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Supported by SCOT CTC

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Civil TC Chairperson

Date: 30 March 2023

PCM Reference : **PCM for Perform Structures and Buildings Engineering 240-53573084**

SCOT Study Committee Number/Name : **SC10F/Structural Design**

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EXECUTIVE SUMMARY

Constructability Assessment Guideline is conducted in conjunction with Engineering Design Reviews to identify potential constructability problems with designs and to optimise the design with regards to construction. Considering constructability within earlier stages of a project will allow for the identification and implementation of necessary corrective measures to mitigate problems which may negatively impact on the construction works and/or place potential restrictions on the construction.

1. INTRODUCTION

A constructability assessment is the process of identifying potential problems with, and optimising on, the constructability of a design, or the construction methodology/sequencing, as early as possible in the project development to take corrective action and minimise the negative impact. The assessment aims to recognise difficulties prior to the commencement of construction activities, to reduce or prevent error, delays and cost overruns.

It can be seen as; the extent to which a design of a facility provides for ease of construction, yet meets the overall requirements of that facility

A constructability assessment allows the design team to study and become aware of every facet and intricate detail of the construction of a design. A properly conducted constructability assessment will identify potential construction difficulties and allows the construction methodology to be considered during the design phase of the project.

A constructability assessment will be beneficial to a project from a cost, time, quality and safety perspective; thereby adding value to a project. A constructability assessment is a more efficient method of solving potential construction related problems as opposed to realising construction constraints during the execution phase of a project.

2. SUPPORTING CLAUSES

2.1 SCOPE

This document provides the reader with a guideline for the execution of a constructability assessment for new builds and modifications to existing plants.

2.1.1 Purpose

The purpose of this constructability assessment guideline is to ensure the project is constructible, while bearing in mind time, cost, quality, risk and safety. These reviews are applicable to both Brownfield and Greenfield projects.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited divisions.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] ISO 9001 Quality Management Systems,
[2] Occupational Health and Safety Act, 1993 (Act 6 of 1993),
[3] Mine Health and Safety Act of 1996,
[4] Construction Regulations 2014,
[5] 240-53113685 : Design Review Procedure,
[6] 240-4332798 : Engineering Policy,
[7] 32-391: Integrated Risk Management Standard
[8] 240 – 53114002: Engineering Change Management Procedure
[9] 240 – 53114026: Project Engineering Management Procedure

2.2.2 Informative

[10] 240-56364545 : Structural Design and Engineering Standard

[11] 240-57127955 Geotechnical and Foundation Engineering Standard

2.3 DEFINITIONS

Definition	Description
Brownfield Project	A project that requires modification or refurbishments of an existing plant.
Constructability	The optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives i.e. the "buildability" in the construction industry. The ease and efficiency with which structures can be built.
Contractor	The party, who carries out all or part of the following activities; design, engineering, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility. The Principal may undertake all or part of the duties of the Contractor.
Demolished material	Material as a result of demolition activity.
Designer	The individual who defines the architecture, structural properties, components, interfaces, and other system components.
Detail design	The process of refining and expanding the preliminary design of a system or component to the extent that the design is sufficiently complete to be implemented.
Greenfield Project	A new build project that is not building on anything existing.
Indicative programme	Programme indicating sufficient detail to determine the major milestones and target dates that have to be achieved during the construction process. The indicative critical path for the construction phase of the project should also be highlighted within the programme.
Principal	The party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal Representative.
Shall	Indicates a requirement.
Should	Indicates a recommendation

2.3.1 Disclosure Classification

Controlled Disclosure: Controlled Disclosure to external parties (either enforced by law, or discretionary).

2.4 ABBREVIATIONS

Abbreviation	Description
CEP	Construction Execution Plan
CoE	Centre of Excellence
CTC	Civil Technical Committee
Gx	Eskom Generation
HVAC	Heating, Ventilation and Air Conditioning
LDE	Lead Design Engineer
PCM	Process Control Manual
SANS	South African National Standard
SCOT	Study Committee of Technology

Abbreviation	Description
TC	Technical Committee

2.5 ROLES AND RESPONSIBILITIES

2.5.1 The Role of Generation Engineering

The role of Generation Engineering is to apply its expertise, skill and processes to produce a high quality output of exceptional standards in line with the organisational requirement

2.5.2 The Lead Design Engineer

The roles of the Civil and Structural LDE and the Design and Specifications LDE are to ensure that this document is applied to all projects with Civil and Structural scope and must have input from LDE's from all disciplines involved.

The LDE is responsible for ensuring that a constructability assessment report is compiled.

2.5.3 Construction Management Department

The role of the Construction Management Department is:

a. To ensure their involvement and input throughout the project life cycle.

b. To participate in and provide input during the design and constructability reviews/assessments.

2.5.4 Constructability Assessment Signatories

Complied by: LDE/Engineer appointed by the EDWL

Functional Responsibility/Approved by: Senior Engineer/Chief Engineer

Authorised by: Corporate Specialist/Generation Engineering Senior Manager

2.6 PROCESS FOR MONITORING

This document will be updated periodically in response to developments in technology and experience, as well as the inspection findings/possible trends.

