal circumstances, but would be closed when storm surges were expected. The decision was made to build a storm surge barrier in the three tidal channels, the deepest parts of the estuary.
The Eastern Scheldt Barrier is estimated to come into use October, 4, 1986.

2. BRIEF DESCRIPTION OF THE BARRIER CONSTRUCTION.

The storm surge barrier, in all 3000 metres long, consists of 65 prefabricated concrete piers, weighing 18000 Tons, between which sliding steel gates have been installed. In normal conditions, the gates will be raised in order to maintain the tidal currents in the estuary, only when a storm is predicted the gates will be lowered. The foundation underneath the piers is formed by a prefabricated foundation mattress filled with sand and gravel as filtering agents. Between the piers prefabricated concrete sill-beams, weighing 2500 Tons, have been installed under water to reduce the flow-cross section and on top of the piers concrete bridge-box girders for traffic crossing.
Lastly there is a sill of rocky material of varying weight around and between the piers; the top layer is formed by basalt blocks weighing up to 10 Tons each.

3. CHOICE OF QUALITY-ASSURANCE SYSTEM

It is obvious that quality assurance in a "billions-project" like the Eastern Scheldt Storm Surge Barrier is of utmost importance.
The Project Management Team consisted of project-managers responsible for the main disciplines of the structure: foundation-, concrete-, steel works and research.
No uniform quality-assurance system has been introduced for the total project, but each project-manager was held responsible for the quality-assurance in his field.
In general, quality-assurance applications in the project were based on the principle of the "feed-back loop":



Measurable values are derived from functional requirements and design specifications, including target values and tolerances. Next the realised values in the construction procedure are to be compared with the target value and the tolerance. Subsequently a judgement of the quality of the product may be expressed. If the judgement is positive, the production can proceed. If the judgement is negative, the decision has to be made: acceptance, reparation or rejection of the product, as well as re-adjustments of the process or raw materials. The circle is to be closed by a report on the measuring results, the decisions and the re-adjustments.

4. QUALITY ASSURANCE APPLICATIONS THROUGHOUT THE PROJECT.

Quality Assurance comprises the total building process, including planning and design, as well as construction and maintenance.
In the following quality assurance applications will be discussed dealing with the total building process:

4.1. Planning.

The Minister of Public Works in the Netherlands is responsible for the choice of the plan to close the Eastern Scheldt by means of a storm surge barrier.
Check on the plan has been carried out by the Dutch Parliament after heated discussions. The Parliament agreed to the plan in 1976, under the condition that the project had to be subjected to a time- and cost target.
Next Rijkswaterstaat (Engineering Division of Public Works Department) was charged to make the detailed design, to tender the project and to supervise the execution.
Rijkswaterstaat reported to the Parliament every 3 months upon the progress of the project, related to technology, time-schedule and costs.
In theory a good system, to inform the Parliament, but not a system to safequard time- and cost conditions at any moment. In general the information to the Parliament was dated about 4-6 months earlier, than the real situation.
When it became clear in a later stage that the time-target as well as the cost-target would be exceeded, the Parliamant established an independent commission of three experts to inquire the Parliament permanently during the remaining part of the execution.
Fortunately the commission concluded that the increase of costs and the delay in time-schedule could be justified. However, an earlier check on the progress of the project, would have opened the possibility for a review of the plan by the Parliament, at the moment that the conditions could not be fullfilled.

4.2. Design.

The design of the storm surge barrier comprises aspects as:
a. hydraulic boundery conditions;
b. foundation / sill part;
c. concrete part;
d. steel part.

