

Fundamentals of Launching a Precast Concrete Segmental Operation for Bridge Construction Projects



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Precast concrete segmental bridge construction is continuously evolving to keep pace in a competitive environment. As segmental bridge construction increases in national popularity, a number of precasters will consider upgrading plant facilities to handle this relatively new product. Historically, general contractors have produced the majority of precast concrete segments for existing precast concrete segmental bridges, and it has been the exception when a contractor has purchased segments from a precast concrete manufacturing facility.

This article explores the necessary facility upgrades a precaster will need to successfully undertake the comprehensive planning, coordination, and transformation process required to enter the segmental bridge production arena and lists sources for industry technical support for this endeavor. While the challenges of upgrading operations to include precast concrete segmental bridge components are considerable, bold innovation and careful risk management and system integration can establish this product line as a true precaster product.

An experienced precaster is the best person to understand what is required to run an efficient, successful business in today's competitive construction market. The forward-thinking precaster may wish to consider expanding plant operations to include a new and growing product line. Most precasters have some knowledge of segmental bridge construction but may have steered clear of segmental assembly because of its perceived complexities. Upgrading a precast concrete operation to handle production of bridge segments can understandably seem to be a daunting task.

While a segmental product line is not the correct choice for every precaster, this business potential should not be dismissed without understanding the assembly line accuracy, high tolerance, and geometry control precision of this next generation of precast concrete products. This article will explore the necessary upgrades that an existing precaster must successfully navigate, including the planning, coordination, and transformation processes. The approach taken here will demystify the start-up process and provide the precaster with the information necessary to make an educated decision. While the limitations of this article preclude providing all the answers, it is hoped that sufficient material is provided herein to allow formulation of the pertinent questions in a methodical evaluation process.

EVALUATING A NEW PRODUCT LINE— ADVANTAGES FOR THE PRECASTER

In light of the recent Senate passage of almost \$400 billion in funding for U.S. transportation infrastructure repair and rehabilitation, the use of precasters in small to medium-sized segmental bridge projects will provide significant improvements to product quality, infrastructure durability, and project scheduling, all important advantages to project owners and contractors.

If there is an upcoming segmental

project within 150 miles (240 km) of an existing precast concrete operation, the information presented in this article will be beneficial to the company's future success.

The following list of publications will be handy reference material to start the segmental library; other sources will be listed throughout the article:

- "Deck Segmentation and Yard Organization for Launched Bridges" by M. Rosignoli;1
- "Casting Box Girder Segments" by Moreton and Janssen;2
- "Segmental Bridges: The Best in the Business" by Barber;3
- American Association of State Highway and Transportation Officials' (AASHTO) Standard Specifications for Highway Bridges and Guide Specifications for Design and Construction of Segmental Concrete Bridges;4
- PCI's Bridge Design Manual, MNL-133;5
- "Contractor Checklist: Precast Yards" by Palmer;6
- American Segmental Bridge Institute's (ASBI) Construction Practices Handbook for Segmental Concrete Bridges;7 and
- For additional reading, review a list compiled by the Federal Highway Administration at www.fhwa.dot.gov/bridge/elibrary.htm.

SEGMENTAL PRODUCTION—PROJECT OVERVIEW

Depending on facility location, available storage area, transportation, site access, project size, geometric complexity, material specifications, delivery schedule, quality control (QC), testing/inspection regimens, reinforcing system complexity, deadlines, and the client, each segmental project will have unique aspects that must be identified by the precaster during the pre-bid process. First, the precaster needs to be generally familiar with the segmental construction methods and proposed erection scheme. Then the precaster should review topics discussed in the following sections.

Bid Document Review

The next step is to derive an anticipated contract award date and identify project milestones to extract erection dates. Use this knowledge to formulate a general inventory for casting yard start-up requirements, segment cast out time frame, and maximum segment storage area needed.

