CIOB
THE CHARTERED INSTITUTE OF BUILDING

Code of Quality Management

Guide to Best Practice
Construction Quality Management

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Foreword

Quality, or rather the failure of quality, is one of the most important issues facing the construction industry today. Whilst many companies are committed to achieving good quality in the buildings and infrastructure that they create, recent events have highlighted that, as an industry, we are failing to consistently deliver the standards of quality that people have a right to expect. The underlying causes of these failures is something that we are only now beginning to understand.

In 2017, the Chartered Institute of Building established the Construction Quality Commission to investigate the issue of quality in the construction industry and what needed to be done to improve it. The Commission wanted to understand the behaviours, both individual and corporate, that were either preventing or promoting the delivery of quality on construction projects.

Research identified that there is an underlying cultural issue and that in parts of the industry, quality is being sacrificed to achieve cost or time targets. If we are to improve the delivery of quality on construction projects, change is needed from the top-down and the bottom-up.

To achieve this, the CIOB has committed to promoting best practice and providing better education and training on quality management, both for our members and the wider construction community.

The Code of Quality Management aims to raise standards by providing the tools and processes to help in the delivery of quality on construction projects.

There is no excuse for poor quality. The quality of the built environment is key to our quality of life and is the legacy that we leave behind for future generations.

We all have responsibility for the reputation of the construction industry and, most importantly, the satisfaction, wellbeing, and safety of those who use the built environment that we design, build and manage.

A commitment to achieving the right quality begins by taking pride in what we do and recognising that how we do it matters.

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Past President and Chair of the Construction Quality Commission

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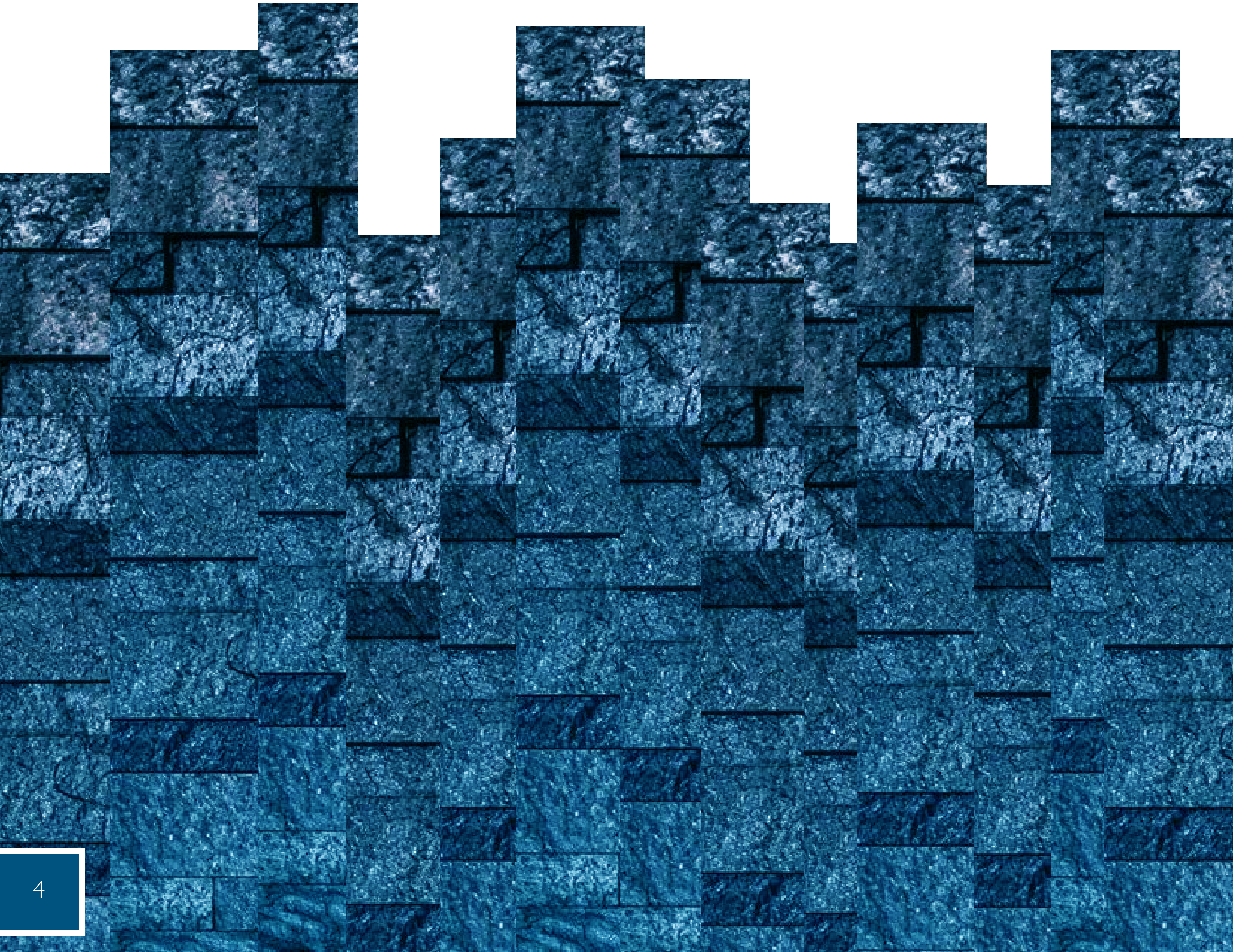

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Section One
Introduction

Introduction

"The Code will not be another report condemning the industry for bad practice – it's easy to criticise, but harder to deliver. It will be a reference document for quality management for everyone involved in delivering customer satisfaction."

The aim is to provide a single point of information on construction quality management for project stakeholders to improve construction quality, by establishing best practice for quality management and quality planning processes.

The challenge of transformation and improvement must bring quality to the fore for the construction industry. Quality engineering should be an integral part of construction.

In today's global economy, companies must demonstrate a commitment to deliver consistent quality products and service. The construction industry needs to treat quality issues in the same way it manages safety and health, with clear ownership of the results, good lines of communication, good training, effective supervision, and robust reporting mechanisms. Construction Design and Management Regulations (CDM) have led to transformation for safety and health in building and construction work in the UK, quality management has no comparable set of regulations. Instead, there is a muddle, with a reliance on compliance with standards, codes, and regulations, backed up by building control, and contract terms and conditions. The plethora of rules, standards, and regulations is complex, not easily understood, or accessible.

It would be disingenuous to say that design and construction site teams are not deeply concerned about the quality of their products or services.

As construction increases in complexity, rules and regulations proliferate, often becoming more complicated and consequently, less intelligible. Worse still, they impinge upon more people, who may lack the time, the inclination, or the ability to study them. Commercial pressure means that sites are under more scrutiny. The Code attempts to simplify the mythology that surrounds quality and to seek a better way of understanding how to improve quality in an industry that is increasingly complex.

Site teams face pressure from stakeholders, with contractual requirements, and compliance with standards, regulations, and legislation. Regulatory oversight is increasing. Social media means any failure is widely broadcast.

Construction involves a long supply chain. Companies must verify that their supplier's quality management system is suitable for the supply chain. Quality is not just about the products, it is also about behaviours, ethical sourcing, and environmental responsibility.

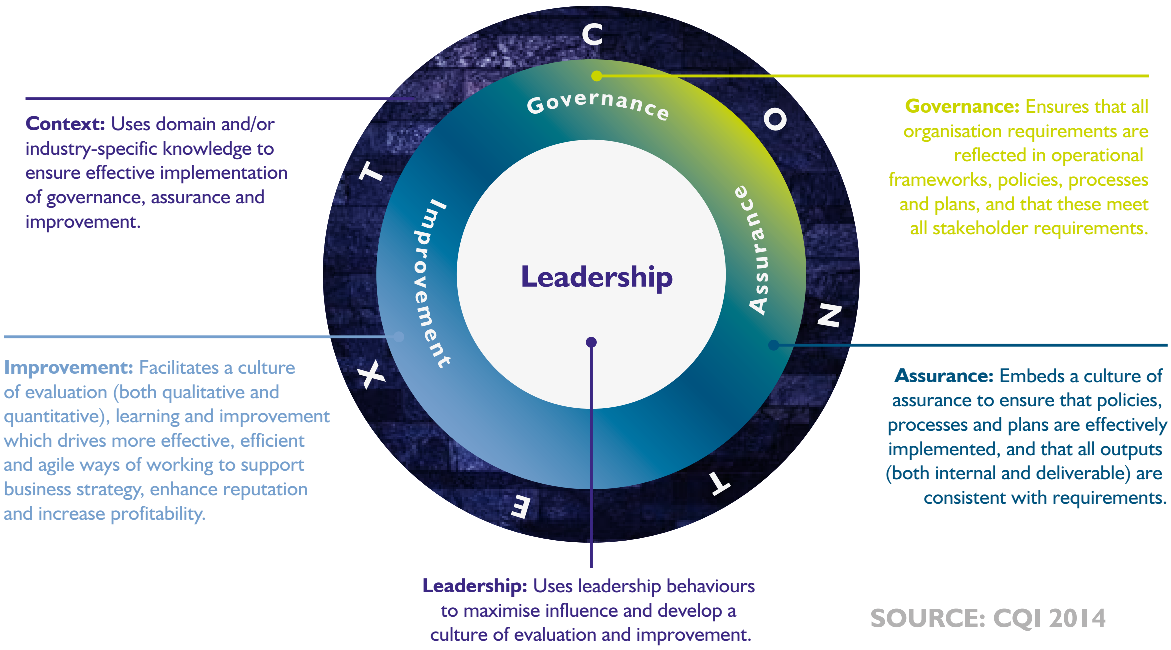
The people in suits don't talk enough to the people in boots!

1.1 Quality matters

Clients want good quality, reliability and consistency with projects that meet their expectations and requirements. Quality matters to everyone in the construction business. It should:

- Innovate and delight customers by exceeding their expectations.
- Allocate responsibility to ensure work meets the required standards and is reliable, robust, and consistent.
- Ensure a culture of continuous improvement and quality assurance for both service and production.
- Create pride in the job with a workforce proud of their achievements.
- Correct any snagging items in a timely and objective manner, with a no-quibble mentality to putting it right.
- Learn from mistakes and resolve issues together without blame.
- Adhere to the mutually agreed terms of delivery and performance.
- Make the construction industry a desirable place to work through quality of the workplace and the workforce.
- Respect the environment, communities, and the people who work in the construction industry.
- Create public confidence in its ability to deliver good quality.
- Display high ethical standards.

Figure 1-1
CQI competency framework



SOURCE: CQI 2014

There is no common definition of construction quality. It is subjective and viewed from different perspectives: the client, design team, principal contractor, specialty contractors, end user, companies in the supply chain and the workforce.

The Chartered Quality Institute (CQI) says quality comes down to three things: strong governance to define the organisation's aims and translate them into action, robust systems of assurance to make sure things stay on track, and a culture of improvement to keep getting better.

They suggest every product, service, process, task, action or decision in an organisation can be judged in terms of its quality – how good is it, is it good enough, how can it be better? The CQI Competency Framework shown in Figure 1-1 sets out the abilities and types of behaviour that quality professionals need in governance, assurance, and improvement.

Leadership, skills, education, training, culture of continuous improvement, governance, assurance, and attitude are important ingredients in the quality mix.

A knowledgeable, motivated and empowered workforce backed up by a committed management (to the highest level) can deliver quality construction given the tools, the time, and the opportunity.

Achieving job satisfaction through good workmanship needs to be the aim across all the stakeholders, from the contractor's workforce to the specialty contractors[1], suppliers and manufacturers.

The Hackitt Report reiterates the important themes of culture, attitude, education and training, effective communication, and the identification of roles and responsibilities. Improving the regulatory framework would provide a valuable structure within which best practice quality management can be pursued.

1.2 The Quality Tracker

The Quality Tracker, an initiative by the RIBA, CIOB, and RICS provides a good framework for tracking quality. It differentiates different kinds of quality. Minimum quality is the minimum standard compliant with a standard, code or performance requirement, whereas 'legacy quality' embodies functionality, aesthetics, flexibility, sustainability, social value, and health and safety[2].

The suggestion is for a "chain of custody" for passing the quality baton (responsibility for quality) in the design and construction team. The 'golden thread' of good information suggested in the Hackitt report[3a] is strongly advocated.

The five missing pieces to improve quality:

1. Lack of a common definition of quality
2. Better ability to predict future quality
3. Methods of measuring quality
4. Benchmarking quality
5. Risk control, how uncertainty affects quality

1.3 The quality challenge

Quality across construction, from pre-production to completion, requires a Quality Management Policy and a Quality Management Plan[3], outlining areas to be covered, monitored, and supervised in the quality management process.

The Code offers a generic quality management process to provide the basis for a project-specific plan with assigned responsibilities, lines of communication, documentation details, storage and tracking of information for an audit trail.

A Code must be outcome based, not based on prescriptive rules and regulations. It must be simple to use and understand, transparent, capable of audit, and based on collaboration and partnership, and not conflict. If you do not trust someone to deliver the quality required, do not appoint them for the job.

Governance is an important requirement. Ignorance, lack of clarity on roles and responsibilities, indifference, and lack of controls and enforcement are all challenges for the governance of quality management in the construction industry.

Responsibility for quality control is often confusing. Prescriptive regulation and guidance are not always helpful; bureaucracy reigns and sometimes the worker feels ground down by paperwork that adds little to quality control. Using the Hackitt example (see 1.12.2), an outcomes-based framework requires people who are part of the system to be competent, to think for themselves, rather than blindly following guidance, and to understand their responsibilities to deliver and maintain quality.

1 The term specialty contractor is used throughout the Code. In some countries, the term sub-contractor, works contractor, trade contractor, specialist contractor, or co-contractor is used. Specialty contractors can be micro, small, medium, and large companies that have a specialism. It may involve supply only materials, labour only services, supply and fix design, and supply and fix. Specialty contractors are an integral part of the supply chain.

2 Report of the Independent Inquiry into the Construction of Edinburgh Schools, Professor John Cole 2017.

3 For simplicity and clarity, the terms Quality Policy and Quality Plan are used throughout the Code to represent Quality Management Policy and Quality Management Plan.

3a Refers to the 'Building a Safer Future - Independent Review of Building Regulations and Fire Safety' report published May 2018.

The process driving quality is weak and not robust for a modern construction industry. The product testing, labelling and marketing regime is insufficient to ensure good quality. A more effective testing regime with clearer labelling and product traceability is needed, including a periodic review process of test methods and the range of standards in order to drive continuous improvement, higher performance and encourage innovative product and system design with better quality control. This is not suggesting more paperwork, but acceptance that the client is seeking more reliability and traceability should something not be right. They want certainty on who to contact when something is not right.

There are those fearful that more documents will slow the process, cost more money, and lead to unnecessary bureaucracy. The opposite is true; getting it right first time and reducing defects will save huge amounts of money spent on needless re-work. Time spent planning, managing, and focusing on quality will pay dividends for everyone across the supply chain. Defects are disruptive, de-motivating, and costly. Delivering quality needs embedding in the culture of the industry.

1.4 Raising the bar on quality

Problems with quality start at the design phase; quality must be designed into the project. Procuring on the lowest price will not add to quality on the job. Reducing professional design fees does not reduce the overall cost; passing design responsibility to the specialty contractors will not necessarily improve quality. The pressures are always to meet budget and the time requirements.

The problem is that when bidding for a project, the bid is often based on incomplete design information. It is not the design team's fault; the complexity of the process causes the difficulty.

1.4.1 Embedding quality into contracts

Standard forms of contract require quality management plans to be incorporated within the contract. NEC4[4] refers to quality management where the contractor must prepare and issue a quality management policy statement, and plan. If defects occur, the plan identifies the procedure and timing to be followed.

In Joint Contracts Tribunal (JCT) contracts, the emphasis is on the responsibility of the 'Employer' to provide drawings / bill of quantities / specification / schedule to define quantity and quality. They also address the issue of risk related to different types of procurement.

The FIDIC[5] suite of contracts has a quality management requirement. It uses the term 'quality assurance', where the contractor must institute a quality assurance system to demonstrate compliance with the contract requirements. Details of all procedures and compliance documents must be submitted to the engineer before each execution stage is commenced. The Quality Management (QM) system must ensure co-ordination and management of interfaces between the specialty contractors and the submission of documents to the client[6] for review. It requires the contractor to carry out regular internal audits of the quality management system, and at least once every six months. If the contractor is required by the quality assurance certification to be subject to external audit, the client must be informed of any failings. FIDIC also requires a compliance verification system requiring tests, inspections, and verification to be undertaken.

The terminology used in some forms of contract is not conducive to achieving good quality. For example, the term 'practical completion' condones projects handed over incomplete, with 'snagging items' permitted to be cleared post-handover. Good practice is to provide a definition of quality assurance for the project.

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4 NEC4 is the New Engineering Contract 4, engineering and construction contract, Thomas Telford Ltd

5 FIDIC is the International Federation of Consulting Engineers suite of conditions of contract for construction, published by FIDIC, Geneva, Switzerland

6 The term client is used throughout to represent the client/employer/owner/project sponsor of the works.

1.5 Quality professionals

Quality professionals have titles such as quality manager, quality engineer, quality director or assurance manager, while others deal with quality as part of a broader remit. The role of the Clerk of Works has been as a quality checker on site employed by the client.

1.6 Culture matters

Culture and attitude are vital in achieving quality success and should begin at the tender stage with effective quality planning. This comes from training and education, backed by a commitment from the stakeholders to deliver good quality construction. Attitude must start at the top of the organisation, not just the workforce, driving the right behaviour to make sure that high quality is a pre-requisite to a successful project.

A focus on creating a culture of quality provides the foundation that fosters the implementation of quality. Assessing the quality culture in the organisation helps identify the extent to which all employees understand the philosophy and approach to quality, as well as the degree to which quality is integrated in everything they do. Nice words but not always easy to achieve in construction, with the gaps between head office and the site, and the gaps between companies in the supply chain (all of whom want to produce a good quality job) reliant upon other organisations. One weak link in the supply chain causes disruption.

1.7 How to deliver quality

The big question is how to deliver quality in an industry that builds bespoke products, with low standardisation and off-site assembly, on projects not fully designed at the outset. It relies upon a long supply chain that is interdependent and interconnected.

Smaller companies often cannot afford to have a quality manager and have to resort to inspection by the site manager or trades specialist.

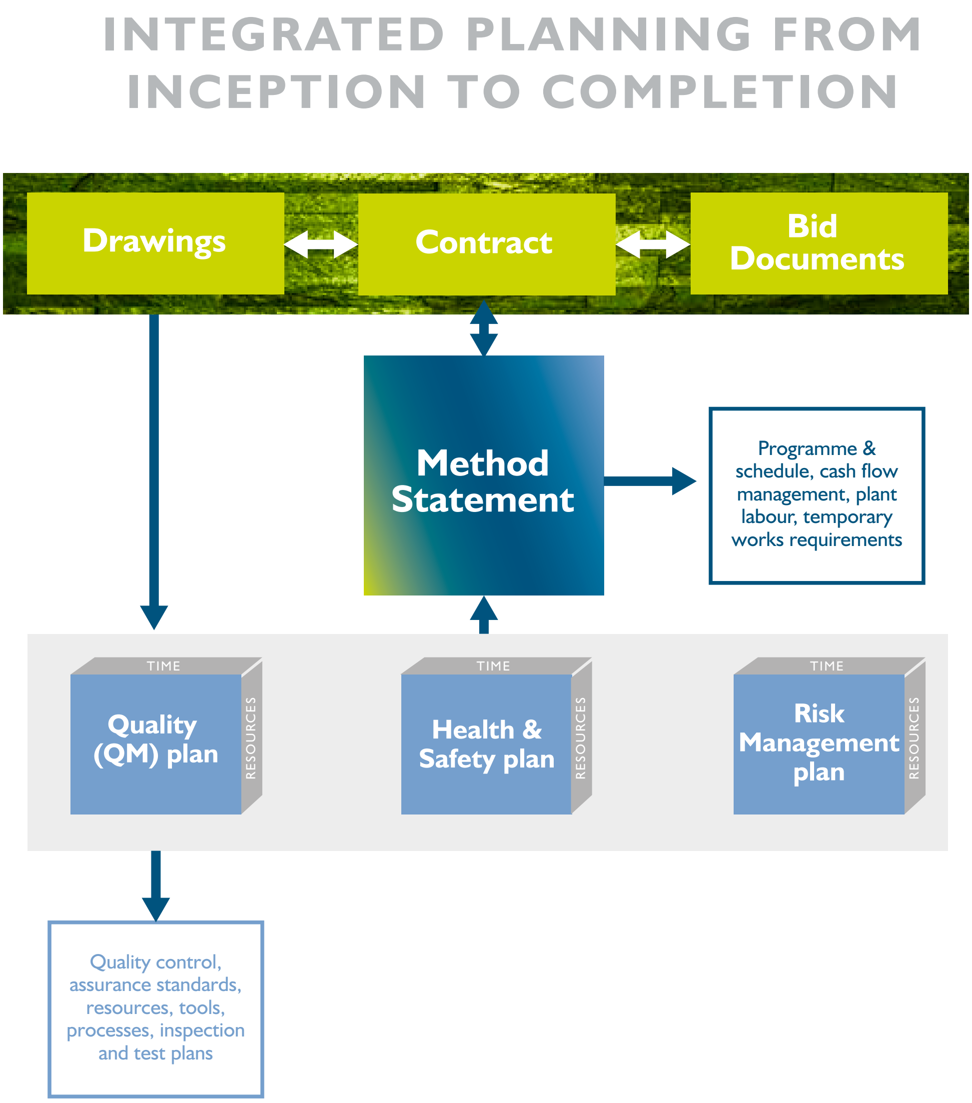
Keywords for quality delivery are engendering a culture of quality, leadership and commitment from the top, responsibility, and respect.

Integration of the processes, keeping all the stakeholders informed, and having the right information, is key to developing an effective quality management plan.

Figure 1-2 shows the documents from the beginning of the process (post contract award pre-production prior to commencement on site) – the contract, bid documentation, and drawings. If quality management is to be taken seriously, then a quality management plan should be equally important with health and safety, and risk. Ideally, the plan should be integrated with the method statement.

It is a like being in a relay race with the baton passed to the next runner; the team is only as good as the slowest runner. If someone drops the quality baton, the whole team suffers.

Figure 1-2
Integrated planning from inception to completion



They guarantee quality; construction struggles with the concept of guarantees and liability, mainly because of the procurement approach, the fragmented supply chain, and the way the contracts allocate risk and responsibility between a multitude of parties. Roles and responsibilities are often poorly defined across the project lifecycle, but particularly lacking during the pre-construction phase.

It is no use having the mentality that there is always time and money for re-work, but insufficient time to do the job properly in the first place!

Construction is renowned for being a low profit margin industry. Poor quality is costing the industry annually more than the combined profits of the large construction companies in the industry.

The drive for quality management must involve the development of a planning mentality that focuses on problem prevention. Preventive actions will reduce the overall cost of quality. Re-work to remedy defects costs time, money, reputation and motivation, and leads to unhappy clients and an unhappy workforce. Very often, the true cost of time, labour and attitudes is not recorded, and rework is 'accepted' on a day-to-day basis. It is often easier to identify the cost of poor quality, where things go wrong, the cost of re-work and remedying defects.

A cost-of-quality approach means a company can ascertain what resources are used to prevent poor quality, but that is a cost where nobody wins. Getting it right first time saves money and stress, and leads to satisfied customers.

Digitalisation makes communications faster and more reliable. Digitalisation, virtual reality, augmented reality, with automation have all improved the link between design and production. However, on the job site, it is the people that matter; given the right tools, the information, and the right materials, they want to produce a good quality product.

1.8 Push-pull factors

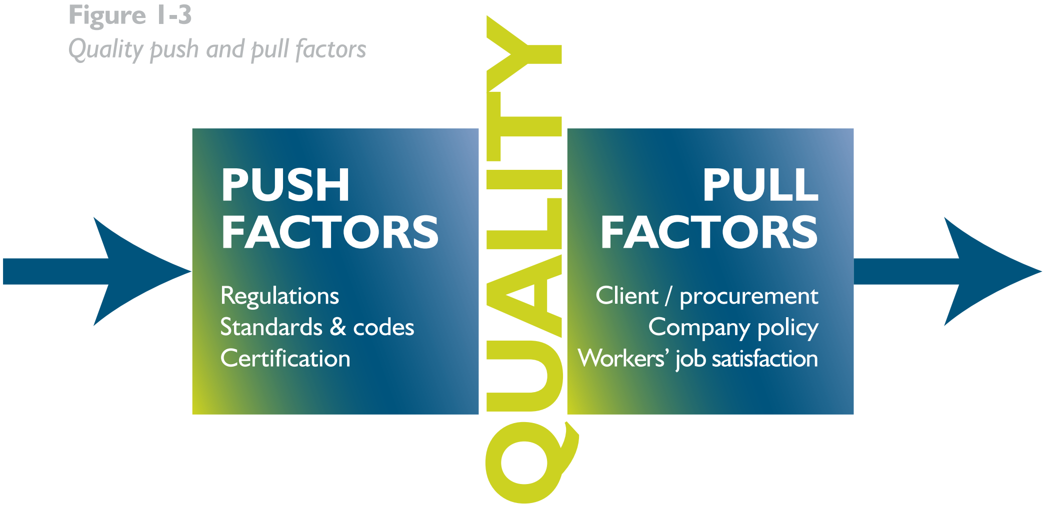
Quality is about push and pull factors – see Figure 1-3. The 'push' being the need for compliance with regulations, standards, and codes that govern construction, with registration and certification requirements. Some countries choose to licence registration for contractors, specialty contractors, and consultants. The registration system can define type of work, size of work, and the regions in which a licensed company can operate.

The UK has chosen an open approach by allowing the industry to self-regulate without registration and licensing, except for specialist trades such as asbestos removal. Construction Skills Certification Scheme (CSCS)[7] is the leading skills certification scheme within the UK construction industry. CSCS cards provide proof that individuals working on construction sites have the required training and qualifications for the type of work they carry out. Holding a CSCS card is not a legislative requirement. It is up to the principal contractor or client whether workers are required to hold a card before being allowed on site.

Japan, China, South Korea, Malaysia and many countries have taken the opposite approach to the UK. For example, in Japan a construction license is required in accordance with the Construction Business Act in order to carry on a construction business, regardless of whether this is for public or private works. Under the licensing system, there are 28 classifications of work; each represents a trade or field of the construction profession (See Appendix One Glossary). A contractor is licensed for each work classification in which it intends to engage. A Construction License is for a five-year period and then requires review and renewal. The advantage of the licensing system is creating the barrier to entry for unscrupulous companies, and the protection of standards. The disadvantage is the bureaucracy required to police and operate the system.

7 CSCS is a not-for-profit limited company. Its directors are from employer organisations and unions representing the breadth of the industry.

Figure 1-3
Quality push and pull factors



The 'PUSH' pressures are from:	The 'PULL' is from:
Quality imposed by regulations, to be in accordance with codes and standards.	Clients wanting a 'fitness for purpose' quality product, built into the procurement method and/or contract.
Independent certification by accredited organisations to provide quality assurance and ensure compliance with a standard.	A company's policy is the desire to produce quality construction to increase profitability and reputation.
Clients demanding higher quality and defect free construction.	An individual's aspirations for quality and job satisfaction.

1.9 Achieving quality on site

Job site workers have little power to change policy; they face making a design buildable on site within a constrained time. Design for manufacture and assembly is gaining traction in the industry. Having workable and well-considered design solutions manufactured in factory conditions will improve quality, but that finished quality needs maintaining on site installation.

Achieving industry-wide construction quality requires one of four approaches:

1. Regulatory/compliance led. Regulatory compliance means conforming to a rule, such as a specification, policy, regulation, standard, or law. Contractual compliance is equally important, for instance, the amount of retention withheld on interim payments is influenced partly by quality issues as well as financial stability. Compliance may also be voluntary. Checks and penalties are used, with responsibility allocated through national and international standards, such as ISO9000, and ISO14000; these can be contractual or voluntary.

The project specification defines the compliance requirements to meet the standard required, controlled in-house, or by independent parties, and validated by specialists (clerk of works, independent consultant).

Some overseas governments have set up quality assurance agencies to help with compliance. For example, established in 1989 as a non-profit-distributing organisation by the Hong Kong Government, the Hong Kong Quality Assurance Agency (HKQAA) helps industry and commerce in the development of quality, environmental, safety, hygiene, social and other management systems.

2. Market led. Companies decide on the establishment of their quality standard. BMW proved this worked in the automotive sector, where the product has a long-term guarantee that demonstrates the quality.

3. Industry-led registration schemes. Trade bodies establish minimum standards and requirements; members must comply with those standards to ensure membership of the body, such as Checkatrade, Corgi, and the Considerate Constructors' Scheme.

4. Compensatory / insurance-led. Offering warranties and guarantees, such the NHBC , clients seek an external body to validate the quality guarantee.

Health and safety in UK construction has benefited greatly from the regulatory / compliance nature of the Construction Design and Management (CDM) Regulations, with a legal requirement subject to punishment by fine / penalty. These set out the roles and liabilities of the client, designer, and contractor in a project. The rail, petrochemical, oil and gas, water, and energy industries clearly stipulate what they need from a quality system and what they are prepared to accept.

It is not just about being paid to deliver good quality construction; quality should be a given right.

Clients want projects to be quality assured. This defect prevention in quality assurance differs subtly from defect detection and rejection in quality control.

1.10 Balancing cost, time, and quality

There is always a balance between time, cost, and quality, with each taking on varying degrees of importance across the project. It is about the apportionment of risk.

Quality is profit to the maker, value to the user, and satisfaction to both.

Defective work, re-work, remedial work, and poor quality means everyone loses.

Estimates suggest that between 2%-5% of construction cost is spent on remedying defects and getting it right. In an industry with wafer thin net profit margins of 1%-3%, improving quality and customer satisfaction should have high priority.

Early stage planning will identify significant (delaying / costly) issues such as:

- Key dates for statutory approvals
- Client / design constraints
- Commissioning, testing and hand-over requirements
- Incomplete design items
- Short delivery lead-time items

Delays caused by uncertainty will affect quality on site. Lack of design information will cause frustration and delay.

The Bonfield Review[9], 'Each Home Counts' notes the risk that poor quantity installations could cause bigger problems than those they are seeking to solve, such as detriment to health of occupants, possible property damage, short term remedial costs, and longer term damage to the industry's reputation and consumer trust.

OFGEM's Technical Monitoring Report inspected 6.9% of the almost 1.5 million measures installed during the first ECO period between January 2013 and March 2015. Of these, 9.9% did not meet the necessary installation standards in the first instance and required additional work to be undertaken. The majority of these failures are not due to intentional poor performance, but the result of gaps in standards or the training provided.

In the quality process, everybody is reliant upon each other. One weak link and it all falls down. The system needs to be more robust than it is today.

Identifying where, why, and how failure occurs is important. The associated costs may be the result of defects (during and post production), non-compliance to the specification, standards and codes, poor information not communicated effectively, and the cost to reduce / eradicate failures. The consequential economic and reputational loss caused by poor quality can be significant.

Quality: a systematic approach to the search for excellence (synonyms: productivity, cost reduction, schedule performance, sales, customer satisfaction, teamwork, the bottom line). ASQ[10]

The specification / bill of quantities, local, national and international standards, building codes / regulations, codes of practice, and contract conditions stipulate the requirements for quality on the project. The contract will state there is an absolute obligation to carry out and complete the works 'in a proper and workmanlike manner and in compliance with the contract documents.' The contractor must perform the works where there is an absolute obligation to carry out and complete the works with reasonable skill and care.

Under Section 14 of the Sale of Goods Act 1979, a term is implied into a contract for the sale of goods that the goods will be fit for purpose (legislation.gov.uk, 2019), whether or not that is the purpose for which such goods are commonly supplied.

