PIP STE01100
Constructability Design Guide
PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

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1. Scope

This Practice provides engineers and designers with guidelines for improving constructability of a project.

This Practice describes guidelines for improving constructability of civil, structural, and architectural components of a project. This Practice provides guidelines for grass root projects, revamp projects, and turnarounds.

2. References

Applicable parts of the following PIP Practices, industry codes and standards, and government regulations shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 Industry Codes and Standards

- Construction Industry Institute (CII)
  - CII SP34-1 - Constructability Implementation Guide

3. Definitions

constructability: The optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives

contract documents: Any and all documents, including codes, studies, design drawings, specifications, sketches, practices, and data sheets, that purchaser or engineer of record has transmitted or otherwise communicated, either by incorporation or reference, and made part of the legal contract agreement or purchase order between purchaser and constructor

conventional construction: A method of construction where individual elements and components from multiple fabricators, vendors, and suppliers are shipped to the construction site and assembled piece-by-piece into the final structure or building; sometimes referred to as “stick built.” This traditional method of construction tends to concentrate craft labor hours in the field.

glass roots project: A project where construction is substantially performed in a clear, open site with minimal interference from constructing around existing facilities

modularization: A method of construction where individual elements and components are shipped to one or more module fabrication shops where they are assembled into complete units that are shipped to the construction site for installation. This type of construction tends to move a portion of craft labor hours from the field to a controlled shop environment.

owner: Party who has authority through ownership, lease, or other legal agreement over site, facility, structure, or project wherein what is to be provided or installed will be used

pre-assembly: A process by which various materials, prefabricated components, and/or equipment are joined together at a remote location for subsequent installation as a unit
revamp project: A project (i.e., retrofit) that is substantially constructed in and around existing facilities, typically containing significant modification to existing structures and plant equipment and systems. Often, the project goal is to increase current product output or change the types of products produced.

turnaround: Scheduled plant or unit outage when modification work is performed

4. General

4.1 Process Introduction

4.1.1 Constructability is a process driven by the desire to improve execution of the construction phase, especially by considering construction issues during planning and design phases, resulting in improved overall project delivery costs and schedules. See CII SP34-1 for detailed implementation guidance.

4.1.2 The constructability process is implemented through a team effort involving the owner project team, engineering contractor, and construction contractor (including vendors, suppliers, and subcontractors if applicable) working towards the common goal of producing a quality facility, while optimizing cost, schedule, and safety.

4.1.3 Guidance provided in this Practice is generic with respect to project execution strategy (i.e., principles should be applicable regardless of the contracting strategy) provided that key project members participate in constructability planning.

4.1.4 Construction site development shall include temporary facilities to support project construction activities. It may involve one or more of the following items:
   a. Temporary/permanent access ways
   b. Temporary buildings, parking area and other facilities
   c. Temporary site drainage and permits
   d. Temporary power, communications and utilities
   e. Temporary fencing, security and signage
   f. Temporary wash down areas
   g. Construction laydown areas and fabrication yards
   h. Topographical survey

4.2 Project Initiation and Development

4.2.1 The life cycle of a typical process industry project matures from identification of a need or business opportunity to an operating or producing facility through several distinct phases or stages. Although most owners have their own uniquely defined project development process, most projects progress through stepped phases with similar traits. These project execution strategies are often characterized by end-of-phase hold points (i.e., gates) when decisions are made to continue funding or cancel a project based on successively refined total installed cost estimates.
4.2.2 Initial phases of a project typically involve appraisal of the business case for a particular need or opportunity. These initial phases typically have limited civil, structural, and architectural discipline involvement. A selection phase follows where multiple options are narrowed to the one deemed most likely to achieve business objectives. The selection phase often culminates in a process design package with major process equipment needs identified and a plot plan proposed. The next phase is called the project definition phase. This phase involves preliminary engineering that defines a project to the point where the owner’s review board may approve final funding for latter phases (i.e., detailed engineering and construction). Attention to concepts of constructability should begin no later than the end of the selection phase and incorporation of concepts into the project should continue throughout the project’s duration.

4.2.3 Successful projects are typically achieved through good definition and detailed planning. Plans for executing a project should address strategies for executing engineering, procurement, and construction. Constructability planning can add value to project execution through cost and schedule reductions.

4.2.4 Key constructability suggestions for consideration in early project front end development are:

a. Engage construction team members as early as possible in project initiation for development of the construction strategy.

b. Communication among team members is of paramount importance. Encourage input on constructability from owner’s operations representative, design engineer, construction representative, geotechnical consultant, etc.

c. Develop constructability checklists for use by the project team for each phase of the project.

d. If land use for temporary facilities (e.g., construction field offices, site fabrication yards, material storage and contractor parking) is required, seek input from construction representative. Locate these items considering site traffic patterns, access for trucks, and high risk areas (e.g., blast zones, chemical exposure). Avoid relocating these items later in the project.

e. Decide on final plot plan/equipment arrangement. Include considerations for permanent support facilities (e.g., warehouses, roads, crane access, parking lots, and maintenance shops). Ensure construction sequencing cannot close haul routes for heavy equipment because of height, width, length, and weight restrictions. Obtain agreement from stakeholders to hold to plan.

f. Perform transportation studies to identify water or land routes, maximum shipping weights, dimensional envelopes, and methods of transport.

g. Develop a strategy for site survey dimensional control that considers different challenges that revamp or grass roots projects present.

h. Develop plans for addressing soil contamination, pollution control, erosion control, wetlands preservation, storm water discharge, asbestos abatement, disposal of hazardous waste, other environmental issues, and worker health and safety. These plans need to be identified in project documentation and drawings where applicable.
i. Solicit owner and construction representative input on selection of materials of construction.

j. Consider impact of likely weather and seasonal climate conditions on construction activities when preparing schedules.