Carefully review contract drawings to determine segment types, quantities, weights, anchor block configurations, and special project requirements, including mixture proportions, curing regimens, and testing protocol. Determine quantity and type of formwork required, and identify the required versatility of each form to efficiently handle the project schedule. Map out a preliminary casting yard layout, potential workforce requirements, and existing (but in need of modification) and/or new equipment needs.

In particular, thoroughly understanding the geometry control aspects of a segmental product line will ensure a successful outcome. A healthy fear of a costly mistake is not a bad business perspective to maintain, and successful precasters use a detailed, methodical approach to daily procedures. A comprehensive review of software (provided by others) and monitoring survey instrument maintenance will keep the project on track.

The theoretical casting curve will be detailed by the contract drawings and interpreted by the geometry control software with the approved geometry control data files for each bridge span. This span-specific data will provide the necessary information to understand the vertical, horizontal, and super-elevation alignment for the bridge. The daily, short-line casting operation will be controlled by varying the position of the match-cast segment in relation to the casting form or wet-cast segment. Horizontal control points are based on the project plane coordinate system, using north and east surveying conventions. The baseline alignment is established as tangent and/or curved sections through the horizontal control points.

Do not limit a review to the contract's structural drawings, but further identify all electrical and mechanical



Photo courtesy of Parsons Brinckerhoff.

Fig. 1. Warm-climate casting yard.

pipework to be installed within the segments. All hardware and embed plate inserts should be laid out in the segment shop drawings provided by others, but assume precast concrete plant installation of all these items according to plans and specifications. All incoming material deliveries should be inspected and logged into a project inventory system. Monitoring material usage and reorder points is usually the precaster's responsibility because complete inventory control directly affects the production schedule.

Specifications, Testing, and Certification

Material specifications and testing requirements of the concrete need to be closely reviewed. Typical requirements include petrographic analysis of the course and fine aggregates, testing for alkali-silica reaction, determining modulus of elasticity, and evaluating creep and shrinkage. These procedures will provide a critical analysis of the mixture proportions to ensure concrete durability and structural longevity. Certain tests will require completion by an AASHTO-certified lab at the precaster's expense.

Assess any requisite casting personnel certifications and experience needed, especially that of specialized labor for post-tensioning and grouting operations. Attend all pre-bid meetings

to keep abreast of project changes and specifics, develop contractor contacts, and know the competition. Most contractors will welcome the precaster's participation and will provide answers to any questions. Carefully determine a comprehensive scope of work to complete the project while addressing risk concerns.

FACILITY ASSESSMENT

An important aspect of a manufacturing facility's in-house self-examination is to analyze existing plant and staff strengths and weaknesses. A snapshot perspective of the existing company assets is vital to properly assess additional action items for each department to undertake for this new product line to be competitive in the marketplace. If the concept stage is not brought to a thorough visualization by each department, followed by a managerial cross-checking analysis to avoid omissions and questionable areas, the overall process will be incomplete.

If the existing facility is not large enough to handle a proposed project, the next step is locating a suitable manufacturing facility with an adequate casting yard area. Once the casting site is determined, the next step is to calculate the maximum segments to be erected per day and determine appropriate transport and site-delivery methods for the segments. If existing transport is

insufficient for the loads, overall size, or delivery schedule for the pending contract, the precaster must consider upgrading facility trucking capability or bidding the segments as freight-on-board (FOB) plant.

Concrete Batching

Examine project concrete batching and delivery requirements to properly match all aspects of existing facility capacity with the specific project requirements and to identify any requirements that may be beyond existing plant production capacity. Seriously consider the benefits of value engineering proposals or a schedule acceleration, each of which have the potential to dramatically increase the chances of a successful project. Concentrate on particular in-house corporate skills or talents that present a clear advantage over the competition or capture value-added advantages that may augment the overall sales volume.

Determine any concrete batch plant component upgrades necessary to handle segmental batching requirements, including the adequacies of central mixer size (production and volume), cement silos, aggregate bins, and admixture dispensing setups. Perform regional cost comparisons of concrete materials that meet project specifications.

