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Quality management at construction projects: Case study of a stormwater network project

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Abstract

This paper summarizes the common procedures and measures used on construction sites to control the quality of executed works. The presence and implementation of a quality management system will ensure that the construction meets client requirements. The presence of a quality management system alone is not sufficient; the correct and strict implementation of a quality management system is substantial. The implementation of a quality management system in construction requires the collaboration of the client, contractor, and engineer (a client representative). The practical side of quality management systems is discussed in this paper, and the construction of a stormwater network in the UAE is taken as an example and case study.

This paper is mainly focused on quality in construction projects. Controlling the quality of construction projects will pass through various stages. And it is not limited to construction activities. The control of construction activities is not sufficient to produce a meticulous final product. A quality system should be implemented in every aspect of a project, such as the project document, materials, testing, construction process, etc. Involving a case study in this paper will assist in a better understanding of the quality management system at construction projects. Moreover, some examples of quality violations and the actions taken to correct the breach will be furnished as part of this study. The stormwater network was constructed as part of the development and construction of a new community. The stormwater network has a length of 22 km, and it involves the construction of all components of the stormwater network.

1. Introduction

Quality is simply defined as the degree of fulfilling customers' needs and requirements. It is essential to establish, implement, and continuously improve a quality management system. The presence and true application of the quality system will assist in achieving output products that satisfy the customer's requirements in the first place. Other indirect benefits of implementing a quality management system include cost savings. The proper application of QMS will save on the cost of repair that may arise due to the rejection of works or products that do not meet the requirements. Furthermore, preventing rejection and redoing of work will result in proper utilization of time and preventing delay. In general, QMS are essential for every organization. Appropriate establishment and implementation of QMS will assist organizations in thriving and meeting their customers' expectations. Also, QMS will improve the organization's performance and reputation.

This paper will focus mainly on the quality system in construction projects. A brief review and clarification of the different aspects of quality management systems in construction projects. The following points will be discussed:

- Quality management system: a brief review of the QMS Quality assurance and quality control Project documents and record: project documents such as specifications, shop drawings, method statements, prequalifications, etc.
- Quality assurance and control at construction sites: how to assure quality and prevent poor and defective output
- Daily quality control at construction sites: The method of controlling quality at construction sites
- How to report a quality violation: the method used at the construction site to report a quality violation.
- Quality audit
- Case study project: (examples of testing, daily inspection, site observation, and quality violations)

2. Quality management system

Establishing, maintaining, and implementing a QMS system is essential for the organization. A successful organization requires effective management of resources to produce a product that meets customer needs and requirements. Therefore, an effective management system is essential for

an organization to be successful, and quality management is an important part of it. The QMS is a system that defines the process, procedure, policies, responsibilities, and roles necessary to achieve a desired quality product or service. Establishing a quality management system for construction organizations requires a comprehensive understanding of the construction processes and the interaction between the activities. The construction processes are an activity or a number of activities that transform the resources into output. Moreover, a deep knowledge of local or international standards and specifications is very important to establishing a successful QMS.

The steps needed to establish a successful QMS should include the following:

- The processes and their application in the organization should be determined for establishing the QMS.
- The sequence of processes and how they interact should be determined precisely.
- Effective methods and criteria should be created to ensure and control the execution of these processes, the methods created should be effective and satisfy the quality requirements.
- The created system should ensure that the provided resources and information are sufficient to support and monitor the processes.
- The organization shall enact actions to achieve goals and maintain the continuous improvement of the QMS.

The establishment of a QMS requires great effort and sufficient experience and knowledge. However, the appropriate implementation of the QMS requires effort, strong will, and the correct culture. Spreading a quality culture among organization employees and workers is highly important for achieving the organization's goals.