4.3 Modularization

4.3.1 Potential for modularizing structures, pipe racks, platforms, stair towers, roof framing sections, electrical rooms, etc., should be reviewed at the beginning of the selection phase. Other installations may be modularized at the steel fabrication shop or on the jobsite before erection.

4.3.2 Modularization tends to decrease a project’s onsite construction schedule and number of onsite craft workers. These potential benefits can add value to projects located in geographical regions with climate extremes, craft labor resource shortages, or high craft labor rates. However, these benefits may be offset by additional design, material, transportation, and lifting costs.

4.3.3 Front end project planning, including transportation studies, becomes critical with any significant degree of modularization. It is often necessary to accelerate detailed design schedules, including vendor documentation, to accommodate modular shop schedules and material required-at-shop dates.

4.3.4 Construction crane size requirements for modules are typically increased and large cranes may need to be scheduled much longer in advance because of their specialized nature.

4.4 Pre-Assembly

4.4.1 If modularization is not used, construction representatives should still participate in conceptual planning of structures, pipe racks, and bridges to provide input into practicality of pre-assembly and erection techniques.

4.4.2 Some of the schedule and field labor benefits of modularization can still be realized by incorporating pre-assembly concepts. Fewer large components can be erected versus conventional construction piece-by-piece methods. Pre-assembly can be performed onsite or coordinated with fabricators. The concept of pre-assembly can be extended to pre-cast concrete components.

4.5 3D Models, Design Drawings and Contract Documents

4.5.1 Consider using computerized 3D models for improved constructability, operability, and maintainability of plant designs.

4.5.2 References to codes should be minimized on drawings, except drawings for general notes. If necessary to reference codes on drawings, be specific by citing the code, page, paragraph, section, etc.

4.5.3 Where discipline interfaces occur (e.g., Civil, Mechanical, Electrical, etc.), drawings should be cross referenced between disciplines. Appropriate cross references can save more hours in the field than those required to incorporate references on drawings.
4.5.4 For revamp projects, cross references to relevant existing drawings should be shown on new construction drawings. Include copies of relevant existing drawings in the contract documents.

4.5.5 All plan drawings for each discipline should use the same orientation, grid and scale, if possible.

4.5.6 For locating equipment and facilities, all disciplines should use consistent reference points for dimensioning.

4.5.7 Contract documents should clearly specify procurement responsibilities for contractor provided material.

5. **Civil**

5.1 **General Considerations**

5.1.1 Fence plans and details should be developed early in the detailed engineering phase to aid with security measures.

5.1.2 Design of all foundations, manholes, sumps, underground piping, and site improvement plans including rough grading, drainage, and roadways should be completed early in the detailed engineering phase of the project.

5.1.3 Design and installation of underground facilities should be coordinated to avoid interferences and rework.

5.1.4 Design and installation of heavy haul roads, roll on/roll off ramps, bulk materials handling, and other logistics facilities should be completed early in the project to ensure they are available when required.

5.2 **Geotechnical and Site Survey**

5.2.1 Geotechnical and topographic surveys should be obtained early in project definition phase.

5.2.2 Obtain location surveys of existing facilities, particularly underground facilities. Consider laser scanning of existing equipment and structures.

5.2.3 Survey control monuments should be established so that monuments remain accessible and undisturbed for the duration of the project.

5.2.4 The need for a soil structural assessment for heavy load requirements should be determined.

5.2.5 Construction input should be obtained for establishment of benchmarks and/or reference points to be used during construction.

5.2.6 A copy of the geotechnical report should be furnished to the civil contractor.

5.3 **Excavation and Backfill**

5.3.1 If possible, excavations below the water table should be avoided. Alternate foundation schemes should be investigated.

5.3.2 Appropriate requirements for backfill compaction and maximum lifts for traffic versus non-traffic areas should be specified.
5.3.3 Geotextile fabric, geogrid, granular material, mud mats or lean concrete should be used in the bottom of excavations as appropriate.

5.3.4 If possible, use of sheet piling for temporary shoring should be avoided. Trench boxes are preferred for shallow excavations.

5.3.5 Regulatory (e.g., OSHA) shoring requirements for excavations for foundation and underground utility designs should be incorporated. To eliminate excessive shoring, deep cuts should be avoided.

