QUALITY FEATURES IN STRUCTURAL ELEMENTS

4.1 STEEL STRUCTURES
4.2 PRECAST CONCRETE ELEMENTS
The physical properties of steel e.g. its durability, flexibility and strength, lend itself to many varied uses, one of which is in construction. The choice of structural steelwork system as an alternative to reinforced concrete structures has many advantages. Steel can be easily formed and joined and its strength to weight ratio is the highest among common building materials. This makes it lightweight and yet strong as compared to concrete structures. Steel can also be recycled and is a good alternative building material that contributes to sustainable construction. The following section highlights the benefits of using steel and its contribution to building quality.
4.0 QUALITY FEATURES IN STRUCTURAL ELEMENTS

4.1 STEEL STRUCTURES

4.1.1 Buildings with accurate tolerances

Steel is dimensionally more stable, unlike other materials that shrink, expand, warp and twist with age. This leads to less settlement cracks or squeaking floors that require costly repairs. Steel buildings can be built with better tolerances and quality and are longer lasting.

Fig. 4.3- Steel is strong, lightweight and buildings can be built with better tolerances.

4.1.2 Architectural aesthetics

The use of steel structures permits designers to experiment with many architectural forms and artistic expressions which are more difficult to build in conventional concrete framed structures. With steel, more challenging and creative designs can now be considered leading to buildings that are aesthetically distinctive and of high build quality.

Fig. 4.4 - Complicated structures using steel: A dome shaped auditorium (left) and curved skylight entrance (right).
4.1.3 Quality standards for steel buildings

Stringent requirements are imposed to ensure quality in steelwork construction. Though there can be no meaningful comparison between standards for steel and reinforced concrete construction, the tolerance requirements in CONQUAS are higher for the former. These result in buildings built to more exact requirements and hence better build quality.

Detailed requirements on quality assurance for steelwork, especially for welding, bolting and protection, are based on established international or national standards e.g. the National Productivity & Quality Specifications (NPQS), British National Steelwork Specifications, etc. To ensure quality construction, the stringent requirements are required to be met during fabrication and installation.

![Fig. 4.5 - Steel structure office building with curtain wall envelope: More space without obstructive internal columns and beams.](image1)

![Fig. 4.6 - Quality internal finishing can be achieved in a steel structure building.](image2)
4.0 QUALITY FEATURES IN STRUCTURAL ELEMENTS

4.1 STEEL STRUCTURES

- Quality checks in steel construction

The images below show typical inspections carried out during fabrication and installation of steel structures.

Fig. 4.7a - Material inspection.

Fig. 4.7b - Fit-up inspection.

Fig. 4.7c - Welding inspection.

Fig. 4.7d - Dimension checks.

Fig. 4.7e - During erection checks.

Fig. 4.7f - Post erection checks.

Fig. 4.7 - Stringent process checks during fabrication and installation ensure safety and quality in structural steelwork.
4.1.4 Faster construction

Structural steel is lighter than other framing materials. This leads to less heavy foundations which reduces both the time and cost of construction. Productivity is therefore improved and projects can be completed faster.

Another example is the use of metal decking for floor construction. Once the steel framings are in place, installation of metal decking can be completed rapidly. Reinforcement design for such slab is simple and straightforward, and prefabricated reinforcement can be used. As a result, the works can be completed earlier and there is better assurance of concrete quality because of the system of construction.

Fig. 4.8 - Metal decking floor: Faster construction and better concrete quality.
4.1.5 Dry and clean construction

Steelwork enhances productivity because of its predominantly dry construction method. External wall cladding systems (aluminium and glass) are used in conjunction with steelwork and this contributes to rapid construction progress. The stringent tolerances specified for steel framing and cladding systems contribute to good quality finishing.

Scaffolding can be avoided as installation of external wall systems can be carried out by tower cranes and maximizing its use. This scaffold-free method saves on construction costs, makes the site tidier and reduces housekeeping efforts on site.