2.7 RELATED/SUPPORTING DOCUMENTS

[12] Appendix B: Constructability Checklist

[13] 240-161321889 Constructability Report Template

3. CONSTRUCTABILITY ASSESSMENT OVERVIEW

The primary purpose of a Constructability Assessment/Analysis is to ascertain whether it is technically feasible that a system, plant or facility can be constructed. It also serves to verify that the construction plan, if executed as specified, will not lead to unexpected delays, installation problems and construction costs higher than anticipated. Constructability issues do not only involve issues of "buildability" but also the sequence of construction and integration of systems in a logical sequence using standard sub-structures. During a constructability assessment, risks which may impact on the construction are identified. Mitigation measures or workable solutions are proposed to address the identified risks. Examples of adverse impacts include methods or means of construction that may escalate the cost of a project, cause disruptions to plant operations and negatively impact the planned construction period which may result in project delays. A further objective of the constructability assessment is to optimise construction costs and construction time.

Constructability considerations in design should be implemented as early as possible within the design progression. This ensures that any changes to the design are made during the early design phases of a project. Essentially, all parties involved in the design and construction phases should analyse and review constructability as an ongoing activity.

Regardless of project timeframe or size, the constructability review should commence as early as the client brief stage and run right through the design process stages and into construction. The Constructor must be involved in reviewing constructability during the design freeze before construction commences.

3.1 CONSTRUCTABILITY ASSESSMENT REQUIREMENTS

In order for a constructability assessment to be properly conducted, the following must be available:

- Access to site for inspection
- Geotechnical overview
- Environmental Impact Assessment
- Required Operational Capability Report (ROC) and Stakeholder Requirements Definition (SRD)
- Arrangement design, depicting layout and 3D model of plant (Brownfield or Greenfield) to identify clash detection and other potential hazards
- For modifications to existing plants, it is recommended that the 3D model be based on a 3D scan of the existing plant to ensure that all relevant information is captured.
- Power station representation (i.e. Gx), including maintenance personnel; this is of particular importance when a modification or refurbishment to existing infrastructure or plant is required.
- Survey showing underground utilities
- Feedback from previous similar projects, documented lessons learnt
- A mark-up of the area required for construction activities showing amongst others excavation perimeter and laydown area to enable the Engineer to assess interfaces with others.
- Involvement of construction personnel, in planning the construction execution sequence to reduce the potential of rework and schedule deviations. Apparent design or procurement savings may actually cost more because of the additional construction costs to implement the "less costly" approach
- The completed Constructability Report 240-161321889

3.2 BENEFITS

Benefits of a constructability assessment include:

- Identify whether a designed system or facility can be constructed, as intended
- Identification or proposal of alternative designs
- Identification of potential risk
- Identification of alternative methods of construction or prioritisation of activities

4. PROJECT CONSTRUCTABILITY ENHANCEMENT DURING PLANNING PHASE

a. It is advisable that all project stakeholders be involved in the constructability assessment. Alternative solutions proposed must include input from all relevant disciplines.

b. A project team comprising of experienced representatives of the client, stakeholders external to Engineering, and engineers must be established. This is done in order to consider constructability from the onset of the project and throughout all its phases.

c. To facilitate ease and efficiency of on-site operations, all major construction methods must be discussed ad analysed as early as possible to direct the design according to these methods.

d. Individuals with relevant construction knowledge and experience must be involved in design works at the early stages of project planning to identify construction considerations which pose potential risks. This will aid in developing a well thought out construction methodology that addresses the identified risks.

e. The construction methods and interfaces between multiple contracts must be taken into consideration when choosing the type and the number of contracts required for the execution of projects.

f. The Project Manager's indicative programme indicating key dates and possible milestones must be produced at tender stage and included in the tender documentation. This is even more important if it is planned to have more than one contractor working at the same time on the same site. The programme ensures that interface management between multiple contractors can be maintained, as individual schedules can be aligned to milestone dates.

g. Site layout and underground utilities must be studied carefully to ensure that the construction, operation, and maintenance proceeds efficiently, and to avoid any interference between the operations performed during these phases. Existing drawings must be verified to be a true representation of what is on site if required.

h. State requirements, as necessary, for the use of detection equipment for the location of underground services. This is of particular relevance to brownfield sites.

i. Impacts on existing structures in close proximity to the proposed construction must be assessed and measures or alternative solutions developed accordingly. In extreme cases the possibility of relocating the proposed plant or structure must be evaluated.

j. Impacts on current operations and the necessary measures that would have to be implemented to mitigate these impacts would have to be work-shopped and solutions or alternative construction methodologies developed.

5. CONSTRUCTION PLANNING CONSIDERATIONS

During the planning aspect of the Planning and Design Stage of a project, focus must be placed on the range of criteria, requirements or tolerances that are applicable to the project. This allows the planning process to be undertaken in a concise manner. The following are examples of these planning considerations:

5.1 SITE:

5.1.1 Geotechnical Considerations:

When assessing the location of the site for construction, it is advisable that a desktop study be carried out based on available historical data. A geotechnical investigation should be conducted to establish the relevant input parameters required for the civil engineering design of structures and footings. The site must be evaluated to determine whether the preferred founding method is practical or economical. The following points must be considered:

- What site restrictions prefer a piling solution?
- What impact (both financial and methodological) would large excavations have on construction activities or existing facility operations?