Form Enclosures

The type of casting enclosure required for proper concrete curing depends on the climatic zone of the production site. In a warm or temperate climate, the precaster might use a temporary wood or fabric structure for protection during inclement weather to maintain productivity and enhance the concrete curing process (**Fig. 1**). A cold climate may require a more substantial structure to protect the concrete and ensure uninterrupted productivity. The precaster may use an existing structure or set up a pre-engineered metal building to manage the anticipated adverse climatic conditions.

To obtain a comprehensive picture for each segmental form layout, the approximate preliminary footprint will need to be known. For form assembly width, consider the widest segment on the bridge and add 6 ft (1.8 m) to each

side; this measurement should be close enough for a preliminary layout. Next, form assembly length will be about 3.5 times the length of the longest segment—usually 10 ft (3 m). The form assembly overall height will be 3 ft to 5 ft (1 m to 1.5 m) plus the height of the tallest segment, with additional allowance for safety rails. Special limitations should be discussed with the form manufacturers.

One option for an existing precast concrete manufacturing building that is too narrow in general plan is to consider that the mandrel form can use rails to run outside the building. Another option is to have completed segments moved along the rails to slide outside the building proper to be removed by crane or straddlecrane to the designated plant storage areas.

Casting Forms, Foundations, and Layout

Determine plant casting yard layout with an eye toward maximizing efficient workflow and minimizing equipment usage. Precise foundation design for the casting formwork is crucial to maintaining proper and consistent geometry results in the completed segments. Review the plant site to ensure consideration of these items: Concrete slab thickness is adequate to support production weights, site drainage is

functioning properly, and local frost conditions do not have the potential to adversely affect curing. A 12-in.-thick (305 mm) concrete floor slab in the plant should be regarded as a minimal thickness for segmental operations; driving piles will be required to establish a solid mechanical foundation. When a straddle crane will be extracting segments, the equipment foundations for the casting formwork should be isolated from the lift crane travel lanes to prevent adverse vibratory effects.

Segmental Unit Storage Capacity

Figure 2 shows pier segments in storage ready for shipment to the bridge construction site. The assumed casting schedule compared with erection delivery dates will determine maximum storage capacity requirements. Obviously schedules change—due to adverse weather or labor problems—and a significant buildup from an assumed casting schedule could occur. Even environmental regulations protecting nesting birds at bridge sites have been known to shut down construction. It is important, therefore, to consider at what point the available storage yard will be filled and whether overflow contingencies are established.

Another layout consideration proposal point is to clearly address the assumed maximum segment storage

area relegated to the project based on the parameters set by the contractor's bid schedule. An aerial photograph showing the approximate storage area (crosshatched) with estimated acreage is helpful.

OPERATIONAL PLANNING

Concrete Placement

There are a number of choices for concrete placement in segmental production depending on the material volume demands, project size, and expected budget (reimbursement). Options for concrete placement range from a crane and concrete bucket delivery to using a stationary or truck-mounted concrete boom. Determining the most reasonable delivery method will depend on the number of forms, the total volume of concrete, the needed height of forms versus clear height to ceiling supports within the building, and the proximity of the batch plant and overall plant volume.

Segment Geometry Control

A short-line casting procedure uses a stationary casting form to match cast succeeding segments against the previous unit. The first segment is cast between bulkheads. Successive segments are cast, one at a time, against the bulkhead on one end and the previous cast segment on the other end. A thorough



Fig. 2. Pier segments ready for shipment.

Photo courtesy of Parsons Brinckerhoff.

Labor Requirements

For preliminary estimating, start with a direct labor force of a five-person crew on forms and a four-person crew on reinforcement jigs, and then adjust the number of workers according to the size and complexity of segments. Discussions between management and production can further identify the direct and indirect personnel needed for the project, including any specialized equipment or tooling and integration of existing machinery to meet project material demands.