5.3.6 Minimum elevations for excavation should be established. Mass excavate if possible.

5.3.7 Foundations in congested areas should be designed with bottom of concrete at same elevation if possible. Mass excavation (e.g., bathtub) design concepts should be used.

5.3.8 Depth of excavations for foundations, including any mud slabs, aggregate beds, etc., should be limited to 4 feet (1200 mm) maximum if consistent with geotechnical engineer's recommendations in order to minimize requirements for confined space, sloped back excavations, or shoring.

5.3.9 Unless the area has a potential for re-excavation, use of Controlled Low-Strength Material (CLSM) or flowable fill to backfill around foundations in confined or congested areas should be considered.

5.3.10 Use of a lightweight aggregate backfill for retaining walls should be considered if the reduction of backfill unit weight and reduced active wall pressure provide an economical alternative to a cohesionless soil backfill.

5.3.11 Studies should be performed to determine if contaminated soils are present, and plans should be included in contract documents to address contaminated soil handling issues (e.g., personnel exposure, equipment exposure, wash down, etc.).

5.3.12 If contaminated soil exists at the site, a plan for disposal of the soil should be developed.

5.3.13 Rather than including contaminated soil location and removal in typical construction contracts, owners may decide to separately handle the risk of locating and disposing of the soil, which can be more cost effective. A specialty contractor with appropriate equipment and properly trained staff may be employed ahead of the main construction contract to mitigate and/or advise on methods to minimize disposal of contaminated soil.

5.3.14 Depending on the consequences of finding contaminated soil, a radical re-design of the work (e.g., building a unit above existing grade to avoid excavation of potentially contaminated soil) may be considered necessary.

5.3.15 If soils are to be hauled off-site, a plan should be developed to minimize additional handling and to avoid any delays associated with trucking.

5.3.16 Dewatering issues for soil excavations should be addressed. If contaminated soils are present, typically contaminated groundwater is also present. Locations for power for dewatering pumps, groundwater storage, and groundwater discharge should be identified during the design phase of the project.
5.3.17 Along with the site plan, a general grading plan should be developed that addresses rough and final grading issues and any heavy lift site preparation requirements. Requirements for transporting heavy equipment to the site (e.g., heavy haul roads, etc.) and off-loading should be developed.

5.3.18 Care should be taken to not undermine existing foundations or utilities. If undermining cannot be avoided, temporary support requirements should be addressed during the design phase and included on excavation drawings.

5.3.19 Site layout should be arranged for maximum use of mobile or self-propelled compaction equipment.

5.4 Grading and Roadways

5.4.1 During the construction phase, site water runoff disposal should be provided.

5.4.2 If possible, cut and fill should be balanced. Provide stockpile areas to avoid moving excavated material multiple times.

5.4.3 Erosion control requirements should be determined in accordance with regulatory requirements and local codes.

5.4.4 Available locations for construction water access for site earth work and dust control should be determined.

5.4.5 If possible, permanent roads and drainage should be used to provide good access and mobility during construction.

5.4.6 If parking areas are being relocated, reusing base course materials and asphalt should be considered.

5.4.7 Plot elevation should be raised and sloped to facilitate drainage during the construction phase and for the permanent facility. Use of temporary ditching during the construction phase should also be considered.

5.5 Underground Piping and Utilities

5.5.1 Typical sections on detail drawings should be provided to show requirements for bedding materials for underground utilities.

5.5.2 A culvert schedule should be developed. If heavy loading or roadway loading occurs at a culvert location, the loading should be considered in underground piping design.

5.5.3 Underground utility corridors should be located in areas that cannot interfere with construction of deep foundations.

5.5.4 If possible, common excavation trenches should be used for underground piping, direct buried cable, and duct banks.

5.5.5 Developing a composite drawing of all temporary, new, and existing underground installations (i.e., foundations, piping, and electrical) should be considered.

5.5.6 If leak detection and secondary containment of process sewers and piping is required, trenches should be considered.
5.5.7 Underground piping, grounding, duct banks, and ductwork should be designed early enough to permit installation during the site work and foundation installation phase.

5.5.8 Corrugated arch pipe, precast elliptical pipe, or precast box culverts should be considered for use at road crossings rather than cast-in-place box culverts.

5.5.9 Existing underground utilities should be located and shown on underground piping drawings and foundation location plans.

5.6 Sumps, Pits, and Manholes

5.6.1 If facility standards permit, precast manholes, sumps, and electrical pull boxes should be used if possible.

5.6.2 Details for valve boxes, small sumps, and manholes should incorporate reinforced concrete pipe (RCP) if possible. Details should avoid cutting of RCP if practical.

5.6.3 Sumps or pits with interior lining (e.g., for acid proofing) should have a plastic barrier installed under the bottom slab and walls should be externally coated with a waterproofing material, before backfill, to prevent seepage through cracks caused by concrete shrinkage. Seepage can impair installation of interior coating.

5.6.4 For pits with vertical concrete walls, use of fabricated ladders should be considered rather than cast-in-place rungs.

5.6.5 Manhole frames and covers can have long lead times and should be ordered in time to accommodate construction schedule.