5.1.2 Environmental considerations:

An environmental impact assessment must be conducted based on the concept designs produced, and the following must be considered, but not limited to:

- Environmental Effects: effects on the natural environment including aesthetics, topography, vegetation and water resources. Effect of increased run-off, seepage and infiltration often the consequence of land clearing and deforestation.
- Socio-Environmental Effects: effects on the living environment such as noise, vibration, air and water pollution. Effect during construction including noise, vibrations, pollution, dumping of earth material, settlement, landslides and soil erosion

5.1.3 Structure Orientation

After selecting the site and all the analyses related to the location have been completed, consideration must be given to the location and orientation of structures and equipment by taking into consideration the following:

- The type of structures
- Construction access requirements,
- Construction Occupancy requirements,
- Drainage requirements during construction.
- Craneage Requirements

For example, an administration building should be orientated to take advantage of the natural vistas, micro-climates, natural drainage, natural lighting and topography.

5.1.4 Risks and Mitigations

If a Project Risk Register does not exist, a risk register with classification and proposed mitigations be established. The above considerations and associated risks shall be included in the risk register. A standard template should be used to capture the risks and mitigations. All identified risks shall be recorded and managed as per 32-391: Integrated Risk Management Standard [7]

5.2 STRUCTURAL DIMENSIONS (OR DIMENSIONS OF THE STRUCTURE)

Thought must be given to the size and scale of structures located in the area when determining the maximum height of the structure. There may also be statutory limitations that must also be considered with particular regard to the National Building Regulations. When considering building heights, one must also consider:

- Access heights, including maintenance operation
- Crawl beam heights
- Gantry crane heights
- Equipment heights
- HVAC ducts
- Small power and lighting
- Nearby Airports
- Building regulation limiting the construction height
- Clearance heights (eg: electrical servitudes)

5.3 STRUCTURE SETBACKS

The regulations of the various municipalities will dictate the minimum building line restrictions of a property relating to the positioning of any structure. This is also dependent on the type of structure and location.

5.4 EXCAVATIONS & ACCESS WAYS

5.4.1 Vehicular Access

Consideration on how vehicles will enter and exit the proposed site must be made taking into account i.e. access to minor and major roads. For example, where a building is located on a corner plot between a minor and a major road, access off the minor road is preferable. Right of way, road signs and traffic light considerations must be considered and authorisation obtained from the relevant local authority. Easy accessibility will minimise the chance of accidents, and save time in manoeuvring to arrive and leave the site. Proper planning is required to layout the roads leading from the nearest highway. The provision of internal access roads should be based on the operational conditions or requirements of the plant or facility. The relevant parties should be involved in the constructability assessments to provide the necessary input should there be risks or concerns raised about the location of these roads. Solutions tabled should meet with the approval of all parties.

5.4.2 Vehicular Access during construction

The placement of construction equipment such as tower cranes must be assessed such that primary and secondary access ways are not obstructed. In the event an access way is obstructed, the necessary traffic accommodation measures or detours should be assessed and implemented to suit construction activities. If a road is temporarily unavailable, road barricading equipment must be used to indicate closure of road. Internal access road closures must be authorised by the management of the facility. Similarly, any works impacting on municipal, provincial, or national roads must be authorised by the relevant authorities inclusive of any traffic accommodation measures. When considering vehicular access during construction, one must look at other active projects on site and the sharing of work space.

5.4.3 Pedestrian Access

Entrances and exits of a building must be designed so as to provide convenient access to parking areas, walk-ways and adjacent streets, with particular attention being given to the needs of the physically handicapped. The impact of construction activities on existing pedestrian accesses should be assessed and the necessary accommodation or safe making measures should be evaluated for implementation.

5.4.4 Excavations

The sub-surface information in a form of as-built drawings and/or utility survey scans must be obtained for all proposed excavation sites. The knowledge of the underground utilities is to assist with the most suited excavation site selection. In an event the excavation site has underground utilities, the proposed reroute of these utilities must form part of the design. NB**:** The underground utilities information will form part of the requirements for the excavation permits during the construction phase of a project.

Demolished material

Projects may require demolition of existing structures and infrastructure. The demolished material can be transported directly to a dump or temporarily stored on site and transported later to a waste disposal facility. In both cases; prior to storage or transport; the demolished material must be assessed to determine if the spoils are contaminated. If the materials are contaminated, storage on site is prohibited and the materials must be dumped in specialised dumps. The vicinity of existing dumps must be assessed and costs taken into account if demolished material must be transported off site.

5.5 SAFETY AND SECURITY

When performing a constructability assessment, one must assess the potential safety and security risks associated with a design. If a design does not adequately address these risks, this could lead to unsafe working conditions. Ultimately the design will have to be revisited and these risks addressed.

When considering safety in a design, one must also note safety issues when performing construction in confined spaces.

One must consider construction site safety and emergency requirements such as; emergency response routes, egress/evacuation routes, emergency staging areas, medical/first aid facilities. Emergency Response Plan (Fire Response, Medivac, Crisis, etc.).