Site Delivery Requirements

A successful general contractor must provide the maximum number of segments to be delivered per day to sustain the construction schedule and the overall erection schedule for bidding purposes. For transport of precast concrete segments, contact the appropriate state and local authorities to determine permitting authority for special hauling loads and permit requirements and costs. Normally, the majority of bridge segment shipments will require overweight permits, perhaps even vehicle or police escort services. Axle loading diagrams will be needed to specify trailer capacities, and several transport dealers can usually provide technical assistance. A drop-deck or lowboy trailer configuration will often be necessary to lower a transport load's center of gravity. Never assume existing facility trailers will be adequate to fulfill the requirements of segmental transport without a complete analysis of project loads, sizes, and estimated delivery cycles.

DOCUMENTATION AND PROCESS

The complexities of undertaking a segmental unit operation demand a thorough analysis of every start-up, inventory, production, testing, QC, and delivery task. The more complete the analysis, the more clarity can be achieved and expressed by the plant team members. In this detailed and collaborative effort, the precast concrete company energizes and empowers all



Photo courtesy of Parsons Brinckerhoff.

Fig. 3. Reinforcement jigs produce daily reinforcing steel cages.

review of geometry control provisions will lead to selection of appropriate survey equipment followed by the erection of a survey tower layout. Keep the survey tower layout simple, depending on the existing facility/site floorplan limitations. When setting up multiple forms, try to utilize each survey tower for maximum utility for more than one form; this will reduce survey equipment needs and surveyor time restraints and will speed up the casting cycle.

Reinforcement Fabrication

The Concrete Reinforcement Steel Institute's (CRSI) *Manual of Standard Practice* is an excellent source of practical information on reinforcing steel standards.⁸ Figure 3 shows jigs producing the daily reinforcing steel cages necessary to maintain the established casting schedule. A consideration in fabricating bent reinforcement for segmental construction is whether to set up an in-house shop or hire a local reinforcement fabricator. Depending on the complexities of the segmental reinforcing steel assembly, some caution is advisable to avoid casting delays when contracting existing reinforcement fabricators. Their equipment is primarily set up to handle CRSI tolerances and not special bar bend tolerances typical of segmental design, which will have to be specified.

Accelerated Curing

A steam generator is typically used to accelerate the concrete curing process. A 1 million to 5 million BTU unit will service most casting yard production output. The steam machine manufacturer will provide a piping design to optimize the unit; any variation on this design will drastically affect equipment performance. The steam generator units can be outfitted with a variety of options, from simple manual controls to a sophisticated computerized system with thermocouples at each form. Computerized steam systems can be programmed to start the unit after concrete preset, provided that the correct ramp up to optimum temperature is set and that the ramp down setting the unit for proper release strength is also calibrated. Carefully weigh the cost benefits for each option—manual or automated—especially if the equipment capital outlay can be expensed over multiple projects. The multizone systems can increase cost but add versatility and efficiency to the casting operation. A multizone system will separate each form into a separate concrete curing chamber using a computerized value system, which is programmed to introduce enough steam to provide the proper curing time and temperature controls.

department staff to focus the combined expertise of each individual to ensure a successful project.

QC Manual

A concise and comprehensive QC manual detailing every step of every process is a vital tool to underscore the thoroughness of the precast concrete plant and, moreover, to ensure the client and owner's representative that every aspect of segmental production has been carefully considered. If there is an existing QC manual, consider augmenting the manual to include a precast concrete segmental operation.

Geometry Control Manual

A geometry control manual is typically provided by the contractor's segmental engineer and will provide an excellent detailed account of daily operations, including the geometry software package procedures and hand calculation examples. Request a copy of a previously used project manual for review and the program software with some sample data so the plant surveyor can become acquainted with program operation.