3. Quality assurance and quality control

Creating a proper QMS required adequate knowledge of QA and QC terms. Quality assurance focuses on ensuring that quality will be achieved by planning and documenting the process. Furthermore, quality assurance is a systematic approach for maintaining the quality as required by implementing systematic activities, procedures, and measures, as well as by documenting the processes that ensure a product complies with the expectations and standards. Quality assurance aims to prevent the occurrence of quality problems and violations. An example of quality assurance is the quality plan. The quality plan is a document that specifies the standards, quality control and assurance procedures, resources, project documents, records, and responsibilities to achieve quality objectives for a particular project. Another example is the method statement for different activities. A method statement is a quality document that provides the correct procedure to execute a specific activity and the testing plan (ITP). A method statement is a quality assurance and control document that provides the correct procedure to execute a specific activity and assures quality. Also, it contains a testing plan to control the quality on site. Quality assurance deals with the process, while quality control deals with the product. Quality control is the technique used to verify the product's conformance with standards and expectations through physical testing, measurement, etc. Therefore, quality control is dealing with the product, and it is a tool to find deviations from the required quality by conducting planned testing and inspection of the product. Moreover, determining the cause of deviation and eliminating it. An example of quality control at the construction site is measuring concrete temperature, slump, and compressive strength. Another example is measuring the pipe trench dimension and ensuring it matches the approved details. Quality control is a daily task of the quality engineer. Quality assurance is a preventive technique, while quality control focuses on finding and correcting defects.

4. Project documents and record

Achieving customer needs and expectations requires the availability of specific documents that explain the requirements of the customer or client, such as project specifications, contract drawings, etc. Project specifications are essential documents in construction projects, and they identify the standards of workmanship, materials, testing requirements, and quality acceptance criteria of executed works. A project specification is an inclusive document that holds technical information about each activity and material that will be used at the construction site, and it may vary for different clients and different projects. Contractors are obliged to follow the project specification and ensure that all the executed works comply with it.

Project specifications alone are not sufficient to execute the work. Contract drawings are vitally important. Shop drawings are a simple interpretation of the design and client requirements. Shop drawings contain vital details and information about the work to be constructed by the contractor. The contract/shop drawings will hold information such as dimensions, reinforcement details, road details, type of structure, pavement layers, road layout, etc. The contractor has to follow contract drawings and project specifications to produce quality work that

meets client expectations and needs. Project documents are not limited to project specifications and contract/shop drawings. Throughout the life cycle of the project, the contractor has to submit many documents. Here are some documents related to the QA/QC of construction projects:

- Project quality plan
- Material submittals
- Prequalification for subcontractors and suppliers
- Method statement
- Request for information
- Daily inspection reports
- Material inspection reports

The contractor and Engineer should keep appropriate records and copies of project documents and all correspondence. Logs of project documents should be established at the beginning of the projects. The updating of logs should be done on daily basis. Records and logs simplify and facilitate the process of finding specific documents or information.

5. Quality assurance and control at construction sites

The quality of work on construction projects is protected through various QA/QC procedures. In general, the client (customer) hires a consultant company (Engineer) to supervise the work and ensure it is not deviating from the project specification and matching the expectations of the client as agreed in the project contract and furnished in project documents such as contract drawings, specifications, etc.

Completing a specific construction activity correctly in general will require:

Project documents such as contract drawings and specifications

- Manpower: labor, supervisors, engineers, etc.
- Suitable equipment and tools
- Materials

Achieving quality in construction projects requires special attention to the above-listed elements. Completing any activity is impossible without the presence of manpower. Labor with poor workmanship will never produce quality work. Therefore, special attention should be given to laborers and supervisors by providing periodic training to improve labor skills in executing the work. Training is not limited to labor only; supervisors and engineers should also be given training to promote their skills. Thus, producing quality work requires special attention to each and every detail of the construction project.

Figure 1

Therefore, attaining the required quality begins by selecting a skilled and renowned engineering company to design and supervise the construction activities. Design plays a vital role by supplying the contractor with designs that serve the purpose, match client expectations and project standards, are easy to establish, and don't contain discrepancies. Moreover, the supervision team should have good and relevant experience with the executed work. Also, they should be aware of the project specifications and standers. On the other hand, the selected contractor should have proven experience in constructing similar projects, and the contractor shall group a team of engineers and supervisors that are capable of completing the job as required. Choosing poorly skilled manpower can lead to improper execution of work and impaired work.