'Fitness for purpose' warranties can be expressly agreed or implied in construction contracts or consultancy agreements to ensure that, whatever is being designed, built or supplied is fit for its intended purpose. A fit for purpose obligation in a construction contract simply means the contractor agrees that the design will meet the employer's demands. Some contractors say, "I will not accept a fitness for purpose obligation because it is too onerous and is not insurable". The effect of including a fitness for purpose clause in a construction contract can be very significant.

9 Independent Review of consumer advice, protection, standards and enforcement. Consumers rely on a framework of standards to ensure that they get a good quality outcome when choosing to install energy efficiency or renewable energy measures. The Review draws together evidence about weaknesses in the existing framework of standards. (Department of Energy & Climate Change and Ministry of Housing, Communities & Local Government 2015)

10 The American Society for Quality (ASQ), formerly the American Society for Quality Control (ASQC), is a knowledge-based global community of quality professionals, with nearly 80,000 members dedicated to promoting and advancing quality tools, principles, and practices in their workplaces and communities.

1.10.1 Design quality

The Commission for Architecture and the Built Environment (CABE) based quality on:

- Functionality: will it perform?
- Firmness: will it last?
- Delight: does it look good?

Design quality is about functionality and fitness for purpose, safety, buildability, and about service delivery, with the right information provided at the right time for the job site, with no delays in approving and signing off shop drawings.

Design quality is also about completeness of design, with sufficient information for the workforce to convert the design into production. The impact of the quality of the finished product is very important; a good environment with reliable performance will improve the quality of life, and the productivity of the workforce in everyday life.

Design quality reflects how the asset will perform, and how it can be maintained, repaired, and replaced. Having a shower mixer valve behind tiling with no access will not delight the client when it starts to leak.

Robustness, reliability, resilience, and consistency are equally important to the client. Conformance to the specification and being defect free is important to the client once the asset is in use.

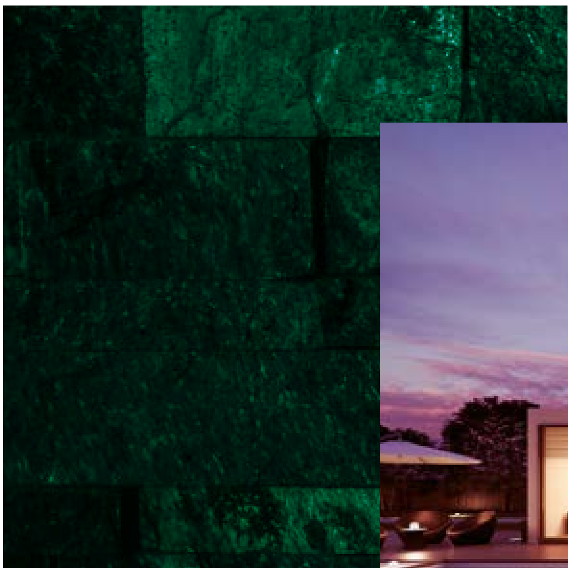
Paying lip service to quality, ticking boxes, imposing unnecessary bureaucracy, and having procedures that do not add value, does not lead to satisfied customers, or a satisfied workforce.

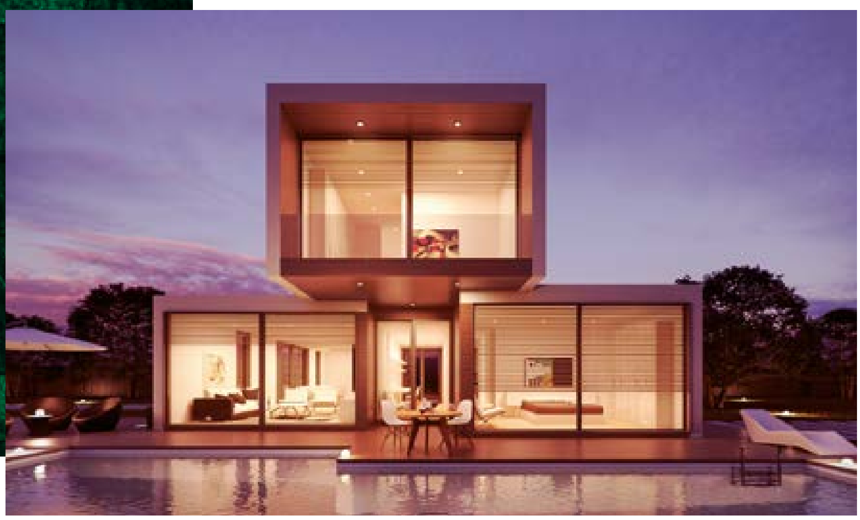
The principal contractor and the specialty contractors will embed a Quality Management system into the site delivery process on large projects, by use of manuals and checking procedures. For a smaller contractor, procedures may not be formalised in manuals, but they will exist; such systems may be withholding payment until the required standards are met, or not giving a poor performer further work. Unless everyone on the project understands the standards expected, the project can only be as good as the weakest link; there is no satisfaction in the client saying the quality of the joinery on the project is wonderful, but they are experiencing water leaks in the building!

The key to success is the variety of people who come together to construct a project working as a temporary team, many of whom work on casual contracts.

Specialist consultants with clipboards understand process; they need to understand site production, with everything in construction becoming more complex and interdependent.

"It is no longer acceptable to think of quality as merely meeting the technical and performance specifications in the contract….. that will lead to mediocrity."





1.11 Quality standards

1.11.1 International Organisation for Standardisation (ISO)

The International Organization for Standardization (ISO), an international agency composed of the national standards bodies of more than 160 countries, provides guidance and certification on a range of issues. EN- ISOs are used throughout the world, including the European Union. They become BS EN ISOs when adopted in the UK. See Appendix One for the ISO standards relevant to quality management.

ISO 9000/9001/9002/9003 is the definitive standard across industries for quality issues. Regardless of the size, the nature of business or the industry sector, the ISO 9000 standards are a generic management system that have evolved through the years and can apply to any organisation.

ISO 9000 defines the quality management approaches applicable across all industries. Standards continue to play a crucial role in construction work. For the quality profession, they are a tool for both measurement and improvement, while providing confidence to the market.

Experts say production line manufacturing is different; quality control is easier in a factory environment than on a job site. Whilst that argument may be true, a modern economy demands efficiency, certainty, safety, and embedded quality; delivered in a fast changing complex environment. The construction industry can no longer hide behind the complexity of the industry as an excuse for low quality standards. Blaming someone else is not acceptable; everyone must deliver good quality products and services.

It is tempting to say construction IS DIFFERENT because of the bespoke nature of every project, the separation of design from site production, and the large number of specialty contractors and suppliers of goods and services. Every industry has its fragmentation; claiming to be different is not an excuse!

ISO 1006 (BS EN 10006) gives guidelines for the application of quality management in projects. It covers quality management systems in projects (Clause 4); management responsibility in projects (Clause 5); resource management in projects (Clause 6); product / service realization in projects (Clause 7); and measurement, analysis and improvement in projects (Clause 8).

1.11.2 European Foundation for Quality Management (EFQM)

The EFQM Excellence Model is a framework for assessing applications for the European Quality Award. The model is used as a management system that encourages the discipline of organisational self-assessment and is a practical tool to help organisations to measure where they are on the path to Excellence; helping them understand the gaps; and stimulating solutions. It is applicable to organisation irrespective of size and structure, and sector. Self-assessment has wide applicability to organisations large and small, in the public as well as the private sectors. The outputs from self-assessment can be used as part of the business planning process and the model itself can be used as a basis for operational and project review.

1.12 Defining quality – an industry view

1.12.1 Building in Quality

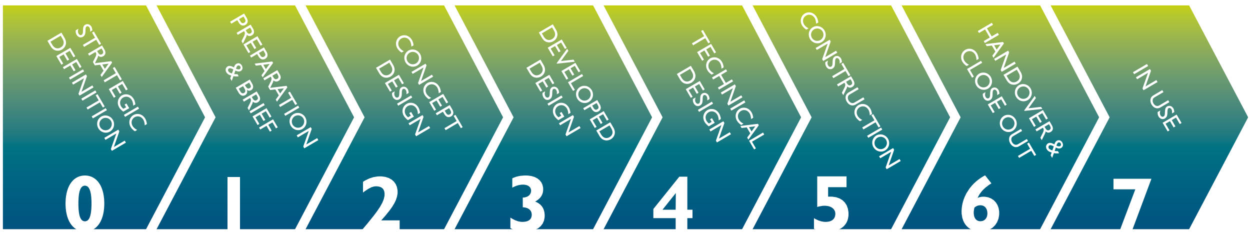
The ‘Building in Quality’ report[11], a collaboration between the RIBA, CIOB and RICS, established three dimensions of quality:

- Build quality – completed asset performance
- Functionality – fitness for purpose
- Impact – the degree to which the asset adds social, economic, cultural and environmental value and improves wellbeing for those that buy, use, or manage an asset

Gaps are identified in the pursuit of quality in the industry:

- Lack of an agreed definition
- Need for better prediction of the asset’s final quality
- Available methods of measurement, monitoring etc.
- Data against which benchmarking can be undertaken
- Risk control and handling uncertainty

To address the gaps, a digital system for monitoring the risks to quality – the Quality Tracker is proposed. “The Quality Tracker is at the heart of a chain of custody system for overcoming the often fragmented composition of project teams and the resultant inconsistent governance of quality” (Building in Quality, p. 25). The process is important in identifying quality issues for the client, which needs to be agreed by the project team and, importantly, recorded and signed off impartially at pre-agreed stages. “The quality baton is passed on until finally issued to the client’s representative, the investors, the purchasers and / or tenants as a verified statement of the ways in which risks to quality were handled during the project”. At each work stage, risk assessments may be interpreted in the context of the quality targets set out in the project brief. Each ‘page’ of the Tracker covers one of the stages in the RIBA Plan of Work. The construction / production phase is Stage 5 of seven stages.



1.12.2 The Hackitt Report

The Hackitt report is an “Independent Review of Building Regulations and Fire Safety”. The report states that there was “insufficient focus on delivering the best quality building possible, in order to ensure that residents are safe, and feel safe”. The report identifies a need for a new regulatory framework that would provide both positive incentives and effective deterrents to ensure competence levels are raised and quality and performance of construction products improved.

A more effective testing regime is needed and innovative product and system design with efficient quality controls.

Effective and accurate information management is crucial, across the project and over the life of a facility, to improve quality and performance – the ‘golden thread of information’.

11 Building in Quality: a guide to achieving quality and transparency in design and construction. RIBA 2018

Dame Judith Hackitt[12] referred to three important issues:

1. Ignorance - regulations and codes were misunderstood and misinterpreted; this is partly because the way the codes are written, with legalistic and technical terminology. This equally applies to some of the codes and standards on quality.

2. Lack of clarity on roles and responsibilities – there is ambiguity over where responsibility lies, exacerbated by a level of fragmentation within the industry, and precluding robust ownership of accountability.

3. Indifference – the primary motivation is to do things as quickly and cheaply as possible, rather than to deliver quality homes that are safe for people to live in.

"The above issues have helped to create a cultural issue across the sector, which can be described as a 'race to the bottom' caused either through ignorance, indifference, or because the system does not facilitate good practice. There is insufficient focus on delivering the best quality building possible." Hackitt Report (2018)

The 'race to the bottom' is often driven by unrealistic and uninformed clients/budgets.

1.12.3 Get it Right Initiative[13]

The initiative has four objectives:

- To generate significant change in the efficiency of the UK construction industry through reducing the amount of errors made in construction.
- To undertake research to identify, evaluate and prioritise the principal systemic errors in the construction process.
- To develop a strategy to address these errors and in particular to address deficiencies in skills.
- To develop new training products and processes to address the skills deficiencies.

Industry opinions on the issue of 'getting it right first time,' identified the sources, root causes and cost of most frequent errors, together with how to avoid making errors. The Strategy for Change outlines: a skills development programme; a campaign to change and align attitudes across the sector so that "all involved are committed to reducing errors and improving the quality", and improvements needed in management processes and systems, particularly design management and construction planning.

Comment: This Get it Right initiative focuses on education, skills and attitudes, backed up by data on types of errors, their costs and frequencies.

12 Building a Safer Future, Independent Review of Building Regulations and Fire Safety: Final Report. Presented to Parliament by the Secretary of State for Housing, Communities and Local Government, May 2018.

13 The Get it Right Initiative is an organisation that is tackling avoidable error in the construction industry. Membership is by subscription. Get It Right Members work together to steer the agenda and build a better UK Construction industry.

1.13 The Drivers, Issues, Disruptors and Enablers of construction quality management

The CIOB Call for Evidence and research identified major drivers that influence construction quality summarised into eleven main Drivers:

- **Good design** means well developed design that is buildable and sufficiently complete at the project award stage, to allow commencement on site without information gaps. Everyone suffers when there is lack of sufficient information.
- **Realistic project programming** at the outset of the project, with sufficient float in the programme to cope with uncertainty.
- **Climate** and the impact of weather on materials, workforce and the process. Over optimistic assumptions about the impact of inclement weather lead to delays and poor quality.
- **Timely and relevant data and information** provided by the design team and by the principal contractor to the supply chain and the site workforce.
- **Site management and production**, with a production team that has the appropriate skills for the project, with a supply chain that is fully committed to deliver to the required quality.
- **People and performance** by motivating the workforce, training the workforce, and respecting the work of others. Engendering a culture of the importance of quality on projects.
- **Clients** understanding the importance of effective and timely decision-making. Recognising that changes in scope and design after production has commenced on site.
- **Governance** structures and principles identify the distribution of rights and responsibilities among different stakeholders and include the rules and procedures for making decisions. Governance should provide transparency. Good governance for quality systems should be clear, simple, and understandable. Over burdensome governance and regulations / procedures that add little to improve quality take time and add unnecessary paperwork for the site.
- **Corporate behaviour** demonstrating leadership from the top about the importance of quality.
- **Realistic budgeting** at the outset, taking account of risk and uncertainty, and building in contingencies to take account of the unexpected. Avoiding the blame culture and focusing on commitment to quality.
- **Materials** procurement, storage and handling, with clear information about the requirements to ensure the materials and components meet the design specification.

The eleven Drivers come at the top of a 'quality pyramid'. Figure 1-4 presents a hierarchical system of Drivers, Issues, Disruptors, Enablers and Actions.

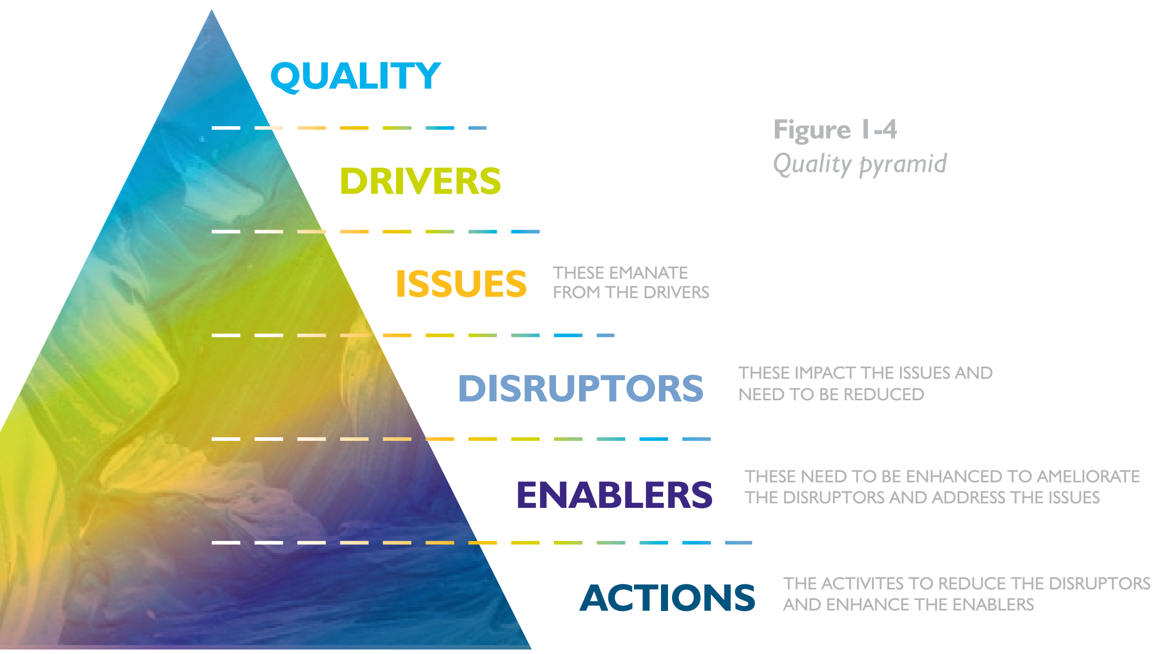


Figure 1-4
Quality pyramid

The Issues comes from the Drivers. For example; climate will create a multitude of issues, such as productivity on site, requirements for temporary protection of finished work against inclement weather to ensure quality standards are maintained. The Disruptors and Enablers are the items that will influence each of the Drivers and Issues. It may be necessary to increase expenditure on plant commissioning by an independent team to ensure all the plumbing systems are working effectively. The actions are a summary of the items to be included to ensure the maintenance of the quality standard.

Realistic programming and budgeting are key to project success that will heavily influence quality. As one respondent commented in the Call for Evidence (CfE):

"Design is about buildability and appropriate specifications as well as the importance of being close to 100% complete before production begins."

Timely information means there is not the last minute rush because of lack of information when the work package started. Everyone will change their minds, but there has to be recognition that late changes are de-motivating for the workforce and can slow the project, putting pressure on the workforce to deliver top quality in an unrealistic time frame.

People's attitude to quality and the underlying culture cuts across all the drivers. They are particularly important in site production, the delivery team / supply chain,corporate culture and data and information e.g. their willingness to share information and collect data effectively.

Site issues such as the procurement, correct delivery, storage and handling of materials can influence quality. Furthermore, the materials specified need to be appropriate to their designed function.

Corporate culture needs to focus on customer care and demonstrate a commitment to quality. Regulations, codes and standards require compliance, which in turn, necessitate a programme of monitoring / supervision. Governance and compliance are important drivers in health and safety, and quality.

1.14 Driver interconnections and interdependencies

Drivers do not stand-alone, they are interconnected to (and often dependent on) each other. For example; there are strong links between site production and realistic programming and realistic budgeting. Some issues may be shared by different Drivers. For example; 'design changes' would appear under 3 different issues: Design, Site production, and, Data and information. A honeycomb pattern is used to show the interconnectedness of the issues, barriers and disruptors, and the enablers – see Figure 1-5.

The Driver / Issue honeycomb will show the linkages across the Issues, Barriers, Disruptors, and the Enablers. Each Driver may be linked to, or be interdependent with, other Drivers creating a Driver honeycomb at the top level.

Figure 1-5
Quality driver / issue honeycomb

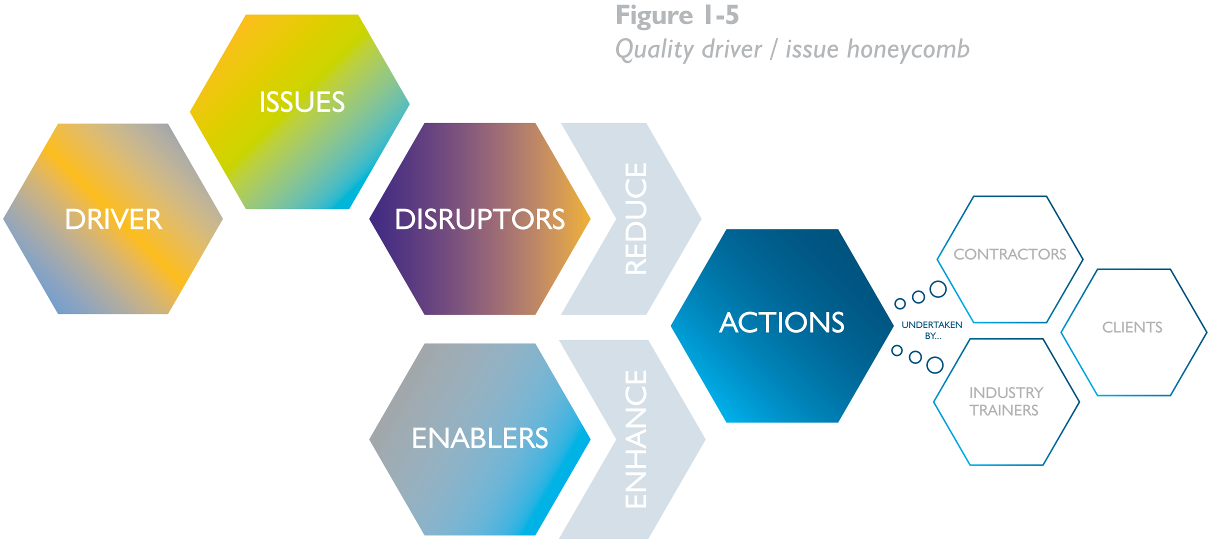


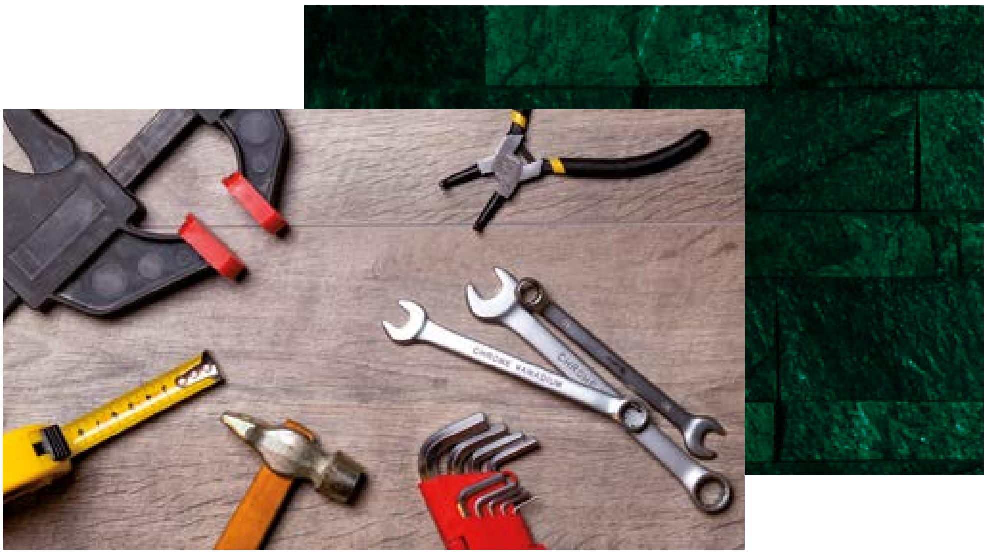
Figure 1-5 shows that, against the Disruptors and the Enablers, are chevrons leading to the 'Actions' hexagon. The actions should be consistent with reducing the barriers and enhancing the Enablers. The actions need to be undertaken by a few, or all stakeholders – these include industry trainers, clients and contractors.

Industry trainers include government bodies, professional institutions, education establishments, and training organisations.

1.15 Repair and maintenance and refurbishment projects

In existing buildings, quality starts with the analysis of the building. The opportunities for quality are dominated by knowledge, skills and initial pathology / condition assessments. Whilst the same basic principles for QM will apply, their implementation and focus will be different. Knowledge of conservation / material science / building physics / occupier behaviour are all very different from new build projects. This means that a slightly different set of skills and requirements are necessary to create a high quality environment / project. For example; in heritage buildings, traditional binders consisted of clay, lime and gypsum for mortars, render, and plaster, followed by the development of natural and artificial cements. Lime-based mortars are of central importance for traditional (pre 1919) buildings, and are the materials of choice for repair, maintenance and conservation of these. BS EN 459 Building Lime gives guidance on this type of material.

Refurbishment of an occupied building presents challenges to ensure all the stakeholders are happy; it is not just the quality of the workmanship and materials. Disruption to the daily life of the tenants will influence their perception of quality. They will remember the driven piles with the noise and vibration, whereas an alternative may have alleviated the problem.



Section Two
The Code

The Code

2.1 Actions on Quality

Actions classify into four headings:

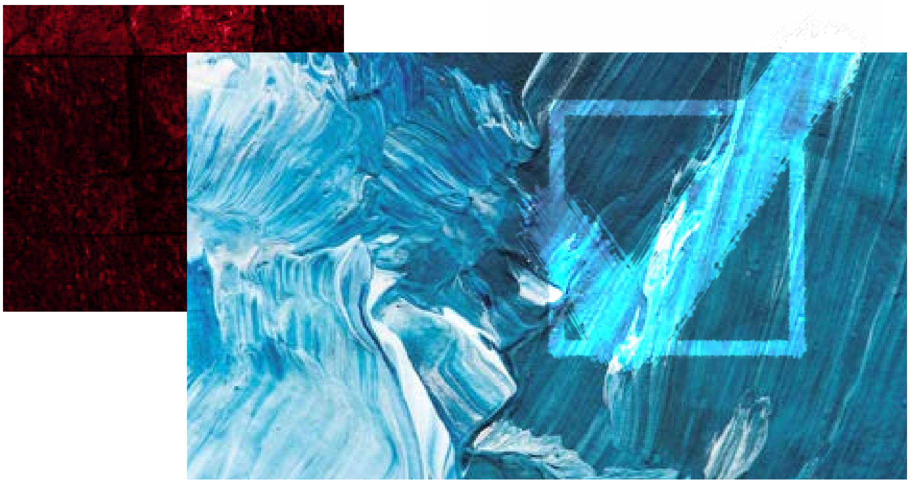
- **Prevention**: develop activities that ensure right-first-time performance through leadership, good governance, and continuous improvement. Ensure effective management of the interfaces between design and production by design management and effective communications to all members of the supply chain.
- **Assurance**: activities that check whether right-first-time is achieved, not ticking a box, but ensuring the quality requirements are met from manufacture, delivery and storage, through to site installation, testing, commissioning, and handover.
- **Remediation**: remedial activities that result from not conforming to right-first-time by failure to meet the specification and compliance requirements. Failure causes delay to the project and costs everyone money.
- **Understanding implications**: there is a desire to hunt the guilty in a litigious world. For instance; equipment failure can result in significant consequential financial loss and business interruption. Someone has to take responsibility. Insurers are not charities; they will only pay for gross neglect, not poor quality.

Quality costs are both direct and indirect – the direct costs are getting it right first time and the cost of remedial work, the indirect costs are loss of reputation and future work, as well as client and user dissatisfaction.

Quality management procedures are much less expensive than litigation!

There is a plethora of quality-related codes and standards; the site team needs to be aware and understand the requirements and implications. However, their format and language is not conducive to quick reference by the site team. Time is money, site teams are always time constrained, with information in a form that is user friendly and easy to obtain. ISO/British Standards and codes must be relevant and up-to-date.

Section 5 of this Code outlines the codes and standards in each work section, outlining the advantages, disadvantages, and the related quality issues as well as lists of codes and standards, both national and international.



2.2 Planning for quality

Planning for consistent and good quality should be considered alongside risk, and health and safety.

If planning and scheduling is to add value then it should look at both costs and benefits. Remedying defects costs time, money, and reputation. It leads to unhappy clients and a demotivated workforce – nobody wins!

Construction planning and scheduling is about ensuring the effective use of resources (people, plant, and equipment) as well as space, information, time, and money to deliver on time, on budget, and to the required quality.

Failing to plan = planning to fail.

Robust planning and programming requires the integration of inspection and testing requirements, achieved through an Inspection and Testing Plan (ITP), which defines roles and responsibilities, employs continuous or discrete checking, and identifies hold points where appropriate.

Quality Planning is a process that quality departments, quality managers, and quality professionals undertake in their organisations to identify the quality initiatives to manage quality today and into the future.

The production plan should include inspection procedures and testing, and their frequency (incorporating a contingency should remedial work be necessary) and commissioning. Quality assurance protocols need to be established. A project quality plan should identify the quality requirements, the project team's quality-related roles and responsibilities, and the resources required to ensure adherence to the plan. The plan should detail the procedures for dealing with defects and the document control procedures.

2.3 Company policy on quality

The Quality Policy should outline the systems and procedures in pursuit of the quality targets, stating expectations of the project team, and all other stakeholders that work on / visit the site. It should state the roles, responsibilities and authorities of the project team and the specialty contractor requirements to ensure they meet the quality standards on the project.

The objectives and effectiveness of the Quality Policy should be subject to audit on a regular basis, at least annually, to ensure targets are met and the Policy remains effective in a changing business, construction and compliance / legislation environment.

Comment: Site-based quality management is a very broad and multi-faceted area, involving the supply chain and a complex team of stakeholders across the value chain. The Code addresses the need to focus on the detail of the production process. It can be an important part of a quality management toolbox alongside the Quality Tracker.

2.4 Site-based procedures

Consistent quality relies upon having the skills available, learning from mistakes, continuous improvement, and a mind-set that recognises quality is paramount. However, it cannot exist in a silo. Quality depends upon everybody playing a part from the consultant team to the site production team. Good design and suitable specifications delivered at the right time are paramount. A design detail that fails to reflect the reality of how the production team will construct it, can lead to difficulties. Buildability will make a difference; a poorly planned project with an untidy site will not deliver good quality work; pride in the job is important. Materials, components, and systems must be assembled and constructed in a way that is safe, and fit for purpose.

On medium to large projects, site management relies upon a team of people working together. On smaller projects, there may be just one site manager who may also be the contractor. Whatever the size of the project, the aim is the same; it is about planning and co-ordination of production to deliver on time, on budget and to the required quality. It is not about size; it is about attitude to quality.

Clients are sometimes unclear as to what they want at the outset on small projects. They think it can be designed and changed as the work proceeds, which is where confusion arises. Any change of mind will have consequences for the time, cost, and quality.

Time becomes a cost pressure, and time becomes the biggest enemy of quality management because of the need to deliver to the agreed target. Multiple layers of specialty contractors exacerbate the complexity. Often the organisation at the bottom of the chain becomes remote from those at the top, with pressure on cost and time to deliver the task / work package to ensure other packages are not delayed. Pressure manifests itself in stress for the workforce, with the target to deliver on time irrespective of the consequences.

2.5 Quality through the supply chain

The supply chain is crucial to controlling / maintaining quality across a diverse set of stakeholders. Specialty contractors should submit their Quality Plan / Policy as soon as possible in the procurement process. If they do not have these, they must adopt the contractor's version. If a specialty contractor's quality plan is considered not sufficiently stringent, they must adhere to the contractor's quality plan. They must submit material certificates, product data, installation instructions, warranties, personnel qualifications, and results of any independent laboratory tests. The specialty contractors may need to provide their own test / inspection personnel where the material / component / system is specialised.

Training / induction on quality issues is as important for the specialty contractors as it is for the principal contractor's site workforce; it must take place before starting work on site. Regular meetings with all specialty contractors must review the procedures, critical activity inspections, and other quality-related issues. The person responsible for quality needs to work closely with the supply chain to ensure compliance with the quality requirements.

2.6 People

Maintaining continuous quality improvement depends on the daily behaviour of employees and contractors. The competency of both the site workforce and the managers / supervisors is key to the success of the quality plan. There should be emphasis of building the 'conscience of the customer's requirements' into the fabric of the site organisation. Continuous briefing and training should be in place, keeping competencies up-to-date and relevant.

For people, the key words are: empowerment, ownership, attitude, responsibility, behaviour.

The quality manager works closely with the construction / project manager and site manager on day-to-day issues, keeping in close communication with other stakeholders including the design team, health and safety manager, risk manager, compliance officer, and contracts manager. On small projects the relationships will be more personal and informal, but equally important.

2.6.1 Culture and attitude

A workforce lacking motivation will underperform. Motivation may be financial or non-financial, the important aspect is to motivate a worker to maximise their potential, ensure work satisfaction, and to maintain good quality standards. Motivation can be at project level though a 'pain and gain' contract[14] such as the NEC 4 suite of contracts.