Repair Procedure Manual

Even if a repair procedure manual is not mandatory for a given project, it is a highly recommended document because it details numerous common plant repairs and lists any prior implementation approval required. Outlining a general agreement on a variety of repair issues, materials, equipment, and techniques will foster confidence in the precast concrete team's ability to address typical industry concerns regarding plant production, reliability, and efficiency.

Prepour and Postpour Review

Prepour review consists of three main inspections: raw material receiving and inspection, reinforcement cage assembly review when completed in the jigs, and a thorough review of the segment blockouts prior to casting. An initial postpour review is conducted after casting and prior to the match-casting process. Postpour review involves a structural inspection and a visual check of the bulkhead face that will be used to match cast the next segment. On the

day following casting, a thorough segment review should take place.

Post-Tensioning and Grouting Operations

The project specifications will detail the required concrete compressive strength to achieve prior to casting. To ensure a highly productive environment, the concrete should be at post-tensioning strength two to three days after casting. Prebagged grout mixture suppliers can discuss equipment needs and technician availability for plant training purposes. It should be noted that most project specifications reject prepackaged grout mixtures over six months old.

Specialized post-tensioning suppliers bidding the bridge project can discuss the particular requirements of the systems and can assist with employee training. The supervisor responsible for grouting operations should have current certification from the ASBI Grouting Certification Training Program.

PROCUREMENT SPECIFICS

Purchasing Segment Casting Forms

Precasters forward contract drawings and specifications to segmental formwork manufacturers and discuss project requirements. The form manufacturer will provide a design that satisfies the

casting requirements of the plan and specifications. However, it is important to remember that the manufacturer will understandably design for form fabrication ease for cost reduction, so the pre-caster must review the contract drawings from the perspective of labor analysis and in-house constructibility. Form needs are determined based on the tightest horizontal segment radius and maximum lengths of each type of segment.

It is wise to analyze all of the form manufacturer proposals and make sure to look beyond the recommendations of the lowest bidder. It's very easy to base formwork purchase on price alone without considering an apples-to-apples comparison to identify what the overall proposal includes and excludes. The initial form set up time and daily operational costs are affected by labor costs and existing plant and equipment needs to successfully transition or accommodate these new forms through all the setup configurations. Efficient form layout and plant set up are crucial for smooth production cycles (Fig. 4). Make sure that a technical representative will be at the plant for form assembly. Normally, three to five weeks is considered standard in the industry. Maintain complete installation overview responsibility, making sure segmental form assembly ensures that daily casting productivity is optimized.



Fig. 4. Segmental casting machine setup before fixed bulkhead is installed.

Photo courtesy of Southern Forms.

Review component changes necessary to adapt form to anchor block modifications in a typical span. Review and approve all form shop drawings prior to fabrication.

There are several review parameters for analyzing the casting form proposals. Segmental form limitations must be checked for the following: scupper placement, maximum casting lengths, acceptable bulkhead post-tensioned blockout locations, tightest radius for form constructibility, combined upper and lower anchor block clearances, and keyway layout interference.

Typical Segment Forms (Nonpiers)

Figure 5 shows the mandrel or core form setup for daily casting operations. The form manufacturer will provide instruction details for either a manual or hydraulic internal mandrel operation. Discuss each option with the production supervisor to assess the casting cycle implications and determine cost-effective needs.

Also part of the review of the casting form proposal is to look at simplicity and ease of daily wing setup and the pallet's smooth hydraulic operation, which cannot be overestimated, in particular, the rigidity of the fixed bulkhead, as any movement in the form will delay cycling time. Determine the daily

adjustment procedures that will be necessary to maintain the correct geometry control. If the forms have to adapt to different segment configurations, it is critical that the components are modularized to speed operations. The hydraulic jacking system (provided by the form manufacturer) can be ordered with 110V or three-phase wiring, depending on the voltage specified and the voltage that works best for plant operations. You must also calculate any anticipated costs of integration into the plant system.

Questions that the precaster needs to ask include: Is there a thickened haunch area, wing breaks, or scuppers penetrating the segmental wingform? How does each form manufacturer handle these configuration changes, and will the solutions or required modifications affect casting labor costs?