Project documents are also an important factor in ensuring the quality of work. For example, the project quality plan serves as a guide for maintaining the quality of the executed work as per specifications and standards. A project quality plan should include project organization, audit requirements, QA/QC measures and procedures, non-conformance and corrective actions, subcontractor management and acceptance criteria, inspection and testing plan, etc. The quality plan should be carefully reviewed and followed by the site team. Project documents are not limited to quality plans. I will list some of the important QA/QC documents:

- Method statement and ITP (inspection and test plan): The method statement details the correct steps for conducting the work, along with suitable resources. The ITP is part of the method statement. ITP lists inspections and tests for a specific activity.
- Sub-contractor pre-qualification: pre-qualification is a QA/QC document to prove the eligibility of a

contract to execute a specific work. This document will include the contractor's proven experience, completed projects by the contractor, an organization breakdown, and any other client requirements. The main benefit of this document is to eliminate inexperienced contractors and award jobs to experienced contractors.

- Material submittals: material submittals are another important QA/QC document. Material submittals certify the compliance of materials with project specifications and standards. Material submittals will hold all the important data about the material, such as the source, specification, ISO certificate, tests conducted on materials, etc. This document should be available before supplying the material to the construction site.
- Appraisal report: The engineer and client may decide to conduct a visit to factories supplying the materials to assess the manufacturing process and its compliance with standards. The visit is not limited to factories; the engineer and client may visit the testing labs to verify the testing process and its compliance with standards. An appraisal report will be prepared for these visits, and it will include any observed violations. Based on these visits, the client may approve, reject, or revoke the approval for the visited institute.

These documents are some of the QA/QC documents utilized at construction sites to assure and control the quality of work. The required documents may vary depending on the project size and the client. Proper selection of the contractor and the engineer, in conjunction with implementing QA/QC procedures and measures as specified in the project quality plan, plays a vital role in achieving and maintaining quality.

6. Daily quality control at construction site

The control of site activities quality is not limited to executed work; it extends to every aspect of the project, such as delivered materials, subcontractors, field testing, etc. The engineer should, on a daily basis, inspect and verify the compliance of executed work with project specifications and approved shop drawings. The method statement and ITP will guide the engineer and provide him with a comprehensive understanding of the procedure for conducting a specific activity. On the other hand, the field testing and inspections to be performed by the consultant engineer will be specified in the ITP. Daily follow-up and inspections are very important in controlling the quality of work. Poor supervision by the engineer can result in negligence by the contractor, and the final result will be poor quality work that does not comply with client expectations. Keeping records of all inspections is essential, and it is part of QA/QC procedures.

For a better understanding of daily inspection, I will give a simple example of reinforcement and formwork for footing. The inspection will consist of inspecting the reinforcement quantity, size, and arrangement against the approved drawings, the cleanliness of the reinforcement, the cover size, etc. Another inspection will be conducted by the surveyor to verify the location of the formwork and the level of casting. The presence of a detailed ITP can be helpful for engineers, as it specifies all the required inspections and tests for each activity. Over and above that, the engineer should confirm the source of reinforcement. The engineer should inspect the delivered material on site. The received reinforcement source and amount should be checked and recorded. Recording the received material quantity is essential to satisfying the test requirement as per the specified frequency.

7. Reporting quality violation

The occurrence of quality violations is common on construction projects. The root cause of violations can be the absence of QMS, poor workmanship, insufficient and incompetent supervision, poor quality culture, etc. The procedure for reporting a quality violation can vary depending on the seriousness of the violation. Verbal reporting of violations is an option, and it can be used for minor violations. The engineer will verbally inform the contractor for immediate rectification. However, verbal reporting is not sufficient for all cases, and when the contractor is not sufficiently responding and correcting the quality breach.

A quality plan usually includes the method of reporting any quality breach. Usually, a site observation report (SOR) or non-conformance report (NCR) is issued to report the violation. SOR and NCR are commonly used at construction projects to report and record any quality deviation. SOR is considered an initial warning of an undesirable practice or violation committed at the construction site. SOR will be issued to the contractor by the engineer. The contractor is obliged to propose corrective and preventive actions. Corrective actions are proposed to correct the deviation and restore the work quality, while preventive actions aim to prevent the occurrence of quality violations again. Corrective and preventive actions have to be reviewed and approved by the engineer. NCR is a stronger tool, and usually it is used when the deviation is serious or when the contractor didn't take sufficient action to close the issued SORs.