Fig 4.9 - Scaffold free construction saves time and costs and is less cluttered.
4.0 QUALITY FEATURES IN STRUCTURAL ELEMENTS
4.1 STEEL STRUCTURES

4.1.6 An example of steel structure construction process

A case example of a commercial project employing steel structure construction is Fusionopolis. It comprises 3 uniquely designed steel structure towers each 24 storeys high. The major construction works were completed within 25 months.

The fabrication of the steelwork is done offsite at factory locations where there is skilled labour and the environment and systems are well controlled and conducive for quality output. This is an essential consideration when deciding on the use of steel in design or the choice of steel fabricators.

Flexibility in design and the construction method allow many activities to be carried out concurrently e.g. erection of trusses, metal deck flooring, curtain wall installation and other finishing work, etc, and this leads to faster completion of the project.

FUSIONOPOLIS – PROJECT PROGRESS

Fig. 4.10a
2nd month: Core wall construction.

Fig. 4.10b
4th month: Core wall construction.

Fig. 4.10c
7th Month: Core wall and steelwork framing.

Fig. 4.10d
11th Month: Core wall and steelwork framing.

Fig. 4.10e
18th Month - Framing, curtain wall and finishes.

Fig. 4.10f
23rd Month - Curtain wall and finishes.
4.1.7 Challenges in structural steelwork

While there are many advantages in choosing structural steelwork systems, there are also issues particular to steelwork that need to be considered. The safe erection of structural steelwork requires concerted effort by many parties during its fabrication and installation. Instances of poor quality welds and other shortcomings if not detected and rectified early can compromise structural safety. This can lead to serious consequences especially in long span structures.

Proper fabrication and installation require specialized knowledge, appropriate equipment and resources and a comprehensive inspection and testing regime. To enhance safety of the installation, the steelworks should be carried out by accredited steel fabricators, checked by qualified site supervisors and tested by Independent Testing Agencies.

It is necessary to give attention to fire and corrosion protection measures as steelworks exhibit particular vulnerability in these aspects. The local fire safety standards and codes should be complied with. Finally, the higher cost of steelworks construction should be balanced against the expected benefits.
4.0 QUALITY FEATURES IN STRUCTURAL ELEMENTS
4.2 PRECAST CONCRETE ELEMENTS

Precast concrete technology is widely used in the industry to support buildability and improve construction productivity. Such technology also results in better quality workmanship as the precast elements are manufactured under controlled factory conditions before its installation at site. BCA has many publications that provide information on good practices for precasting e.g. ‘Structural Precast Concrete Handbook’, ‘Buildable Solutions for Landed Residential Development’ and ‘Buildable Solutions for High-Rise Residential Development’. This section highlights the better workmanship quality that can be achieved when precast technology is integrated in the design of the building.

Fig. 4.11 - Precast technology is integrated in the design to improve quality.

4.2.1 Dimensional accuracy

Precast concrete elements achieve superior dimensional tolerances and finished concrete surfaces compared to cast in-situ concrete. This is largely due to the favourable environment in factories where these elements are produced and the stringent quality control measures taken to meet specified or national standards during production.

Fig. 4.12 - Precast elements are produced in a controlled environment.

Fig. 4.13 - Dimensional tolerances and finished surfaces are generally superior.
Better dimensional control results in precise openings for window frame installation.

Fig. 4.14 - Window frame installed by dry method using backer rod and sealant.

Better dimensional control results in precise openings for window frame installation.

Fig. 4.15 - Controlled gap with proper filling ensures better water-tightness at window/wall joints.

In traditional brickwork construction, it is a challenge to ensure consistency in forming openings for windows and door frames. Any excessive gaps or improper filling of such gaps may lead to water seepage at the frame and wall joints.

Fig. 4.16 - Difficult to ensure accurate openings with on-site operations.

Fig. 4.17 - Improper filling may lead to water seepage at frame/wall joints.
4.2.2 Better quality critical elements

Precasting is often the solution to quality problems when there are difficulties in executing the particular type of work in-situ. Staircases, refuse chutes and lift walls are examples where formwork, rebar placement and provisions for openings often pose considerable challenges leading to grout loss, inconsistent joints, surface damages and imperfections. Using pre-cast elements for these components, such defects can be reduced.