5.6 SPACE CONSIDERATION FOR ON SITE TEMPORARY LAYDOWN AREA

During the planning phase it is important that the construction site layout is identified and defined taking into consideration working space, laydown areas, site offices, stores and workshops and any other facility required for the construction. If required, construction roads must also be studied and built prior the contractor taking possession of the site. If there are existing roads within the plant, it is then necessary to define the construction vehicle route.

The site layout will be studied and allocated by the client defining both the construction boundary and the laydown areas. The Contractor will propose a site layout plan which should fit within the boundaries. For safety and security reasons, the construction site and laydown area must be fenced.

Without a defined site layout the Contractor may refuse to work for safety and security reasons. The proposed laydown area site/s will require an environmental impact assessment. Preliminary desktop studies will be required to determine if an environmental impact will be triggered. Should there be any environmental risks then these should be addressed in the works information.

5.7 PROJECT CONSTRUCTABILITY ENHANCEMENT DURING DESIGN

At the outset of every design, after the evaluation of clients' needs and the installation site, the most appropriate construction option must be designed, namely onsite construction or a combination of onsite and modularized construction.

5.7.1 Modularisation and Prefabrication

The maximum amount of on-line construction and pre-work (prefabrication, preassembly, and modularization) should be accomplished to allow completion of work within the shorter construction Collectively known as pre-work, prefabrication, preassembly, and modularization are work execution strategies that have the potential to significantly reduce project duration, improve productivity, and reduce craft labour needs. Each of these pre-work methods will have various degrees of applicability during construction depending on the specific conditions of the project. Some pros and cons of using pre-work are listed as follows:

Pros

- Reduces schedule duration.
- Reduces field labour costs.
- Improves quality.
- Allows parallel path work, resulting in reduced schedule duration.
- Reduces schedule and safety risks caused by weather.
- Compensates for lack of skilled field labour.

Cons

- Increases design engineering time.
- Requires an accelerated design schedule.
- Requires increased emphasis on communication between Eskom, designer, supplier, and contractor.
- Increases quality control manpower for shop and field inspection and testing.
- Requires more complex rigging and lift plans.
- Allows less design flexibility (drives more standardization)
- Requires more complex material procurement, expediting, and logistics procedures.
- Requires a larger lay-down and fabrication area.

Careful planning and decision making are required to balance the degree of pre-work used against the additional expense caused by using it. It is not a matter of deciding if pre-work methods should be used on the project, but one of determining what degree of pre-work provides the best reduction in project cost, duration, and craft labour man-hours. Modularization of main OEM components by the supplier presents major material transport, storage, and setting challenges and will only be undertaken if site conditions and project drivers are favourable for, or dictate, its use. Decisions to modularize components will be made by the CM Team and discussed with the EPC package contractors during the early stages of conceptual design. Prefabrication and preassembly methods are less challenging and will be largely based on cost analysis. Decisions to incorporate prefabrication and preassembly into construction execution will be made later in the design stage of the project.

Carry out a structural and cost analysis study. This study should include, but not limited to:

a. Constructability, i.e. can the plant be constructed with modularised elements? If yes, then:

   i. The size and weight of the modular sections must be determined in relation to functionality, transportation, storage, crane capacity, erection etc.

   ii. The adoption of onsite workshops should be evaluated in order to eliminate road transportation costs and time, and to facilitate construction. The evaluation should include consideration of transportation of material and equipment to on-site workshops as well as electrical requirements.

b. For existing plants, a study needs to be conducted to ensure that the modularisation can be economically and structurally applied to the existing plant.

c. The constructability methodology must be reviewed to ensure that any construction concerns are met and that the scheduled sequence of module fabrication matches the preferred erection sequence on site.

6. STAGES OF CONSTRUCTION FOR CONSTRUCTION ON EXISTING PLANT

The constructability assessment for construction in an existing power plant needs to be broken down into three distinctive stages:

- Pre-outage stage – Any construction activities that will have no impact on the normal operation of the plant can be carried out during this stage;
- Outage stage - All construction activities that cannot be constructed whilst the plant is in operation;
- Post-outage stage - Any construction activities that will not impact on the normal operation of the plant.

In order to maximise time utilisation, construction must as far as possible be scheduled to take place in parallel activities, not neglecting safety of personnel.

7. INTERFACE WITH OTHER PROJECT PACKAGES

Interface management plays a significant role in construction management, hence all concurrent projects on the construction site must be considered in the Project Manager's indicative programme. This programme should be developed by studying how the other projects may affect each other, developing the correct interface between the various projects by studying how they are affected by other activities. An integration engineer or manager should be appointed to ensure that the various Contractors interface with each other as per the programme. As part of this constructability analysis, for work during outages, a preliminary schedule should be developed with all the relevant stakeholders to ensure integration of the stakeholders is considered and taken into account on the schedule to mitigate any delays that may arise (i.e. Lifting, rigging and cranes).