5.6.6 Precast manholes should be provided with means for lifting.

6. Structural

6.1 Concrete

6.1.1 Foundations

6.1.1.1 Small pump foundations and other lightly loaded piers and pads should be placed on a thickened slab rather than on deeper foundations requiring more excavation.

6.1.1.2 If placing walls on a slab, slab dimensions should be extended to permit setting outside forms for walls on the slab.

6.1.1.3 If structural and site conditions permit, foundations should be designed to permit placement of concrete directly against face of earth, thus eliminating need for forms.

6.1.1.4 For positioning large vertical vessels during equipment setting, the length, threads, and projection of one anchor should be greater than the rest in the group.

6.1.1.5 For small foundations and slabs-on-grade, full depth foundations without edge grade beams should be considered.
6.1.1.6 Use of standard diameter concrete piers rather than square and rectangular shapes should be considered for ease of forming.

6.1.1.7 If varying the surfaces or sections of concrete, the additional form costs should be considered. Haunches and other labor intensive forming should be avoided.

6.1.1.8 For supporting vertical vessels, pedestals 6 feet (1800 mm) and greater in diameter should be octagonal or round in shape. Smaller pedestals should be square, or round if forms are available.

6.1.1.9 Foundation sizes for pumps, piperacks, structures, and miscellaneous supports should be standardized as practical.

6.1.1.10 Foundation dimensions should be designed in increments that allow for maximum use of commercial form sizes. Use re-useable forms where possible to reduce cost. Disposable forms are often more costly.

6.1.1.11 Use of Concrete Maturity Method should be considered for testing concrete rather than conventional cylinders.

6.1.1.12 Combining footings for structural columns that are located in close proximity to one another should be considered. Equipment foundations and structural columns should be combined on a common mat in congested areas.

6.1.1.13 Concrete column dimensions should remain the same from floor to floor.

6.1.1.14 Straight walls should be used rather than battered walls. Savings in form work for straight walls can offset the cost of additional material.

6.1.1.15 Increasing column sizes to facilitate placement and consolidation of concrete should be considered. If columns/piers are greater than 6 feet (1800 mm) high, a minimum of 6 inches (150 mm) clear space should be provided through column reinforcement for concrete placement.

6.1.1.16 Where piers need to be omitted for crane access, use of dowel bar splice kits on large diameter reinforcing should be considered.

6.1.1.17 Use of key ways in wall joints should be minimized. To eliminate key ways, steel reinforcement in joints should be designed for shear friction.

6.1.1.18 The construction representative should be consulted regarding complex concrete placements (e.g., tabletops). Forming hardware, shoring methods, joints, and special embedded items can impact design.

6.1.1.19 For deep wall foundations, use of sheet piling or soldier pile and lagging systems as permanent, external forms should be considered.

6.1.1.20 Foundation requirements for any heavy lifting equipment should be considered.

6.1.1.21 Local availability of concrete aggregates, cements, pozzolans, and admixtures for special mix designs should be investigated.
6.1.1.22 If possible, foundations (depth and proximity) should be located and designed to prevent undermining adjacent foundations, manholes, sumps, etc. Use of shoring should be minimized.

6.1.1.23 For buildings, embedded floor channel for supporting switchgear should be installed flush and level with top of floor to permit easy installation and removal of switchgear.

6.1.1.24 Conduit and piping stub-outs and penetrations should be shown on foundation drawings and other appropriate discipline drawings should be referenced.

6.1.2 Piles and Drilled Piers

6.1.2.1 Advantages and disadvantages of different types of deep foundations (e.g., caissons, H-piles, pipe, auger flight, augered cast-in-place or precast concrete piles) should be investigated. Avoid underream or bell bottom footings if possible.

6.1.2.2 Use of test piling should be considered to maximize economy in design of production piling.

6.1.2.3 Where vibration effects on nearby facilities can be detrimental, drilled piles (e.g., augered cast-in-place, slurry/casing drilled piers or mini piles) rather than driven piles should be used.

6.1.2.4 Multiple mobilizations for piling contractors should be avoided.

6.1.2.5 For individual columns in offsite areas, drilled piers rather than spread footing foundations should be considered.

6.1.2.6 For drilled piers which employ casing for hole stability, hooked reinforcing should not be permitted to extend past the casing in order to avoid interferences when extracting the casing.

6.1.2.7 To facilitate placement of concrete and anchors, a construction joint below the bottom of anchors should be considered.

6.1.2.8 Where drilled piers or augered cast-in-place piles are used, pier/pile installation must be staggered in spacing or timing to provide sufficient room for accessibility for cranes and/or other equipment and allow for sufficient concrete/grout set time.

6.1.2.9 Drilled piers or piles which can support heavier loads on a wider spacing interval should be considered.

6.1.3 Pre-cast Concrete

6.1.3.1 Use of pre-cast manholes, pull boxes, sumps, retaining walls, and other miscellaneous concrete items should be maximized. Pre-casting small spread footings should be considered.