Fig. 4.18 - Precast staircases: Better dimensional accuracy and quality finish.
4.0 QUALITY FEATURES IN STRUCTURAL ELEMENTS
4.2 PRECAST CONCRETE ELEMENTS

4.2.3 Better quality architectural elements

Precast architectural elements such as facades, fascia and gable end walls, parapets, sunshades, secondary roofing panels, bay windows, etc can be used instead of wet in-situ works to achieve correct dimensional tolerances and better quality finish.

Fig. 4.19 - Architectural precast elements reduce wet works and enhance finish quality.
4.0 QUALITY FEATURES IN STRUCTURAL ELEMENTS

4.2 PRECAST CONCRETE ELEMENTS

4.2.4 All-in-one components

In total precast concrete systems, architectural elements can also perform their structural functions. It therefore reduces the number of construction operations and trades. Combining architectural and structural members lead to better organized design and construction. The following precast elements can be combined for greater efficiency and quality:

- Columns
- Shear wall
- Facade walls
- Air-conditioning ledge
- Sun shades
- Bay window
- Beams
- Planter box
- Pipe-duct
- Staircase
- Household shelter
- Refuse chute

Fig. 4.20 - Total precast system results in better build quality building.
4.2.5 Design flexibility

Precast components can be custom made to match design requirements. Complex shapes, sizes and specific technical requirements can be easily fabricated in precast plant. Without such prefabrication, complex designs may be difficult to build or the desired quality hard to achieve on-site using conventional construction. Precasting allows greater design flexibility and repeated use of similar shapes and sizes lead to better economy.

![Fig. 4.21 - Complex shapes and elements can be fabricated and installed without compromising quality.](image1)

4.2.6 Speed and Productivity

Traditional concrete construction involves many trades such as formwork, rebar and concreting. These activities have to be carefully planned and co-ordinated in a non-conducive site environment which affects the speed of construction and quality of output. In contrast, precasting is carried out in controlled factory environment leading to ease of production and better quality output.

![Fig. 4.22 - Precast construction is less labour-intensive, faster and more productive.](image2)
4.0 QUALITY FEATURES IN STRUCTURAL ELEMENTS
4.2 PRECAST CONCRETE ELEMENTS

4.2.7 Better quality external wall

Alignment, verticality and surface finish of external elements are critical areas in building facade. Factory made precast wall panels require minimal surface preparation before final finish. Scaffolding is generally not required for the finishing works. This makes the construction site tidier and the works can be carried out faster, apart from savings in scaffolding cost. Typical quality problems in traditional plastered external walls such as hollowness, plaster waviness and cracks can be avoided when precast external facade system is used.

Fig. 4.23 - No scaffolding and plastering required for final finish of precast facade.

Fig. 4.24 - Traditional formwork construction: Untidy scaffolding and uncertain build quality outcome.
4.2.8 Challenges in precast installation

To reap the full benefits of using pre-cast elements, it is important to ensure that pre-cast elements are installed properly. Results from CONQUAS assessments show that despite the expected better finish surfaces, cracks and damages are frequent non-compliances for precast elements. This is often the result of damage to the components during transportation, lifting and installation.

![Cracks and damages](image)

Fig. 4.25 - Cracks and damages: Result of damage during transportation, lifting and installation.

Attention and planning are needed at the design and execution stage to prevent such damages. Provision should be made for lifting and handling devices within the pre-cast elements. The capacity of lifting equipment, gears, rigging arrangement, weight of precast elements, concrete strength and expertise of the installers are to be considered during transportation, lifting and installation. This will ensure the benefits of using pre-cast elements are not negated during final installation.

4.2.9 Optimizing design and use of recycled concrete aggregates (RCA) in precast elements

The use of precast concrete elements should incorporate sustainable development practices. This is in line with trends to optimize the use of natural resources and products and materials that are environmentally friendly. Recycled concrete aggregates (RCA) can be used to replace natural aggregates in non-structural components e.g. non-structural precast internal partition walls. This will reduce the depletion of natural resources by turning wastes into resources through reuse and recycling.

Where it is not possible to use such alternative materials e.g. in structural precast concrete components, the design should be optimized to achieve the most efficient sizes and reduced concrete usage.