Quality assurance related to the hydraulic conditions (waterlevel and waves) was hardly possible due to lack of data.
A certain quality-assurance has been found in a probabilistic approach of expecting waterlevels in relation to the wave-heights. In this approach a life-time of 200 years was estimated and a chance of failure 10^{-7}.
In addition, for all the important parts of the structure "error-trees" have been made in order to find the "weakest chain" in the design and/or execution.
The alternatives for the foundation of the piers have been made by the projectteam, and have been checked by external expertise in the soil-mechanics field (M.I.T: Prof. Lambe; University of Manchester: Prof. Rowe) by means of a constant auditing during the design period. Especially for the problem of liquefaction of the subsoil due to the cycling loading, a reliable solution have been found by the application of deep-compaction with vibrating needles.
Concerning the concrete part of the barrier, the ideal quality assurance would have been a complete "shadow-calculation" by an independent design-team. Unfortunately must be stated, that such a procedure is hardly impossible because of the organizational and especially financial problems. Therefore the choice has been made to check some critical parts of the design-calculations by external specialists (TNO-IBBC and University of Technology Delft). In this way external advice has been obtained concerning the shear force capacity, the "early" strenght of concrete and the durability aspects. This system of a selective check on critical parts has worked satisfactory and, in some cases, has resulted in a design-adaption.
The same procedure has been followed concerning the steel part of the barrier.
Critical parts of the gates, as well as the hydraulic equipment for moving the gates, has been checked by external consultancy.
The hydraulic system has been subjected to a probabilistic approach in order to determine the chance of failure of the system.
The study was carried out by an independent institute with experience in the field of nuclear power plants.

4.3. Construction phase.

4.3.1. Organization and personnel.

At the start of the concrete construction activities a temporary training-school has been founded on site. Skilled as wel as unskilled personnel were trained in the school in prefabricating the, in general, complicated formwork of the piers during about 8-12 weeks. By means of this special training, the quality of an important part of the concrete construction could be assured with implementation on quality, time-schedule and costs.
Another essential element for quality assurance was the establishment of independent sections for Quality Control. These sections worked independent of the production line and under direct responsibility of the Project Management Team.
These sections have been working in different fields of execution: foundation-, concrete- and steelworks. Due to the complexity of the design and the innovative developments in the execution, a high level of quality assurance was necessary, in which also design-expertise was represented.

In general terms, the task of the sections for quality-control was:
- to establish admissible values and tolerances;
- to design appopriate methods for approval;
- to saveguard the quality;
- to indicate solutions in case of disapproval;
- to propose process- improvements.

There was a regular consultation between the Project Management Team and the sections for Quality Control, especially in cases of important decisions.

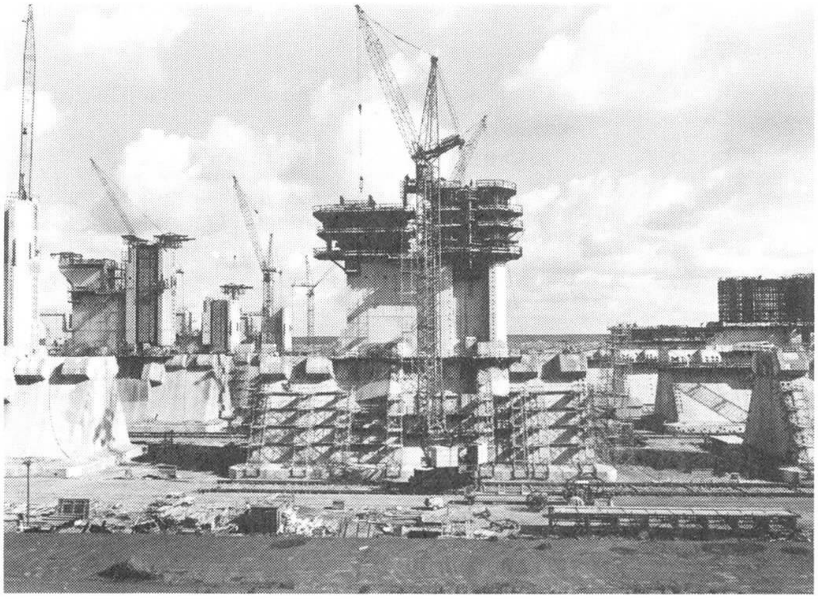


Photo 1 Piers under construction with formwork (Sept. '81)

4.3.2. Activities.

There are several examples of application of quality assurance in the construction phase, from which three examples will be given:

4.3.2.1. Negative overlap.

Since the centre to centre distance between the piers is 45 m and the width of the foundation mattress is 42 m, an opening remains of 3 m to cover the subsoil. This opening had to be filled bij ordinary gravel to be dumped in three layers (1/32 mm, 30/6/ mm and 40/230 mm) and this filter carried the name: negative overlap. It was essential for the stability of the barrier, that the "negative overlap" functioned perfectly.
The quality of the "negative overlap" is determined by the quality of the three layers individually. For that reason it was necessary to check the granual properties and the thickness of each layer, and to be sure that no sedimentation of sand had taken place on top of the layers.
The thickness of the layer can be measured by sounding, but the accuracy of sounding is dependent of the thickness of the dumped layer itself.
Therefore a process-control procedure has been established for the dumping of the layers 30/60 mm and 40/230 mm, with the following check-points:

- capacity belt conveyor;
- thickness layer on belt conveyer;
- level of material in dumping-pipe by remote-control system.
- waterpressure in dumping-pipe;
- current-velocity;
- movements of dumping-pontoon.

For every layer an additional check, after dumping, has been made by sounding and samples have been taken to check the granular composition. In this way the quality of the "negative overlap" has been assured by a double check.

4.3.2.2. Placing of the sill-beams.

Placing of the sill-beams was estimated as one of the most complicated and riskful operations.
On one side the working conditions between the piers (increasing current-velocity and irregular flow-pattern) had to be faced, because of the fact that the flow-crosssection was reduced with 30 %.
On the other hand the extreme small tolerances between piers and sill-beams (minimum 5 cm) and the necessary fixation of the beams.

Photo 2 Sill-beams in construction dock (Jan. '85)

For this complicated problem "audit-days" have been organized with a number of external specialists in offshore-techniques.
These audit-days resulted in remarkable tips for improvement in design and operation.
After some weeks this procedure has been repeated in order to come to an optimal and safe placing-operation.
These audit-days have proved that a procedure like that is a very appropriate one, or even stronger, in certain cases, is a necessity!

4.3.2.3. Hardening of concrete.

The independant section Quality Control for the concrete part has not only fulfilled the expectations, but has worked in an innovative way.
To determine the step-by-step method of prestressing, it was a necessity to know the development of the compression strenght of the concrete in time.
Although the Dutch Code gives methods to investigate the hardening-strenght of concrete, the section Quality Control developed an innovative method adapted to the circumstances on site. In this method the hardening-cubes are kept in a waterbasin, of which the temperature, at any moment is the same as the temperature in the concrete pour on site.
The temperature-development in the concrete pour is measured contineously by thermo-couples and is directed to a computer-steered temperature regulator in the waterbasin. The temperature regulator (ΔT-regulator) takes care that the temperature development in the waterbassin with the hardening cubes is exactly the same as the temperature development in the pour on the site. In this way a very reliable interpretation of the hardening cubes was possible with a high level of accuracy.

4.4. Operation

For the operational use of the barrier, including maintenance aspects, it is very important to know the behaviour of the barrier under external loading and the critical parts to observe.
For every structural part of the barrier a "Certificate of Birth" has been made with all the necessary data, such as: dimensions, material properties, tolerances, shortcomings, etc.
E.g. Certificates of Birth has been made for the piers, the foundation mattresses and the soil mechanics properties of the subsoil.
In order to assure the quality of the barrier, also in the operational phase after completion, a "Maintenance Handbook" was established. In the handbook a description is given of the structural parts to consider and the frequency of inspection.
Also the way of inspection is indicated, in some cases a visual inspection is enough, in other cases measuring is necessary.
A significant example of measuring is the behaviour of the pore-pressures underneath the piers:
For the overall stability of the barrier the pore-pressure development in the foundation mattress and the subsoil is most critical.
Therefore two piers have been provided, in the construction phase, with a system of open ducts reaching from the top till the bottom of the piers.
In this way it is possible to install a measuring system in a later stage, to measure the pore-pressure development in the foundation mattress and the subsoil.
Installing of a measuring system in the foundation mattress means penetration of the mattress and chance of damage; experimental research, however, pointed out that a controlled penetration is possible and reliable.
The "Certificate of Birth" as well as the "Maintenance Handbook" will be handed over to the local authority in charge of the operation of the barrier.
In this way the quality of the barrier can be assured, also during the operational phase, after completion.