7.1 KEY POINTS THAT MUST BE CONSIDERED:

- The construction schedule to determine when will the interface occur
- The need for different contractors to be sharing a working area and the impact they may have on each other's activities. The works information/scope of work must ensure that each contractor working on the site are identifiable and has their working area clearly demarcated
- Every Contractor is responsible for his own safety file. It is the Employer's safety officer's/representative's responsibility to manage safety between the various contractors
- The effect of construction plant and equipment on other contractors working space and activities.

Interface events may impact the project negatively with regards to time, cost, quality and safety, thus effectively managing and tracking interfaces of the construction is necessary. In practice, clear communication via a collaboration meeting is a good approach for addressing interface issues.

Where interfaces exist with other construction packages, such should be well documented in all relevant interfacing Works Information/ Scope documents to clearly indicate to the various contractors that tie in points with others. A Terminal Point register and LOSS diagram is the tool used in Eskom to manage such interface points. The overall works need to be scheduled such that all Contractors do not impede on each other's Works including quality, health, safety and schedule. Managing these interfaces form an integral part of the constructability assessment and is based on the Contractors method statements and the construction schedule which are both managed by Project and Construction Management with input from Engineering. Such should be coordinated and reviewed to ensure that the interfacing Contractors do not hinder the Works of the other, nor affect existing plant, temporary works incl. cranes and contractor yards of Others.

Interfaces between subcontractors shall be managed by the main Contractor and are not required to be part of the Constructability assessment.

8. CONSTRUCTION PLANT AND EQUIPMENT

Depending on the nature of the works, all construction plant and equipment, necessary for the execution of the works, must be determined during the design phase. It must be assessed if the required construction plant and equipment are able to access the site of the construction activities.

It is also necessary to assess if a concrete batch plant is necessary or ready-mix concrete can be transported from commercial source. This should be based on the amount of concrete necessary for the construction, the availability of the commercial sources, and their distance from site. If both solutions are possible the economic study will determine which one to be adopted.

8.1 EXAMPLES OF PLANT AND EQUIPMENT THAT MUST BE CONSIDERED

8.1.1 Tower cranes

The following criteria must be taken into account in selecting and sizing of the cranes:

a. Boom length and Trolley travel

- The boom must be able to swing 360 degrees unless it is possible to secure the boom against wind force during standby.
- The crane hook must be able to reach all areas of the works without interference to the existing structures.

b. Boom height

- The height of the crane must be sufficient such that no interference to the existing structures occurs.
- An assessment must be performed to establish if more than one tower crane is required. In the event that multiple tower cranes are required, the boom heights of each individual tower crane must be staggered to allow for a 360-degree swing of the boom unless the option of securing the boom against wind is available.

c. Load capacity

- During design, if modularisation and preassembly for project elements are required, the weight of the element must be communicated to ensure the required crane capacity is available.

d. Tower Crane erection

- Sufficient space must be available for the erection of tower cranes. It must be assessed if it will be practical to erect the required tower crane(s) with the use of mobile cranes. Careful attention must be paid to congested areas.

8.1.2 Mobile crane

In the event it is not possible for a tower crane's boom to access a required working area, the use of a mobile crane may be utilised to supplement the tower crane. Ensure there are adequate access routes to the working areas and that there is sufficient space for the mobile crane to operate.

8.1.3 Other Typical site construction equipment

Apart from the cranes, other site construction equipment may cause congestion on site and must be considered when completing a constructability assessment. This equipment includes, but is not limited to:

- Scaffolding
- Forklifts
- General trucks
- Scrap low-bed trailers
- Cherry picker
- Bosun's chairs
- Lifting equipment
- Power handheld tools
- Welding & gas cutting equipment and machines.
- Support light delivery vans (LDV's)
- Piling equipment
- Excavation Plant
- Nicolas trailers

It must be noted that some of these equipment may belong to other contractors.

9. CONSTRUCTABILITY REVIEW PROCESS

9.1 PREPARATION FOR THE CONSTRUCTABILITY REVIEW

- Notice of the event should be given within the required time according to company/project policy
- The review team should include individuals with the relevant direct construction field experience
- The review team should include, or have access to, a project and/or company official that is authorised to approve decisions by the team, up to the anticipated level of impact
- In order for a constructability assessment to be properly conducted, the following must be available:
    - Explanation of the format, or agenda;
    - Access to site for inspection
    - Geotechnical overview
    - Environmental Impact Assessment
    - Required Operational Capability Report (ROC) and Stakeholder Requirements Definition (SRD)
    - Technical documentation, such as plans, design drawings, etc;
    - Arrangement design, depicting layout and 3D model of plant (Brownfield or Greenfield) to identify clash detection and other potential hazards
    - For modifications to existing plants, it is recommended that the 3D model be based on a 3D scan of the existing plant to ensure that all relevant information is captured.
    - Power station representation (i.e. Gx), including maintenance personnel; this is of particular importance when a modification or refurbishment to existing infrastructure or plant is required.
    - Survey showing underground utilities
    - The Constructability Report.
    - The Constructability Checklist.
    - The Construction Execution Plan
    - Feedback from previous similar projects, documented lessons learnt
    - Reports of corrective action from previous reviews; and
    - Roles to be played by members, e.g. chairman, secretary.