Empowerment is being able to make decisions in the workplace that are accountable and responsible, which is especially important for quality; being free to speak out about something that is poor quality allows someone to take responsibility and pride in their work. Empowering workers so that they feel an integral part of the whole process / company can be motivating. Relationships across the project and the supply chain must be developed and maintained, they do not just happen. The company's quality objectives should be explained and attention drawn to the quality management plan with the supervisory, monitoring and testing processes at site induction.

14 NEC4 stipulates that at the end of the contract, a comparison is made between the final Defined Costs and Fee (the final "Price for Work Done to Date") and the target costs. If the final Price Work Done to Date is less than the target then the Contractor will make a share in the saving depending on the level agreed. If, however, it is greater than the target cost, the Contractor will pay a share of the difference (again at the level agreed).

2.7 Product

2.7.1 Materials / components

The quality of materials / components is a key ingredient of a quality plan, i.e. to produce, as effectively as possible, a product that meets all the quality requirements of the client, the relevant regulations and any quality management standard / certification.

Not all sites will have a quality manager to call upon. Somebody must take responsibility to review and manage submittals of materials, including design data, samples, and shop drawings.

Construction Shop drawings are the actual detail of all manufactured or fabricated items and indicate proper relation to adjoining work, amplify design details of equipment in relation to physical spaces in the structure, and incorporate minor changes of design or construction to suit actual conditions. Shop drawings must be submitted with such promptness as to cause no delay.

Where appropriate, any manufacturers' data, including dimensions, characteristics, capacities, and operation and maintenance information / schedules, must be reviewed. Copies of the submittals should be kept on site as part of the document control system (see 2.8.3). Colour samples and mock-ups should be regularly compared with site production. Photographs are useful in identifying specific requirements of a product, component or material. A submittal register may be kept and maintained by the construction / project manager.

The delivery, storage and handling of materials affects the quality of materials and processes / standards. If a materials (logistics) plan is available, this should be integrated in the Quality Plan. The delivery and handling of materials requires resources – human, plant and equipment – and this should be considered within the Quality Plan or in the correlation between it and the method statement. Reference should be made to the requirements of Building Regulations 2010 Approved Document 7 – Materials and workmanship.

2.7.2 Material / component and supplier traceability

Materials and component suppliers may be specified by the design team. The details of the source and any necessary certification e.g. FSC certificate, Agrément Certificate, CE mark etc. are required. The responsibility for the controlling documentation needs to be assigned with the assurance that material and supplier traceability can be maintained.

2.7.3 Plant and equipment

Any plant and equipment that needs to be repaired / replaced should be identified as soon as possible and non-conformance to quality or safety standards recorded and acted upon.

2.7.4 Materials quality

Materials delivery is checked for the right quantity and quality. Packaging protects goods in transit, with the supplier's aim to deliver materials and components in perfect condition. More thought must be given to handling the packaging and recycling of packaging material. Before installation, materials are vulnerable to damage in handling, storage, and adverse weather conditions. Damage costs money and time; expensive materials need respect. Vulnerable materials may need temporary protection after installation, which is important to ensure maintenance of quality.

An inventory tracks the type, quantity, quality, and placement of materials on site, and the control of site materials information (e.g. existing materials on site, existing stock, and despatched materials).

Both internal and external controls can be carried out for assuring quality. For example, the quality control of concrete supply can be carried out by an independent entity; the execution of steelworks can be controlled by the project manager (on behalf of the client), or the construction company can establish an internal control for the execution of the building work.

Materials include manufactured products such as components, fittings, items of equipment and systems; naturally occurring materials such as stone, timber and thatch; and backfilling for excavations in connection with building work. Approved Document 7: Materials and workmanship, Building Regulations 2010

2.7.5 Certification of materials, components and systems

The specification should include certified materials / systems / components in order to satisfy performance requirements. Performance specifications are written for projects that are straightforward and are well-known building types. Prescriptive specifications are written for more complex buildings, or where the client has requirements that might not be familiar to suppliers and where certainty regarding the exact nature of the completed development is more important to the client.

2.8 Process

The project may be broken down into work packages and / or phases. It is important for the Quality Plan to cover all the important / major processes, such as:

- Highways, footways etc.
- Bridges
- Force mains
- Gravity sewer
- Plumbing
- Electrical
- HVAC
- Lifts
- Masonry
- Concrete
- Landscape
- Erosion control
- Fire alarm
- Fire suppression
- Hazardous material abatement
- Instrumentation and control
- Trenching
- Excavation work
- Formwork
- Roofing

2.8.1 Testing and inspection

The contract and the company's Quality Policy will set out the required testing and inspection (and their timing / frequency) of work and materials. Testing and inspection requirements will be drawn up for each work package, which may include factory tests, quality control inspections, installation verification tests, and acceptance tests.

Inspections should be by qualified personnel, either the company's employees, or third party inspections, in three stages:

1. **Preparatory meetings** (related to specific work packages) review the specifications, plans, and sequence of work. The testing and frequency should also be discussed. At this point, the safety plan needs to be checked against the quality requirements and the level of workmanship required for a particular work package. Figure 2-1 shows the discussion points for a preparatory meeting, with the minutes / report stored and distributed in accordance with the documentation control policy / procedures.

2. **Initial Inspections** at the start of a work package should be repeated whenever new operatives are assigned to the work, focusing on the workmanship and inspection and testing. The initial inspection meeting should review the items from the preparatory meeting to ensure raised issues are addressed. The minutes / report of the meeting are distributed in accordance with the documentation control plan. Figure 2-2 shows a generic checklist that might form part of the initial inspection(s).

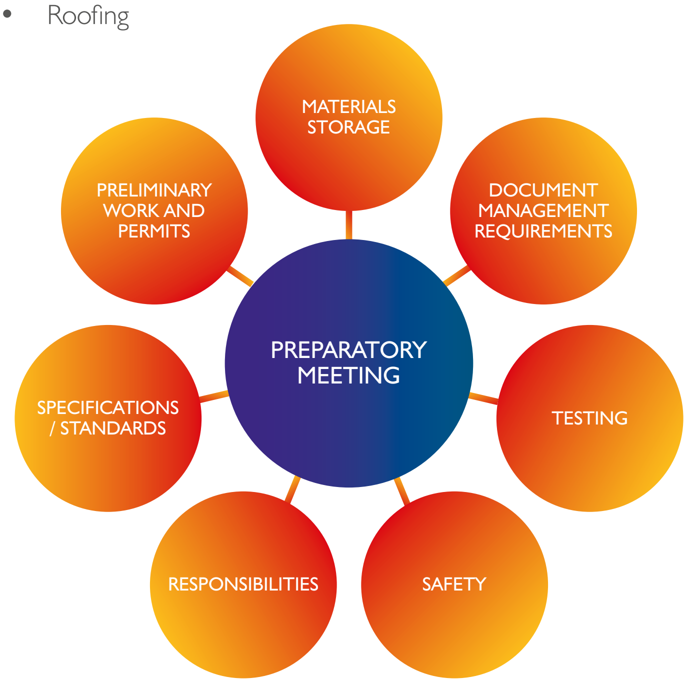


Figure 2-1
Components of preparatory meeting

3. **Follow-up Inspections** should occur frequently to ensure the work meets contractual and compliance requirements. Any non-conformity is recorded and the procedures in the Quality Policy followed. If replacement materials / components, or repairs are required, they must be inspected and re-tested. Documentation should follow the agreed control procedures and communicated to the relevant stakeholders.

Ongoing as-built surveys can help to identify any quality issues; identification at an early stage avoids mistakes being repeated.

One of the following should clear failed tests:

- Retest – Retest if there is any doubt that the first test was not adequate.
- Rework – Re-inspect and re-test.
- Failed Material – Remove, replace, re-inspect and re-test.

Figure 2-2
Initial inspection checklist

2.8.2 Testing, commissioning, and performance testing

When a project is close to handover, there is often pressure to shorten the testing and commissioning tests. Commissioning sets up the plant and equipment, followed by performance testing; when a series of tests, with adjustments and balances to the various building services systems comes into operation. The Quality Plan monitors testing. Under performance, or failure of the engineering services in-use will lead to client dissatisfaction and quality concerns. Static testing happens before the services become live. Live testing is required before handover as part of the commissioning. Services cannot become live until completion of the quality checks, with the relevant certificates.

Testing involves the electrical works, the water, gas, plumbing installation, any lift installation, and the mechanical / air conditioning system balanced, with fire protection and lightning protection. On small projects, the requirements are on a smaller scale, but equally important. Quality is compromised by insufficient time spent on ensuring all the tests are complete.

Testing water tightness of the fabric and roof is an integral and important part of testing in the Quality Plan. Sound tests should be undertaken, with air pressure testing to detect leakage. All works approved under Part L of the Building Regulations are required to be commissioned in accordance with the design intent.

Computer installations have increased the pressure on testing and quality planning. IT systems are now an integral part of any project that must be robust, and reliable.

There is a growing recognition that not all aspects of the commissioning of a building and its engineering services systems can be carried out during the contract period. The concept of seasonal commissioning recognises that some aspects of the systems need to be commissioned when the external temperatures and indoor occupancy patterns are close to peak conditions.

CIBSE[15] Commissioning Codes set out clearly and systematically the steps required to commission buildings and building services in a proper and timely manner. Good commissioning leads to better quality.

A co-ordinated approach to commissioning and testing is necessary to ensure all specialty contractors understand the key dates. Leaving it to the last minute and rushing the handover compromises quality.

2.8.3 Document control strategy

Document management lays a framework for regulatory compliance. Document management is fundamental to business, providing a process for making sure that controlled documents can be accurate, complete and up-to-date. An organisational shift is needed from managing documents as a bureaucratic necessity, to managing documents in order to strengthen the foundation of a project. Making it easier to access documents to make sure that quality documents can be accurate, complete and up-to-date and they can be reviewed, approved and signed off, make compliance during any audit more likely.

Quality-related documentation must be accessible, transparent, and kept up-to-date. Automatic, electronic systems can be used to formalise naming and version procedures, help track, store, and retrieve documents, as well as sharing them across stakeholders.

The Quality Plan should include a strategy for document control, setting out the means of filing / numbering and distribution / routing and archiving of all project documentation. Documents may be controlled by site and administrative staff, but the procedures for document control should be audited by the quality manager on a regular basis.

Documentation, information, and retrieval are a key part of a Quality Plan.

Checking and approval systems need to be part of a document management system (DMS), while the use of templates (if an automatic system is not being used) can help formalise / standardise documentation. Documents created externally that need to be part of the system should be controlled by the DMS. A process map or a flow chart can help by showing the processes, and people involved with the iterations. Stakeholders need to see their role in the process. Keeping track of changes, either to the design or the project, requires a classification system (nomenclature) that is both understood and transparent, and importantly the responsibility for updating being specified.

2.9 Quality certification and standards

2.9.1 ISO 9001:2015

Where ISO 9001:2015 has been adopted or certification is sought, every effort must be made to integrate the ISO requirements into the company's Quality Policy.

ISO 9000 principles involve a process approach, using a systematic definition and management of processes, and their interactions, through a Plan-Do-Check-Act (PDCA) cycle. The cycle enables the:

- Understanding and consistency in meeting requirements
- Consideration of processes in terms of added value
- Achievement of effective process performance
- Improvement of processes based on evaluation of data and information

The standard is designed as an overall preventative approach and provides the foundation for a long-term and sustainable management system. If ISO 9001 is adopted, then a quality plan should be prepared to conform to its requirements for each project. 'ISO 10005:2018 Quality management – guidelines for quality plans' provides guidance that may be used independently of ISO 9001. There is correlation between the two standards - see Section 6, Appendix Two. Neither standard is construction specific.

15 Chartered Institution of Building Services Engineers- CIBSE Commissioning Codes set out clearly and systematically the steps required to commission buildings and building services in a proper and timely manner.

2.9.2 ISO 10005:2018 Quality management - Guidelines for quality plans

This ISO standard adopted by British Standards sets out the processes required in the production of a quality plan. The guidelines are intended for any industry, and applicable to construction. Table 2-1 shows a comparison between the ISO 10005 headings and those found in industry practice.

Where a contractor does not have an established management system, quality plans provide a framework to meet a project's requirements. ISO 10005 can also help a contractor develop their own management system and processes. The standard suggests there are a number of different formats that a quality plan can follow e.g. table, flow chart, or process map.

Figure 2-3 shows the quality plan process with the various steps that need to be undertaken. It is important to remember that developing the quality plan does not happen in isolation. Many other plans, schedules and project members are impacted. It needs to follow the 'rules' i.e. the contract, client and statutory requirements.

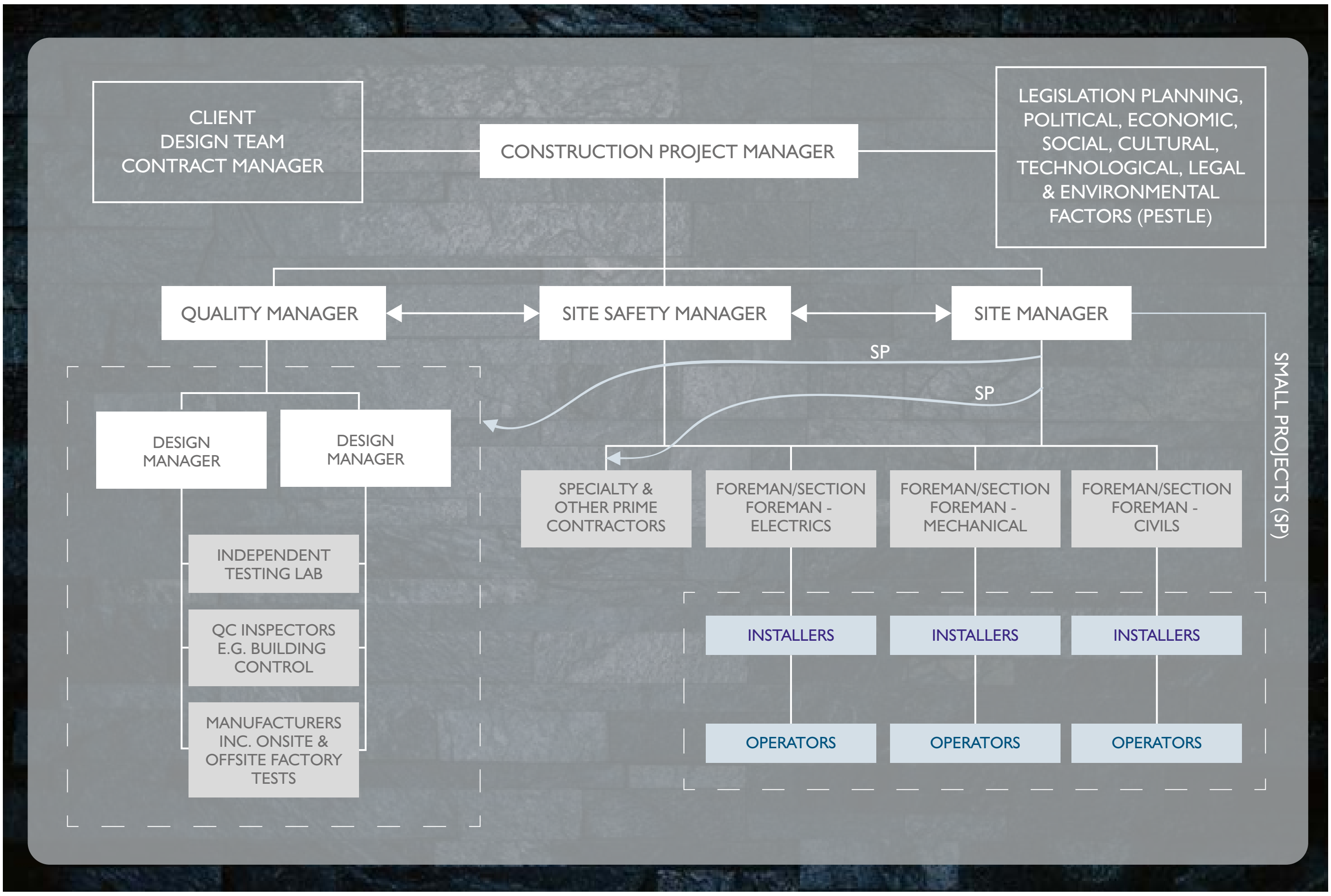
Table 2-1
Comparison between the ISO 10005 headings and those developed from industry practice

ISO 10005: 2018	Industry practice
Scope of the Quality Plan	Project-related information e.g. scope, phases, schedule, risks, company Quality Policy
Quality objectives	
Quality Plan responsibilities	Roles, responsibilities and hierarchy
Documentation	Reporting lines / communication Document strategy – filing, numbering, security
Resources	
Design and development	Codes, standards and specifications and planning consents and conditions Design development and management
Procurement	Supply chain - externally provided processes, products and services
Identification and traceability	Identification and traceability Materials, components, systems – storage, access, delivery and handling
Storage and handling	
Monitoring and measurement	Inspection, testing and verification plan - internal and third party
	Performance monitoring and project reporting
Non-conformance	Control / monitoring of non-conformity plan
Commissioning and testing	Testing and commissioning

The quality plan process in Figure 2-3 follows the headings developed from construction practice and ISO 10005: 2018. For the roles and responsibilities and the reporting lines, an organisation chart is useful (see Figure 2-4). This should be widely available to all the project team, including the supply chain.

Figure 2-3
Quality Plan process

Figure 2-4
A generic organisation chart



Such organisation charts may look daunting for the micro, small and medium sized enterprises, who do not have large staff, with specialist departments. They rely on individuals to take responsibility to deliver quality on site. However, whilst their approach may be different, the principles remain the same.

2.10 Temporary works

Temporary works can constitute a significant part of the project cost. Their design, execution and management are important for quality, engineering, safety, and efficiency.

The Quality Plan should include information about temporary works with the monitoring / inspection processes. The design of temporary works should follow a design brief and involve independent checking of the temporary works design. The erection / installation is inspected regularly to ensure compliance with temporary works legislation, e.g. formwork, falsework, shoring etc. Dealing with the requirements for, and management of, temporary works require consideration early in the project lifecycle.

2.11 Off-site manufacturing

Whether supplied as fully volumetric models, such as structural insulated panels, laminated timber framing systems, or plumbing and electrical systems assembled off-site, the result is that specialist companies will price their part of the work on a supply-only or supply-and-install basis. The important issue is a full understanding of all the interfaces and specialisms to incorporate such systems into the project and the impact on the quality.

The factory-based production of the components can lead to a better quality product as cutting, aligning, screwing etc. involves accurate computer numerical control (CNC) machines connected to the CAD drawings. However, quality cannot be assumed and will depend on the quality assurance / control procedures within the factory.

Whilst off-site manufactured components / modules may go through stringent factory quality controls, once on site they need careful supervision to ensure continuing quality. This type of product is often large scale and requires specialist transport and handling as well as the space and expertise to put them into place. Thus, on projects involving a high degree of pre-assembly, the role of experienced site management staff becomes more important. Site workers become assemblers rather than traditional builders. The system will have been quality assured at the factory; its performance in the proposed structure will only be as good as its assembly / installation on site. The factory may stipulate installation by specialist contractors if any guarantee / warranty is given. The integration of the system into the existing framework on site is crucial to ensure weather tightness, durability and achieving fit-for-purpose.

Off-site systems are standardised, taking full advantage of 'production line' techniques. Thus, integration into complex architectural designs takes time and consideration how quality can be achieved. The integration of the system into the existing framework on site is crucial to ensure weather tightness, durability, and achieving fitness for purpose. It requires skills and relies upon regular inspections to ensure good quality materials and components.

The interface between off-site manufacturing and the site assembly and production process is key to ensure quality control. The quality plan must show the process of checking quality and sign off once the site team takes delivery.

2.12 Governance and compliance

Governance is the set of rules by which a company operates. The rules fall into two categories, firstly, those dictated by legislation, codes and standards; secondly, the corporate 'rules'. The latter cover the infrastructure and processes that the company put in place for the projects function in order to ensure compliance. The need for compliance with regulations, standards and codes that govern construction as well as registration and certification requirements are the 'push' factors in the drive to achieve quality. See Figure 1-3. Compliance is increasingly important; companies face a growing amount of regulation and legislation to document and report activities on site. All the stakeholders have an obligation to ensure that work on the project complies with the legislation. Failure can result in fines, and legal action.

Table 2-2

A selection of certification schemes covering construction materials etc.

CE	From 2014, the CE (Communauté Européenne) marking of structural steelwork and aluminium was mandatory. CE is a 'declaration of performance' not a quality mark. It covers 400 products including: Timber; Wood flooring, wood panelling, cladding; Concrete, wall elements, Beam: precast blocks; Glass blocks and pavers
	The Kitemark, which indicates that a product has been independently tested by BSI (the British Standards Institute) to confirm that it complies with the relevant British Standard, and have licensed the product manufacturer to use the Kitemark.
FSC	FSC stands for 'Forest Stewardship Council' - an international non-profit organisation dedicated to promoting responsible forestry. FSC certifies forests all over the world to ensure they meet the highest environmental and social standards.
BBA	The British Board of Agrément (BBA) is a construction industry approvals body that was set up in 1966 by the UK government offering product and installer approval. Agré-ment certificates cover 200 different product sectors; the largest of these are insulation and roofing. The BBA runs an insulation Approved Installer Scheme, linking installations of injected cavity wall insulation to BBA approval and dealing with both the system upplier and installer. BBA approvals show compliance with Building Regulations and other requirements, including installation quality. The BBA also inspects for the Fenestration Self-Assessment Scheme (FENSA) and the Federation of Master Builders. The BBA runs the Highways Authorities Product Approval Scheme (HAPAS), County Surveyors Society and other UK agencies.
UKAS	The United Kingdom Accreditation Service (UKAS) is the sole national accreditation body for the United Kingdom. UKAS is recognised by government, to assess against internationally agreed standards, organisations that provide certification, testing, inspection and calibration services. UKAS provides accredited testing, calibration, inspection and certification to give consumers, suppliers, purchasers and specifiers the assurance that construction projects run efficiently, construction sites are safe and reliable materials are used. They also provide Government and Regulators with reliable evidence that completed projects meet regulatory compliance.
bre	BRE Global, a UKAS accredited certification body, provides independent, third-party certification of fire, security and environmental products and services.

2.13 Data and information

2.13.1 Project document management

Documentation must be accessible, transparent, and kept up-to-date. Automatic electronic systems formalise naming and version procedures, help track, store, and retrieve documents, as well as sharing them across stakeholders.

ISO 9001-2015 is a document control procedure system for quality management. It classifies project documents in a 3-tier system:

- Level 1: The top level of the quality documentation includes all documents describing the project. These include Quality Policy (short, concise statements of the project's guiding principles), general responsibilities, general administrative rules and references to quality procedures.
- Level 2: Procedures provide organisational know-how that briefly show inputs, outputs, activities, and responsibilities for each business process. Process is a system of activities that uses resources to transform inputs into outputs. Procedures document the specific realisation of a process in a project. They are very useful for analysing the existing project, identifying overlaps and gaps and confused responsibilities.
- Level 3: Instructions, the day-day instructions for a task. The levels 1 and 2 form a network that connects the instructions which contain technical or professional know-how. It is important to find the balance between what is essential to record in order to do the job properly and what can be assumed from the performing operator's knowledge through their training and education. The instruction has to ensure that every appropriate trained operator is able to follow it.

When an organisation's quality management system is ISO 9001 certified it provides a level of confidence in that organisations ability to deliver products or services that meet the needs and expectations of their customers.

A distribution matrix can clarify the distribution of documents. Organising documentation into a process map or a flow chart can help. This shows the processes and the people involved, with the iterations. Connections in these types of graphics are important for stakeholders to see their role in the process. Track any changes that need to be organised in a classification system (nomenclature) that is easy to understood and transparent.

Different types of important information need to be distributed:

- Test certificates
- Commissioning (testing) installations, including safety rules
- As-built drawings and information
- Technical manuals
- Design and performance specifications
- Spare parts list and source information
- Warranties and guarantees
- A record of the equipment and services installed
- Operating and maintenance instructions, including safety rule
- Building log book (Key responsibilities and schedule of contacts; a description of services, building's operational strategies; Health and safety requirements; maintenance requirements, and; building performance in use investigations and targets
- Health and safety file.

2.13.2 Information management

Every industry suffers from information overload. In quality management, there is a plethora of information on codes, standards, legislation and associated contract clauses, but it cannot be ignored. Ignorance costs money.

The cost of non-conformance can be high for any rework of a particular element, and the work involved in reaching/uncovering that element.

Computer-based systems support information management and speed up the processes, but they need management to follow the correct procedures. Such systems may cope with large amounts of data, but the input matters. Collecting the right data and information can be costly, but it will pay benefits in the end. Information storage must be secure and accessible, especially lessons learned about quality failures or non-conformance.

Whilst information and communication technologies (ICT) play an important role in construction quality management, the effectiveness of face-to-face meetings and physical system / component checks is paramount. 'Human' approaches can be supported by auto-ID systems, such as bar codes, radio frequency identification tags (RFID) and so on. As much information as possible is needed about the quality required, how to achieve it, and how to manage it. Innovative approaches to embed information into materials, components and the drawings are available, but the cost of collecting the data to 'service' these systems can be high for small and medium enterprises.

Quality management software enables quality management teams and engineers to increase closeout rates and shorten time to rectification by streamlining forms, records management, and workflows.

2.14 Quality management (QM)

Quality management should be capable of being third party certificated to an international standard. QM includes planning, control, assurance, and improvement of outputs. The challenge in construction is the diversity of organisations in the supply chain and their interdependence to produce a final project. Small, medium, and large projects have the same characteristics with long supply chains and organisations being dependent on each other to meet project requirements. Ultimately, it is about responsibility, and a willingness to deliver the best quality possible.

2.14.1 Certification, verification, and accreditation for quality management

Certification, verification, and accreditation is part of the independent process to ensure independent checks in the system. The Clerk of Works acts as the independent verifier of quality.

Verification, testing and certification by an independent accredited body for quality assurance and control can be part of the contract conditions, with the client wanting independent checks to ensure quality is maintained.

Accreditation is the formal tool to provide assurance that the organisations implementing these processes (activities or tasks) are meeting the required standards. Accreditation delivers confidence in certificates and conformity statements. It underpins the quality of results by ensuring their traceability, comparability, validity and commutability. Outcomes and performance by accredited organisations are important to maintain accreditation. Accredited checkers check quality management systems. Samples, products, services, or management systems are evaluated against specified requirements by laboratories, certification bodies, and inspection bodies. Accreditation is the independent evaluation of these conformity assessment bodies against recognised standards to carry out activities to ensure their integrity, impartiality, and competence. Accreditation provides the assurance for the client to rely on commercial providers of evaluation and inspection services

The United Kingdom Accreditation Service (UKAS) is the sole national accreditation body for the United Kingdom. Government recognises UKAS to assess against internationally agreed standards, organisations that provide certification, testing, inspection and calibration services. Accreditation by UKAS demonstrates the competence, impartiality and performance capability of these evaluators. In short, UKAS checks the checkers.

Surveillance visits from the certification body aim to find out whether a QMS really works in everyday operations, or not. It focuses on whether all corrective and preventive actions are recorded and implemented, and whether the top management really supports the QMS.

2.15 Difference between quality assurance and quality control

Quality assurance and quality control are integral parts of quality management.

Quality management is a whole-business approach; quality control is about workmanship inspection.

Quality assurance is the process of managing for quality.

Quality control verifies the quality of output. It provides the tools and processes for quality management.

Whilst quality assurance is the responsibility of everyone involved in a project, quality control is usually the responsibility of a specific team / person. The aim of quality assurance is to improve processes and development to prevent defects; quality control's goal is to identify and correct defects as soon as possible.

Quality assurance is a management tool that is process-oriented

Quality control is a corrective tool that is product oriented.

2.16 Quality control

2.16.1 Quality testing

Apart from regular testing and inspections, the on-site inspections that require the presence of a specialty contractor (or designated third party) are electromechanical systems, conveying systems, and electrically operated equipment, including:

- HVAC system
- Firefighting system
- Fire alarm system and telephone system
- Communication system
- Electrical lighting and power system
- Electrically operated equipment
- Emergency power supply system
- Electronic security and access control system
- Public address system
- Integrated automation system (building automation system)
- Water supply, plumbing, and public health system
- Grounding (earthing) and lightning protection system

2.16.2 Quality inspection

The aim of an inspection is to ensure that the material, component or system conforms to the relevant standards and the required performance. Inspections during the production stage may be non-destructive, such as visual, ultrasound, eddy current or thermography. An inspection undertaken at a later stage than planned, may involve dismantling of the construction. Accuracy in inspection is important and depends upon the people involved (level of human error), instrument accuracy and the efficiency / thoroughness of the inspection routine planning and operation.

Most construction projects specify that the contracted works are subject to inspection by the owner / consultant or their / owner's representative. Specialised testing and inspection may be a requirement of the manufacturer's specifications and / or the specialty contractor. For example, the need to detect cracks, heat build-up and so on.

Manufactured goods come under the manufacturer's quality control procedures, but these should still be checked for conformance before use. Being aware of the level of stringency used by the manufacturer / supplier can give the contractor confidence in the material or component.

The person responsible for the execution of the quality plan should ensure that inspection and testing routines are in place and at the set frequency. The test status is identified by labels, tags, stamps etc. Reports should be monitored for any flagged up items / issues. Final inspections will be part of the handover process, with the relevant documentation, test certificates etc. handed over to the client (see 2.9.1).

2.16.3 Commissioning

Commissioning is a series of tests, adjustments and balances that are undertaken when building services systems are brought into operation. It may be carried out by the main contractor if the system is a simple one, but more complex systems are undertaken by the relevant specialty contractor. The processes and results need to be monitored under the quality plan.

2.17 Quality management tools and techniques

Tools and techniques are the means to implement quality management systems. Tools can solve problems; for example, brainstorming can highlight the relevant issues pulling together ideas and information from a group of team members. Techniques use statistical methods to interrogate and make sense of data collected on quality issues. The techniques may contain tools.

2.17.1 The tools

1. **Check sheets** are a valuable way of collecting data, which then transforms into information to inform the quality process. Data in collected in real-time and at the location where the data is generated.

2. **Histograms** chart how often something happens and therefore highlights its likelihood. Histograms are used to show distributions of variables, while bar charts are used to compare variables.

3. **Scatter diagrams** can be used to verify a cause and effect relationship and find the correlation between two variables – dependent and independent.

4. **Pareto analysis** helps to evaluate the importance of items where resources may be best focused. Pareto observed that 80% of the country's wealth was owned by just 20% of the population. Better known as the 80/20 rule, it stipulates that 80% of the outputs result from 20% of the inputs. Frequency data are input along the x and y axes - see Figure 2-5

5. **Cause and effect analysis (fishbone diagrams)**. The benefit of the diagram is its level of detail, which is linked to a larger network, linked to another wider network and so on – see Figure 2-6. The causes and effects may be identified by various project teams brainstorming. It can bring together issues whose relationship they may not have been seen previously as being connected and to identify root causes.

6. **Control charts**. A method of measuring and controlling quality by monitoring the production process. Quality data is collected in the form of product or process measurements or readings from various machines or instrumentation. The data is collected and used to evaluate, monitor and control a process.