6.1.3.2 If cost or schedule savings are possible, concrete structures should be designed for pre-cast construction.

6.1.3.3 Pre-cast concrete trenches should be considered for roadway utility crossings and process applications. If containment is critical, special care should be given to joint design.
6.1.3.4 Deliveries of pre-cast concrete items should be coordinated to allow items to be off loaded in final locations to avoid multiple handling.

6.1.4 Reinforcement

6.1.4.1 Unless different grades of rebar are required by codes or special applications (e.g., seismic and blast ductility, epoxy coatings for corrosion, and cryogenic environments), use of various grades of rebar should be avoided.

6.1.4.2 Congestion of reinforcing steel, ties, and anchors in cross section should be reduced using the following design concepts to facilitate concrete placement:

   a. Use fewer reinforcing bars of larger diameter, rather than more reinforcing bars of smaller diameter.
   
   b. Arrange ties within cross sections to provide maximum clearance between bars.
   
   c. If permitted by code, use ties with 90 degree hooks rather than closed ties.
   
   d. Consider use of mechanical couplings in congested areas rather than lap splices.

6.1.4.3 Welded wire reinforcement or fiber reinforced concrete should be considered for area paving rather than rebar. Flat sheet welded wire reinforcement should be used rather than rolled welded wire reinforcement.

6.1.4.4 Consider using consistent beam sizes and rebar sizes throughout the structure.

6.1.4.5 Show rebar, post-tensioning cables, and conduits on one overall design drawing in order to detect interferences before construction.

6.1.4.6 Consider using rebar in foundations for grounding.

6.1.5 Roadways and Area Paving

6.1.5.1 The construction representative should be consulted to define areas where early construction of roadways and area paving would be beneficial.

6.1.5.2 Area paving drawings should be developed that show locations of contraction and expansion joints.

6.1.5.3 For contraction or construction joints in large area paving, use of metal screed keys with removable strips should be considered.

6.1.5.4 Curb heights should be specified to facilitate forming with standard dimensional lumber unless a paving machine is being used.

6.1.5.5 For roadways and area paving, consider thicker section and/or fiber reinforcement to eliminate steel reinforcement.
6.1.6 Concrete Mixing

6.1.6.1 For large concrete placements or special mix designs, a preplanning meeting should be held with concrete suppliers and contractors.

6.1.6.2 Requirements for an on-site batch plant versus a local concrete supplier should be determined in the project definition phase. Allowance for additional inspections, if required, should be included in the project schedule.

6.1.6.3 If practical, a common concrete compressive strength should be used. Unique mix identifiers should be shown on delivery tickets.

6.1.7 Anchors and Embeds

6.1.7.1 If practical, anchors should be standardized as follows:
   a. Specify consistent material, length, and thread requirements.
   b. Minimize use of different diameters and anchor lengths.
   c. Use minimum increments of 1/4 inch (6mm) if different diameters are required.
   d. Specify plate and nut or end nut rather than J-Hook anchors.

6.1.7.2 Cast-in-place anchors should typically be considered as follows:
   a. For anchors 3/4 inch (19 mm) or larger in diameter
   b. For anchoring major equipment or structures
   c. Use templates rather than sleeves if precise alignment is required for anchors greater than 1 inch (25 mm).
   d. Use sleeves if pre-tensioning is required.

6.1.7.3 Post-installed bonded anchor systems should be considered as follows:
   a. For anchors 3/4 inch (19 mm) or smaller in diameter
   b. For larger anchors where constructability issues noted below are encountered:
      1. For anchoring equipment to existing concrete
      2. If securing the anchors in required location is difficult before concrete placement
      3. If pre-installed anchors can interfere with equipment setting, concrete placement, or finishing

6.1.7.4 Post-installed mechanical anchor systems should be considered as follows:
   a. If recommended by equipment supplier
   b. Typically for anchors 7/8 inch (22 mm) or smaller
   c. Especially suitable for overhead anchoring
   d. Generally not recommended for dynamic load applications
6.1.7.5 Special anchor requirements (e.g., alloy steel, high-strength, or hot-dipped galvanizing) should be determined early in detailed engineering phase.

6.1.7.6 Adequate embeds should be provided in concrete surfaces for miscellaneous attachments.

6.1.7.7 If possible, embedded items should be designed to be flush with concrete for ease of forming. If required, the remainder of the embedded item should be welded on later.

6.1.7.8 Where dense rebar is located in foundations, clearances for anchors or embedded items should be checked.

6.1.7.9 If projecting anchors can interfere with construction or maintenance activities, use of coupled type anchorage should be considered.

6.1.7.10 If jacking screws are not provided and pre-tensioning is not required for lightly loaded equipment skids, leveling nuts should be added to anchors rather than using shims.

6.1.7.11 Cast-in-place anchors should be designed in a square rather than rectangular arrangement. Anchors placed in a rectangular arrangement are often oriented incorrectly during construction.

6.1.7.12 If design considerations permit, anchors should not be extended into footings (mats).

6.1.8 Grout

6.1.8.1 Weep holes should be provided for piers with grout pockets to permit water to escape.

6.1.8.2 Vent holes should be provided in column or equipment base plates to permit air to escape during grout placement.

6.1.8.3 Responsibilities for installing grout (e.g., surface preparation, equipment positioning) should be clearly specified.