9.2 EXECUTION OF THE CONSTRUCTABILITY REVIEW

- A constructability review should minimise or eliminate potential change orders and schedule delays, during construction;
- The review should ascertain that construction documents are fully co-ordinated, complete and buildable;
- The review should endeavour to eliminate redundancy in quality control reviews, e.g. duplications at the different project participants, such as designers, constructors, licensing agencies and approval by local authorities; and
- The review procedure (and agenda) should allow sufficient flexibility to enable the team to handle identified problems with more serious impact than normally anticipated.

9.3 DOCUMENTATION OF THE CONSTRUCTABILITY REVIEW

- Important aspects of discussions must be documented for the duration of the review;
- All decisions and allocation of responsibilities for action must be documented;
- A Review Report should be prepared after the review to the desired/practical level of detail;
- Corrective actions should be listed and ranked in a separate document for prompt distribution to affected parties; and
- The review documentation should be placed under configuration control.

9.4 CORRECTIVE ACTION AFTER THE CONSTRUCTABILITY REVIEW

- Notice of corrective actions required and the nominated responsible individuals or parties should be given to all stakeholders and affected project team members;
- The execution of the corrective actions shall be included in all project management actions, plans, schedules, budgets and progress monitoring activities; and
- The results and progress shall be reported as input to follow up reviews.

10. REQUIREMENTS FOR CONTRACTORS

10.1 REQUIREMENTS

The Contractor shall have a structured process in place for constructability analysis, for the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve the Employer’s objectives. Qualified people with adequate skills in construction knowledge and experience are involved from the beginning of the project, to maximize the benefits of the constructability analysis. This process includes examining design options that minimize construction costs while maintaining standards of safety, security, quality, and schedule, and is initiated in the front end planning process.

The Contractor shall submit a Constructability Analysis Report based on his general Method Statement to the Engineer, for approval by the Engineer. The first submission of the report shall be submitted as part of the Contractor’s tender documents and shall clearly indicate how the Contractor takes into account interfaces with other Contractors, together with the Site and time constraints and rigging studies. This report clearly illustrates how the construction would be completed within the allowable timeframes and highlights the risks of meeting this requirement. The Contractor shall be required to plan his activities to avoid the following interface risks and any other risks relevant to the Works:

Interface issues arising from working in close proximity to Others

- Access to Site
- Material storage

- Delivery
- Other Works related risks

The report includes a mark-up of the area required for his construction activities showing amongst others excavation perimeter and laydown area to enable the Engineer to assess interfaces with others.

This report clearly illustrates the construction sequencing and durations for the completion of the Works within the contract period. The Contractor shall submit a risk assessment advising on his proposed approach and methodology to mitigate risks described above and any other risks which may impede successful execution of the Works.

The second submission of the Constructability Analysis shall further elaborate on the first submission and shall be submitted one week after design completion of the Works. This report shall be a revision on the first submission to take into account the Contractor’s final design and shall include consideration for modularised construction for faster construction durations. As part of this submission, the Contractor shall create an animation video which clearly shows the construction sequencing of the various parts of the Works.

Constructability reviews shall be performed during the 3D model reviews.

The Contractor shall complete and submit rigging studies prior to start of construction.

10.2 CONSTRUCTION EXECUTION PLAN (CEP)

As part of their contract requirements, each contractor will be required to submit a contract-specific CEP during the bid process, taking into consideration the various phases of the project (and demolition activities), that includes manpower plans, organization, construction equipment usage, material storage and handling, preparation of construction facilities and the means and methods the contractor intends to use in executing their work scope. This plan clearly illustrates how the Contractor accounts for the risks of this project, including the risk of not completing the construction within the allowable timeframe. The CEP is considered a “living” document and will be refined and expanded to cover the work scope as the project progresses through the design and construction phases. The CEP covers all aspects of the project construction work at the site and discusses the primary construction activities listed below:

- Mobilization plan.
- Temporary construction facilities (including accommodation).
- Site facilities (offices, workshops, storage, utilities, communications, and laydown).
- Manpower plan.
- Construction equipment schedule.
- CM staffing plan.
- Site administration.
- Material management (material receipt, inspection, storage plan and site traffic plan).
- Field engineering.
- Safety and Emergency Response Plan.
- Heavy Haul and Heavy Lift Plan
- Field Quality Assurance/Quality Control Plan
- Documentation control.
- Start-up, testing, and commissioning plan.
- Permanent staff training program.
- Industrial relations/community affairs.
- Site demobilization.