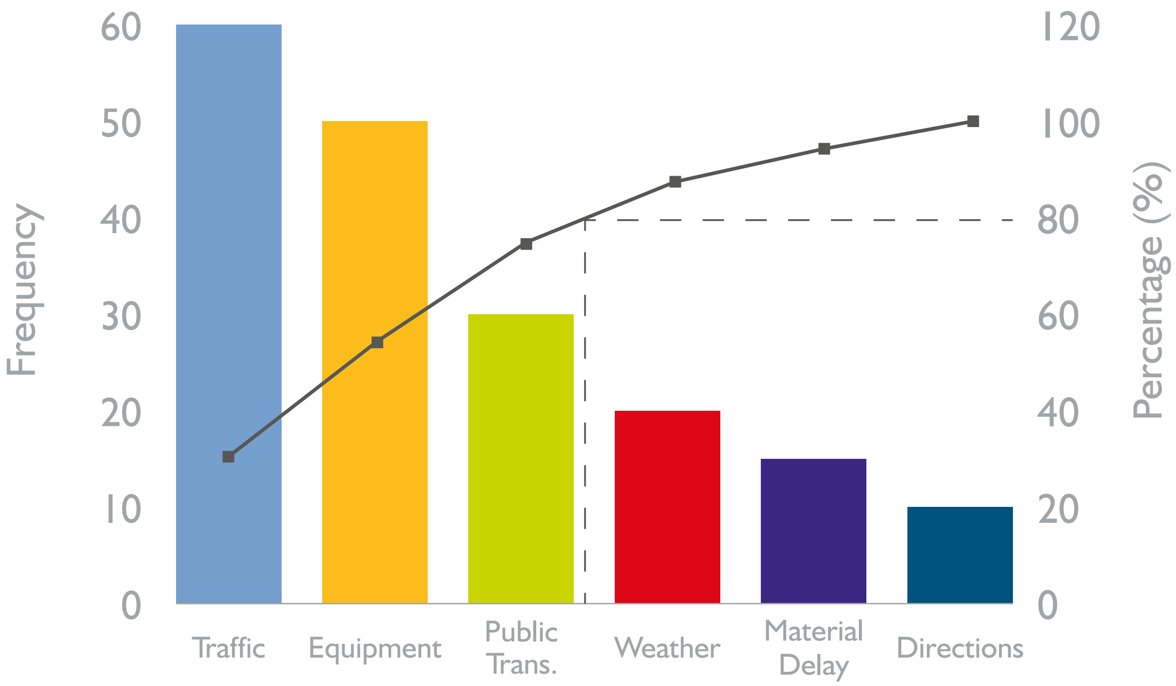
7. **Affinity diagrams**. These encourage creative thinking about a complex issue, where the known facts follow no particular pattern / organisation. Unlike brainstorming, the issues / causes are identified by individuals (without discussion) and then pulled together and sorted into homogenous groups under affinity headings. The headings need to be in production / process order.

8. **Interrelationship digraphs**. Interrelationship digraphs show cause-and-effect relationships, and help analyse the natural links between different aspects of a complex situation – see Figure 2-7. The relationship arrows created are crucial to the end result. A digraph can be used after an affinity / fishbone diagram has been developed to further investigate cause and effect, even when there is no data to support them. It should transcend any disagreements among team members.

9. **Tree diagrams**. Also called a systematic diagram, tree analysis, analytical tree, or hierarchy diagram, shows all the possible outcomes of an event. It can be used to calculate the probability of possible outcomes. It begins with an item which branches into two or more; each of those branches have multiple branches and so on. The tree enables systematic thinking about a process and can help to identify a solution or the steps in a plan. The tree can be used to explain the problem/process and can be used after an affinity diagram has uncovered key issues.

10. **Matrix diagrams** identify and graphically display connections among responsibilities, tasks, functions etc. Data analysis can be performed within an organisational structure to show the strength of relationships between the rows and columns of the matrix.

Figure 2-5
Example of a Pareto chart showing the frequency of late arrival at the site



The figure shows the number of times a particular reason was given by employees who were turning up late at the site. The line shows the cumulative percentage of the responses i.e. traffic accounts for approximately 20% of the reasons, add this to the frequency percentage of equipment and so on until 100% is reached. The line plots the cumulative percentages. The dotted line drawn horizontally from 80% on the second axis to the curve, and the vertical dotted line from that intersection shows the 3 reasons that represent 80% of the total. It is these that should be addressed first as they have the most impact.

Figure 2-6
Simplified fishbone diagram of the causes and effects of poor quality construction

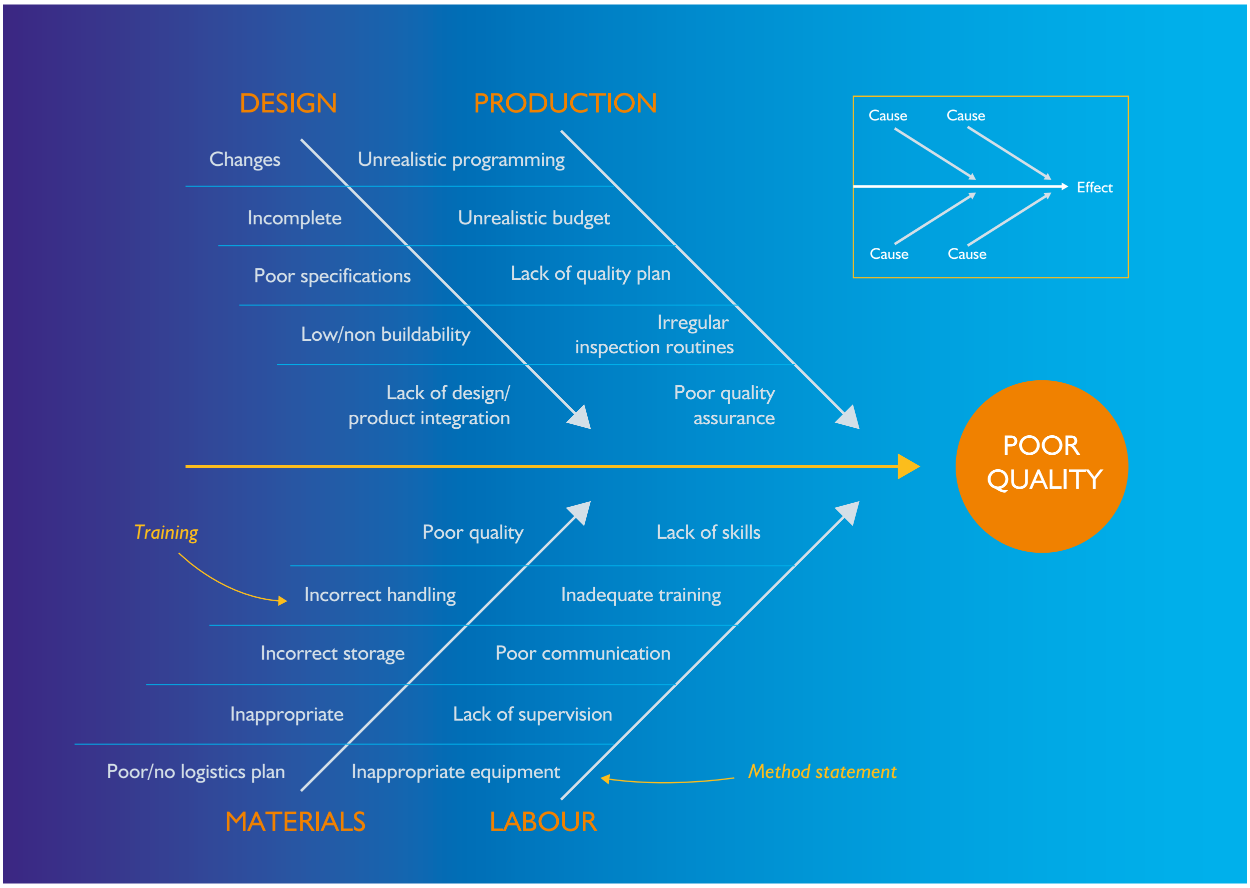
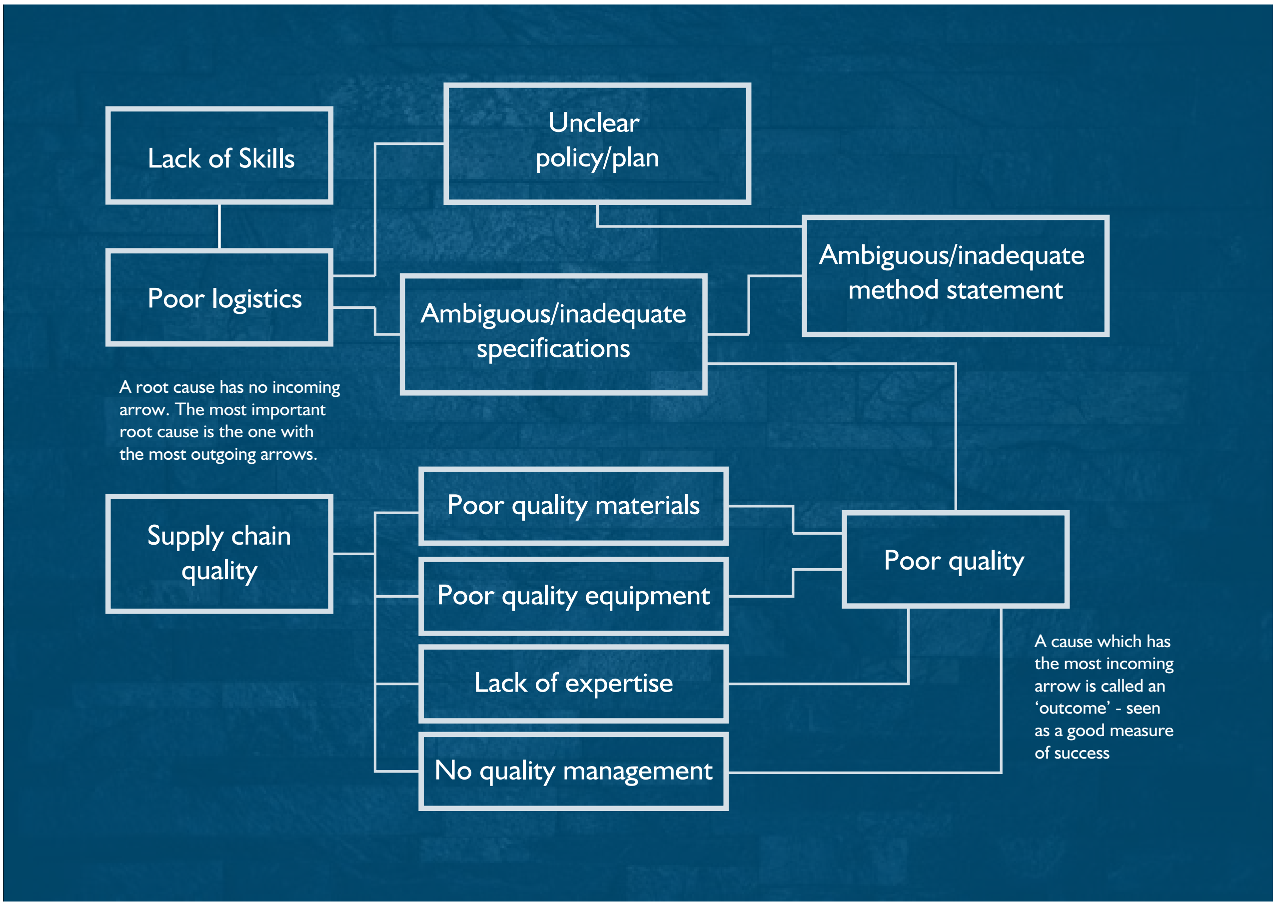


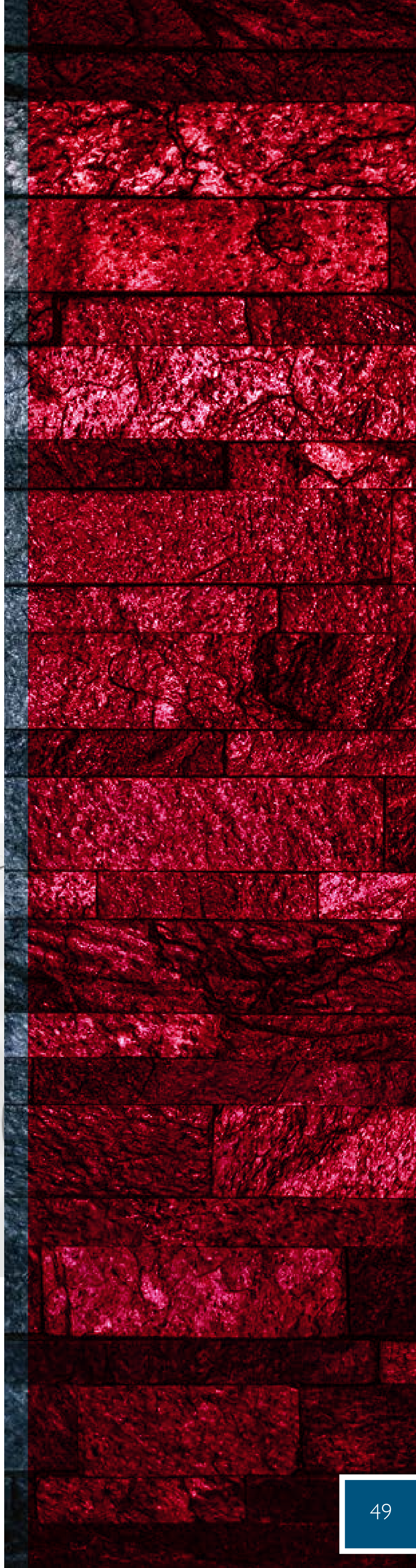
Figure 2-7
Example of an interrelationship digraph related to poor quality



2.17.2 Scenario planning

Scenario planning identifies a set of uncertainties, different 'realities' of what can happen in the future. It is not about predicting events or determining the most likely scenario, but developing plausible stories that describe how the environment in which an entity (e.g. an individual or organisation) lives or operates. How it may develop, given certain future events, trends, and developments, to explore possible 'discontinuities' and 'surprises'.

A scenario is a storyline with a range of interconnected and uncertain future events and their possible consequences. Scenarios are often employed for decision-making activities in which some parameters are uncertain or poorly defined.



Section Three
The Quality Plan

The Quality Plan

3.1 Introduction

A Quality Plan is a document, or several documents, that together specify quality standards, practices, resources, specifications, and the sequence of activities relevant to the delivery of a construction project. It should include the service level expectations, and the organisation for the delivery of quality. The Quality Plan should reflect the aims in the corporate Quality Policy.

Quality Plans should define:

- An overview or introduction of the project, detailing the background, scope, activities, and important dates or deadlines
- Objectives to be attained (characteristics or specifications, uniformity, effectiveness, aesthetics, delivery times with any milestones, constraints in the construction contract appropriate to quality)
- Client and design team requirements and expectations
- Performance standards and how performance will be documented
- Steps in the processes that constitute the operating practice or procedures of the organisation, such as independent or in-house testing requirements
- Allocation of responsibilities, authority, and resources during the different phases of the project
- Work verification (who is responsible for carrying out a task, as well as who is responsible for checking the work)
- Specific documented standards, practices, procedures, and instructions to be applied
- Suitable testing, inspection, examination, and audit programs at appropriate stages, including the commissioning and hand over stage
- Acceptance criteria at the handover stage
- A documented procedure for changes and modifications to a quality plan as a process is improved
- Corrective actions and preventive actions to meet a defect free project
- Required notifications
- A method for measuring the achievement of the quality objectives
- Monitoring and measuring equipment calibration records
- Actions necessary to meet the objectives

Project quality must be clearly defined at the outset – the standards and expectations of the client and to identify critical success factors, and metrics for which to measure success. Each plan is unique based upon the project requirements.

The Quality Plan has many uses[16], for instance:

- Ensuring conformance to customer requirements
- Ensuring conformance to external and internal standards and procedures
- Facilitating traceability
- Providing objective evidence in the event of a dispute
- A basis for training

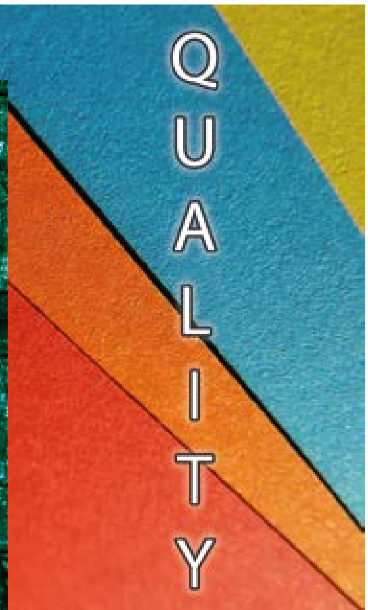
16 Adapted from The Certified Manager of Quality/Organizational Excellence Handbook, ASQ Quality Press, 2014

Quality planning at the bid stage should be undertaken; it is the starting point for the contractor's quality planning for a project. Meeting the quality requirements can be a pre-requisite for the selection criteria at the tender stage. Evidence is required that the contractor has a quality management system in place that will also be applicable to the supply chain.

The contractor needs to be confident in the ability of a supplier / specialty contractor to deliver the required quality standards. The evaluation of each supplier / specialty contractor is based on set criteria for comparisons can be made. Failure to make these checks could result in late delivery, poor standards of work, which may have cost and reputational implications. The methods to monitor and control suppliers / specialty contractors during production should be agreed between both parties.

3.2 Defining project quality

Defining project quality is more than defining compliance with certain standards. If there are parts of the project where special attention is necessary, these must be communicated to the construction team. Hiding behind a Code or Standard, without clear definition of what is required on the project will not satisfy anyone.



The simple breakdown should be:

This is what we want for the quality requirements on the project, defined in sufficient detail and with as much clarity as possible.

This is how we will plan and deliver the quality required, with the acceptance criteria.

These are the checks and balances we will perform to ensure the quality is maintained to the required standard in a consistent way, with the audit and recording process.

These are the tests and validation processes we will undertake validated by an accredited body.

This is how we will hand over the project following inspection and any snagging.

3.3 The Quality Plan

A Quality Plan is a specification of the actions, responsibilities and associated resources for a specific project / object.

ISO9001:2015 defines the requirements for a Quality Plan. The Plan will be influenced by a company-wide Quality Policy and the contract requirements. It provides a framework for inspection, monitoring, and testing processes. The Quality Plan helps in the management of resources (people, materials, plant and equipment) to accomplish quality targets, including setting out the risks that affect quality.

The Quality Plan needs to be dynamic, responding to changes during production. Changes to the plan need to be agreed by the stakeholders and communicated to the project team. To be effective it should show the integration between project personnel, inspections / tests and audits, records and reports – see Figure 3-1 Effective quality planning.

Figure 3-1
Effective quality planning

The key person to help develop, monitor and update the contractor's quality plan is the Quality Manager, they need to:

- Prepare, approve and implement the Quality Plan
- Verify the materials as per project plans and specifications
- Develop the means and methods to store and protect materials
- Maintain documentation of inspection / testing status of materials
- Maintain documentation for material and administrative approvals
- Ensure that all materials and construction are in accordance with the requirements for the completeness, accuracy and constructability in accordance with applicable building codes
- Carry out and participate in weekly progress and quality control meetings
- Maintain documentation of inspection of work executed by specialty contractors
- Ensure the latest version of the plan and the agreed curation and dissemination is being used
- Ensure the interfaces between stakeholders are identified and monitored to avoid any communication breakdown
- Maintain material / component traceability
- Be aware of a zero-defect policy the client may have or that has been included in the contract

The Quality Plan is created as early as possible during the planning phase of the project. The stakeholders are the project manager, site manager, project team, design team, client, and any people whose support is needed to carry out the plan.

At a project level, the Quality Plan should:

- Describe how quality requirements will cascade down and through the supply chain and how quality assurance and quality control will be maintained on the project
- Define the individuals responsible for implementing the plan with their contact details
- Describe the key activities necessary to deliver the project quality and the order in which they will be carried out
- Describe the resources that must be provided, including the requirement for pictures, diagrams and text to be provided
- Describe procedures for dealing with and remedying defects if they occur
- Describe change control procedures when changes are made to the design / specification to ensure everyone in the site team is fully aware of the requirements
- Set out any special training requirements to ensure quality is maintained
- Schedule tools that will be used for quality control.
- List relevant reference material
- Describe any special characteristics relating to quality in the contract terms and conditions for the project

The company's Quality Policy should be part of the plan; in many cases, this is a requirement of the client. The Policy should demonstrate the company's commitment to quality at all levels.

3.3.1 Specialty contractors

Specialty contractor should submit a site-specific quality control plan for approval to the quality control manager / supervisor before work commences. The plan should describe measurements, inspections and testing regimes. Inspection checklists should be provided and accompanied by photographs where applicable. The specialty contractor should identify a responsible person for quality control and assurance.

The Quality Plan should cover:

- Documentation control
- Submittals and material verification
- Responsibilities for storage and handling of materials / equipment
- Pre-installation meetings and first work-in -place inspections
- Quality control checklists and special documentation
- Testing and inspections
- Procedures to be followed for any non-conformances
- Progress photo frequency
- As-built drawing requirements
- Any requirements for commissioning

3.3.2 Digital photography

Photographs should be an integral part of each project-specific quality management plan. Digital equipment needs to be readily available to ensure a photographic record of construction progress and quality-related issues are accomplished. As-built conditions should be photographed during the course of construction. The photos should be taken on a regular basis and labelled and stored accurately as they can provide evidence of work conforming to contract (and other) conditions. The digital library should be on a platform that allows sharing across the production and client team. Pre-cover-up photographs are particularly important.

3.3.3 Key tasks and the importance of quality

There are a number of key tasks in the production process where quality control is particularly important. Table 3-1 shows these tasks and their appropriate test requirements.

Table 3-1
Key tasks and their appropriate test requirements

Task	Test requirements
Cut and fill	Plate load test
Concrete foundations	Concrete cubes
Drainage & Manholes	Water test level and air test
Ground floor slabs	Level survey to RL and formation concrete cubes
Masonry	Panel to be built for inspection and kept
Masonry	Setting out and openings
Masonry	DPC and wall ties, lintels
Steelwork	Plumb line and level checks
Task	Test requirements
Roofing	Visual inspection to confirm specifications and drawings, leak record
Electrical installation	Dead and live load
Mechanical pipework	Air pressure test
Gas pipework	Air pressure test
Chlorination of water	Sample taken of water in installed system
Fire alarms	Sound check
Fire strategy	Drawings to be issued to Building Control
Windows and doors	Hose pipe test
Building air test	Air leakage less than 10 $l s/m^2$
Finishes	Room to be set up as sample of acceptable finish
Fixing pull-out tests	Ensure fixings are secure

Table 3-2 shows a template for a Quality Plan, based on work packages – in these examples, curtain walling and pile cap and ground beam construction are used.

3.4 Quality standards

Although both ISO 9001 and ISO 10005 can be / are used in construction, a construction-specific Quality Plan may be more useful as each project is different. Whilst the overall company Quality Policy may remain the same, the complexities of individual contracts, the supply chain, and codes / standards / legislation need taking into account.

ISO standards are process-driven. The process approach is characterised as a systematic identification and management of processes in the organization and their interactions. Table 3-3 and Table 3-4 show a process / system-based approach to a Quality Plan, describing the inputs, activities and outputs.

Both ISO 9001 and ISO 10005 refer to risk-based thinking. However, there is no requirement to put in place "formal methods for risk management or a documented risk management process". Risk management is key and should be integrated into the quality management process.

3.5 Quality risks

The development of a Quality Plan takes into account any risks that could affect project quality. The contractor's risk management plan identifies the risks, analyses them, and identifies ways of mitigating or removing them. This plan needs to be integrated with the Quality Plan and a link established.

Risk ownership is an important consideration in quality-related activities as failure and non-conformance risks are often related to poor quality management.

Areas susceptible to risk should be addressed at an early stage to avoid any impact on quality or safety:

- Setting out – regular checks need to be undertaken
- Drainage – a testing regime of the system should be put in place; CCTV may be used. Figure 3-2 shows an example of the items that need checking in the drainage installation.
- Movement of bulk excavated material – an on-site vehicle management system to avoid impacting critical parts of the site
- Pre-cast elements – a strict quality assurance regime needs to be in place to ensure quality in strength, durability and aesthetics
- Ineffective waterproofing system – this can have a knock-on effect and once covered up, difficult to locate
- Concrete pour – pre-pour inspections are important as well as checking the formwork and positioning. Post-pour inspections help identify concrete quality issues
- Concrete test results – sampling and testing is crucial to ensure the concrete meets the quality standards required

Figure 3-2

Actions to be taken / checked in drainage installation

3.6 The quality manager and quality control

- Coordinate the Quality Control efforts of the company, the specialty contractors and third party inspectors in complying with project-specific Quality Plan
- Provide direct feedback and advice to the project manager and site manager on the effectiveness of Quality Control activities
- The authority to stop work if workmanship or materials do not conform to project requirements
- Review work-in-place for conformance with submittals, manufacturer's installation instructions and project specifications
- Confirm all inspections and tests are performed in conformance with project requirements
- Inspect the work, issue non-conformance reports, monitor correction and completion of non-conforming work items on a non-conformance report register
- Where specialty construction teams are working together and their work is interdependent, ensure conflicts are not arising
- If there is disruption to the construction programme caused by failure of one of the parties, or by unforeseen events, ensure that the quality of the workmanship will not be compromised by delays
- Ensure the work is properly protected during work in progress, with temporary protection following completion, to ensure no damage ensues by other work packages
- Ensure the site is tidy and any rubbish is removed, with responsibility for removal being clearly defined amongst the parties

The site should be walked every day to check for compliance, and to ensure quality and safety requirements are met.

3.6.1 The three stages of quality control

The three stages are:

1. Preparatory (pre-commencement on site)
2. Initial (first work-in-place)
3. Follow-up (daily inspections)

The stages allow the contractor to plan, schedule and install work in an orderly, consistent way that minimizes rework. Construction quality depends on effective planning, coordination, communication, supervision and testing.

Preparatory – the project manager, involving the contractor, specialty contractors, client and design team (and other interested parties), conducts a pre-installation meeting. The aim should be to prevent deficiencies rather than detect them.

The following documents should be available at the meeting:

- Approved submittals, materials safety data sheets, and shop drawings
- Manufacturer's installation instructions
- Applicable building regulations and codes
- Contract drawings
- Contract specifications
- Construction programme and schedules for the specialty contractors
- Safety hazard analysis
- Inspection checklists and inspection report forms

First work-in-place meeting and inspection should be undertaken prior to commencement of the relevant activity. For significant construction activity, the meeting / inspection should involve the client (or their representative), a member of the design team, relevant consultants, the site manager / trades supervisor and a manufacturer's representative.

Follow-up - follow-up phase inspections should be conducted on a regular basis, preferably daily using an inspection checklist if one is available. The follow-up ensures conformance, quality workmanship, testing, and safety considerations. Also, that the required certifications, calibrations and measurements are accurate.

Additional pre-installation and first work-in-place inspections will be carried out if there are any significant changes to personnel, supervision on site, periods of inactivity, or the quality of on-going work is unacceptable.

3.7 Quality Plan post-construction

The importance of the Quality Plan continues into the post-construction period. Throughout its life in the production stage, a plethora of quality-related information will have been collected, documented and stored.

3.7.1 Documentation

Records of quality-related actions such as inspections, testing, compliance etc. should be carefully archived, easily retrievable, and part of the project's permanent records. The storage should be protected from loss, fire, and flood. The records include:

- Daily reports
- Inspection reports
- Test reports and logs
- Inspecting technician's certification
- As-built drawings contain important information, it is crucial that every construction site has at least one set of completed as-built drawings available at all times.
- Approved submittals
- Quality audit reports
- Certifications of materials
- Non-conformance reports and records of related remedial work and acceptance

- Photo and video documentation
- Required records of personnel qualifications, as applicable
- Results of miscellaneous tests, inspections and examinations performed by any responsible party
- Special process procedures, as applicable
- Final inspections
- Final system testing
- Commissioning reports
- Operation and Maintenance (O&M) Manuals
- Warranties
- Copies of local authority inspection reports
- Copies of Certificates of Occupancy from building officials

3.7.2 Warranties

Failures in design / specification, or those due to poor materials, or bad workmanship can lead to a project not meeting the client's expectations.

Defects can be either patent or latent.

- Patent defects can be discovered by 'reasonable' inspection.
- Latent defects may not immediately be apparent and will not be found with 'reasonable' inspection.

For example, problems with the foundations may not arise until several years after completion. Once the latent defect becomes apparent it is referred to as a patent defect.

Defects must be rectified in a reasonable time before a certificate of practical completion can be issued. If the certificate is issued with defects outstanding, the organisation issuing the certificate may be liable from any problem caused by this action.

The contractor will have warranties in place and will endeavour to satisfy their conditions and any post-construction issues during the warranty period.