If the contractor fails to close the issued NCR and correct the deviation, the client and engineer may decide to escalate the situation and impose fines on the contractor. SOR or NCR should be closed by the contractor without delay. Usually, the duration for closing the SOR or NCR is limited and specified in the project specification or project quality plan.

Furthermore, the contract and project specification should specify further actions and disciplinary measures to be taken, such as deducting money from contractor payments or stopping site activity. SOR and NCR are not issued for contractors only. If the client notices any quality deviation committed by the Engineer, the client may issue a SOR or NCR to the engineer.

8. Quality audit

Audits are essential to measure the compliance of an organization with standards and requirements. An audit has to be systematic and documented to obtain evidence and to evaluate the obtained evidence objectively without any bias. Evidence is acquired to determine whether the policies, standards, and requirements are implemented or not. Evidence can be records, observations from a site visit, interviews with project staff, or any relevant and verifiable information. Audits are important tools to discover and correct any deviation while also improving the overall performance of an organization. The audit can be categorized into process audits, product audits, and system audits.

Audits are also categorized into first-party audits, second-party audits, and third-party audits. A first-party audit is an internal audit, and it is delegated to the auditing body by the organization itself. The first-party audit is essential to ensure that the organization's operations are aligned with policies and standards without any deviation. Second- and third-party audits are external audits. A second-party audit is performed by the customer or an auditing organization on behalf of the customer. This type of audit is necessary for the client to determine the compliance of an organization with quality standards and set requirements. A third-party audit is conducted by an audit organization without any conflict of interest. The purpose of engaging a third party is for certification, like ISO certification.

The frequency and type of audit to be conducted should be determined in the quality plan. Usually, a semi-annual audit is conducted by the client. The frequency of performing audits can be reduced if the audit findings confirm the presence of misconduct and deviations from the standards. The audit findings will be issued in the form of an SOR or NCR to the contractor and consultant. The audit will pass through four stages:

- Audit planning and preparation
- Audit execution
- Audit reporting
- Audit follow-up and closure

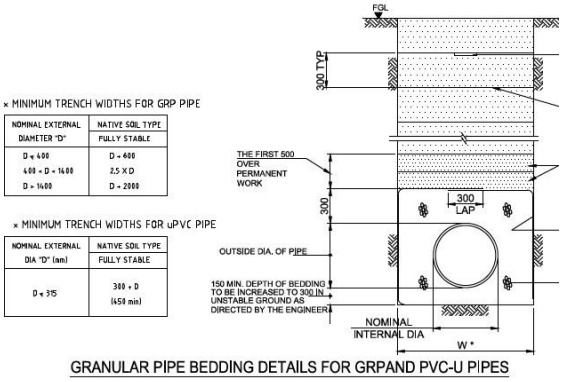
Audit execution is the primary stage of the audit process, and it consumes the most effort and time. In this stage, the auditor will gather information about the system, process, and project. Gathering information can be performed through a site visit, interviews with people, checking out project logs and records, and careful inspection of project documents and records. Any deviation or violation found during the audit execution should be recorded and issued in the form of a SOR or NCR to the negligent party. The issued SOR and NCR should be studied carefully by the organization to understand the root cause of the deviation. And corrections and preventive actions should be implemented to correct the deviation. The auditor should follow up to ascertain the implementation of the correction of the deviation.

9. Case study: stormwater network project

The stormwater network was constructed as a part of new community development in the UAE. The construction of stormwater networks is essential for draining rain and preventing the formation of ponds or floods. The stormwater network extended for a length of almost 22 km, with almost 700 inlets and 110 manholes. The largest pipe diameter is 1200 mm, and the smallest pipe diameter is 300 mm. Various materials can be used to construct a stormwater network, such as uPVC pipes, GRP pipes, and concrete pipes. The size of the pipe, the local specification and design will determine the pipe material. Construction of the stormwater network passes through various stages, including excavation, pipe laying, installation of inlets and manholes, and connecting the new network to the existing stormwater network.