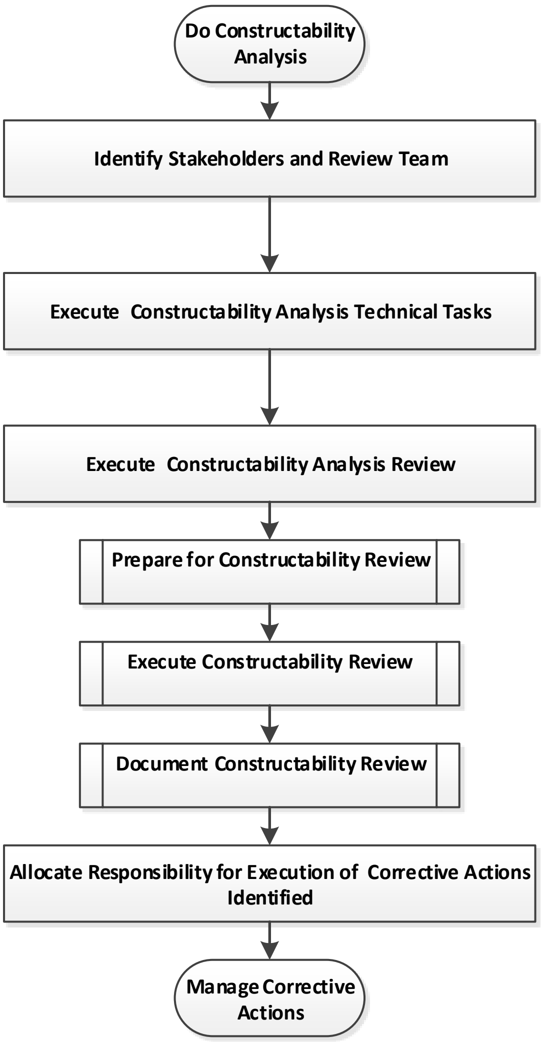

Figure 1: Process Flow Diagram

11. CHALLENGES OF CONSTRUCTABILITY ANALYSIS

11.1 LIMITATIONS

- Not all constructability problems will be identified if the review team does not include experienced individuals with specific domain knowledge;
- Where a project makes use of new technology or immature technology, there is a greater probability that potential constructability problems will go undetected until they appear during the actual construction task; and
- Despite the fact that constructability problems are identified at reviews, the solution often cannot be identified until construction and integration. This can happen due to uncertainty about interface designs that are still incomplete and have been scheduled for completion at a later stage due to the schedule being too constrained. It should be minuted at the review that the possible problems should be addressed when it occurs.

11.2 BARRIERS TO THE IMPLEMENTATION OF CONSTRUCTABILITY ANALYSIS

Research conducted by CII, involving 62 companies, has identified several barriers, which have been categorised and presented in the publication.

Some of these are:

- Complacency with the status quo;
- Reluctance to invest additional money and effort in the early stages of a project;
- Limitations of lump-sum and design-build contracts;
- Lack of construction experience in the design firm;
- The designers' perception that they already performed an analysis; and
- Lack of mutual respect between constructors and designers.

11.3 GENERAL CONSTRUCTABILITY ISSUES

"Many constructability issues occur as a result of a lack of communication between the project owner, architect or designer and the construction company before construction commences."

While the above statement about insufficient communication is very valid, there are also other common causes of constructability problems that often occur, despite the fact that they are elementary.

The real problem often lies in the degree of difficulty involved in detecting the problems. The following are examples of such issues:

- Spatial Interference, i.e. during construction, it is found that some components, structures and layouts are designed to occupy the same area on a site or space in a building. This mostly occurs due to communication problems between different design-groups but also frequently happens due to errors when two dimensional design drawings are interpreted. This is an example of a constructability problem that is increasingly mitigated by the use of three dimensional views, such as the ones produced by CAD systems and other computer resources like SmartPlant;
- Sequence of construction is an aspect that needs special attention because if the schedule calls for elements to be constructed early, due to manpower availability, those elements may prevent construction of elements scheduled for a later date. Completed structures may prevent access to space required for installation of other elements. Such sequencing problems, in the worst case, can lead to demolishing and rebuilding of elements;
- Where designers have utilised out-dated databases concerning interfaces with other elements, delays will occur and re-work may be required. The project must have an integrated information source system to capture the lessons learned throughout all project phases. This includes records of what went wrong, what went right, change orders, variations and commissioning reports. The construction team is required to provide a continuous stream of information into the database so that, when the next project is started, the constructability review is up-to-date.

12. AUTHORISATION

This document has been seen and accepted by:

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13. REVISIONS

Date	Rev.	Compiler	Remarks
March 2016	0.1	Avesh Haricharan	Draft
March 2016	0.2	Avesh Haricharan	Draft Document for Comments Review
April 2016	1	Avesh Haricharan	Final Document for Authorisation and Publication
November 2019	1.1	Kamir Lala	Draft Document for Comments Review Process
December 2020	2	Kamir Lala	Final Draft After Comments Review Process, Rev 2 never completed, signed and published
February 2023	2.1	T. Lesame	Draft Document for Comments Review Process
March 2023	2.2	T. Lesame	Final Draft after Comments Review Process
March 2023	3	T. Lesame	Final Rev 3 Document for Authorisation and Publication

14. DEVELOPMENT TEAM

The following people were involved in the development of this document:

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15. ACKNOWLEDGEMENTS

- K Radebe

APPENDIX A: CONSTRUCTABILITY IMPLEMENTATION ROADMAP

The constructability implementation roadmap, as defined by CII, is used to guide the implementation and utilisation of a constructability program by means of six milestones. These milestones are:

- Commitment to implementing constructability;
- Establishment of a corporate constructability program;
- Obtain constructability capabilities;
- Plan constructability implementation;
- Implement Constructability; and
- Update corporate program.