6.1.8.4 Grout thickness for structural steel and equipment support should be specified between 1 inch and 2 inches (25 mm and 50 mm).

6.1.8.5 Grouting of equipment that is not sensitive to alignment or vibration (e.g., transformers, tanks, minor supports, packaged buildings and enclosures) should be avoided.

6.1.9 Grade Slabs and Elevated Slabs

6.1.9.1 Construction floor loadings for grade slabs and elevated slabs should be established during the design phase to permit use of construction equipment for placement of equipment, pipe, trays, ducts, etc.

6.1.9.2 Drawings that show locations of expansion joints should be developed. Where standard spacing rules are not adequate, the location of control joints should also be shown on drawings. Type of joints to be used should be clearly specified.
6.1.9.3 Elevated slabs drawings should show all penetrations by location and size.

6.1.9.4 If practical, a uniform thickness for elevated slabs should be maintained to minimize field labor costs.

6.1.9.5 Fiber reinforcing and/or thicker sections should be considered for lightly loaded slabs to eliminate steel reinforcement.

6.1.9.6 A vapor barrier should be installed under grade slabs to minimize vapor penetration for any interior floor slabs and where coatings or flooring will be applied.

6.1.9.7 For slabs requiring coatings, surface finish should not be specified other than what is required for flatness and levelness as finish will be removed before adding coatings.

6.1.9.8 Avoid using curing compounds on concrete requiring protective coatings.

6.1.9.9 Avoid scheduling outdoor coating installations during wet/cold conditions.

6.2 Structural and Miscellaneous Steel

6.2.1 Connections

6.2.1.1 Use of through-web beam connections should be avoided. If this type of connection is required, seat angles should be placed on columns.

6.2.1.2 If possible, boxed-in connections should be avoided where corrosion cannot be easily prevented or corrected.

6.2.1.3 Field-welded connections should be minimized.

6.2.1.4 If pipe racks are designed for future expansion, columns should be extended above top level to permit column splice connections.

6.2.1.5 Contract documents should clearly specify responsibilities for providing connection materials (e.g., shim plates, bolt and nut assemblies, and Direct Tension Indicator (DTI) washers).

6.2.1.6 Special care should be used when detailing moment connections. Column stiffeners and doubler plates should be avoided where possible. Where stiffeners are required, connection of beams framing into column web needs to be considered.

6.2.1.7 Avoid full-depth stiffeners where possible.

6.2.1.8 Existing structures can require special connection designs to accommodate fit-up and constructability due to dimensional inconsistencies, misalignment, and existing members that are not level and plumb.

6.2.2 Stairs, Ladders and Platforms

6.2.2.1 Permanent stairways, platforms, and ladders should be designed and erected as soon as practical.
6.2.2.2 As much as possible, ladders, stairways, catwalks, and miscellaneous platforms should be pre-assembled in the shop.

6.2.2.3 Field cutting and banding of grating or floor plate penetrations should be minimized.

6.2.2.4 For grating or floor plate fastening systems, constructor should be asked to provide a preference and erection costs should be considered. Layouts for grating penetrations should be suitable for supporting splits in grating panels.

6.2.2.5 Stair stringers, treads, grating clips, and railing should be shipped with related structural steel to allow erection with sequential access to elevated tiers.

6.2.3 Fireproofing

6.2.3.1 If possible, use of shop-applied fireproofing should be maximized.

6.2.3.2 Impact of the weight of fireproofing on transportation and erection costs should be considered.

6.2.3.3 Cost and schedule impacts due to repair of fireproofing damaged during transportation and handling should be considered when selecting type of fireproofing.

6.2.3.4 Erection clearances should be considered when determining block-out dimensions for shop applied-fireproofing.

6.2.4 Fabrication

6.2.4.1 The construction representative should be consulted for establishing delivery sequence of fabricated steel.

6.2.4.2 Miscellaneous steelwork items (e.g., equipment frames, architectural items, grounding clips, etc.) that are not shown on structural drawings should be checked to ensure these items are included in scope of supplier, contract packages or purchase orders.

6.2.4.3 Field fabrication should be considered for miscellaneous supports identified late in detailed engineering phase.

6.2.4.4 If coatings are used, quality control measures should be implemented to prevent excessive build-up that can block placement of bolts in standard holes.

6.2.5 Design of Structures

6.2.5.1 If possible, structure bay dimensions should be standardized.

6.2.5.2 Consider construction, operation, and maintenance access in locating bracing at ground level.

6.2.5.3 Minimizing use of bracing and small members that are labor intensive to install should be considered.

6.2.5.4 Pipe bridge clearances should be reviewed with construction, maintenance, and operations personnel to verify access for large equipment/oversized loads.
6.2.5.5 If possible, use of different member sizes should be minimized, and special or hard to fabricate shapes should be avoided.

6.2.5.6 Specifications, dimensions, and field connections should be standardized.

6.2.5.7 During the conceptual planning of all structures, pipe racks, and bridges, the construction representative should provide input into the practicality of pre-assembly and erection techniques.