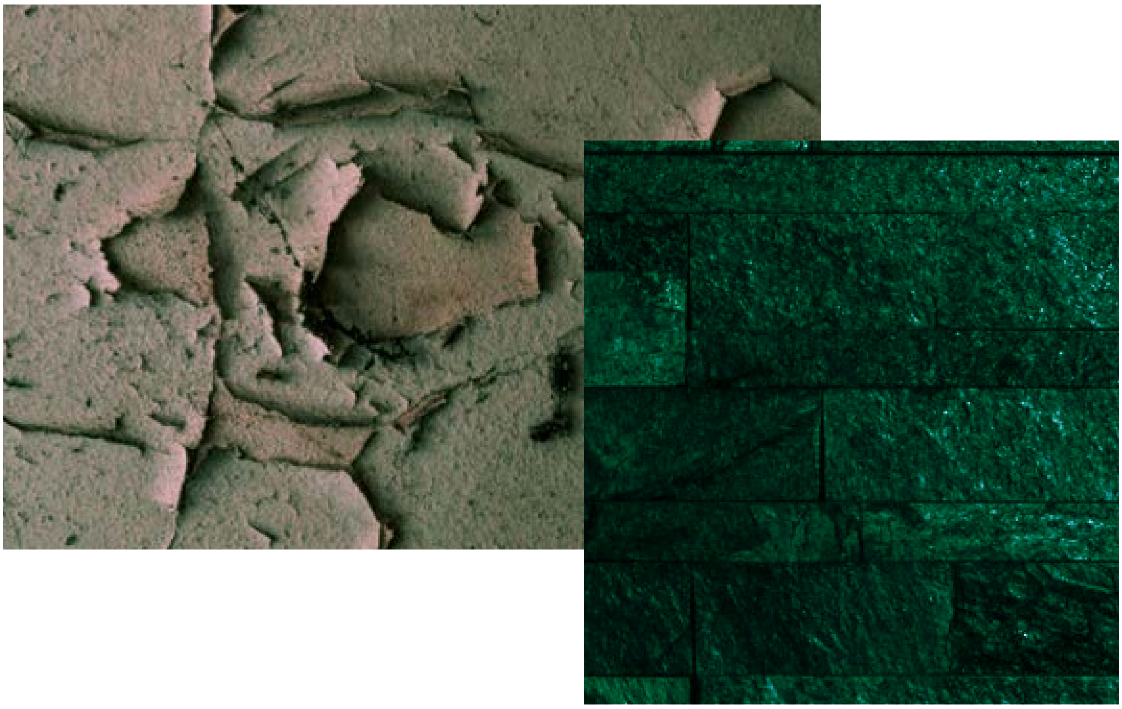


Table 3-2: *Quality plan in a table format, based on work packages*

Work package	Tasks	Responsibility	Input documents / photos / specifications	Document management	Linked to other plans, e.g. risk, H&S, materials
Curtain walling Location: Drawings: Lead person:	Check latest drawings / specifications being used				
	On site survey and measurements to be taken by supplier				
	Specialist suppliers' drawings to be approved and issued				
	Install support / restraint brackets to line & level				
	Install isolation membranes				
	Install and plumb structural framing correctly				
	Install EPDMs				
	Install glazing panels				
	Install gaskets and sealants				
	Install internal insulation				
	Cavity fire barriers location & fixings correct, no gaps		e.g. BS 476: Part 20:1987		
	Check line, level & plumb of walling system				
	Agree testing - extent & location				
	Carry out testing and, if passed, issue certificate				

Work package	Tasks	Responsibility	Input documents / photos / specifications	Document management	Linked to other plans, e.g. risk, H&S, materials
Pile cap and ground beam construction Location: Drawings: Lead person:	Integrity testing for piles				
	Waterproofing as per specifications				
	Gas membrane installed as per specification (if applicable)				
	Reinforcements fixed as per current drawings / scheme				
	Starter bars for columns / wall as per drawing				
	Install cover to reinforcement as per spec & drawings. (Bottom, top & sides)				
	Install lightning conductor as per detail (if applicable)				
	Cast in fixings. (Channels, plates, holding down bolts. etc.) if any				
	Check compliance of line, level and appearance of formwork				
	Install drainage pop ups in correct locations (if applicable)				

INPUT	ACTIVITY	OUTPUT
A. Project description including stages / phases & schedule B. Contract - quality requirements C. Company quality policy D. Project risks	**1** **Project-related details**	i. Scope of QP ii. Project-specific quality management plan iii. Essential and desirable quality objectives (based on client / contract) iv. Information for risk management, safety and cost plans
A. Roles / job titles B. Lines of responsibility C. Competence, awareness, training	**2** **Roles and responsibilites**	i. Organisation chart ii. Pan-project links iii. Project team hierarchy (related to quality)
A. Personnel responsible for filing / archiving documentation B. Format, frequency and language of documentation / communication C. Documented information control requirements	**3** **Reporting lines / communication** **Document strategy - filing, numbering, security**	i. Documentation management system ii. Interoperability / transferability iii. Linkages between quality and other aspects of the project
A. Relevant codes and standards B. Specifications C. Planning consents and conditions	**4** **Codes, standards, specifications and planning consents and conditions**	i. Guidance on conformance ii. Register of planning approvals and conditions iii. Links to health and safety standards
A. Team members involved in change orders / management B. Links between project and design teams	**5** **Design, development and management**	i. Guidance on conformance ii. Register of planning approvals and conditions iii. Links to health and safety standards

Table 3-3: *A Quality Plan using a process-oriented approach*

Table 3-4: *A quality Plan using a process-oriented approach*

INPUT	ACTIVITY	OUTPUT
A. Procurement guidelines B. Requests for quality - related information C. Design specifications requiring external specialists D. List of work packages requiring external input	**6** **Supply chain - externally-provided processes, products and services**	i. Confirmation of specialty contractor's quality plans or adoption of contractor's QP ii. Details of specialty contractor's competence in relation to delivering quality services
A. Available resources as per method statement (to meet quality aims) B. Identify required certificates C. Establish material traceability	**7** **Materials & components -** identifications and traceability, storage, access, delivery & handling	i. Integration of materials logistics plan or similar ii. Procedure for checking appropriate materials handling, storage etc.
A. Manufacturers' specification for testing B. Identification of project team members qualified to undertake inspection / testing C. Information on the relevant 3rd party inspection / testing organisations	**8** **Inspection, testing & verification plan - internal & 3rd party**	i. Inspection and testing plan ii. Line of authority for verification processes iii. Schedule of testing procedures aligned to work packages
A. Performance requirements (as per contract / contractor's guidelines) B. Required monitoring / reporting frequency (as per contract / contractor's guidelines)	**9** **Performance monitoring and project reporting**	i. Schedule and detail of audits required ii. Link to other plans e.g. materials, method statement
A. Non-conformance process (as per contract / contractor's guidelines) B. Control / monitoring requirements	**10** **Control / monitoring of non-conformity plan**	i. Non-conformity records / register ii. Established audit process iii. Statement of impact of non-conformity on the schedule and cost plans
A. Manufacturers' and suppliers' testing requirements B. Relevant contract clauses	**11** **Testing and commissioning**	i. Testing and commissioning report at handover

Section Four
Background Info & Research

Background Info & Research

4.1 Learning from other industries about quality management

The construction industry must learn from other industries. It must discard the idea that it is different to other industries; every industry sector has unique challenges. Yes, construction is a bespoke industry, it cannot stock its products in a warehouse, nor have stocks of unsold goods. It does not hold an annual sale with price reductions. It cannot rapidly generate work by having a special offer sale. It has contractual liabilities with contracts that clearly allocate responsibility and liability. It works on long time-frames from concept through design and approvals, to site ready, which can take years. It separates the design of its products, from the production process. The payment system is slow and laborious. Quality control procedures are not central to everything it does. Quality is seen as a matter of compliance, meeting standards and fitness for purpose, not about exceeding customer expectations.

It all sounds familiar, but unlike an aero engine manufacturer, it is not reliant upon winning work by exploiting advanced technology and then selling to the customers. It does not have long gestation periods for research and development of new projects. It does not have to prove to the legislators and approval agencies that its products are reliable and robust in every eventuality. Quality control, quality assurance, and quality management is central to everything the aero manufacturer does, it is at the core alongside safety, innovation, and exploiting technology. Quality is about exceeding customer requirements by ensuring customers are happy.

Rolls Royce in the aero engine sector has eight Quality Management principles:

1. Customer focus
2. Leadership
3. Involvement of people
4. Process approach
5. Systems approach to management
6. Continual improvement
7. Factual approach to decision making
8. Mutually beneficial supplier relationships

This list would be different for construction companies with seven Quality Management principles:

1. Leadership and engendering a culture of Quality Management
2. Process approach to managing quality
3. Ensuring the supply chain is fully aware of the quality standards expected and delivered
4. Mutually beneficial supplier relationships
5. Systems approach to management
6. Collaborative approach to decision making
7. Customer focus

It is unlikely that continuous improvement would be present in construction, with the argument that the industry builds one-off unique projects, built by temporary project teams assembled to deliver a project. Mutually beneficial supplier relationships exist with framework agreements, but trust and loyalty are lacking, mainly because of the focus on lowest cost, rather than value for money. Project design is rarely complete at the start of a project, so projects start with gaps in the information.

A leap into the future is required by the construction industry to satisfy its clients and itself that quality is a top priority.

4.2 Learning from overseas

The Construction Quality Assessment System (CONQUAS), was introduced in Singapore in 1989, it serves as a standard assessment system on the quality of building projects. A de facto national yardstick for the industry, CONQUAS has been periodically fine-tuned to keep pace with changes in technology and quality demands of a more sophisticated population. In 1998, BCA introduced a number of new features to CONQUAS resulting in the launch of CONQUAS 21. The latest CONQUAS 9th edition was launched in 2016 to promote the adoption of DfMA which supports both high quality and productivity, and to ensure the score commensurate with end users' expectation on workmanship quality.

Construction is assessed primarily on workmanship standards through site inspection. Each component is divided into different items for assessment. The sum of the 3 components gives the CONQUAS score for the project. By using CONQUAS as a standardized method of quality assessment, developers are able to use the CONQUAS score to set targets for contractors to achieve and also assess the quality of the finished building.

If a similar scheme was introduced into the UK construction industry, it could provide a good standardisation tool and a level of benchmarking / competition.

4.3 Practitioners' views

The Call for Evidence issued by the CIOB, prompted important and valuable insights into the management and state of quality in the construction sector. Members were asked a series of questions; the feedback can be divided into the 5 main actors / areas in construction that impact quality:

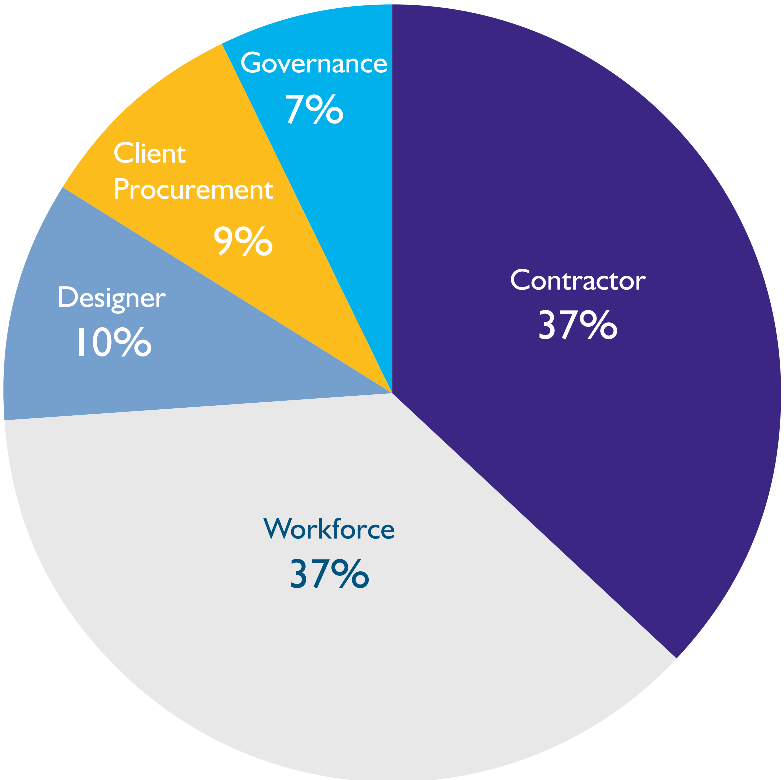
- Clients
- Designers
- Company
- Workforce
- Governance

Based on the number of times an actor was mentioned, the company and the workforce came out on top. Clients and designers were referred to in equal measure and governance mentioned the least – see Figure 4-1. The words 'experience' and 'training' were widely used as being an issue in the delivery of quality. On-the-job training was considered essential by many respondents, who emphasised the need for the training to be consistent and relevant.

The inclusion of quality in a curriculum, either at a university / college, or on site, is seen as important. Views on the responsibility for training were mixed.

"NVQs are no substitute for experience, skill and knowledge."

Figure 4-1
Frequency of the players mentioned in the replies



Some saw the government as responsible, others saw either the companies or construction organisations, such as the CITB, needing to take greater accountability. There was a perceived lack of professional / specialist skills. Management and leadership skills were highlighted as being essential, but often seen as lacking.

Questions were asked whether the current management of quality is adequate in three areas - supervision, sign-off, workmanship.

It is hard to find anyone who is against quality.

4.3.1 Supervision

Site supervision is seen as the key factor in Quality Management. Lack of quality checks is seen as both a contractor and client responsibility. Respondents remarked on the inadequate supervision at the construction stage provided by design team architects and engineers. This criticism may be unfair, it fails to recognise the contractual liability issues of the design team, the reduction in the level of fees paid for professional services, and the consultant's obligation to use skill and care normally used by professionals.

The contractor has a responsibility to check each trade at the end of its work, with the sign-off process being a tracking procedure rather than something undertaken at the end of a task. Trade contractors can be engaged in the checking of previous trades' work before it is covered up / continued. The consultant is not liable for a defect unless they fail to carry out skill and care in their professional duty. The consultants' role is to check compliance once the scope requirements have been specified. Design and build is different where the contractor carries responsibility for both design and site production.

The demise of the independent Clerk of Works position was seen as a retrograde step. The reduction in staff numbers on site puts pressure on the ability to provide adequate supervision. Fees for independent inspections are an additional cost that will pay benefits in the long run by saving money on the cost of re-work, and the cost of defective workmanship. Identifying faults early will save time and money.

4.3.2 Sign-off / taking over the works / practical completion

Most respondents felt that the sign-off process at the end of the project was inadequate. A lack of assigned responsibility was cited as a reason; Inspection and Test Plans (ITPs) were suggested as one solution. There was concern about the clarity of the sign-off process, in particular, the documentation involved, e.g. Building Control Completion Certificate or a Practical Completion Certificate, which are not proof of quality. As-built information is often not sufficient to reflect the changes made during the site production stage.

"The sign-off stage needs to be quality focused and not merely getting payment and let's hand this over."

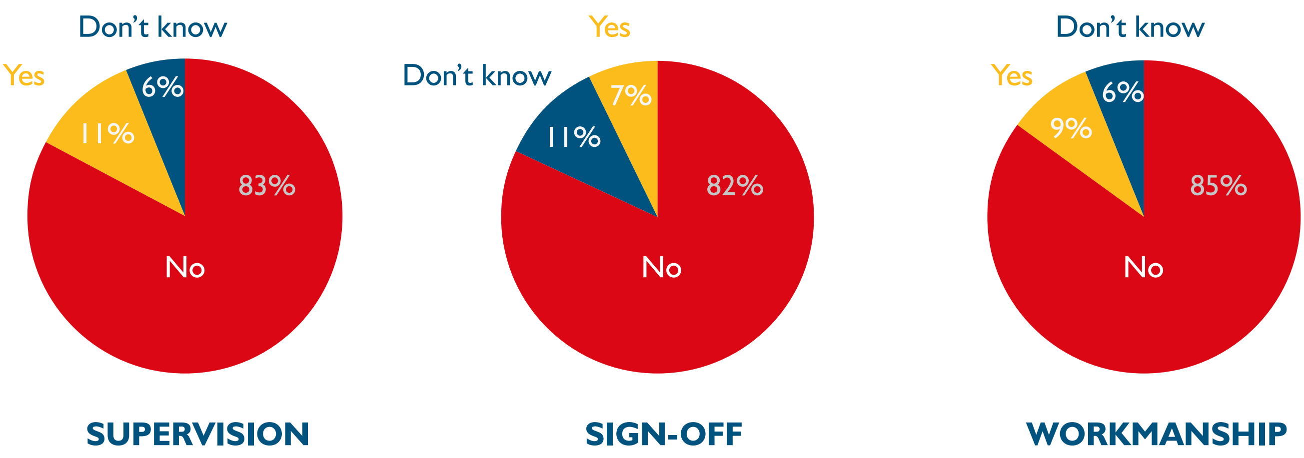
4.3.3 Workmanship

Workmanship is closely linked to supervision. Both can benefit from good training. Incentivisation could be used to reward quality, as well as quantity, of work.

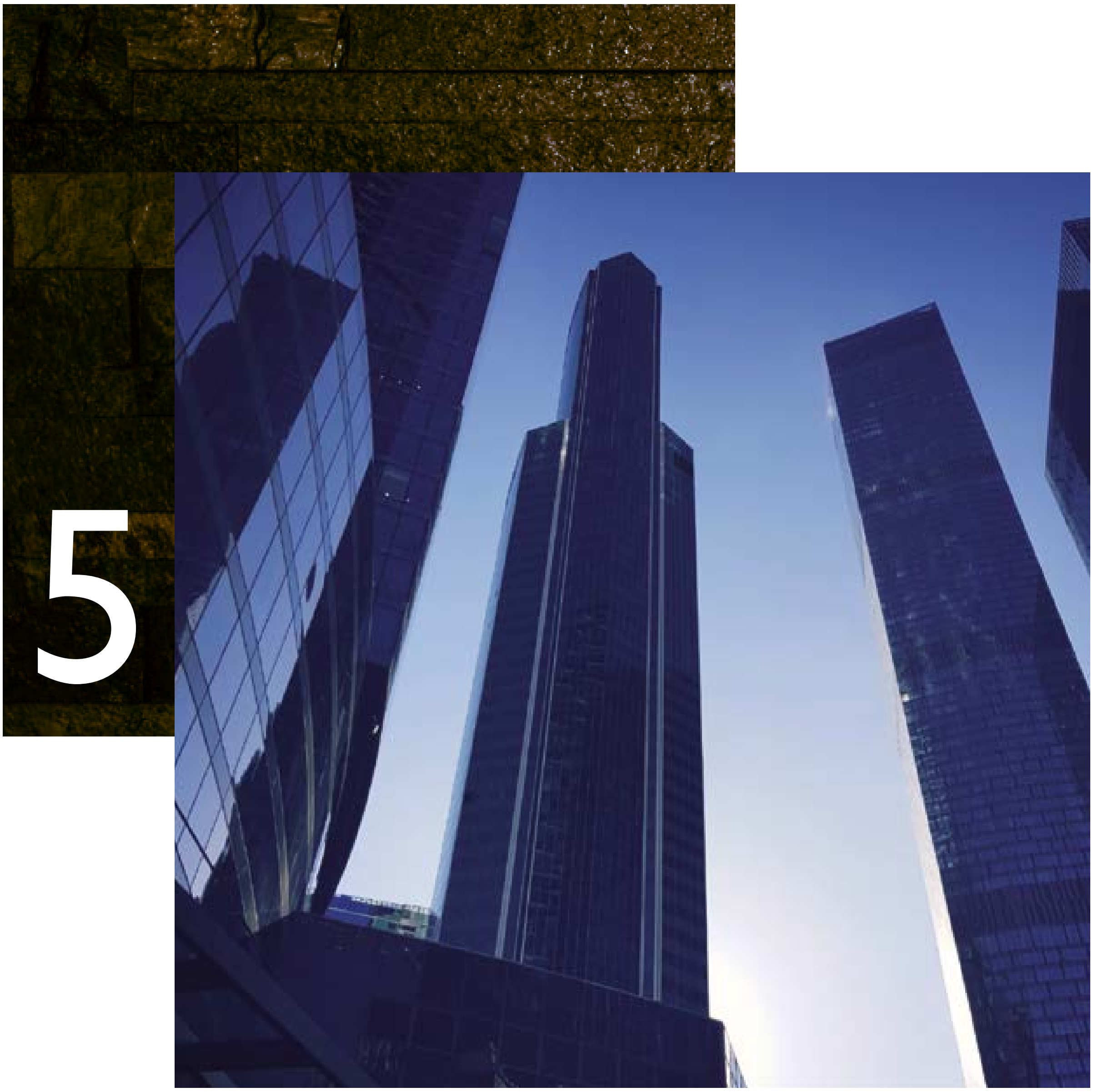
Programme pressures due to contract terms can lead to work being rushed / accelerated, which can lead to poor workmanship. Rework and snagging may be viewed by some as a way of making more money, but this is a short-term naïve perspective.

Figure 4-2 shows the responses from the three questions. Whilst training, incentivisation and supervision can make a difference to quality, placing a greater emphasis on individuals to produce good workmanship is a more sustainable approach, with long-term benefits for both the company and the individual.

Figure 4-2
Responses to the questions about the adequacy of existing quality management in 3 areas



Section Five
Relevant Codes & Standards



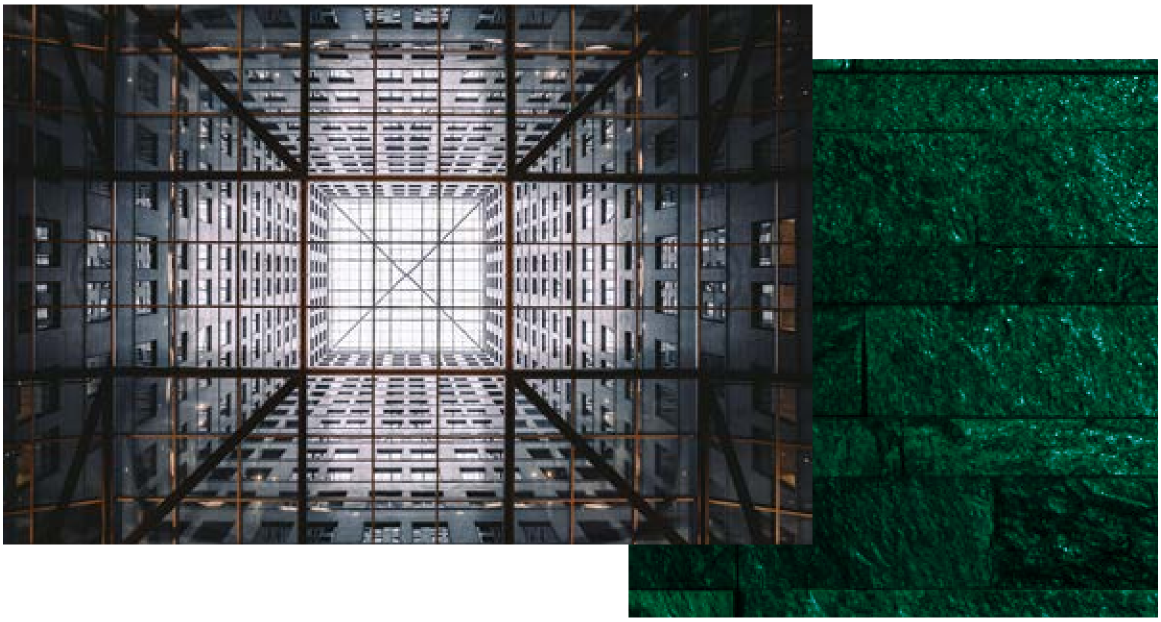
Relevant Codes & Standards

This section looks at the work sections across a project with the relevant standards shown for each sub-section; there are three types:

BS	British Standard
BS EN	British Standard European Norm
ASTM[18]	Globally recognised standard

5.1 Temporary works

Parts of the works that allow or enable construction of, protect, support or provide access to, the permanent works and which might or might not remain in place at the completion of the works.



18 ASTM International, formerly known as American Society for Testing and Materials, is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services

<table>
<tr><th>Type</th><th>Description</th><th>Requirements</th><th>Quality issues</th></tr>
<tr><td>Formwork</td><td>• A temporary mould into which concrete is poured and formed. It is usually fabricated using timber, but it can also be constructed from steel, glass fibre reinforced plastic and other materials. Formwork may be part of the falsework construction and is used in four main areas; walls, columns, beams and slabs. When it is used for the underside of suspended slabs and beams it is known as soffit formwork.

• There are 3 main types of formwork: engineered systems; timber, and; re-usable plastic.</td><td rowspan="2">• Desired shape, size and fit according to the drawings / specifications.

• Select material to ensure required finish of the poured concrete.

• Able to withstand the loading (wet and dry concrete) as specified.

• Should be dismantled and moved as easily as possible so that construction of the building advances.

• Ability to fit and fasten together both tightly and easily.

• Should be simple to build.</td><td rowspan="2">• Type and temperature of the concrete pour is important information.

• The strength / loading of the formwork sides must comply with specifications, particularly important in terms of the initial dead load of wet concrete.

• Sufficient strength reached before striking.

• High level of workmanship and inspection are necessary to ensure a high standard and appearance of the resulting concrete structure.

• Damage to concrete on removal of formwork / falsework. e.g. BS 476: Part 20:1987</td></tr>
<tr><td>Falsework</td><td>• Falsework generally relates to the structural vertical support of concrete decks and so on.

• Supports shuttering and formwork.</td></tr>
</table>

Relevant standards

PAS 8812:2016	Temporary works. Application of European Standards in design. Guide.
BS 5975:2008+A1:2011	Code of practice for temporary works procedures and the permissible stress design of falsework.
BS 8410:2007	Code of practice for lightweight temporary cladding for weather protection and containment on construction works.
BS EN 12813:2004	Temporary works equipment. Load bearing towers of prefabricated components. Particular methods of structural design.
BS EN 12811-2:2004	Temporary works equipment. Information on materials.
BS EN 12811-1:2003	Temporary works equipment. Scaffolds. Performance requirements and general design.
BS EN 12811-3:2002	Temporary works equipment. Load testing.
BS 5974:2017	Planning, design, setting up and use of temporary suspended access equipment. Code of practice.
BS EN 13374:2013	Temporary edge protection systems. Product specification. Test methods.
BS 7909:2011	Code of practice for temporary electrical systems for entertainment and related purposes.
BS EN 1004:2004	Mobile access and working towers made of prefabricated elements. Materials, dimensions, design loads, safety and performance requirements.
BS EN 12063:1999	Execution of special geotechnical work. Sheet pile walls.
BS 7962:2000	Black materials for masking existing road markings. Specification.
BS 4363:1998+A1:2013	Specification for distribution assemblies for reduced low voltage electricity supplies for construction and building sites.
BS 1139-4:1982	Metal scaffolding. Specification for prefabricated steel splitheads and trestles.

Other types of temporary works such as excavation and earthworks are covered in 5.2

5.2 Substructure

Substructure is defined as: All work below underside of screed or, where no screed exists, to the underside of lowest floor finishes including damp-proof membrane, together with relevant excavations and foundations (this includes walls to basements designed as retaining walls).

There are four types of substructure:

Foundations (up to and including the DPC); Lowest floor assembly; Basement excavation, and; Basement retaining walls (up to and including DPC)

5.2.1 Foundations - shallow

<table>
<tr><th>Type</th><th>Description</th><th>Advantages</th><th>Disadvantages</th><th>Quality issues</th></tr>
<tr><td>Pad</td><td>• Isolated footings, often used to support a column. Constructed of a block or slab, which may be stepped to spread the load.</td><td>• Less material needed.</td><td>• Individual pad foundations may interact with each other.</td><td rowspan="3">• Ground conditions.
• Presence of water.
• Load calculation e.g. dead load, imposed load, wind load.
• Minimum width related to type of soil.
• Design needs to be approved by Building Control.</td></tr>
<tr><td>Strip</td><td>• Support a line of loads – a wall or a line of columns</td><td></td><td>• Needs more material and reinforcement than pad footings.</td></tr>
<tr><td>Raft</td><td>• Concrete slab that spreads the load over a wide area. May be stiffened by ribs / beams within foundation.</td><td>• Can reduce differential settlements.
• Can be used on soft or loose soils</td><td>• Prone to edge erosion</td></tr>
</table>

Relevant standards

BS 8004:2015	Code of practice for foundations.
BS 8103-1:2011	Structural design of low-rise buildings. Code of practice for stability, site investigation, foundations, precast concrete floors and ground floor slabs for housing.
Approved Document 10A	Structure.

5.2.2 Foundations – deep: piling

Type	Description	Advantages	Disadvantages	Quality issues
Foundations (up to and including the DPC)	• Column-like structures made from steel, reinforced concrete or timber. A piled foundation is where the depth is three times that of the breadth. • They are classified by their design function – end-bearing, friction (or a combination of both) – or by their method of construction – displacement (driven) or replacement (bored).	• Can transfer loads in relatively weak soil structures. • Can be precast to specifications. • Bearing capacity increases when screw piles are driven into granular soil. • Can be used when working over water.	• Reinforcement needed for precast concrete piles – transporting and piling. • Heavy equipment necessary. • Difficult to determine the required pile length in advance. • Unsuitable for soils with poor drainage. • Vibrations from piling operations may impact neighbouring structures.	• Variability of ground conditions. • Knowledge of ground conditions - detailed site investigation. • Contractor's skill and experience. • Good quality materials. • Appropriate construction procedures. • Good workmanship and site supervision. • Programme and budget pressures. • Ground movements (traffic etc.) during concrete hardening. • Appropriate method for trimming pile head.

Relevant standards

BS EN ISO 22477-4:2018	Geotechnical investigation and testing. Testing of geotechnical structures. Testing of piles: dynamic load testing.
BS EN 1993-5:2007	Eurocode 3. Design of steel structures. Piling.
BS EN 12794:2005	Precast concrete products. Foundation piles.
BS ISO 11886:2002	Building construction machinery and equipment. Pile driving and extracting equipment. Terminology and commercial specifications.
BS EN 12063:1999	Execution of special geotechnical work. Sheet pile walls.
BS EN 1997-1:2004+A1:2013	Eurocode 7. Geotechnical design. General rules.
BS 8008:1996+A1:2008	Safety precautions and procedures for the construction and descent of machine-bored shafts for piling and other purposes.
BS 8004:2015	Code of practice for foundations.
BS 8002:2015	Code of practice for earth retaining structures.
ASTM D8169/D8169M - 18	Standard Test Methods for Deep Foundations Under Bi-Directional Static Axial Compressive Load.
ASTM D4945 - 17	Standard Test Method for High-Strain Dynamic Testing of Deep Foundations.
15/30326284 DC	BS EN 16907-2. Earthworks. Part 2. Classification of materials.
Approved Document A	Structure.

5.2.3 Basement excavation

Type	Description	Advantages	Disadvantages	Quality issues
Underpinning	• Mass concrete or reinforced concrete underpins may be used to increase the depth of the existing foundations.	• Tried and tested methods available.	• Poor specifications or structural engineering can cause collapse. • Soil conditions. • High water table.	• Depth and quality of existing foundations. • State of existing building's fabric or structure. • Sufficient information regarding the construction / state of existing building. • Ground-bearing concrete floors. • Party wall issues. • Soil, geology and hydrology. • Contractor inexperienced in basement construction.
Piling	• Reinforced concrete or steel sheet piles can be used.	• Tried and tested methods available.	• Need a permanent inner reinforced concrete wall or box to provide horizontal strength and waterproofing. • Needs space around the drilling head, thus there is a gap between the pile edge and the existing wall. • Pile size is limited by rig size which is restrained by the available working height and access. • High water table.	

Relevant standards

BS 8004:2015	Code of practice for foundations.
BS EN 13967:2012+A1:2017	Flexible sheets for waterproofing. Plastic and rubber damp proof sheets including plastic and rubber basement tanking sheet. Definitions and characteristics.
BS EN 13969:2004	Flexible sheets for waterproofing. Bitumen damp proof sheets including bitumen basement tanking sheets. Definitions and characteristics.
BS 8102:2009	Code of practice for protection of below ground structures against water from the ground.
BS 8103-1:2011	Structural design of low-rise buildings. Code of practice for stability, site investigation, foundations, precast concrete floors and ground floor slabs for housing.
Approved Document A	Structure.

5.2.4 Basement retaining walls

Type	Description	Advantages	Disadvantages	Quality issues
Basement retaining walls (up to and including DPC)	• A wall in a basement designed to resist the lateral pressure of the surrounding ground and built structures. Normally constructed in concrete or brickwork.	• Construction uses tried and tested methods of brickwork / blockwork.	• Requires accurate / professional calculation of loads. • Site / soil investigations need to be thorough before construction starts. • The impact of bad or lack of proper drainage.	• Badly designed or incorrect temporary works. • Depth and quality of existing foundations. • State of existing building's fabric or structure. • Sufficient information regarding the construction / state of existing building. • Ground-bearing concrete floors. • Party wall issues. • Soil, geology and hydrology.

Relevant standards

BS 8004:2015	Code of practice for foundations.
BS 8103-1:2011	Structural design of low-rise buildings. Code of practice for stability, site investigation, foundations, precast concrete floors and ground floor slabs for housing.
BS EN 13967:2012	Flexible sheets for waterproofing. Plastic and rubber damp proof sheets including plastic and rubber basement.
+A1:2017	Tanking sheet. Definitions and characteristics.
BS EN 13969:2004	Flexible sheets for waterproofing. Bitumen damp proof sheets including bitumen basement tanking sheets. Definitions and characteristics.
BS 8102:2009	Code of practice for protection of below ground structures against water from the ground.
Approved Document A	Structure.

5.2.5 Diaphragm wall and embedded retaining walls

The design, specification and construction details of retaining walls must be provided by the project's engineer. Quality (and safety) issues can arise with backfilling, which can cause instability. Any pressure on the area immediately adjacent to the wall (surcharging) can create a horizontal force which may destabilise the wall. The type of materials used for a retaining wall must depend on the load which is a crucial element. Soil type will need to be taken into account as well as cost but aesthetics should always be secondary. The International Building Code requires retaining walls to be designed to ensure stability against overturning, sliding, excessive foundation pressure and water uplift.

There are four main types of retaining wall, each requiring careful consideration to ensure that they are strong enough for the designed purpose: gravity; cantilever; sheet piling, and; anchored.

Type	Description	Advantages	Disadvantages	Quality issues
Gravity / Crib	• Rely on their mass / weight to hold back a load. Gabions may be used for this.	• Easy to install and remove. • Crib walls: Can be built by hand; easy and quick to build; crib sections can be pre-cast; free draining; top level easily varied • Gabions: Can be built by hand; easy and quick to build; no specialist equipment required; rock fill may be locally sourced; free-draining; can be placed directly on soil.	• Gabions: Possible loss of material through gabion; not suitable for varying ground levels; relatively low unit weight. • Crib walls: often requires a concrete base; uneconomic for short runs; relatively low unit weight.	• Excessive water / moisture • Poor quality materials • Inappropriate choice of retaining wall / techniques. • Level of mobilisation of passive earth resistance. • Poor / lack of guidance and supervision. • Lack of structural engineering drawings / advice / specifications. • Proper drainage must be provided to reduce any hydrostatic pressure of ground water behind the wall. • Impact on surrounding structures.
Cantilever	• Made from mortared masonry or reinforced concrete. The reinforced base means that there is vertical pressure from the ground behind the wall, rather than horizontal. This type of wall has an inverted 'T' shape.	• Unobstructed open excavation. • Tiebacks below adjacent properties not required.	• Excavation depth limited to 6 metres. • Not recommended for use next to adjacent buildings. • Deep excavations may require the rigidity of the wall to be increased considerably, limiting available space within the excavation.	
Sheet piling	• Sheet piles are driven into the ground with the added strength of ground anchors with a cement grout	• Quicker than constructing reinforced concrete walls. • Narrow form of construction, thus maximising usable site space. • Suitable for all soil types. • No requirement for pre-excavation. • Relatively little disturbance of existing ground. • Immediate load bearing capacity. • Can be used on several projects.	• Temporary structures rarely can be used for permanent structures. • Rocks or large boulders will impede piling.	