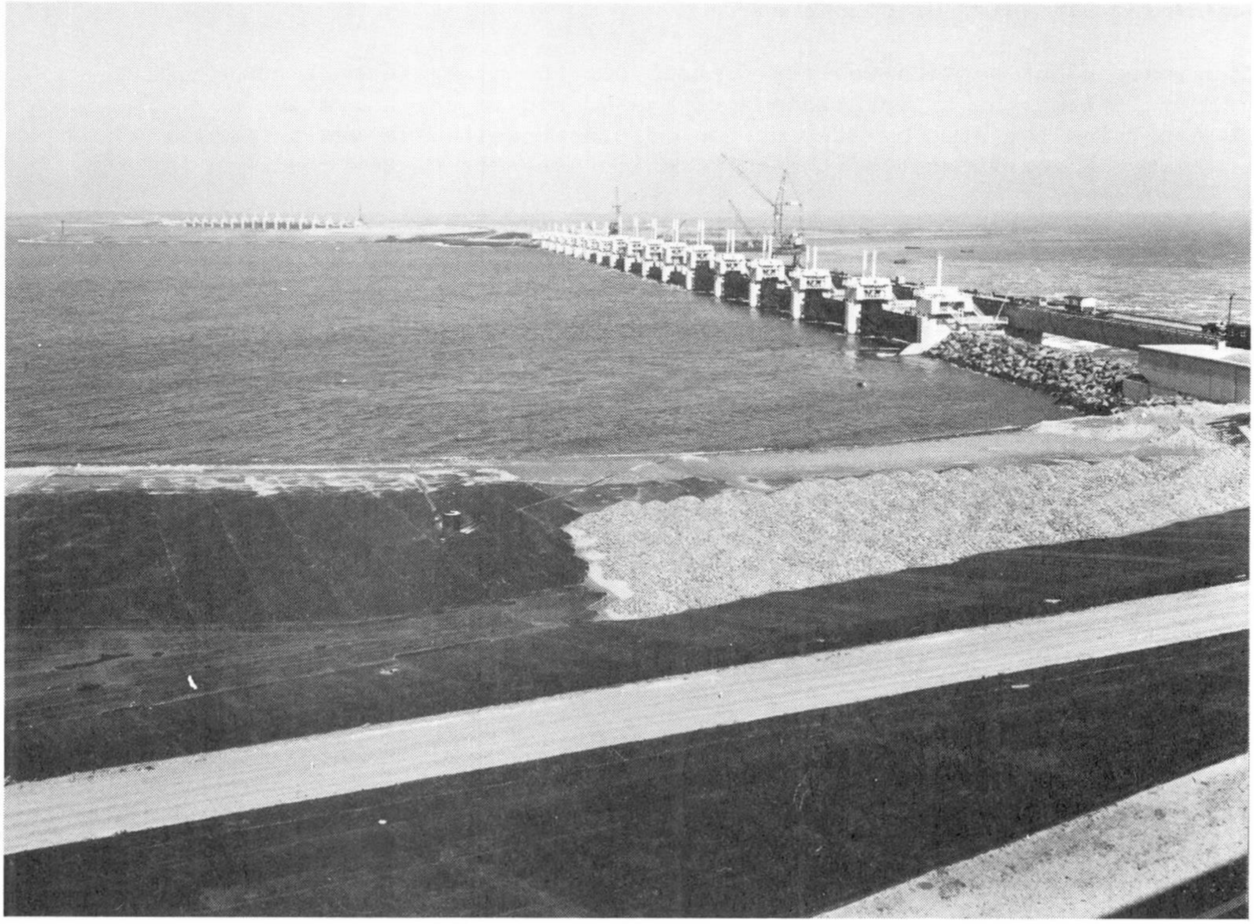


Photo 3 Completed part of storm surge barrier (April '86)

EPILOGUE

It may be stated that Quality Assurance has been applicated in the Eastern Scheldt Project. Also may be stated that at the start of the project no uniform quality-assurance system has been introduced.
During the progress of the project it became clear that quality-assurance was necessary in the different fields of the project. The consequence was that quality-assurance has been limited to the most important parts.
In 200 years, the estimated life-time of the barrier, the world may judge, if the Quality Assurance for the Eastern Scheldt Storm Surge Barrier was sufficient!