9.1 Project documents

An example of a project shop/contract drawing and a project specification are shown in figures 2 and 3, respectively. Figure 2 presents a typical cross-section and arrangement for a stormwater pipe. The section can be used to determine the dimension of the trench for different pipe sizes and other important details. This section is an example of project contract drawings. The presence of clear drawings is essential to ensure appropriate execution of work on a construction project.



× MINIMUM TRENCH WIDTHS FOR GRP PIPE

NOMINAL EXTERNAL DIAMETER "D"	NATIVE SOIL TYPE FULLY STABLE
D ≤ 400	D + 600
400 < D < 1400	2.5 X D
D > 1400	D + 2000

× MINIMUM TRENCH WIDTHS FOR uPVC PIPE

NOMINAL EXTERNAL DIA "D" (m)	NATIVE SOIL TYPE FULLY STABLE
D ≤ 315	300 + D (450 min)

Figure 2

Project specification is also a crucial document, just like shop drawings. Figure no. 03 shows a sample of stormwater water specifications. A project specification will specify the technical information about a construction activity, materials, testing requirements, etc. The exhibited sample in Figure 3 specifies technical information about pipe materials. The presence of a project specification is essential, as it provides valuable technical information that will be used to control the quality of constructed works.

22.2.1 Pipe Design Requirements

A. uPVC pipe shall conform to BS EN ISO 1452 and shall be PN16 / PN10.

i. For gravity pipelines with cover depths less than 6 m, pipes class 10 will be used.

ii. For gravity pipelines with cover depths more than 6 m, pipes class 16 will be used.

B. Pipes up to 90 mm nominal diameter shall have solvent welded joints and pipes of 110 mm and above diameter shall have rubber ring sealing.

C. All uPVC fittings shall be ISO/DIN specification and have a minimum rating of 16 kg/cm² at 20 °C.

D. Fittings shall be suitable for use with the above specified pipes. Where uPVC flanges are required these shall be drilled to PN16 as detailed in BS EN 1092.

Figure 3

9.2 Daily site inspections

The inspection of executed works should be performed on a daily basis. The daily inspection is not only for site activities such as concrete casting. But also for everything related to construction activity like verifying the material source, subcontractor approval, field testing, etc. Appropriate follow-up and inspection as per the approved ITP and project quality will enhance the performance and ensure the quality of the work.

9.2.1 Site activities inspection

Daily site inspections and follow-up are essential for controlling the quality of the work. Spreading the quality culture among the contractor staff and labor assists in producing quality work and reduce the defects and rejection of work by supervising engineer. The supervision consultant engineers have to conduct site inspections on a daily basis to verify the conformance of executed works with approved procedures, drawings, and standards. The importance of daily inspections arises from discovering any quality breaches and taking swift corrective action if possible.

An example of daily inspection is excavation for the pipe line shown in figure no. 4. Upon completion of the work, the consultant civil engineer or inspector will inspect the trench as specified in the ITP. The inspector will visually inspect the trench for cleanliness, water content, and compaction. Moreover, the trench size will be verified against the approved typical section. The inspection is not limited to engineers. In this case, the surveyor should also verify the level and alignment of the trench using suitable surveying instruments. The presence of ITP will be helpful as a guide for conducting inspections and testing. Field testing may also be required, as specified in the project specification. Verifying the degree of compaction is not possible with the naked eye. Therefore, the field density test will be conducted on site by the laboratory team to verify the degree of compaction.

Figure 4

Inspections should be carried out for each activity, like the laying of pipes, as shown in figure 5. The engineer/inspector and surveyor will conduct the inspection as specified in the ITP. The inspections will confirm the compliance of the work with approved drawings and specifications. The engineer/inspector and surveyor may confirm the size of the pipe, the material of the pipe, the source of the pipe material, the alignment, and the level of the pipe. Similarly, all the inspections will be performed as per the ITP for every activity.