Anchored	• Anchored by cables which are secured by concrete	• Can be both slender and withstand high loads. • Used where footing size is an issue. • Ideal for smaller areas that need earth retention.	• Requires specialist equipment and qualified engineers. • Difficult to secure anchors in weak soil and / or at any great depth. • Can impact surrounding construction works.	

Relevant standards

ASTM C1372 - 17	Standard Specification for Dry-Cast Segmental Retaining Wall Units.
BS EN 15258:2008	Precast concrete products. Retaining wall elements.
BS 8002:2015	Code of practice for earth retaining structures.
BS EN 1538:2010+A1:2015	Execution of special geotechnical works. Diaphragm walls.
BS EN 16907-5	Draft for public comment. Earthworks.
BS EN 771-4:2011+A1:2015	Specification for masonry units. Autoclaved aerated concrete masonry units
BS 8006-1:2010+A1:2016	Code of practice for strengthened / reinforced soils and other fills.
BS EN 1993-5:2007	Eurocode 3. Design of steel structures. Piling.
BS EN 16228-5:2014	Drilling and foundation equipment. Safety. Diaphragm walling equipment.
BS EN 1538:2010+A1:2015	Execution of special geotechnical works. Diaphragm walls.
Approved Document A	Structure.

5.3 Superstructure

5.3.1 Stairs, walkways and balustrades

Type	Description	Requirements	Quality issues
Utility stair	• A stair used for escape, access for maintenance, or purposes other than as the usual route for moving between levels on a day-to-day basis	• Stairs may be constructed from a number of different materials including: • Timber • Brick • Stone • Concrete • Metal • Glass	• The type and strength of the materials used need to meet the required use and loading. • The quality / strength / durability of the surface of the stair. • Poor installation which affects the integrity / safety of the stairway.
General access stair	• A stair intended for all users of a building on a day-to-day basis, as a normal route between levels.		
Private stair	• A stair intended to be used for only one dwelling.		

Type (cont.)	Description (cont.)	Requirements (cont.)	Quality issues (cont.)
Protected stair	• A stair discharging through a final exit to a place of safety (including any exit passageway between the foot of the stair and the final exit) that is adequately enclosed with fire resisting construction.	• Requirement K1 of the Approved Document K can be met by ensuring that the steepness, rise and going, handrails, headroom, length and width of any stairs, ladders and ramps between levels are appropriate to afford reasonable safety to people gaining access to and moving about buildings. • Key considerations are: • Width • Length of flight • Handrails • Guarding • Fire safety	
Firefighting stair	• A protected stairway communicating with the accommodation area through a firefighting lobby.		
Common stair	• An escape stair serving more than one flat		

Relevant standards

Approved Document B	Part B Fire safety.
Approved Document K	K1 Stairs, ladders and ramps; K2 Protection from falling; K3 Vehicle barriers and loading bays; K4 Protection against impact with glazing; K5 Additional provisions for glazing in buildings other than dwellings; K6 Protection against impact from and trapping by doors.
Approved document M	Access to and use of buildings.
BS EN 16954:2018	Agglomerated stone. Slabs and cut-to-size products for flooring and stairs (internal and external).
BS 5395-1:2010	Stairs. Code of practice for the design of stairs with straight flights and winders
BS EN 15644:2008	Traditionally designed prefabricated stairs made of solid wood. Specifications and requirements.
BS EN 14843:2007	Precast concrete products. Stairs.
BS 585-1:1989	Wood stairs. Specification for stairs with closed risers for domestic use, including straight and winder flights and quarter or half landings.
BS 585-2:1985	Wood stairs. Specification for performance requirements for domestic stairs constructed of wood-based materials.
BS 5395-2:1984	Stairs, ladders and walkways. Code of practice for the design of helical and spiral stairs.
BS 5578-2:1978	Building construction - stairs. Modular co-ordination: specification for co-ordinating dimensions for stairs and stair openings.
BS 4592-0:2006+A1:2012	Flooring, stair treads and handrails for industrial use. Common design requirements and recommendations for installation.
BS 4592-3:2006	Industrial type flooring and stair treads. Cold formed metal planks. Specification.
BS 8203:2017	Code of practice for installation of resilient floor coverings.
BS EN 13318:2000	Screed material and floor screeds. Definitions.
BS EN ISO 16283-2:2018	Acoustics. Field measurement of sound insulation in buildings and of building elements. Impact of sound insulation.
BS 5385-1:2018	Wall and floor tiling. Design and installation of ceramic, natural stone and mosaic wall tiling in normal internal conditions. Code of practice.

BS EN 15254-7:2018	Extended application of results from fire resistance tests. Non-loadbearing ceilings. Metal sandwich panel construction.
BS EN 115-1:2017	Safety of escalators and moving walks. Construction and installation.
BS 9991:2015	Fire safety in the design, management and use of residential buildings. Code of practice.
BS 9266:2013	Design of accessible and adaptable general needs housing. Code of practice.
BS EN ISO 2867:2011	Earth-moving machinery. Access systems.
BS 6349-2:2010	Maritime works. Code of practice for the design of quay walls, jetties and dolphins.
BS 8103-3:2009	Structural design of low-rise buildings. Code of practice for timber floors and roofs for housing.
BS 5385-5:2009	Wall and floor tiling. Design and installation of terrazzo, natural stone and agglomerated stone tile and slab flooring. Code of practice.
BS EN 516:2006	Prefabricated accessories for roofing. Installations for roof access. Walkways, treads and steps.
BS EN 1168:2005+A3:2011	Precast concrete products. Hollow core slabs.
BS EN 14716:2004	Stretched ceilings. Requirements and test methods.
BS 8204-4:2004+A1:2011	Screeds, bases and in situ floorings. Cementitious terrazzo wearing surfaces. Code of practice.
BS 8204-3:2004+A2:2011	Screeds, bases and in-situ floorings. Polymer modified cementitious levelling screeds and wearing screeds. Code of practice.
BS 8204-5:2004+A1:2011	Screeds, bases and in-situ floorings. Mastic asphalt underlays and wearing surfaces. Code of practice.
BS 8204-1:2003+A1:2009	Screeds, bases and in-situ floorings. Concrete bases and cementitious levelling screeds to receive floorings. Code of practice.
BS 8204-2:2003+A2:2011	Screeds, bases and in-situ floorings. Concrete wearing surfaces. Code of practice.
BS 8000-9:2003	Workmanship on building sites. Cementitious levelling screeds and wearing screeds. Code of practice.
BS EN 13892-5:2003	Methods of test for screed materials. Determination of wear resistance to rolling wheel of screed material for wearing layer.
BS EN 13892-7:2003	Methods of test for screed materials. Determination of wear resistance to rolling wheel of screed material with floor coverings.
BS EN 14231:2003	Natural stone test methods. Determination of the slip resistance by means of the pendulum tester.
BS 8204-7:2003	Screeds, bases and in-situ floorings. Pumpable self-smoothing screeds. Code of practice.
BS EN 13892-1:2002	Methods of test for screed materials. Sampling, making and curing specimens for test.
BS EN 13892-2:2002	Methods of test for screed materials. Determination of flexural and compressive strength.
BS EN 13892-4:2002	Methods of test for screed materials. Determination of wear resistance-BCA.
BS EN 13892-6:2002	Methods of test for screed materials. Determination of surface hardness.
BS EN 13892-8:2002	Methods of test for screed materials. Determination of bond strength.
BS EN 13101:2002	Steps for underground man entry chambers. Requirements, marking, testing and evaluation of conformity.
BS EN 13813:2002	Screed material and floor screeds. Screed material. Properties and requirements.
BS EN 12825:2001	Raised access floors.
BS EN 13213:2001	Hollow floors.

BS 6767-2:1998	Transportable accommodation units. Recommendations for design and installation of services and fittings with guidance on transportation, siting and aspects relating to habitation.
BS EN 1195:1998	Timber structures. Test methods. Performance of structural floor decking.
BS EN ISO 7519:1997	Technical drawings. Construction drawings. General principles of presentation for general arrangement and assembly drawings.

5.3.2 Precast concrete

Using precast concrete in a variety of buildings is well established. The method allows for a wide variety / complexity of layouts, shapes and façade treatments.

Precast concrete has the advantage over on-site cast concrete as it is less labour and time intensive and it is more durable, of better quality and affordable.

Type	Description	Advantages	Disadvantages	Quality issues
Precast concrete	• Precast concrete is poured, moulded cast and hardened off-site in a factory environment.	• Durable. • Controlled manufacture gives greater accuracy (use of CAD) and improved quality control. • The moulds are reusable so repetition can be achieved. • 'Made-to-measure' fabrication can mean less waste. • Off-site factory-based production means can avoid weather variances / interruptions. • Controlled dust and noise pollution.	• Weight • Very small margin for error • Connections may be difficult • Somewhat limited building design flexibility • Because panel size is limited, precast concrete cannot be used for two-way structural systems. • Need for repetition of forms will affect building design. • Joints between panels are often expensive and complicated. • Skilled workmanship is required in the application of the panel on site. • Cranes are required to lift panels.	• Interfaces between precast units and in-situ construction. • Quality testing should be approved using appropriate standards. • Care should be taken in loading and unloading precast concrete forms to avoid damage. Precast elements require proper supports, frames, cushioning and tie downs. Particular care should be taken of the edges of the precast elements.

Relevant standards

Approved Document A	Structure.
BS EN 13369:2018	Common rules for precast concrete products.
ASTM C1675 - 18	Standard Practice for Installation of Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers.

ASTM C858 - 18	Standard Specification for Underground Precast Concrete Utility Structures.
ASTM C1433M - 18	Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers (Metric).
ASTM C1786 - 18	Standard Specification for Segmental Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers Designed According to AASHTO LRFD.
BS 8297:2017	Design, manufacture and installation of architectural precast concrete cladding. Code of practice.
ASTM C1719 - 11(2017)	Standard Test Method for Installed Precast Concrete Tanks and Accessories by the Negative Air Pressure (Vacuum) Test Prior to Backfill.
ASTM C969M - 17	Standard Practice for Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines (Metric).
ASTM C969 - 17	Standard Practice for Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines.
ASTM C1837 - 17	Standard Specification for Production of Dry Cast Concrete Used for Manufacturing Pipe, Box, and Precast Structures.
BS EN 15037-5:2013	Precast concrete products. Beam-and-block floor systems. Lightweight blocks for simple formwork.
BS EN 13225:2013	Precast concrete products. Linear structural elements.
BS EN 12839:2012	Precast concrete products. Elements for fences.
BS EN 13224:2011	Precast concrete products. Ribbed floor elements.
BS 8103-1:2011	Structural design of low-rise buildings. Code of practice for stability, site investigation, foundations, precast concrete floors and ground floor slabs for housing.
BS EN 15191:2009	Precast concrete products. Classification of glass fibre reinforced concrete performance.
BS EN 15037-4:2010+A1:2013	Precast concrete products. Beam-and-block floor systems. Expanded polystyrene blocks.
BS EN 15258:2008	Precast concrete products. Retaining wall elements.
BS EN 15037-3:2009+A1:2011	Precast concrete products. Beam-and-block floor systems. Clay blocks.
BS 6073-2:2008	Precast concrete masonry units. Guide for specifying precast concrete masonry units.
BS EN 15435:2008	Precast concrete products. Normal weight and lightweight concrete shuttering blocks. Product properties and performance.
BS EN 15037-1:2008	Precast concrete products. Beam-and-block floor systems. Beams.
BS EN 15498:2008	Precast concrete products. Wood-chip concrete shuttering blocks. Product properties and performance.
BS EN 15050:2007+A1:2012	Precast concrete products. Bridge elements.
BS EN 14843:2007	Precast concrete products. Stairs.
BS EN 14844:2006+A2:2011	Precast concrete products. Box culverts.
BS EN 14992:2007+A1:2012	Precast concrete products. Wall elements.
BS EN 14991:2007	Precast concrete products. Foundation elements.
BS EN 13747:2005+A2:2010	Precast concrete products. Floor plates for floor systems.
BS 7533-3:2005+A1:2009	Pavements constructed with clay, natural stone or concrete pavers. Code of practice for laying precast concrete paving blocks and clay pavers for flexible pavements.
BS EN 1168:2005+A3:2011	Precast concrete products. Hollow core slabs.

BS EN 12629-6:2004+A1:2010	Machines for the manufacture of constructional products from concrete and calcium-silicate. Safety. Stationary and mobile equipment for the manufacture of precast reinforced products.
BS EN 12794:2005	Precast concrete products. Foundation piles.
BS EN 14649:2005	Precast concrete products. Test method for strength retention of glass fibres in cement and concrete (SIC test).
BS EN 14474:2004	Precast concrete products. Concrete with wood-chips as aggregate. Requirements and test methods.
BS EN 12843:2004	Precast concrete products. Masts and poles.
BS EN 13693:2004+A1:2009	Precast concrete products. Special roof elements.
BS EN 12737:2004+A1:2007	Precast concrete products. Floor slats for livestock.
BS EN 13198:2003	Precast concrete products. Street furniture and garden products.
BS 7533-8:2003	Pavements constructed with clay, natural stone or concrete pavers. Guide for the structural design of lightly trafficked pavements of precast concrete flags and natural stone flags.
BS 7533-2:2001	Pavements constructed with clay, natural stone or concrete pavers. Guide for the structural design of lightly trafficked pavements of clay pavers or precast concrete paving blocks.
BS 7533-1:2001	Pavements constructed with clay, natural stone or concrete pavers. Guide for the structural design of heavy duty pavements constructed of clay pavers or precast concrete paving blocks.
BS 7533-6:1999	Pavements constructed with clay, natural stone or concrete pavers. Code of practice for laying natural stone, precast concrete and clay kerb units.
BS EN 1169:1999	Precast concrete products. General rules for factory production control of glass-fibre reinforced cement.
BS EN 1170-2:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measuring the fibre content in fresh GRC, 'Wash out test'.
BS EN 1170-1:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measuring the consistency of the matrix. 'Slump test' method.
BS EN 1170-3:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measuring the fibre content of sprayed GRC.
BS EN 1170-4:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measuring bending strength. 'Simplified bending test' method.
BS EN 1170-5:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measuring bending strength, 'complete bending test' method.
BS EN 1170-6:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Determination of the absorption of water by immersion and determination of the dry density.
BS EN 1170-7:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measurement of extremes of dimensional variations due to moisture content.
ISO 9883:1993	Performance standards in building. Performance test for precast concrete floors. Behaviour under concentrated load.
ISO 9882:1993	Performance standards in building. Performance test for precast concrete floors. Behaviour under non-concentrated load.
BS 8000-2.2:1990	Workmanship on building sites. Code of practice for concrete work. Sitework with in-situ and precast concrete.

BS 5642-2:1983+A1:2014	Sills, copings and cappings. Specification for copings and cappings of precast concrete, cast stone, clayware, slate and natural stone.
BS 5642-1:1978+A1:2014	Sills, copings and cappings. Specification for window sills of precast concrete, cast stone, clayware, slate and natural stone.
BS ISO 13270:2013	Steel fibres for concrete. Definitions and specifications.
BS 8298-3:2010	Code of practice for the design and installation of natural stone cladding and lining. Stone-faced pre-cast concrete cladding systems.
BS EN 1857:2010	Chimneys. Components. Concrete flue liners.
BS EN 1858:2008+A1:2011	Chimneys. Components. Concrete flue blocks.
BS EN 1739:2007	Determination of shear strength for in-plane forces of joints between prefabricated components of autoclaved aerated concrete or lightweight aggregate concrete with open structure.
BS EN 13791:2007	Assessment of in-situ compressive strength in structures and pre-cast concrete components.
BS EN 1992-1-1:2004+A1:2014	Eurocode 2: Design of concrete structures. General rules and rules for buildings.
BS 5911-6:2004+A1:2010	Concrete pipes and ancillary concrete products. Specification for road gullies and gully cover slabs.
BS EN 13295:2004	Products and systems for the protection and repair of concrete structures. Test methods. Determination of resistance to carbonation.
BS 7533-11:2003	Pavements constructed with clay, natural stone or concrete pavers. Code of practice for the opening, maintenance and reinstatement of pavements of concrete, clay and natural stone.
BS EN 1339:2003	Concrete paving flags. Requirements and test methods.
BS EN 1338:2003	Concrete paving blocks. Requirements and test methods.
BS EN 1340:2003	Concrete kerb units. Requirements and test methods.
BS EN 1917:2002	Concrete manholes and inspection chambers, unreinforced, steel fibre and reinforced.
BS EN 1916:2002	Concrete pipes and fittings, unreinforced, steel fibre and reinforced.
BS 5911-4:2002+A2:2010	Concrete pipes and ancillary concrete products. Specification for unreinforced and reinforced concrete inspection chambers (complementary to BS EN 1917:2002).
BS EN 1740:1998	Performance test for prefabricated reinforced components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure under predominantly longitudinal load (vertical components).
BS EN 1737:1998	Determination of shear strength of welded joints of reinforcement mats or cages for prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure.
BS EN 1742:1998	Determination of shear strength between different layers of multilayer components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure.
BS EN 1741:1998	Determination of shear strength for out-of-plane forces of joints between prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure.
BS 1881-208:1996	Testing concrete. Recommendations for the determination of the initial surface absorption of concrete.
BS 8000-2.1:1990	Workmanship on building sites. Code of practice for concrete work. Mixing and transporting concrete.
BS 6579-8:1987	Safety fences and barriers for highways. Specification for concrete safety barriers.

5.3.3 Precast / composite concrete

The term composite is used when concrete and one or more other materials are used in its fabrication, e.g. steel, timber and plastic. Using these other materials makes use of different characteristics. For example, steel, which, unlike concrete, is very strong in tension, thus the combined characteristics of compression and resistance to tension.

Type	Description	Advantages	Disadvantages	Quality issues
Precast composite concrete	• A combination of concrete and other components to provide different characteristics to concrete-only components.	• Can be lightweight. • Ideal for decking – concrete with reinforced steel bars. • In columns it provides high strength for a relatively small cross-sectional area.	• Very small margin for error. • Connections may be difficult. • Need for repetition of forms will affect building design. • Joints between panels are often expensive and complicated. • Skilled workmanship is required in the application of the panel on site. • Cranes may be required to lift panels.	• Interfaces between precast units and in-situ construction. • Quality testing should be approved using appropriate standards. • Care should be taken in loading and unloading precast concrete forms to avoid damage. Precast elements require proper supports, frames, cushioning and tie downs. Particular care should be taken of the edges of the precast elements.

Relevant standards

Approved Document A	Structure.
BS EN 1994-2:2005	Eurocode 4. Design of composite steel and concrete structures. General rules and rules for bridges.
BS EN 1994-1-1:2004	Eurocode 4. Design of composite steel and concrete structures. General rules and rules for buildings.
ASTM D8173 - 18	Standard Guide for Site Preparation, Layout, Installation, and Hydration of Geosynthetic Cementitious Composite Mats.
ISO 19044:2016	Test methods for fibre-reinforced cementitious composites. Load-displacement curve using notched specimen.
ISO 10406-1:2015	Fibre-reinforced polymer (FRP) reinforcement of concrete. Test methods. FRP bars and grids.
ISO 10406-2:2015	Fibre-reinforced polymer (FRP) reinforcement of concrete. Test methods. FRP sheets.
BS EN 15037-5:2013	Precast concrete products. Beam-and-block floor systems. Lightweight blocks for simple formwork.
ISO 14484:2013	Performance guidelines for design of concrete structures using fibre-reinforced polymer (FRP) materials.

5.3.4 Masonry

Masonry is bricks or pieces of stone which have been stuck together with cement as part of a wall or building.

Type	Description	Advantages	Disadvantages	Quality issues
Masonry	• Brickwork. • Blockwork. • Natural stone. • Masonry systems: external leaf system; internal leaf system; partition system; freestanding wall leaf system.	• Durability and strength. • High thermal mass and good acoustic insulation. • Cavity acts as insulation and a vapour barrier. • Does not require finishing / decorating. • Inexpensive to maintain and repair. • Fire resistant.	• Less effective in the resistance of lateral loading and / or tension forces. • Heavy, requiring strong foundations. • May be prone to frost damage, joint disintegration and discolouration.	• Where strength is an issue, piers / buttresses should be used. • The mortar mix needs to be appropriate, meeting the relevant standards. • Frequent inspections to ensure quality standards are met. • Brickwork reference panels can provide quality guidelines. • Ensure consistent pointing. • Ensure consistent quality, colour and strength. • Only specified admixtures (BS EN 934-3:2009+A1:2012) should be used in the mortar. • Rusting / failure of ties. • Length of wall ties meet specifications in Approved Document A of the Building Regulations (Table 5).

Relevant standards

Approved Document A	Structure.
Eurocode 6	Structure Part 1–1, General rules for reinforced and unreinforced masonry structures; Part 1–2, Structural fire design; Part 2, Design considerations, selection of materials and execution of masonry; Part 3, Simplified calculation methods for unreinforced masonry structures. There are a very large number of standards related to masonry; these can be found in Appendix One.

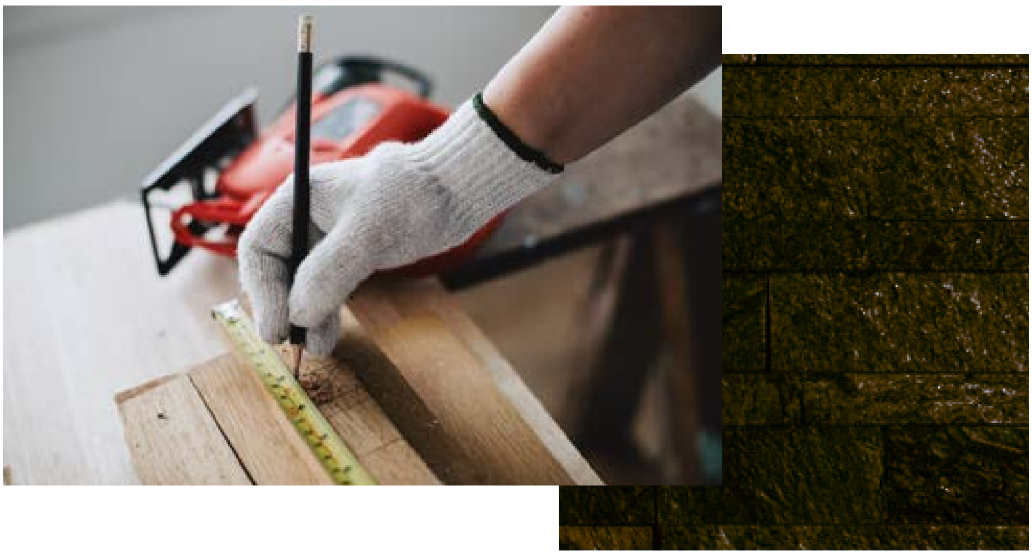
5.3.5 Carpentry

This is a skilled trade which involves cutting, shaping and installation of building materials during the construction of buildings, timber bridges, concrete formwork and so on.

Type	Description	Advantages	Disadvantages	Quality issues
Carpentry	• Types of carpentry: rough; framing; formwork; roofing, joister, trim, cabinet maker. • Timber structures: panels; panel diaphragms.	• Less embodied energy. • Strength of panels built up of sheets. • Compared to steel: more flexible; more energy efficient.	• Wood studs may warp, rot, shrink, crack, or split. • Wastage due to imperfections. • Compared to steel: will burn.	• Adequate storage facilities to prevent warping. • Inspection of timber before use and once constructed. • Ensure that timber meets quality and strength specifications. • Lateral loads should be clearly stated for a panel roof-deck system or any other timber diaphragm wall.

Relevant standards

BS 8000-5:1990	Workmanship on building sites. Code of practice for carpentry, joinery and general fixings.
BS 6100-8:2007	Building and civil engineering. Vocabulary. Work with timber and wood-based panels.
BS 3087-13:1991	Pliers and nippers. Specification for dimensions and test values of carpenter's pincers.



5.3.6 Cladding and covering

Cladding is any material used to cover a structure's exterior. It is mainly used to stop wind and rain from entering the building.

Cladding can also provide sound and thermal insulation as well as fire resistance. It can make a building's exterior more attractive.

Type	Description	Advantages	Disadvantages	Quality issues
Cladding	• Attached to a building's framework or an intermediate layer of battens or spacers. • It can be made of: Wood, metal, brick, vinyl, composite materials that can include aluminium, wood, blends of cement and recycled polystyrene, straw fibres. • Types: Curtain walling; Sandwich panels; Patent glazing; Rainscreen; Timber cladding; Metal profile cladding; Tensile fabric coverings; Brick slips; Tile hanging; Shakes and shingle; uPVC.	• Aesthetic. • Weather proof. • Insulation. • Fire resistance.	• Constructed incorrectly can create a fire hazard. • Cost. • Construction time. • Repair costs.	• Check warranty policies / schedules. • Compliance with and manufacturer's installation specifications. • Regular inspections required, including spot checks of structure, brackets and other components. • Contractor's skill and experience.

Relevant standards

Approved Document A	Structure.
Approved Document B	Fire safety.
BS 8297:2017	Design, manufacture and installation of architectural precast concrete cladding. Code of practice.
BS 5427:2016+A1:2017	Code of practice for the use of profiled sheet for roof and wall cladding on buildings.
BS 5534:2014+A2:2018	Slating and tiling for pitched roofs and vertical cladding. Code of practice.
BS EN 12326-1:2014	Slate and stone for discontinuous roofing and external cladding. Specifications for slate and carbonate slate.
BS EN 14783:2013	Fully supported metal sheet and strip for roofing, external cladding and internal lining. Product specification and requirements.
BS EN 491:2011	Concrete roofing tiles and fittings for roof covering and wall cladding. Test methods.
BS EN 490:2011+A1:2017	Concrete roofing tiles and fittings for roof covering and wall cladding. Product specifications.
BS 8298-3:2010	Code of practice for the design and installation of natural stone cladding and lining. Stone-faced pre-cast concrete cladding systems.
BS 8410:2007	Code of practice for lightweight temporary cladding for weather protection and containment on construction works.
BS EN 14782:2006	Self-supporting metal sheet for roofing, external cladding and internal lining. Product specification and requirements.

BS 8298:1994	Code of practice for design and installation of natural stone cladding and lining.
ISO 14:1982	Asbestos-cement products. Asbestos-cement-cellulose corrugated sheets and fittings for roofing and cladding.
ISO 14:1982	Asbestos-cement products. Trapezoidal section sheets for roofing and cladding.
BS 4904:1978	Specification for external cladding colours for building purposes.
BS EN ISO 12631:2017	Thermal performance of curtain walling. Calculation of thermal transmittance.
BS EN 1364-5:2017	Fire resistance tests for non-loadbearing elements. Air transfer grilles.
BS ISO 17738-1:2017	Thermal insulation products. Exterior insulation and finish systems. Materials and systems.
ASTM C1729 - 17	Standard Specification for Aluminum Jacketing for Insulation.
ASTM C1729M - 17	Standard Specification for Aluminum Jacketing for Insulation.
BS EN 16758:2016	Curtain walling. Determination of the strength of sheared connections. Test method and requirements.
BS EN 14019:2016	Curtain Walling. Impact resistance. Performance requirements.
BS EN 14509:2013	Self-supporting double skin metal faced insulating panels. Factory made products. Specifications.
BS 8000-6:2013	Workmanship on building sites. Code of practice for slating and tiling of roofs and claddings.
BS EN 1304:2013	Clay roofing tiles and fittings. Product definitions and specifications.
BS EN 505:2013	Roofing products from metal sheet. Specification for fully supported roofing products of steel sheet.
BS EN 16301:2013	Natural stone test methods. Determination of sensitivity to accidental staining.
BS EN 12467:2012+A2:2018	Fibre-cement flat sheets. Product specification and test methods.
BS EN 13381-6:2012	Test methods for determining the contribution to the fire resistance of structural members. Applied protection to concrete filled hollow steel columns.
BS EN 14617-12:2012	Agglomerate stone. Test methods. Determination of dimensional stability.
BS EN 771-3:2011+A1:2015	Specification for masonry units. Aggregate concrete masonry units (Dense and lightweight aggregates).
BS EN 771-5:2011+A1:2015	Specification for masonry units. Manufactured stone masonry units.
BS EN 544:2011	Bitumen shingles with mineral and / or synthetic reinforcements. Product specification and test methods.
BS EN 13050:2011	Curtain Walling. Watertightness. Laboratory test under dynamic condition of air pressure and water spray.
BS 6100-6:2008	Building and civil engineering. Vocabulary. Construction parts.
BS EN 14992:2007+A1:2012	Precast concrete products. Wall elements.
NA to BS EN 1991-1-5:2003	UK National Annex to Eurocode 1. Actions on structures. General actions.
BS 6093:2006+A1:2013	Design of joints and jointing in building construction. Guide.
BS EN 1991-1-5:2003	Eurocode 1. Actions on structures. General actions.
BS EN 12152:2002	Curtain walling. Air permeability. Performance requirements and classification.
BS EN 13364:2002	Natural stone test methods. Determination of the breaking load at dowel hole.
BS 8219:2001+A1:2013	Installation of sheet roof and wall coverings. Profiled fibre cement. Code of practice.
BS 6915:2001+A1:2014	Design and construction of fully supported lead sheet roof and wall coverings. Code of practice.

BS EN 13051:2001	Curtain walling. Watertightness. Site test.
BS EN 13116:2001	Curtain walling. Resistance to wind load. Performance requirements.
BS EN 12179:2000	Curtain walling. Resistance to wind load. Test method.
BS EN 12153:2000	Curtain walling. Air permeability. Test method.
BS EN 12155:2000	Curtain walling. Watertightness. Laboratory test under static pressure.
BS EN 12154:2000	Curtain walling. Watertightness. Performance requirements and classification.
BS 5493:1977	Code of practice for protective coating of iron and steel structures against corrosion.
CP 143-10:1973	Code of practice for sheet roof and wall coverings. Code of practice for sheet roof and wall coverings. Galvanized corrugated steel. Metric units.
CP 143-15:1973	Code of practice for sheet roof and wall coverings. Code of practice for sheet roof and wall coverings. Aluminium. Metric units.
CP 143-12:1970	Code of practice for sheet roof and wall coverings. Code of practice for sheet roof and wall coverings. Copper. Metric units.

5.3.7 Roofing

5.3.7.1 Roof coverings

Constructions which may consist of one or more layers of material, but does not refer to the roof structure as a whole. Roof size and shape often dictate material and system selection.

Type	Description	Advantages	Disadvantages	Quality issues
Tiles	• Roof tiles are either plain or interlocking. • Roof tiles are traditionally made from clay and commonly measure 256mm x 165mm. They need to be double-lapped. • Single-lapped tiles are interlocking with a tongue and groove joint.	• Small tiles are easy to handle and transport. • Interlocking tiles reduce the weight of the roof (compared to double lapping).	• Double-lapped tiles can make the roof heavy, slow to lay and therefore relatively expensive. • Single-lapped tiles require a larger baton size and to be fixed by a clip or nail.	• Incorrect or inadequate flashing put in place. • Ensure adequate nailing / fixing is taking place. • Poor cutting around roof vents or other protuberances. • Integration with the rest of the building or neighbouring property. • Drainage criteria associated with roof type.
Slates	• Slate is a natural material that is that is dense, strong, acid resistant and non-absorptive. • Artificial slates are also available.	• Impervious to freeze / thaw cycles. • Fire resistant. • Aesthetically pleasing. • Can be laid on roofs with a pitch as low as 30°.	• It is necessary to nail every slate which increases time and cost. • Double lapping requirement means that slate roofs are heavier. • Artificial slate is cheaper but do not last as long as real slate.	