APPENDIX B: CONSTRUCTABILITY CHECKLIST

No.	Description	Comply Y/N/NA
	Transport to and within site and access	
1	Access routes to site. Are access roadway weight limits and clearances sufficient? Is there sufficient access for the equipment to be moved to the installation area? (Passages and doorways large enough, etc.)	
2	Have the requirements for construction personnel ingress and egress on the project been addressed: bussing, badging and parking area.	
3	Is there an off-site and onsite construction traffic plan. Can traffic conflicts be reduced?	
4	Can the necessary access be constructed to remote locations?	
5	Can emergency vehicles travel through without delays?	
	Laydown and Contractors Yards	
6	Have the required Contractor's yards been allocated and indicated on the site layout drawing with sufficient space for offices, stores, laydown/ storage and fabrication areas.	
7	Pre-assembly and fabrication facilities.	
	Utilities	
8	Consider catering/ food and dining facilities for construction staff	
9	Verify utility locations. Ensure all utility requirements such as water, ablutions, compressed air, electrical power, temporary lighting, welding gases, heat treating services, etc., have been considered	
10	Has the requirement for temporary piping, electrical supplies, fire protection, water diversion, been addressed?	
11	Consider requirements for security of construction site, contractors yards, personnel access, etc.	
12	Accommodation, feeding, transport/bussing, parking and access for construction personnel on-site and off-site.	
13	Requirement and facilities for waste handling and removal	
14	Consider the requirement for a concrete batching plant	
15	Are the necessary fire protection and safety systems in place to enable construction?	
16	Consider construction site safety and emergency requirements such as; emergency response routes, egress/evacuation routes, emergency staging areas, medical/first aid facilities. Emergency Response Plan (Fire Response, Medivac, Crisis, etc.).	
17	Consider housing/accommodation for construction staff.	
	Working Areas	
18	Consider working area requirements around structures	
19	Check for overhead utility conflicts.	
20	Does the equipment fit in the location?	
21	Is the floor loading capacity sufficient to handle the equipment during installation?	

No.	Description	Comply Y/N/NA
22	Ensure that building openings (external and internal) and elevators /lifting hatches are adequate for the installation and removal of equipment.	
23	Are the necessary measures in place to provide protection for sensitive equipment (e.g. environmental; moisture and dust) from surrounding construction activities?	
24	Where blasting is required has the necessary consideration been given to the impact on existing operational equipment and other construction activities in the vicinity?	
25	Are interfaces between various contractors clearly defined (location, flow pressure volume, temperature, etc.)	
	Construction/Modularisation	
26	Can the equipment be installed in one piece or does it need to be supplied in sections?	
27	Consider modularisation to minimise in situ fabrication and reduce construction time.	
28	Are there any hazardous environmental conditions that require specific precautionary actions particular specialised PPE (e.g. heat, noise, radiation, hazardous chemicals, gasses, Materials, etc.)?	
29	Verify that the construction sequence takes into account other construction activities or structures that are affected by the required construction access and laydown areas.	
30	Verify that there is sufficient volume for other rigging equipment required for construction and installation.	
31	Can the equipment be installed safely without affecting other operating equipment and generating units?	
32	Have the necessary health and safety requirements been met; sufficient provision for hook-ups at elevated areas, prevention and protection from falling hazards, ventilation and smoke extraction in confined areas where welding is performed, etc.?	
	Cranes	
33	Check for overhead utility conflicts. Are the overhead clearances sufficient for installation? E.g. Ensure clearance from high voltage power lines.	
34	Verify that a craneage plan been developed and that there is sufficient area and height for cranes; movement during construction as well as laydown areas for erection and dismantling of cranes.	
35	Are the required pick and place areas allocated within the crane envelope?	
	Design	
36	Consider construction methods that “drive” the design	
37	Is weather a factor?	
38	Standardise design elements	
39	Check statutory and local agency requirements e.g. environmental issues. EIA requirements	
40	Minimise restricted areas that eliminate normal equipment use	

No.	Description	Comply Y/N/NA
41	Minimise low production or hand work areas	
42	Strive for simplicity in design	
43	Minimise architectural details	
44	Are interfaces between various contractors, and between contractors and site, clearly defined (location, flow pressure volume, temperature, etc.)	
	For brownfield sites (modifications, retrofits, etc.)	
45	Demolition activities required.	
46	Storage and disposal of demolished materials/waste.	
47	Impact on operating plant; load lifts over operating plant.	
48	Interfaces with existing operating plant	
49	Verify that all existing underground services been considered for excavation requirements and that requirements, as necessary, for the use and availability of detection equipment for the location of underground services have been addressed.	
50	NKP Security requirements/measures required for existing operating plants, such as fencing, access gates, etc.	
51	Are access roads to discharge, loading and unloading points and walkways segregated from road traffic?	
52	Ensure that excavation activities do not impact on existing/built structures and buildings	
	Planning	
53	Assure utility construction coordination with other agencies. Local and regional authorities	
	On tender evaluation	
54	Evaluate the CEP submitted by the Contractor	
55	Is the construction/installation methodology clearly described in a formal document e.g. Construction Execution Plan?	