6.2.5.8 Fabricated piece marked members should be duplicated for use in as many suitable locations as possible.

6.2.5.9 Where fall protection is required, strategically placed and properly designed means should be provided for supporting construction safety cables.

6.2.5.10 Erection clearances for beams framed between existing beams and columns should be verified. Allowances for horizontal alignment with connections should be provided by using horizontal slots and/or field welding.

6.2.5.11 If new equipment is to be installed in existing structures, the capacity of overhead framing should be checked to ensure the framing can support rigging for the new equipment.

6.2.5.12 Use of prefabricated L-shaped bent steel plates installed with the structural steel should be considered to eliminate field forming for exposed perimeter edges of elevated floor slabs.

6.2.5.13 Shear keys at column bases should be used only where required.

6.2.5.14 Special temporary steel required for erection should be identified and provided with the fabricated steel.

6.2.5.15 Unless other arrangements are made with the construction contractor, steel drawings issued for field fabrication should be complete with all necessary fabrication details and bills of material. Notes should be clear on which items are to be field fabricated.

6.2.5.16 Elevated slabs should be designed with galvanized decking (i.e., “Q” decking) rather than forming. Structural steel beams should be designed to support the deck loads without shoring.

6.2.5.17 Temporary guardrails should be avoided by designing permanent guardrails to be attached to supporting steel.

6.2.6 Marking and Identification

6.2.6.1 Marking and tagging method should be legible after final finish coating is applied.

6.2.6.2 Piece marks should be placed in a location consistent with member orientation.

6.2.6.3 If tagging is to be obscured by fireproofing or other membrane, the piece mark should be transferred to the exterior of membrane in the same relative orientation.
6.2.6.4 Receiving process should include verification of materials received against the shipping papers.

6.2.6.5 Pieces should have the weight shown on the bill of lading and on shop detail drawings so that suitable lifting equipment can be selected.

6.2.6.6 Fasteners for a shop order should be delivered before or with the first delivery, and should be accompanied with a packing list giving proper identification as to use. A bolt list and splice plate list should be provided by fabricator. Bolts should be shipped in weather resistant containers.

6.2.7 Bolting

6.2.7.1 If possible, bolt diameters and assemblies should be standardized to minimize errors and complexities in the field.

6.2.7.2 A simple procedure for meeting bolt tensioning requirements should be provided that can be used by erector and inspector.

7. Architectural

7.1 Design Considerations

7.1.1 Architectural items (e.g., door hardware and fixtures) should be standardized.

7.1.2 Electrical and construction representatives should be consulted regarding substation floor design (e.g., embedded channels).

7.1.3 Elevation of computer floors (if applicable) should be adequate to permit cable run tie-ins to equipment.

7.2 Openings

7.2.1 Schedules and specifications for doors, windows, and hardware should be developed early to facilitate ordering.

7.2.2 Structural, HVAC, piping, and electrical penetration details should be coordinated with modular aspects of unit masonry.

7.2.3 Access requirements for process, electrical, and other equipment that is oversized should be identified early in the detailed engineering phase.

7.2.4 Future expansion requirements should be considered during design of structures. For fireproofed rooms and walls, kits should be used for wall penetrations of cables and piping; and access panels and doorways for removal and replacement of equipment.

7.2.5 Layout and details of all utility floor, roof and wall penetrations should be developed and shown on civil/architectural drawings.

7.2.6 Block-out requirements should be reviewed to ensure correct location for electrical bus duct locations.

7.2.7 If designing for blast effects, blast dampers, and doors should be specified early to facilitate ordering.
7.3 Coatings and Finishes
7.3.1 Architectural painting systems for structural, architectural, equipment, and piping should be standardized.
7.3.2 Finishes for acoustical ceilings, wall coverings, painting, vinyl, and ceramic tile should be standardized.
7.3.3 Special coatings that require application before installation of equipment should be identified.

7.4 Scheduling
7.4.1 HVAC & fire detection are typically critical path systems that should be completed early enough to permit installation and testing of control equipment.
7.4.2 Design methods should be considered that permit installation of equipment room walls after placement of large equipment.

7.5 Coordination
7.5.1 Scope and interface definition for electrical, instrumentation, piping, and mechanical equipment should be clearly specified in subcontract packages for buildings.
7.5.2 Structural representative should be consulted regarding having structural steel fabricator provide miscellaneous items (e.g., frames for louvers, vents, HVAC supports, clips, etc.) that are shown on architectural drawings.

8. Revamp and Turnaround Work

8.1 General
8.1.1 This section provides additional constructability guidelines for revamp and turnaround work. These guidelines should be considered in addition to those found in other sections of this Practice.
8.1.2 Most of the items in this section are applicable to both revamp work in an operating facility and turnaround work in a shutdown facility. Turnaround work typically requires a more detailed (i.e., hour by hour) plan, whereas consideration of specific safety issues may be an issue working in an operating plant.