Type (cont.)	Description (cont.)	Advantages (cont.)	Disadvantages (cont.)	Quality issues (cont.)
Wood shingles and shakes	• Shingles are sawn, shakes split. • Although they are naturally durable, timber preservative treatment is usually applied.	• Renewable source and therefore sustainable.	• Fire retardant treatment may also be required. • Fixings should be stainless steel and care should be taken with acidic run–off from cedar shingles.	• Incorrect or inadequate flashing put in place. • Ensure adequate nailing / fixing is taking place. • Poor cutting around roof vents or other protuberances. • Integration with the rest of the building or neighbouring property. • Drainage criteria associated with roof type.
Sheet coverings	• These are used for flat roofs. • Materials used include bituminous felt, asphalt and metal (e.g. lead or copper).	• Metal sheets are mould and fungus resistant. • Easier to fit than tiles.	• Poor longevity of flat roofs. • Prone to weakness when the sheets are bent or penetrated by ducts, flues etc. • Possible weakness at joints or seams. • Large unit sizes requiring adequate manpower.	

Relevant standards

BS EN 12691:2018	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of resistance to impact.
ASTM E1592 - 05(2017)	Standard Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference.
ASTM D5636/D5636M (2017)	Standard Test Method for Low Temperature Unrolling of Felt or Sheet Roofing and Waterproofing Materials.
BS EN 12039:2016	Flexible sheets for waterproofing. Bitumen sheets for roof waterproofing. Determination of adhesion of granules.
BS 5427:2016+A1:2017	Code of practice for the use of profiled sheet for roof and wall cladding on buildings.
BS EN 13859-1:2014	Flexible sheets for waterproofing. Definitions and characteristics of underlays. Underlays for discontinuous roofing.
BS EN 16240:2013	Light transmitting flat solid polycarbonate (PC) sheets for internal and external use in roofs, walls and ceilings. Requirements and test methods.
BS EN 13707:2013	Flexible sheets for waterproofing. Reinforced bitumen sheets for roof waterproofing. Definitions and characteristics.
BS EN 1844:2013	Flexible sheets for waterproofing. Determination of resistance to ozone. Plastic and rubber sheets for roof waterproofing.
BS EN 12311-2:2013	Flexible sheets for waterproofing. Determination of tensile properties. Plastic and rubber sheets for roof waterproofing.
BS EN 12316-2:2013	Flexible sheets for waterproofing. Determination of peel resistance of joints. Plastic and rubber sheets for roof waterproofing.
BS EN 495-5:2013	Flexible sheets for waterproofing. Determination of foldability at low temperature. Plastic and rubber sheets for roof waterproofing.
BS EN 14783:2013	Fully supported metal sheet and strip for roofing, external cladding and internal lining. Product specification and requirements.
BS EN 1109:2013	Flexible sheets for waterproofing. Bitumen sheets for roof waterproofing. Determination of flexibility at low temperature.

BS EN 505:2013	Roofing products from metal sheet. Specification for fully supported roofing products of steel sheet.
BS EN 502:2013	Roofing products from metal sheet. Specification for fully supported roofing products of stainless steel sheet.
BS EN 13956:2012	Flexible sheets for waterproofing. Plastic and rubber sheets for roof waterproofing. Definitions and characteristics.
BS EN 13583:2012	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of hail resistance.
BS EN 508-2:2008	Roofing products from metal sheet. Specification for self-supporting products of steel, aluminium or stainless steel sheet. Aluminium.
BS EN 1548:2007	Flexible sheets for waterproofing. Plastic and rubber sheets for roof waterproofing. Method for exposure to bitumen.
BS EN 14782:2006	Self-supporting metal sheet for roofing, external cladding and internal lining. Product specification and requirements.
BS 8219:2001+A1:2013	Installation of sheet roof and wall coverings. Profiled fibre cement. Code of practice.
BS 6915:2001+A1:2014	Design and construction of fully supported lead sheet roof and wall coverings. Code of practice.
BS EN 13416:2001	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Rules for sampling.
BS EN 1848-2:2001	Flexible sheets for waterproofing. Determination of length, width and straightness. Plastic and rubber sheets for roof waterproofing.
BS EN 1850-2:2001	Flexible sheets for waterproofing. Determination of visible defects. Plastic and rubber sheets for roof waterproofing.
BS EN 1107-2:2001	Flexible sheets for waterproofing. Determination of dimensional stability. Plastic and rubber sheets for roof waterproofing.
BS EN 1296:2001	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roofing. Method of artificial ageing by long term exposure to elevated temperature.
BS EN 12310-2:2000	Flexible sheets for waterproofing. Determination of resistance to tearing (nail shank). Plastic and rubber sheets for roof waterproofing.
BS EN 1931:2000	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of water vapour transmission properties.
BS EN 1928:2000	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of watertightness.
BS EN 12316-1:2000	Flexible sheets for waterproofing. Determination of peel resistance of joints. Bitumen sheets for roof waterproofing.
BS EN 12311-1:2000	Flexible sheets for waterproofing. Determination of tensile properties. Bitumen sheets for roof waterproofing.
BS EN 12310-1:2000	Flexible sheets for waterproofing. Determination of resistance to tearing (nail shank). Bitumen sheets for roof waterproofing.
BS EN 12317-1:2000	Flexible sheets for waterproofing. Bitumen sheets for roof waterproofing. Determination of shear resistance of joints.
BS EN 1108:2000	Flexible sheets for waterproofing. Bitumen sheets for roof waterproofing. Determination of form stability under cyclical temperature changes.
BS EN 1850-1:2000	Flexible sheets for waterproofing. Determination of visible defects. Bitumen sheets for roof waterproofing.
BS EN 1107-1:2000	Flexible sheets for waterproofing. Determination of dimensional stability. Bitumen sheets for roof waterproofing.

BS EN 1848-1:2000	Flexible sheets for waterproofing. Determination of length, width and straightness. Bitumen sheets for roof waterproofing.
BS EN 1849-1:2000	Flexible sheets for waterproofing. Determination of thickness and mass per unit area. Bitumen sheets for roof waterproofing.
BS EN 507:2000	Roofing products from metal sheet. Specification for fully supported roofing products of aluminium sheet.
BS EN 504:2000	Roofing products from metal sheet. Specification for fully supported roofing products of copper sheet.
BS EN 501:1994	Roofing products from metal sheet. Specifications for fully supported roofing products of zinc sheet.
ISO 14:1982	Asbestos-cement products. Short corrugated and asymmetrical section sheets and fittings for roofing.
ISO 14:1982	Asbestos-cement products. Asbestos-cement-cellulose corrugated sheets and fittings for roofing and cladding.
ISO 14:1982	Asbestos-cement products. Trapezoidal section sheets for roofing and cladding.
ISO 14:1982	Directives for fixing asbestos-cement corrugated and asymmetrical section sheets and fittings for roofing.
CP 143-10:1973	Code of practice for sheet roof and wall coverings. Code of practice for sheet roof and wall coverings. Galvanized corrugated steel. Metric units.
CP 143-15:1973	Code of practice for sheet roof and wall coverings. Code of practice for sheet roof and wall coverings. Aluminium. Metric units.
CP 143-12:1970	Code of practice for sheet roof and wall coverings. Code of practice for sheet roof and wall coverings. Copper. Metric units.
CP 143-5:1964	Code of practice for sheet roof and wall coverings. Code of practice for sheet roof and wall coverings. Zinc.
ASTM D6380/D6380M - 03(2018)	Standard Specification for Asphalt Roll Roofing (Organic Felt).
ASTM D8154 - 17	Standard Test Methods for 1H-NMR Determination of Ketone-Ethylene-Ester and Polyvinyl Chloride Contents in KEE-PVC Roofing Fabrics.
ASTM D7505/D7505M - 17	Standard Specification for Self-Adhesive Polyester Fabric Reinforced Polymer Modified Asphalt Steep Slope Roll Roofing Surfaced with Mineral Granules.
ASTM D7530/D7530M - 17	Standard Specification for Self-Adhesive Glass Fiber Fabric Reinforced Polymer Modified Asphalt Steep Slope Roll Roofing Surfaced with Mineral Granules.
BS EN 494:2012+A1:2015	Fibre-cement profiled sheets and fittings. Product specification and test methods.
BS EN 12467:2012+A2:2018	Fibre-cement flat sheets. Product specification and test methods.
BS EN 15976:2011	Flexible sheets for waterproofing. Determination of emissivity.
BS EN 1849-2:2009	Flexible sheets for waterproofing. Determination of thickness and mass per unit area. Plastic and rubber sheets.
BS EN 14964:2006	Rigid underlays for discontinuous roofing. Definitions and characteristics.
BS EN 15057:2006	Fibre cement profiled sheets. Impact resistance test method.
BS EN 534:2006+A1:2010	Corrugated bitumen sheets. Product specification and test methods.
BS EN 612:2005	Eaves gutters with bead stiffened fronts and rainwater pipes with seamed joints made of metal sheet.
BS 5803-5:1985	Thermal insulation for use in pitched roof spaces in dwellings. Specification for installation of man-made mineral fibre and cellulose fibre insulation.
BS EN 544:2011	Bitumen shingles with mineral and / or synthetic reinforcements. Product specification and test methods.

5.3.8 Doors, shutters and hatches

A hinged, sliding, or revolving barrier at the entrance to a building, room, or vehicle, or in the framework of a cupboard.

Type	Description	Requirements	Quality issues
Doors	• Door types: Automatic; Batwing; Bi-fold; False; Fire; Flush; French; Half; Ledge and brace; Louvred; Pivot; Revolving; Rolling shutter; Saloon; Security; Single-leaf; Sliding; Wicket.	• Minimum fire resistance according to BS 476-22:1987. • Flashing for exterior doors is critical for shedding rain water. • Doors in public spaces, corridors, stairwells etc. should open in the direction of escape. • Good energy rating of door glazing.	• Inadequate / incorrectly installed flashing on exterior doors. • Damage to doors by other trades. • Inconsistent alignment. • Joints and gaps. • Poor dimensional quality.
Roller shutters	• Typically made of steel, this type of door is usually found in warehouses, garages, shops, and so on		
Hatches	• A hatch is an opening which is usually flush with the surface of a floor, roof, or ceiling.		

Relevant standards

There are over 200 standards relating to doors. A selected few are shown here.

BS EN ISO 10077-2:2017	Thermal performance of windows, doors and shutters. Calculation of thermal transmittance. Numerical method for frames.
BS 8214:2016	Timber-based fire door assemblies. Code of practice.
BS 8213-4:2016	Windows and doors. Code of practice for the survey and installation of windows and external doorsets.
ASTM E2112 - 18	Standard Practice for Installation of Exterior Windows, Doors and Skylights.

5.3.9 Windows, screens and lights

Type	Description	Requirements	Quality issues
Windows	• Window types: Fixed light; Vertical slider / sash; Casement; Tilt and turn; Pivot; Bi-fold; Louvre. • Made of timber, metal or PVC.	• Suitable materials that have good thermal and sound properties, are easily maintained, provide safety and security and capable of resisting wind and rain. • The efficiency of windows is improved by double glazing, treble glazing, low-e coatings, the construction of the frame, the type of glass, the gas used to fill the sealed unit and so on. • If required, suitable egress from windows in the event of a fire.	• Poor installation leaving gaps, unsafe operation etc. • Safety glass not used where specified. • Poor dimensional quality. • Weatherproofing / waterproofing.
Screens	• Screen types: Sliding, pocket, hinged, pivot or bi-folding.		
Lights	• Skylights • Rooflights • Roof windows		

Relevant standards

There are over 200 standards relating to doors. A selected few are shown here.

BS EN ISO 10077-2:2017	Thermal performance of windows, doors and shutters. Calculation of thermal transmittance. Numerical method for frames.
BS 8213-4:2016	Windows and doors. Code of practice for the survey and installation of windows and external doorsets.
ASTM E2112 - 18	Standard Practice for Installation of Exterior Windows, Doors and Skylights.

5.3.10 Insulation, fire stopping and fire protection

Board, sheet, quilt, sprayed, loose fill or foamed insulation and fire protection.

Type	Description	Requirements	Quality issues
Insulation	• Insulation types: Mineral fibre; Plastic beads; Cellulose fibre; Hemp fibre, cork, wood fibre boards, sheep's wool; Expanding foam; Other type of blown or injected material.	• Scientific calculations to insulation selection but other peripheral factors that will affect installation need to be considered. • Requirement to adhere to manufacturers' instructions and general best practice/ workmanship. • To recognise that laboratory-based performance tests may not relate well to the installation of insulation on site.	• Facility / building may not be suitable for certain types of insulation. • Wet insulation can encourage mould growth. • Compliance with manufacturer's installation specifications. • Contractor's skill and experience. • Risk of cold bridging and thermal bypass.
Fire stops	• Fire stop types: Horizontal; Vertical; Raking; Stepped; Curved.		

Relevant standards

Approved Document Part C Energy Efficiency and Historic Buildings - Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings	Site preparation and resistance to contaminates and moisture.
ASTM C1859 - 17a	Standard Practice for Determination of Thermal Resistance of Loose-Fill Building Insulation in Side Wall Applications.
BS 7457:1994	Specification for polyurethane (PUR) foam systems suitable for stabilization and thermal insulation of cavity walls with masonry or concrete inner and outer leaves.
BS 7456:1991	Code of practice for stabilisation and thermal insulation of cavity walls (with masonry or concrete inner and outer leaves) by filling with polyurethane (PUR) foam systems.
BS 5617:1985	Specification for urea-formaldehyde (UF) foam systems suitable for thermal insulation of cavity walls with masonry or concrete inner and outer leaves.
BS 5618:1985	Code of practice for thermal insulation of cavity walls (with masonry or concrete inner and outer leaves) by filling with urea-formaldehyde (UF) foam systems.
BS ISO 17738-1:2017	Thermal insulation products. Exterior insulation and finish systems. Materials and systems.
BS EN ISO 10140-1:2016	Acoustics. Laboratory measurement of sound insulation of building elements. Application rules for specific products.
BS EN 14064-1:2010	Thermal insulation products for buildings. In-situ formed loose-fill mineral wool (MW) products. Specification for the loose-fill products before installation.
BS EN 14316-2:2007	Thermal insulation products for buildings. In-situ thermal insulation formed from expanded perlite (EP) products. Specification for the installed products.

BS EN 14317-2:2007	Thermal insulation products for buildings. In-situ thermal insulation formed from exfoliated vermiculite (EV) products. Specification for the installed products.
BS EN 14317-1:2004	Thermal insulation products for buildings. In-situ thermal insulation formed from exfoliated vermiculite (EV) products. Specification for bonded and loose-fill products before installation.
BS EN 13499:2003	Thermal insulation products for buildings. External thermal insulation composite systems (ETICS) based on expanded polystyrene. Specification.
BS EN 13500:2003	Thermal insulation products for buildings. External thermal insulation composite systems (ETICS) based on mineral wool. Specification.
BS EN 14318-1:2013	Thermal insulating products for buildings. In-situ formed dispensed rigid polyurethane (PUR) and polyisocyanurate (PIR) foam products. Specification for the rigid foam dispensed system before installation.
BS EN 14315-1:2013	Thermal insulating products for buildings. In-situ formed sprayed rigid polyurethane (PUR) and polyisocyanurate (PIR) foam products. Specification for the rigid foam spray system before installation.
BS EN 16883:2017	Conservation of cultural heritage – Guidelines for improving the energy performance of historic buildings.

5.4 Internal finishes

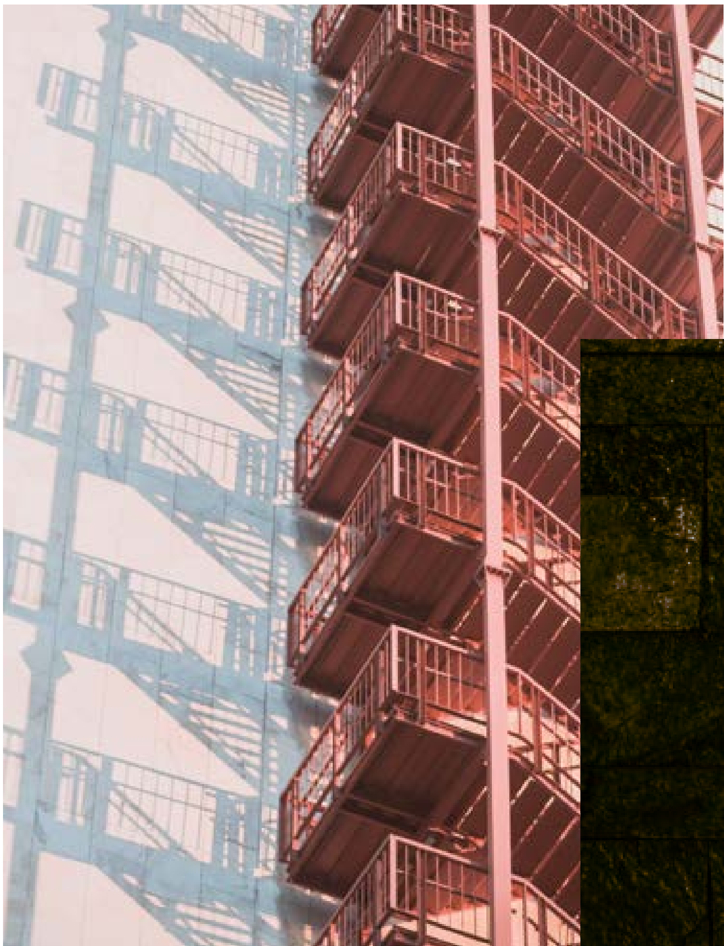
5.4.1 Proprietary linings and partitions

Metal framed systems to walls and ceilings and drylining and partitioning systems to walls and ceilings

Type	Description	Requirements	Quality issues
Plasterboard	• Used in drylining / Drywall. • Good fire-resistant characteristics. • Easy to install. • It is durable and is relatively easy to maintain. • Specialised forms of Drywall: Fire-rated; Moisture resistant; Sound board; Lead-lined; Flexible; Blue.	• Needs to be cut to size unless a standard size is specified. • Cavity barriers in a stud wall or partition, or provided around openings may be formed of gypsum-based boards at least 12mm thick. • Should be stored in dry conditions.	• Badly finished joints. • Installed against damp walls / ceilings. • Check a vapour barrier has been fitted where necessary.
Studwork		• A load bearing stud wall should be no higher than 2.25m. • Cavity barriers in a stud wall or partition, or provided around openings may be formed of: a. steel at least 0.5mm thick b. timber at least 38mm thick c. polythene-sleeved mineral wool, or mineral wool slab, in either case under compression when installed in the cavity d. calcium silicate, cement-based or gypsum-based boards at least 12mm thick	• Poor dimensional quality.

Relevant standards

Approved Document A	Structure.
Approved Document B	Fire safety.
BS EN 14209:2017	Preformed plasterboard cornices. Definitions, requirements and test methods.
BS EN 14353:2017	Metal beads and feature profiles for use with gypsum plasterboards. Definitions, requirements and test methods.
BS EN 13915:2017	Prefabricated gypsum plasterboard panels with a cellular paperboard core. Definitions, requirements and test methods.
BS EN 14566:2008+A1:2009	Mechanical fasteners for gypsum plasterboard systems. Definitions, requirements and test methods.
BS EN 520:2004+A1:2009	Gypsum plasterboards. Definitions, requirements and test methods.
BS 8212:1995	Code of practice for dry lining and partitioning using gypsum plasterboard.
BS 8000-8:1994	Workmanship on building sites. Code of practice for plasterboard partitions and dry linings.
BS EN 14496:2017	Gypsum based adhesives for thermal / acoustic insulation composite panels and gypsum boards. Definitions, requirements and test methods.
BS EN 14195:2014	Metal framing components for gypsum board systems. Definitions, requirements and test methods.
BS EN 14190:2014	Gypsum board products from reprocessing. Definitions, requirements and test methods.
BS EN 13963:2014	Jointing materials for gypsum boards. Definitions, requirements and test methods.
BS EN 13950:2014	Gypsum board thermal / acoustic insulation composite panels. Definitions, requirements and test methods.



5.4.2 Floor, wall, ceiling and roof finishing

Type	Description	Requirements	Quality issues
Finishes	• Finishes can protect a component / system from impact, water, frost, corrosion, abrasion, and so on, and / or can be decorative. • Calcium sulfate based levelling screeds. • Cement based levelling / wearing screeds. • Decorative papers / fabrics. • Edge fixed carpeting. • Insulation with rendered finish. • Intumescent coatings for fire protection of steelwork. • Mastic asphalt flooring / floor underlays. • Metal lathing / anchored mesh reinforcement for plastered / rendered coatings. • Painting / clear finishing. • Plastered / rendered / roughcast coatings. • Resin flooring. • Rubber / plastics / cork / lino / carpet tiling / sheeting. • Sprayed monolithic coatings. • Stone / concrete / quarry / ceramic tiling / mosaic. • Terrazzo tiling / in-situ terrazzo. • Wood block / composition block / mosaic parquet flooring.	• Should be applied to suitable substrates. • Flooring - the floor must be fit for purpose and should have adequate stiffness to support the tiles and adhesive or other covering. • Where building services pass through the screed, allowance should be made for thermal movement between the screed and the service, and so that service pipes can resist chemical attack from the screed. • The paint and stain systems specified should be compatible with any timber preservatives and timber species used. • Bond and moisture protection are important considerations.	• Uneven substrate / finish • Poor joints • Integration with other components / systems. • Integrity of covering existing services. • Quality of materials used.

Relevant standards

NHBC Standards Part 8	Services and internal finishing.
ASTM C1516 - 05(2017)	Standard Practice for Application of Direct-Applied Exterior Finish Systems.
BS EN 15286:2013	Agglomerated stone. Slabs and tiles for wall finishes (internal and external).
ASTM C1528/C1528M - 18	Standard Guide for Selection of Dimension Stone.
ASTM F2419 - 11(2017)	Standard Practice for Installation of Thick Poured Gypsum Concrete Underlayments and Preparation of the Surface for Resilient Flooring.
ASTM E2404 - 17	Standard Practice for Specimen Preparation and Mounting of Textile, Paper or Polymeric (Including Vinyl) and Wood Wall or Ceiling Coverings, Facings and Veneers, to Assess Surface Burning Characteristics.
ASTM C1288 - 17	Standard Specification for Fiber-Cement Interior Substrate Sheets.

BS 8203:2017	Code of practice for installation of resilient floor coverings.
PD CEN/TR 17024:2017	Natural stones. Guidance for use of natural stones.
BS EN 13914-1:2016	Design, preparation and application of external rendering and internal plastering. External rendering.
BS EN 1468:2012	Natural stone. Rough slabs. Requirements.
BS EN 15388:2008	Agglomerated stone. Slabs and cut-to-size products for vanity and kitchen tops.
BS 8481:2006	Design, preparation and application of internal gypsum, cement, cement and lime plastering systems. Specification.
BS 6150:2006+A1:2014	Painting of buildings. Code of practice.
BS 8204-4:2004+A1:2011	Screeds, bases and in-situ floorings. Cementitious terrazzo wearing surfaces. Code of practice.
BS 8204-5:2004+A1:2011	Screeds, bases and in-situ floorings. Mastic asphalt underlays and wearing surfaces. Code of practice.
BS 8425:2003	Code of practice for installation of laminate floor coverings.
BS EN 235:2002	Wallcoverings. Vocabulary and symbols.
BS 5325:2001	Installation of textile floor coverings. Code of practice.
BS EN 259-1:2001	Wallcoverings in roll form. Heavy duty wallcoverings. Specifications.
BS EN 259-2:2001	Wallcoverings in roll form. Heavy duty wallcoverings. Determination of impact resistance.
BS EN 12781:2001	Wallcoverings. Specification for cork panels.
BS EN 13085:2001	Wallcoverings. Specification for cork rolls.
BS EN 12956:1999	Wallcoverings in roll form. Determination of dimensions, straightness, spongeability and washability.
BS EN 12149:1998	Wallcoverings in roll form. Determination of migration of heavy metals and certain other elements, of vinyl chloride monomer and of formaldehyde release.
BS EN 234:1997	Wallcoverings in roll form. Specification for wallcoverings for subsequent decoration.
BS EN 266:1992	Specification for textile wallcoverings.

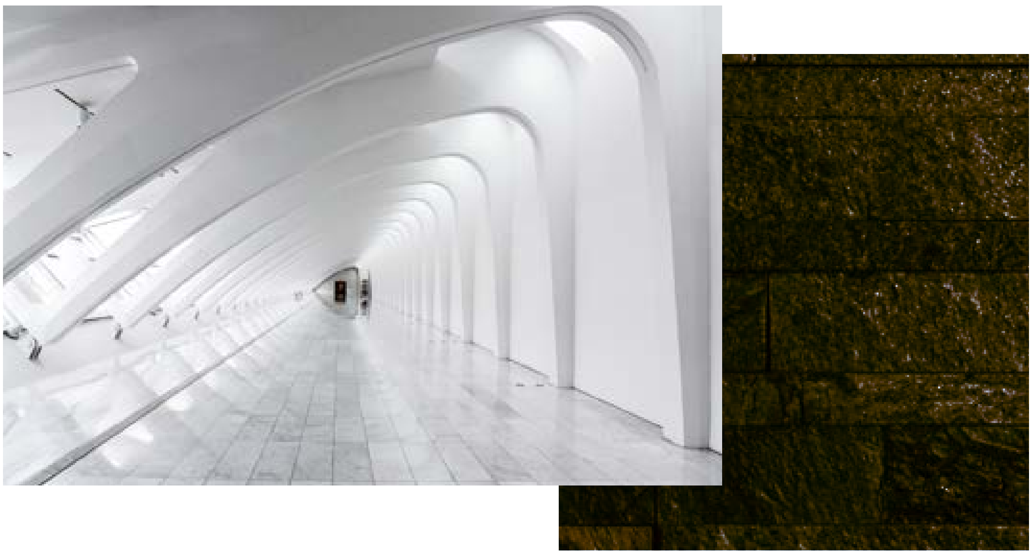
5.4.3 Suspended ceilings

Type	Description	Requirements	Quality issues
Suspended ceiling (or dropped ceiling)	• A suspended ceiling can provide a clean, smooth finish to the internal ceiling of a room, whilst hiding electrical wires, pipework and other services. • Suspended ceilings are hung from a bracket fixed to the underside of the floor slab supporting a series of interlocking metal sections that form a grid into which panels such as ceiling tiles can be fitted.	• Need to be carefully designed in order to integrate with partition systems; tiles, grids and partitions should intersect neatly. • Partitions may stop at the underside of the suspended ceiling to provide maximum ease of installation and flexibility, or may run through the ceiling to the underside of the floor slab.	• Integration with other components / systems. • Integrity of covering existing services. • Quality of materials used.

Type (cont.)	Description (cont.)	Requirements (cont.)	Quality issues (cont.)
Suspended ceiling (or dropped ceiling)	• Beam systems are also available, in which tiles are laid between parallel beams rather than a grid, and there are a wide range of different grid profiles and tile edge details that can be used to allow the grid to be exposed, flush, recessed or concealed. • A suspended ceiling can contribute to the overall fire resistance of a floor/ ceiling assembly. • Acoustic-absorbing materials can be used. • The void can also be used as an air 'plenum', in which the void itself forms a pressurised 'duct' to supply air or extract it from the occupied space below.	• Where partitions do not run through the ceiling void, care must be taken to ensure that a flanking path is not created for the transmission of sound between adjacent spaces or for the spread of fire. • Acoustic insulation or fire separation can be provided in the ceiling void if necessary.	

Relevant standards

ASTM C1858 - 17a	Standard Practice for Design, Construction, and Material Requirements for Direct Hung Suspended T-bar Type Ceiling Systems Intended to Receive Gypsum Panel Products in Areas Subject to Earthquake Ground Motions.
BS EN 14246:2006	Gypsum elements for suspended ceilings. Definitions, requirements and test methods.
ASTM E580/E580M - 17	Standard Practice for Installation of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Subject to Earthquake Ground Motions.
ASTM C754 - 18	Standard Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products.
BS EN ISO 10848-2:2017	Acoustics. Laboratory and field measurement of flanking transmission for airborne, impact and building service equipment sound between adjoining rooms. Application to Type B elements when the junction has a small influence.



5.4.4 Glazing

Windows are one of the most important elements of a building's thermal envelope; providing aesthetics, letting in light, helping control sound, and serving as a means of natural ventilation.

Type	Description	Requirements	Quality issues
Glazing	• Glass or transparent or translucent plastic sheet used in windows, doors, skylights, or curtain walls. • Glass can be tinted to reject sunlight, coated in a translucent film to increase energy efficiency, or be self-cleaning. • There are many varied forms of glass: etched; textured; frosted; stained or tinted glass for privacy or aesthetic purposes. • There are a number of different ways to manufacture glass: float; annealed; heat-strengthened; fully-tempered; heat-soaked tempered; laminated; wired; low emissivity, and; self-cleaning.	• Energy ratings of the glass based on an A+ to G scale. • Efficiency depends upon all the components: the frame; the glazing, and; the air tightness of the finished window. • Building Regulations have certain requirements for glazing in terms of safety, means of escape and ventilation. • Part K of the Building Regulations require that where 'building work' is carried out in a critical location involving glass, that safety glazing is used. Safety glazing is required. • In any glazed area within a window below 800 mm from floor level. • In any glazed area within a window that is 300 mm or less from a door and up to 1500 mm from floor level. • Within any glazed door up to 1500 mm from floor level.	• Professionalism / competency of installers. • Appropriate glazing type.

Relevant standards

Approved Document K	Protection from falling, collision and impact.
BS EN ISO 52022-3:2017	Energy performance of buildings. Thermal, solar and daylight properties of building components and elements. Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing.
BS EN ISO 52022-1:2017	Energy performance of buildings. Thermal, solar and daylight properties of building components and elements. Simplified calculation method of the solar and daylight characteristics for solar protection devices combined with glazing.
ASTM E2358 - 17	Standard Specification for Performance of Glazing in Permanent Railing Systems, Guards, and Balustrades.
BS EN 12758:2011	Glass in building. Glazing and airborne sound insulation. Product descriptions and determination of properties.
BS EN 15269-20:2009	Extended application of test results for fire resistance and / or smoke control for door, shutter and openable window assemblies, including their elements of building hardware. Smoke control for hinged and pivoted steel, timber and metal framed glazed doorsets
BS 5516-1:2004	Patent glazing and sloping glazing for buildings. Code of practice for design and installation of sloping and vertical patent glazing.

BS 5516-2:2004	Patent glazing and sloping glazing for buildings. Code of practice for sloping glazing.
BS 8000-7:1990	Workmanship on building sites. Code of practice for glazing.
BS EN 1279-2:2018	Glass in building. Insulating glass units. Long term test method and requirements for moisture penetration.
BS EN ISO 10077-2:2017	Thermal performance of windows, doors and shutters. Calculation of thermal transmittance. Numerical method for frames.
BS EN ISO 12631:2017	Thermal performance of curtain walling. Calculation of thermal transmittance.
BS EN ISO 10077-1:2017	Thermal performance of windows, doors and shutters. Calculation of thermal transmittance. General.
BS EN 1634-1:2014+A1:2018	Fire resistance and smoke control tests for door and shutter assemblies, openable windows and elements of building hardware. Fire resistance test for door and shutter assemblies and openable windows.
BS ISO 18292:2011	Energy performance of fenestration systems for residential buildings. Calculation procedure.
BS 6375-3:2009+A1:2013	Performance of windows and doors. Classification for additional performance characteristics and guidance on selection and specification.
BS 7412:2007	Specification for windows and doorsets made from unplasticized polyvinyl chloride (PVC-U) extruded hollow profiles.
BS EN ISO 12567-2:2005	Thermal performance of windows and doors. Determination of thermal transmittance by hot box method. Roof windows and other projecting windows.
BS 8213-1:2004	Windows doors and rooflights. Design for safety in use and during cleaning of windows, including door-height windows and roof windows. Code of practice.
BS EN ISO 14438:2002	Glass in building. Determination of energy balance value. Calculation method.
BS EN 12898:2001	Glass in building. Determination of the emissivity.
BS 6206:1981	Specification for impact performance requirements for flat safety glass and safety plastics for use in buildings.