Figure 5

The engineer should record each and every inspection. The record should be clear and include the work location, activity, date of inspection, and any observations if found. Records are essential to track the completed inspections and activities at a construction site. On the other hand, the contractor should submit a work inspection request for each activity at the construction site as per the approved ITP and quality plan. The consultant engineer or inspector will inspect the activity and approve the request or reject the request for defective work. The contractor will be paid for approved work only. Therefore, the WIRs are considered an evidence and measure of completed work at a construction site.

9.2.2 Delivered material inspection

Controlling the received materials for a construction site is essential for preserving the QA/QC of a construction project. The consultant engineer or inspector should inspect all delivered materials; the engineer should verify the source of materials against the approved sources and the amount of delivered materials. The contractor should submit a material inspection request (MIR) to the engineer for every material received at the site.

Then, the engineer will conduct a site inspection of the received material and verify the source and amount of material. The amount of material received should be recorded. The frequency of material testing will depend on the amount of material consumed during a construction project. Therefore, the contractor should maintain a record of the received material to conduct specified tests when the quantity of material reaches the specified testing frequency.

Figure 6

Figure 6 shows uPVC pipes delivered to a construction site. Upon receiving the material, the contractor will issue an MIR and conduct a joint inspection. The inspection will be conducted by the contractor and consultant engineers. The joint inspection verifies the source of material and the amount of material. Moreover, site measurements can be taken at the site to verify the pipe diameter and thickness against the specified in the project standards and approved material submittal. Moreover, a sample should be taken jointly to conduct all specified tests. The sampling frequency for a specific material will be as specified in the project specifications. Therefore, it is important to keep and update the record of material received at a construction site.

9.3 Quality violation reporting

Reporting a quality violation is an important tool to improve and control the quality at a construction site. Reporting a quality breach at the construction site can be performed by issuing an SOR or NCR detailing the location of the violation, the activity, and the deviation. The contractor is obliged to correct any deviation within a specific timeframe and ascertain the non-occurrence of similar violations in the future. Figures No. 7 and No. 8 exhibit two different quality deviations.

Poor storage of material is a common violation, as shown in figure no. 7. Storage of pipes or any material should comply with project specifications or manufacturer requirements. Pipes should be appropriately stored, elevated from the ground, and covered. The occurrence of such a violation necessitates the issuance of a SOR to correct the nonconformity. The contractor is obliged to correct any deviation. And any delay by the contractor to correct the misconduct may necessitate a tougher action

against the contractor to restore quality at the construction site.

Figure 7

Figure no:8 shows the process of anchoring of reinforcement for pipe shear nip at stormwater manhole. The figure presents a serious violation and it can be summarized in the following:

- No material submittal and MIR submitted for anchoring material.
- Drilling hole depth is not as per requirement.
- Grouting is not done properly for anchoring material, workers only place the material at the manhole surface (around the hole), which results in the separation of some bars.
- Reinforcement is not fixed as per approved shop drawings.
- Bad workmanship (incompetent worker and supervision).

Figure 8

Upon observing the serious deviation by the engineer, an NCR was issued to the contractor immediately to correct the nonconformance at the site. The contactor immediately investigates the matter and implements the following corrections and preventive actions:

- Acquiring approval of material and MIR.
- Removal of installed reinforcement.
- Assigning a skilled and competent team
- A training session has been held to educate the team about the correct method of anchoring reinforcement. During the training session, the Engineer provided information about the method of determining the required hole depth, hole diameter, method of cleaning the hole, and filling the hole with grout as per manufacture's manual and requirements.
- Providing suitable drilling equipment and tools.

The contractor implements all the correction and preventive action and rectifies the defective work. Figure 9 shows the reinforcement after rectification. Reporting any quality deviation is essential for improving the performance of the contractor and correcting any deviation.

Figure 9

10. Conclusion

The construction sector occupies a large portion of any economy, and it is essential for the growth of any nation. As a result, the correct implantation of QMS is important to produce a durable and sustainable product. This, in turn, will reduce the cost of maintenance and enhance government spending. Therefore, strict implementation of QMS and QA/QC procedures is essential to maintain the required standards and meet customer and client expectations.

More emphasis should be placed on educating people and consolidating the quality culture. A strong quality culture is essential for the successful implantation of QMS. and producing quality products that comply with standards and meet customer or client expectations.

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