Discussion of the mechanics involved in forming the segments will provide a clear picture of any necessary changes to complete the project.

Pier and Expansion Forms

The size and weight of the interior pier and expansion form components are important. Whether the interior components are manually set or machine installed will dramatically affect labor costs and casting cycle times. Study all

form prepping procedures between casts for productivity and safety concerns.

Casting Forms—Miscellaneous Items

Three to five ton (2700 to 4500 kg) winch units with a $\frac{3}{8}$ in. (9 mm) minimum cable diameter are typically used to move segments along the production rail system. A pulley assembly, floor mounted on the opposite side of the rails, will allow movement in both directions using one winch. Air and electrical winches are available depending on the plant operator's particular preference. Of course, for extreme economy, a forklift could be used to move the precast concrete segments, but the author does not recommend this equipment for segmental operations.

Within each segment, post-tensioning ducts will be required. Forming bladders—basically a long balloonlike liner—at the duct locations are inflated during casting to avoid migration of concrete into the voids and to maintain stability.

As an operational approach on segments, secondary external vibrators can be mounted on the lower third of the form at the outside web area. The aesthetic quality of the finished segments is greatly enhanced with external vibrators, and this optional measure could save costs on remedial patching after segments are cured. Of course, all plant safety walkways, stairs, and fencing installations must meet Occupational Safety and Health Administration (OSHA), state, and local workplace regulations. A complete safety walk-through and inspection of work stations at regular intervals is mandated by OSHA.

Geometry Control

For geometric control of the segments, a one-second accuracy theodolite is used for centerline checks and elevation readings. A builder's level capable of reading to an accuracy of 0.001 ft (0.3 mm) using an invar rod is usually suitable. Review project specifications thoroughly for geometric tolerances. Monopod setups for the survey instruments are normally used with at least two permanent site benchmarks for instrument calibration.



Photo courtesy of Southern Forms.

Fig. 5. Mandrel or core form.

Lifting Equipment Concerns

The standard choices for lifting segments at a precast concrete facility are a straddle crane or crawler crane. Both machines have acceptable capacity and maneuverability, but the characteristics of each machine have implications that bear on the entire operation. It is easier to train an employee to operate a straddle crane than a conventional crane. In addition, the straddle crane can lift and transport the finished segments to the storage area, avoiding excessive plant use of tractor-trailers. The size of the plant storage yard and expertise of employees will determine which piece of equipment is the best fit for production. Examine strong-back and rigging needs carefully for safe and efficient operation. A site-specific safety manual and mandatory employee safety training will be key components for any successful precast concrete operation.

When evaluating a straddle crane, consider all equipment specifications, including lifting capacity, overall height, wheelbase, maximum hook height, turning radius, and travel speed. It is important to remember that every aspect of casting, storage, and shipping operations will be controlled by the capacity and limitations of the segmental lifting equipment selected. For material handling, the use of a crane or forklift depends on the project size and precaster preferences. Normally a forklift will be sufficient to handle most situations. Plant equipment selection will largely depend on the demands of the daily tasks assigned to each piece.

Personnel

Precast concrete manufacturing plant personnel must utilize and follow a safety manual and labor training schedule to ensure federal, state, and local compliance. The quantity of casting forms in operation will add to the daily coordination difficulties. Production efficiencies are enhanced by keeping activities in close proximity, but a concentration of work activities requires paramount safety vigilance.

Concrete Equipment

Location, capacity, and accessories of the concrete batch plant directly affect material quality. The quality and volume of concrete required for the bridge project will dictate the cement and aggregate storage capacity needs and the central concrete mixer capacity. Local climate at the precast concrete manufacturing site will be the basis for considering other items, such as an optional water chiller, ice machine, and boiler components. Proper component choices and capacity, quality, and supply of concrete material resources are the keys to producing a consistently high-quality product. The weight hopper will need certification for accuracy, and the plant will need to obtain National Ready-Mix Concrete Association (NRMCA) Plant Certification.