5.5 Fittings, furnishings and equipment

Type	Description	Requirements	Quality issues
Fittings, Furnishings and Equipment (FFE)	• The procurement of furniture, fixtures and equipment. • These might be procured separately to the main construction contract (or elements of them), especially by clients with procurement systems in place for procuring FFE, e.g. schools, universities, or hospitals. • A fixture is defined as an asset that is installed or otherwise fixed in or to a building or land so as to become part of that building or land in law.	• The building work or any services required for FFE needs to be identified in the contract. For example, fume cupboards or drinks stations that require M&E connections; built-in equipment not requiring services; stand-alone FFE that require power, air, water, drainage or telecommunication connections; stand-alone FFE that do not require services. • Programming and planning of the FFE procurement and installation is important. • Relevant manuals / instructions need to be available at handover. • Should meet codes and standards for properties such as flammability, toxicity, and slip resistance.	• Adequate maintenance plan in place. • Contractor's skill and experience. • Quality of materials. • M&E parts of the installation need to meet safety and quality standards.

Relevant standards

The Furniture and Furnishings (Fire Safety) Regulations 1988 (as amended in 1989, 1993 and 2010) set levels of fire resistance for domestic upholstered furniture, furnishings and other products containing upholstery.

Many of the standards under other headings in the above sections apply here, relating to individual materials.

5.6 Services

Type	Description	Requirements	Quality issues
M&E	• Mechanical systems can include elements of infrastructure, plant and machinery, tool and components, heating and ventilation and so on. • Electrical systems might include, power supply and distribution, telecommunications, computing instrumentation, control systems and so on.	• M&E requirements need to be identified and planned for at an early stage to avoid clashes / rework. • Need to meet standards of energy efficiency, safety, emissions and sustainability. • Work on electrical equipment, machinery or installations should be: thoroughly planned; carried out by competent people using suitable equipment and work standards.	• Adequate maintenance plan in place. • Contractor's qualifications, skill and experience. • Inadequate detailing in specifications. • Conformance to safety / quality standards. • Poor understanding of interaction between components. • Not meeting predicted performance levels. • Miscalculation of power loads.

Relevant standards

Electrical Equipment (Safety) Regulations 1994
The Electricity at Work Act 1989.

BS 7671:2001	Requirements for electrical installations, IEE Wiring Regulations
Building Regulations Part L	Conservation of fuel and power.

Many of the standards under other headings in the above sections apply here, relating to individual materials.

5.7 External works

All items outside the building footprint but inside the site boundary, encompassing wastewater and surface water drains, supply of utilities (e.g. gas, electricity and cabled services), footpaths, and access for vehicles including car parks and hard standings to be found in the vicinity of buildings.

Type	Description	Requirements	Quality issues
Fencing and other external 'furniture'	• Fencing, railings and walls. • Bollards. • Street furniture. • Shelters.	• Security. • Aesthetics. • Boundary treatment. • To provide shelter.	• Poor quality materials. • Conformance to standards. • Appropriate maintenance plan.
Soft landscaping	• Plants, shrubs, trees, groundcover. • Irrigation systems.	• To provide a soft boundary, good visual appearance, ameliorate carbon emissions and provide a natural filtration system.	• Poor quality materials. • Appropriate maintenance plan. • Soil, geology and hydrology issues.
Drainage below ground (foul drainage)	• A system to carry foul (waste) water from appliances within a building to: a public sewer; a private sewer; a septic tank, or: a cesspool. • Subsoil water. • Surface water. • Foul and soil water.	• To provide a safe and effective way to transport foul and soil water into appropriate systems.	• Incorrect sizing of pipework. • Incorrect pipe gradient. • Incorrect backfill. • Cross-connections or Miss-connections. • Poor drainage design. • Poor construction.
Drainage above ground (sanitary pipework)	• Waste pipes and fittings connected to sanitary appliances (WCs, hand basins, kitchen sinks, baths and shower) and services equipment (dishwashers and industrial washing machines).	• To provide adequate drainage in accordance with requirements of water companies.	• Inadequate sealing of fire stopping at service penetrations. • Safety devices not provided on unvented hot water systems. • Incorrect pipework and couplings used and mismatched. • Lack of support throughout the full height of the soil stack. • Vertical stacks terminating into 92° junctions. • Pipework connections into soil stacks. • Opposed connections into the base of soil stacks. • Inadequate falls to horizontal pipework. • Missing sound insulation to pipework.

Type (cont.)	Description (cont.)	Requirements (cont.)	Quality issues (cont.)
Site works	• Roads, paths, pavings and surfacings.	• To provide safe and appropriate works for workers, pedestrians and vehicles. • Cycle routes. • Sightlines, radii, gradients to meet standards. • Access for emergency services. • Dropped kerbs, tactile paving and facilities at signalled controlled crossings, lighting, signage as detailed in the Disability Rights Commission's Code of Practice - 'Rights of Access: Goods, Facilities, Services and Premises'.	• Uneven surfaces. • Poor / lack of maintenance plan. • Poor programme planning leading to untimely construction of road systems.

Relevant standards

Approved Document H	Drainage and waste disposal.

There are a huge number of relevant standards, for example just the paving-related ones are numerous:

BS EN 1338	Concrete Paving Blocks.
BS EN 1339	Concrete Paving Flags.
BS EN 1340	Concrete Kerb Units.
BS EN 1341	Natural Stone Flag Paving.
BS EN 1342	Natural Stone Setts.
BS EN 1343	Natural Stone Kerbs.
BS EN 1344	Clay Pavers.
BS 7533-1:2001	Guide for the structural design of heavy duty pavements constructed of clay or concrete pavers.
BS 7533-2:2001	Guide for the structural design of lightly trafficked pavements.
BS 7533-3:2005+A1:2009	Code of practice for laying precast concrete paving blocks and clay pavers for flexible pavements.
BS 7533-4:2006	Code of practice for the construction of pavements of precast concrete flags or natural stone slabs.
BS 7533-6:1999	Code of practice for laying natural stone, precast concrete and clay kerb units.
BS 7533-7:2010	Code of practice for the construction of pavements of natural stone paving units and cobbles, and rigid construction with concrete block paving.
BS 7533-8:2003	Guide for the structural design of lightly trafficked pavements of precast concrete flags and natural stone slabs.
BS 7533-9:2010	Code of practice for the construction of rigid pavements of clay pavers.
BS 7533-10:2010	Guide for the structural design of trafficked pavements constructed of natural stone setts and bound construction with concrete paving blocks.
BS 7533-11:2003	Code of practice for the opening, maintenance and reinstatement of pavements of concrete, clay and natural stone.
BS 7533-12:2006	Guide to the structural design of trafficked pavements constructed on a bound base using concrete paving flags and natural stone slabs.
BS 7533-13:2009	Guide for the design of permeable pavements constructed with concrete paving blocks and flags, natural stone slabs and setts and clay pavers.

Section Six
Appendices

Appendix One

6.0 Glossary

Quality Management (QM) is the generic term that embodies all aspects of managing quality, including quality assurance.

Quality Management System (QMS) establishes, documents and maintains a quality system as a means of ensuring that the project conforms to specified requirements.

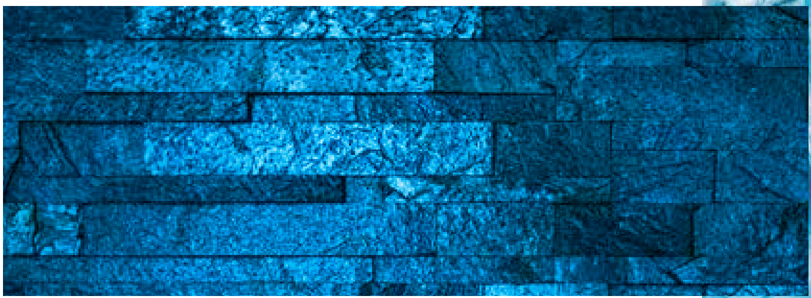
Quality Policy defines the objectives for quality and the organisation's commitment to quality. The quality policy shall be relevant to the organisational goals and the expectations and needs of its customers. The organisation must ensure that the policy is understood, implemented, and maintained at all levels of the organisation.

Quality Plan is the implementation plan for delivering a quality product devised from the QMS.

Quality Assurance (QA) is a way of preventing mistakes and defects in manufactured products and avoiding problems when delivering solutions or services to customers. "QA is part of quality management focused on providing confidence that quality requirements will be fulfilled" (ISO 9000). QA is an evaluation to indicate needed corrective responses; the act of guiding a process in which variability is attributable to a constant system of chance causes.

Quality Control (QC) is "a part of quality management focused on fulfilling quality requirements. The system used to maintain standards is by testing a sample of the output against the specification." (ISO 9000)

Construction Licence classifications (Licence issued by Ministry of Land, Infrastructure, Transport and Tourism (MILT) of Japan). The 28 classifications are: General Civil Engineering, General Building, Carpentry, Plastering, Scaffolding, Earthwork and Concrete, Masonry, Roofing, Electrical, Plumbing, Tile, Brick and Block, Steel Structure, Reinforcement Steel, Paving, Dredging, Sheet Metal, Glazing, Painting, Waterproofing, Interior Finishing, Machine and Equipment Installation, Heat Insulation, Telecommunication, Landscaping and Gardening, Well Drilling, Fittings, Water and Sewerage, Fire Protection Facilities, Sanitation Facilities.



Appendix Two

7.0 ISO standards related to quality management

- ISO 9001 is the international standard that specifies requirements for a quality management system (QMS). Organisations use the standard to demonstrate the ability to consistently provide products and services that meet customer and regulatory requirements.
- The ISO 9000 series has different standards, related to quality and quality management which are described as follows:
- ISO 9000:2015 (2015) clarifies the basic quality-related concepts and provides guidelines selecting and using a variety of standards.
- ISO 9001:2015 (2015) covers the requirements of quality management systems. Companies must meet the requirements of ISO 9001 in order to obtain quality certification. Many large and medium-sized contractors and subcontractors have passed the ISO 9001 certification.
- ISO 9004:2018 (2018) – provides guidelines for improving and enhancing organisations' ability to achieve continued success.
- ISO 19011:2018 (2018) provides internal and external audit guidelines for quality management systems.
- ISO 10006:2017 provides guidelines for the application of quality management. The concepts of quality management and quality management systems in project are addressed.

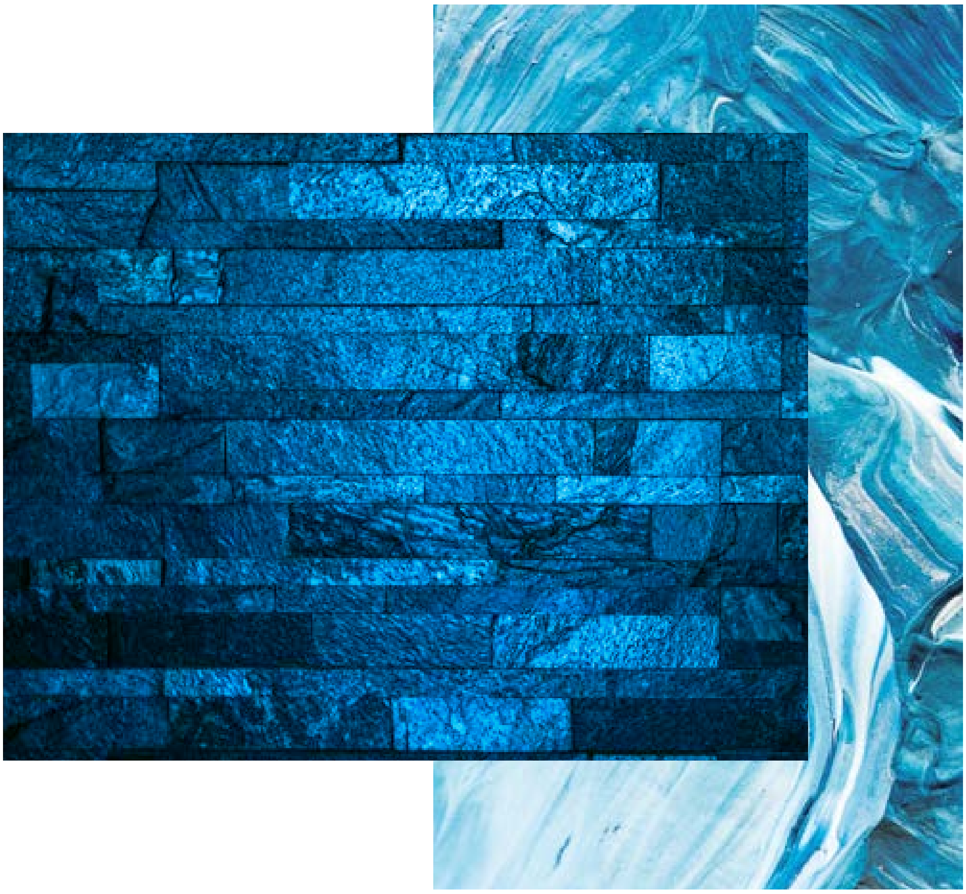
Appendix Three

8.0 Correlation between the clauses in ISO 10005:2018 and ISO 9001:2015

Clause in this document	Heading	Clause in ISO 9001:2015
Clause 5	Development of a quality plan	4.1, 4.2, 6.1, 7.1.1, 8.1
Clause 6	Content of the quality plan	7, 8, 9, 10
6.1	General	8.1
6.2	Scope of the quality plan	4.3, 8.2
6.3	Quality plan inputs	8.1, 8.2, 8.6, 9.1.1
6.4	Quality objectives	6.2, 9.1.1
6.5	Quality plan responsibilites	5.3
6.6	Control of documented information	7.5
6.7	Resources	7.1
6.7.1	Provision of resources	7.1.1
6.7.2	Materials, products & services	8.2
6.7.3	People	7.1.2, 7.2, 7.3
6.7.4	Infrastructure and environment for the operation of processes	7.1.3, 7.1.4
6.7.5	Monitoring and measuring resources	7.1.5
6.8	Interested party communication	7.4, 8.2.1, 8.4.3
6.9	Design and development	8.3
6.9.1	Design and development process	8.3.1 to 8.3.5
6.9.2	Control of design and development changes	8.3.6
6.10	Externally provided processes, products and services	8.4
6.11	Production and service provision	8.5.1, 8.5.5, 8.5.6
6.12	Identification and traceability	8.5.2
6.13	Property belonging to customers or external providers	8.5.3

6.14	Preservation of outputs	8.5.4
6.15	Control of nonconforming outputs	8.7, 10.2
6.16	Monitoring and measurement	8.1, 8.6, 9.1
6.17	Audits	9.2
Clause 7	Operation and control of the quality plan	7, 8, 9, 10
7.1	Review and acceptance of the quality plan	7.5.2, 8.1, 8.2.1, 8.2.3
7.2	Implementation and monitoring of the quality plan	7.2, 7.3, 7.5.3, 8.1, 9.1.3, 9.2
7.3	Revision of the quality plan	7.5.3, 8.2.4, 8.5.6
7.4	Feedback and improvement	9.3, 10.1
NOTE	Correspondence between clauses does not imply conformity	

Source: BS 10005:2018 Quality management — Guidelines for quality plans. 3rd Edition



Appendix Four

9.0 Standards relating to masonry

ASTM C476 - 18	Standard Specification for Grout for Masonry.
ASTM C91/C91M - 18	Standard Specification for Masonry Cement.
ASTM C1660 - 10(2018)	Standard Specification for Thin-bed Mortar for Autoclaved Aerated Concrete (AAC) Masonry.
ASTM C140/C140M - 17b	Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units.
ASTM C144 - 17	Standard Specification for Aggregate for Masonry Mortar.
ASTM C404 - 11(2017)	Standard Specification for Aggregates for Masonry Grout.
ASTM C1691 - 11(2017)	Standard Specification for Unreinforced Autoclaved Aerated Concrete (AAC) Masonry Units.
ASTM C1384 - 17	Standard Specification for Admixtures for Masonry Mortars.
ASTM C62 - 17	Standard Specification for Building Brick (Solid Masonry Units Made From Clay or Shale).
ASTM C652 - 17a	Standard Specification for Hollow Brick (Hollow Masonry Units Made From Clay or Shale).
ASTM C216 - 17a	Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale).
ASTM E3121/E3121M - 17	Standard Test Methods for Field Testing of Anchors in Concrete or Masonry.
ASTM C1623 - 17a	Standard Specification for Manufactured Concrete Masonry Lintels.
ASTM C1670/C1670M - 17	Standard Specification for Adhered Manufactured Stone Masonry Veneer Units.
ASTM C331/C331M - 17	Standard Specification for Lightweight Aggregates for Concrete Masonry Units.
ASTM C1400 - 11(2017)	Standard Guide for Reduction of Efflorescence Potential in New Masonry Walls.
ASTM C279 - 17	Standard Specification for Chemical-Resistant Masonry Units.
ASTM C1780 - 17	Standard Practice for Installation Methods for Adhered Manufactured Stone Masonry Veneer.
ASTM C129 - 17	Standard Specification for Nonloadbearing Concrete Masonry Units.
ASTM C1713 - 17	Standard Specification for Mortars for the Repair of Historic Masonry.
ASTM C139 - 17	Standard Specification for Concrete Masonry Units for Construction of Catch Basins and Manholes.
ASTM C780 - 17	Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry.

ASTM E3069 - 17	Standard Guide for Evaluation and Rehabilitation of Mass Masonry Walls for Changes to Thermal and Moisture Properties of the Wall.
BS EN 459	Building lime.
BS EN 998-1:2016	Specification for mortar for masonry. Rendering and plastering mortar.
BS EN 998-2:2016	Specification for mortar for masonry. Masonry mortar.
BS EN 1015-12:2016	Methods of test for mortar for masonry. Determination of adhesive strength of hardened rendering and plastering mortars on substrates.
BS EN 1052-2:2016	Methods of test for masonry. Determination of flexural strength.
BS EN 772-5:2016	Methods of test for masonry units. Determination of the active soluble salts content of clay masonry units.
ASTM A951/A951M - 16e1	Standard Specification for Steel Wire for Masonry Joint Reinforcement.
ASTM C1713 - 15	Standard Specification for Mortars for the Repair of Historic Masonry.
BS EN 16572:2015	Conservation of cultural heritage. Glossary of technical terms concerning mortars for masonry, renders and plasters used in cultural heritage.
BS 8103-2:2013	Structural design of low-rise buildings. Code of practice for masonry walls for housing.
BS EN 845-1:2013+A1:2016	Specification for ancillary components for masonry. Wall ties, tension straps, hangers and brackets.
BS EN 845-2:2013+A1:2016	Specification for ancillary components for masonry. Lintels.
BS 8539:2012	Code of practice for the selection and installation of post-installed anchors in concrete and masonry.
BS EN 846-14:2012	Methods of test for ancillary components for masonry. Determination of the initial shear strength between the prefabricated part of a composite lintel and the masonry above it.
BS EN 846-5:2012	Methods of test for ancillary components for masonry. Determination of tensile and compressive load capacity and load displacement characteristics of wall ties (couplet test).
BS EN 846-6:2012	Methods of test for ancillary components for masonry. Determination of tensile and compressive load capacity and load displacement characteristics of wall ties (single end test).
BS EN 846-7:2012	Methods of test for ancillary components for masonry. Determination of shear load capacity and load displacement characteristics of shear ties and slip ties (couplet test for mortar joint connections).
BS EN 771-2:2011+A1:2015	Specification for masonry units. Calcium silicate masonry units.
BS EN 771-1:2011+A1:2015	Specification for masonry units. Clay masonry units.
BS EN 771-3:2011+A1:2015	Specification for masonry units. Aggregate concrete masonry units (Dense and lightweight aggregates).
BS EN 771-4:2011+A1:2015	Specification for masonry units. Autoclaved aerated concrete masonry units.
BS EN 771-5:2011+A1:2015	Specification for masonry units. Manufactured stone masonry units.
BS EN 771-6:2011+A1:2015	Specification for masonry units. Natural stone masonry units.

BS EN 413-1:2011	Masonry cement. Composition, specifications and conformity criteria.
BS EN 772-1:2011+A1:2015	Methods of test for masonry units. Determination of compressive strength.
BS EN 772-11:2011	Methods of test for masonry units. Determination of water absorption of aggregate concrete, autoclaved aerated concrete, manufactured stone and natural stone masonry units due to capillary action and the initial rate of water absorption of clay masonry units.
BS EN 772-16:2011	Methods of test for masonry units. Determination of dimensions.
BS EN 772-18:2011	Methods of test for masonry units. Determination of freeze-thaw resistance of calcium silicate masonry units.
BS EN 772-21:2011	Methods of test for masonry units. Determination of water absorption of clay and calcium silicate masonry units by cold water absorption.
ASTM C144 - 11	Standard Specification for Aggregate for Masonry Mortar.
BS EN 934-3:2009+A1:2012	Admixtures for concrete, mortar and grout. Admixtures for masonry mortar. Definitions, requirements, conformity and marking and labelling.
BS 6073-2:2008	Precast concrete masonry units. Guide for specifying precast concrete masonry units.
BS EN 1062-3:2008	Paints and varnishes. Coating materials and coating systems for exterior masonry and concrete. Determination of liquid water permeability.
NA to BS EN 1996-1-2:2005	UK National Annex to Eurocode 6. Design of masonry structures. General rules. Structural fire design.
NA to BS EN 1996-2:2006	UK National Annex to Eurocode 6. Design of masonry structures. Design considerations, selection of materials and execution of masonry.
NA to BS EN 1996-1-1:2005+A1:2012	UK National Annex to Eurocode 6. Design of masonry structures. General rules for reinforced and unreinforced masonry structures.
BS EN 1996-2:2006	Eurocode 6. Design of masonry structures. Design considerations, selection of materials and execution of masonry.
BS EN 1996-3:2006	Eurocode 6. Design of masonry structures. Simplified calculation methods for unreinforced masonry structures.
BS EN 1996-1-1:2005+A1:2012	Eurocode 6. Design of masonry structures. General rules for reinforced and unreinforced masonry structures.
BS EN 1052-5:2005	Methods of test for masonry. Determination of bond strength by the bond wrench method.
BS EN 1996-1-2:2005	Eurocode 6. Design of masonry structures. General rules. Structural fire design.
BS EN 1015-18:2002	Methods of test for mortar for masonry. Determination of water absorption coefficient due to capillary action of hardened mortar.
BS EN 1015-21:2002	Methods of test for mortar for masonry. Determination of the compatibility of one-coat rendering mortars with substrates.
BS EN 1052-3:2002	Methods of test for masonry. Determination of initial shear strength.
BS EN 1062-6:2002	Paints and varnishes. Coating materials and coating systems for exterior masonry and concrete. Determination of carbon dioxide permeability.
BS EN 772-14:2002	Methods of test for masonry units. Determination of moisture movement of aggregate concrete and manufactured stone masonry units.
BS EN 846-4:2002	Methods of test for ancillary components for masonry. Determination of load capacity and load-deflection characteristics of straps.
BS EN 846-13:2001	Methods of test for ancillary components for masonry. Determination of resistance to impact, abrasion and corrosion of organic coatings.

BS EN 772-6:2001	Methods of test for masonry units. Determination of bending tensile strength of aggregate concrete masonry units.
BS 8000-3:2001	Workmanship on building sites. Code of practice for masonry.
BS EN 772-15:2000	Methods of test for masonry units. Determination of water vapour permeability of autoclaved aerated concrete masonry units.
BS EN 1015-17:2000	Methods of test for mortar for masonry. Determination of water-soluble chloride content of fresh mortars.
BS EN 1052-4:2000	Methods of test for masonry. Determination of shear strength including damp proof course.
BS EN 12418:2000+A1:2009	Masonry and stone cutting-off machines for job site. Safety.
BS EN 772-13:2000	Methods of test for masonry units. Determination of net and gross dry density of masonry units (except for natural stone).
BS EN 772-19:2000	Methods of test for masonry units. Determination of moisture expansion of large horizontally perforated clay masonry units.
BS EN 772-20:2000	Methods of test for masonry units. Determination of flatness of faces of masonry units.
BS EN 846-10:2000	Methods of test for ancillary components for masonry. Determination of load capacity and load deflection characteristics of brackets.
BS EN 846-11:2000	Methods of test for ancillary components for masonry. Determination of dimensions and bow of lintels.
BS EN 846-2:2000	Methods of test for ancillary components for masonry. Determination of bond strength of prefabricated bed joint reinforcement in mortar joints.
BS EN 846-3:2000	Methods of test for ancillary components for masonry. Determination of shear load capacity of welds in prefabricated bed joint reinforcement.
BS EN 846-8:2000	Methods of test for ancillary components for masonry. Determination of load capacity and load-deflection characteristics of joist hangers.
ISO 9652-5:2000	Masonry. Vocabulary.
BS EN 1015-10:1999	Methods of test for mortar for masonry. Determination of dry bulk density of hardened mortar.
BS EN 1015-11:1999	Methods of test for mortar for masonry. Determination of flexural and compressive strength of hardened mortar.
BS EN 1015-9:1999	Methods of test for mortar for masonry. Determination of workable life and correction time of fresh mortar.
BS EN 772-10:1999	Methods of test for masonry units. Determination of moisture content of calcium silicate and autoclaved aerated concrete units.
BS EN 1015-3:1999	Methods of test for mortar for masonry. Determination of consistence of fresh mortar (by flow table).
BS EN 1015-1:1999	Methods of test for mortar for masonry. Determination of particle size distribution (by sieve analysis).
BS EN 1015-2:1999	Methods of test for mortar for masonry. Bulk sampling of mortars and preparation of test mortars.
BS EN 1015-4:1999	Methods of test for mortar for masonry. Determination of consistence of fresh mortar (by plunger penetration).
BS EN 1015-6:1999	Methods of test for mortar for masonry. Determination of bulk density of fresh mortar.
BS EN 1015-7:1999	Methods of test for mortar for masonry. Determination of air content of fresh mortar.
BS EN 1052-1:1999	Methods of test for masonry. Determination of compressive strength.

BS EN 1015-19:1999	Methods of test for mortar for masonry. Determination of water vapour permeability of hardened rendering and plastering mortars.
BS EN 772-2:1998	Methods of test for masonry units. Determination of percentage area of voids in masonry units (by paper indentation).
BS EN 772-3:1998	Methods of test for masonry units. Determination of net volume and percentage of voids of clay masonry units by hydrostatic weighing.
BS EN 772-4:1998	Methods of test for masonry units. Determination of real and bulk density and of total and open porosity for natural stone masonry units.
BS EN 772-7:1998	Methods of test for masonry units. Determination of water absorption of clay masonry damp proof course units by boiling in water.
BS EN 772-9:1998	Methods of test for masonry units. Determination of volume and percentage of voids and net volume of clay and calcium silicate masonry units by sand filling.
BS EN 1934:1998	Thermal performance of buildings. Determination of thermal resistance by hot box method using heat flow meter. Masonry.
BS 7457:1994	Specification for polyurethane (PUR) foam systems suitable for stabilization and thermal insulation of cavity walls with masonry or concrete inner and outer leaves.
BS 5080-1:1993	Structural fixings in concrete and masonry. Method of test for tensile loading.
BS 7456:1991	Code of practice for stabilization and thermal insulation of cavity walls (with masonry or concrete inner and outer leaves) by filling with polyurethane (PUR) foam systems.
BS 8215:1991	Code of practice for design and installation of damp-proof courses in masonry construction.
BS 5080-2:1986	Structural fixings in concrete and masonry. Method for determination of resistance to loading in shear.
BS 5617:1985	Specification for urea-formaldehyde (UF) foam systems suitable for thermal insulation of cavity walls with masonry or concrete inner and outer leaves.
BS 5618:1985	Code of practice for thermal insulation of cavity walls (with masonry or concrete inner and outer leaves) by filling with urea-formaldehyde (UF) foam systems.
BS 6515:1984	Specification for polyethylene damp-proof courses for masonry.
BS 6398:1983	Specification for bitumen damp-proof courses for masonry.
ASTM C1019 - 18	Standard Test Method for Sampling and Testing Grout.
ASTM C1586 - 17	Standard Guide for Quality Assurance of Mortars.
ASTM C1088 - 17	Standard Specification for Thin Veneer Brick Units Made From Clay or Shale.
ASTM C1364 - 17	Standard Specification for Architectural Cast Stone.
ASTM C1372 - 17	Standard Specification for Dry-Cast Segmental Retaining Wall Units.
ASTM C1272 - 17	Standard Specification for Heavy Vehicular Paving Brick.
ASTM C212 - 17	Standard Specification for Structural Clay Facing Tile.
ASTM C980 - 17	Standard Specification for Industrial Chimney Lining Brick.
ASTM C55 - 17	Standard Specification for Concrete Building Brick.
ASTM C34 - 17	Standard Specification for Structural Clay Loadbearing Wall Tile.

ASTM C1634 - 17	Standard Specification for Concrete Facing Brick.
ASTM C73 - 17	Standard Specification for Calcium Silicate Brick (Sand-Lime Brick).
BS EN 13914-1:2016	Design, preparation and application of external rendering and internal plastering. External rendering.
BS 8002:2015	Code of practice for earth retaining structures.
BS ISO 13033:2013	Bases for design of structures. Loads, forces and other actions. Seismic actions on non-structural components for building applications.
BS EN 14617-1:2013	Agglomerated stone. Test methods. Determination of apparent density and water absorption.
BS EN 14617-13:2013	Agglomerated stone. Test methods. Determination of electrical resistivity.
BS 8221-1:2012	Code of practice for cleaning and surface repair of buildings. Cleaning of natural stone, brick, terracotta and concrete.
BS EN 14617-10:2012	Agglomerated stone. Test methods. Determination of chemical resistance.
BS EN 14617-12:2012	Agglomerate stone. Test methods. Determination of dimensional stability.
BS EN 14617-4:2012	Agglomerated stone. Test methods. Determination of the abrasion resistance.
BS EN 14617-5:2012	Agglomerated stone. Test methods. Determination of freeze and thaw resistance.
BS EN 14617-6:2012	Agglomerated stone. Test methods. Determination of thermal shock resistance.
BS 8103-1:2011	Structural design of low-rise buildings. Code of practice for stability, site investigation, foundations, precast concrete floors and ground floor slabs for housing.
BS 8298-3:2010	Code of practice for the design and installation of natural stone cladding and lining. Stone-faced pre-cast concrete cladding systems.
BS EN 1998-3:2005	Eurocode 8. Design of structures for earthquake resistance. Assessment and retrofitting of buildings.
BS EN 14617-11:2005	Agglomerated stone. Test methods. Determination of linear thermal expansion coefficient.
BS EN 14617-15:2005	Agglomerated stone. Test methods. Determination of compressive strength.
BS EN 14617-16:2005	Agglomerated stone. Test methods. Determination of dimensions, geometric characteristics and surface quality of modular tiles.
BS EN 14617-9:2005	Agglomerated stone. Test methods. Determination of impact resistance.
BS EN 13139:2002	Aggregates for mortar.
ISO 15709:2002	Masonry. Part 4: Test methods.
BS 8221-2:2000	Code of practice for cleaning and surface repair of buildings. Surface repair of natural stones, brick and terracotta.
BS 8298:1994	Code of practice for design and installation of natural stone cladding and lining.
BS 5977-1:1981	Lintels. Method for assessment of load.
BS 1199 and 1200:1976	Specifications for building sands from natural sources.

Notes

Notes

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