8.2 Piling Considerations
8.2.1 Obstructions for accessibility (i.e., vertical and horizontal clearances) for pile driving/drilling equipment for new pilesshafts should be considered. Low headroom piling equipment and additional design may be considered where clearances are limited.
8.2.2 Whether driving piles is permitted in the construction area near the facility should be determined. Non-displacement piles (e.g., augered cast-in-place piles) may be required to minimize transmitting vibrations to nearby operating equipment.
8.3 Field Verification

8.3.1 Locations of existing obstructions should be field verified to confirm that new steel and foundations can be installed as designed without interferences. Existing obstructions require field verifications because they may not be shown correctly on existing drawings compared to the as-built condition.

8.3.2 Access requirements for operations and maintenance should be field verified in order to avoid interference with new facilities being constructed.

8.4 Pre-Turnaround and Post-Turnaround Work

8.4.1 Part of the detailed planning process for turnarounds should include determining what work can be completed pre-turnaround (i.e., while the facility is still operating) and what work can be completed post-turnaround (i.e., after the facility is started up again) in order to minimize the work required to be completed during the turnaround.

8.4.2 Pre-turnaround preparation work should be completed to the greatest extent possible to limit production down time. All work involved in the turnaround should be sequenced to limit schedule impacts and minimize downtime.

8.5 Bolted Versus Welded Connections

8.5.1 Because facilities typically have restrictions on field welded connections during normal operation, drilled and bolted connections may be required.

8.5.2 Typically, welding is not prohibited during a turnaround.

8.5.3 Bolted connections may require special considerations (e.g., existing fireproofed members require fireproofing to be removed on both sides of joint).

8.5.4 Field bolted connections of structural steel are typically more economical than field welded connections. Bolted connections do not require hot work permits, x-ray or other inspection procedures required for welded connections.

8.5.5 For extensive field fabrication, multi-spindled drilling machines can be used to provide accurate hole location and efficiency.

8.5.6 If a completely non-slip or water tight connection is required, welding may be preferred.

8.5.7 Availability of qualified welders should be considered before field fabrication begins.

8.6 Temporary Supports

8.6.1 Temporary support of existing piping, electrical, and structural steel during demolition and construction should be considered; and who will be responsible for this work should be determined.

8.6.2 If structural steel is to be demolished, using the steel to create temporary supports should be considered.
8.7 Site Work Considerations

8.7.1 The following items are often excluded from demolition and construction work descriptions and may require a specialty contractor and permits to complete the work:

a. Asbestos materials and mastics
b. Lead based paints or other hazardous materials
c. Siding on existing buildings
d. Heavy machinery/equipment transportation and operations

8.7.2 Safety in revamp projects might require the addition of a new work task to ensure that existing equipment and facilities including pipelines, electrical and instrumentation cables are protected against damage to prevent major setbacks or even catastrophic events during the construction phase of the projects.

8.7.3 All site specific safe practices (e.g., Job Safety Analysis, Hot Work, Lift Plans, Lockout/Tagout, Personal Protective Equipment, etc.) should be considered in the work plan.

8.7.4 All craft workers should be familiar with Safety Data Sheets (SDSs) for issues concerning their work areas.

8.8 Work Packages

8.8.1 Complete work packages for every individual portion of the work should be developed. Work packages should include complete information on materials and their sources and a detailed method statement of the work.

8.8.2 All planning and research should be completed and everyone involved should have a complete understanding of the work to be performed.

8.8.3 Work packages should be descriptive enough to permit breaking up the package as required to manage the work.

8.9 All stored job materials should be organized, identified, and verified before beginning any work.

8.10 Smaller components should be pre-assembled into units as large as are manageable before going to the field for the turnaround.

8.11 All anchorage layouts should be verified to ensure proper installation.

8.12 Space requirements for pre-positioning construction equipment and materials before beginning turnaround work should be considered. Space requirements for rolling stock, bottled gas requirements, scaffolding, and test equipment should be considered.

8.13 During the planning process, siting of temporary contractor facilities and requirements for emergency egress and evacuation should be considered.

8.14 To ensure proper sequencing of the work, sequential completion of the work, and subsequent turnover of the facility, all parties should agree to the turnaround detailed schedule.
8.15 Consideration should be given to the critical relationship between adjacent equipment items or column lines for revamp work that may require locating all the work in an area based on dimensions from an existing item.

8.16 Additional surveys, photography and laser mapping should be considered.

8.17 All design disciplines should reference the same benchmarks. Typically, different benchmarks around an existing facility are not tied together properly. If some work is designed with conflicting benchmarks, or if the work is engineered with one benchmark and constructed with another, fit-up issues can occur.

8.18 In some cases a more complicated, lengthy revamp procedure performed before a turnaround can be more economical than a simple demolition and replacement. For example, dowelling into and modifying foundations of existing equipment may be more economical than replacing a foundation during the turnaround.

8.19 Civil, structural, and architectural construction work should be coordinated with that of other construction groups and engineering organizations. In conjunction with revamp work, simultaneous construction of unrelated work by others can occur. Physically marking the spots where items are to be constructed and communicating the plans to owner’s area supervisor should be considered.