Concrete handling equipment can vary depending on the overall complexity of the project. A more limited operation can be handled with a straddle crane and a concrete bucket. A larger operation may require either a stationary boom or boomtruck-mounted concrete pump. The distance between batch plant and the casting production area and the concrete itself will determine concrete mixer truck requirements.

Concrete consolidation methods, such as internal and/or external vibrators, should be used at every 18 in. (460 mm) concrete lift (maximum). A small roller or air screed system to finish the deck surface is desirable.

Accelerated curing of the concrete is most commonly handled with a steam generator. Purchase of a steam generator is typically a long-lead item, and the precaster is advised to obtain a firm delivery schedule commitment.

Successful segment handling can be accomplished using several options: strand picking eyes, post-tensioned rod assemblies with holes formed near the webs, and nylon slings wrapped under the wings. Each segment-handling option has its advantages and associated labor costs, and final selection will depend on the erection contractor's equipment needs to some degree. It is imperative to carefully evaluate the handling system proposed for bid purposes.

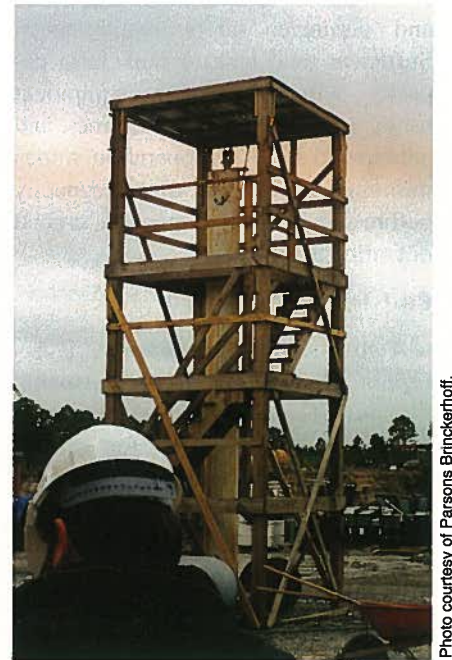


Photo courtesy of Parsons Brinckerhoff.

Fig. 6. The survey tower needs to be stable but can be a very simple design.

ADDITIONAL SETUP GUIDELINES

Casting Forms Production Area

Surveyors should lay out the entire facility casting area, including the accurate installation of brass plugs and wall targets—reference points for establishing form centerlines and fixed bulkhead setup lines. Double check to ensure that delivered form components arrive based on the required project start-up needs. Depending on the segment and reinforcing assembly complexity, each form setup should take about three weeks.

Geometry-Controlled Equipment and Setup

The plant's survey equipment is positioned in a survey tower using monopod setups. Each casting form is outfitted with manual screws and/or hydraulic jacks, which move the match-cast segment and casting form into correct geometric position. Survey towers need to be vertically and horizontally stable but can be of very simple construction, as shown in Figure 6.

Accelerated Curing

If propane is utilized in precast concrete segmental operations, research the proper storage area distance from the work zone mandated by OSHA

and perimeter safety requirements. Sufficient total tank or tank farm capacity will depend on equipment usage, local temperature extremes, and anticipated hours of operation minus minimum tank pressure capacity before equipment stops are crucial operational concerns.

Post-Tensioning System

A good source of information is *Acceptance Standards for Post-Tensioning Systems*.⁹ The contractor will choose a post-tensioning supplier for project components. Review the post-tensioning systems being considered because unique details could add significant specialized labor and equipment allocation costs. The post-tensioning supplier will supply the strand, chucks, jaws, and certain bursting stress reinforcement. The precaster has to determine which raw materials are to be included in the supplier's bid price.

Reinforcement Fabrication

Detailed procedures are necessary if reinforcement coatings are required, especially if coating processes require adapting existing plant reinforcement fabrication equipment. Consider the different reinforcement ordering choices available in the market, and order steel reinforcing bars by segment or by

span with each anchor block separately identified.

Transporting Segments

A casting manufacturing yard built alongside the project will probably require a mobile segment hauler for site delivery. For longer distances, custom lowboy trailers designed with the particular local, federal, and state regulations applicable to the project will be required. The precaster should consult the proper authorities to review the intended travel route, permitting process, and required escorts. Once the travel route has been determined, the necessary en route bridge survey data will need to be checked for minimum clearance heights.

Reinforcement Jigs

Reinforcing steel bar assemblies can be made of wood or steel, depending on a variety of factors. The author recommends a minimum of two jigs for each typical casting form. Each typical segment and reinforcement jig assembly must operate in a simple, efficient manner. These jigs, however, must adapt to the versatility and variability of the casting forms that are served. Prior to fabrication, analyze every segment configuration requirement to ensure smooth transitions between the rein-

forcement assemblies and positioning in the forms. Most piers and expansion joints can be pre-tied up to the tops of the webs, accelerating the casting process, which is especially important in match-casting operations.¹⁰

Fabricating Post-Tensioning Blockouts

Determine quantities of post-tensioning anchorage blockouts or form assemblies that are not provided by the form manufacturer. These items can be fabricated with wood or steel depending on the plant production manager's preference. Generally, the symmetry of post-tensioning design will utilize a given series of similar in repetition. Making an in-house reference mark for each setup could speed fabrication by having the fabrication shop staff begin an inventory of typical blockouts.¹¹

Transverse Post Tensioning and Grouting

The majority of transverse post-tensioning and grouting operations will be completed at the precast concrete facility. *PTI Specification for Grouting of Post-Tensioning Structures* is an excellent introduction manual to become acquainted with present industry standards to eliminate steel corrosion.¹²



Fig. 7. Casting form prepped prior to placement of the reinforcing steel cage.

Photo courtesy of Parsons Brinckerhoff.



Photo courtesy of Parsons Brinckerhoff.

Fig. 8. Precise reinforcement and post-tensioning layout requirements produce excellent quality.

Grout pumps have become increasingly more complex in recent years to ensure proper mixing. Determine the precise project requirements because most states will require a high-speed or colloidal grout mixer/pump setup. Adjust the precast concrete bid numbers accordingly because high-speed equipment is more expensive than regular paddle mixers. A few states still allow cement and water mix designs, but today most owners are specifying prepackaged grout. Depending on a precast concrete plant's regional conditions, a grout with thixotropic qualities might be a good choice.

Many suppliers produce mono-strand jacks for post-tensioning, but prior to pricing this item, check with the contractor about whether the post-tensioning jacks and appropriate calibration records are provided by the post-tensioning material supplier.

Final Segment Prep

The segment's match-cast joints will require a light sandblast finish prior to leaving the casting yard for erection to ensure epoxy adhesion unless the project uses a dry-joint system.

TYPICAL CASTING FORM CYCLE

The following is a brief list of tasks to be performed during an average casting cycle; upon closer inspection, the activities that can be completed simultaneously will be apparent:

1. Quality control staff breaks concrete cylinders from previous cast;
2. Uncover segment;
3. Surveyor performs after-cast survey;
4. Dismantle mandrel and lower form wings for stripping completed segment;
5. Winch mandrel from casting form;
6. Winch match-cast segment from wet-cast segment and remove from area;
7. Winch wet-cast segment into match-cast position;
8. Perform QC visual check of completed segment and complete postpour report on the previous day's match-cast segment;
9. Clean and prep the casting form and mandrel for casting; **Figure 7** shows a casting form being cleaned prior to placement of the reinforcement cage;
10. Complete any anchor block configuration changes to the mandrel;
11. Complete QC reinforcement cage inspection and place the cage into the casting form;
12. Winch the match-cast segment into place;
13. Surveyor performs preliminary survey, and the form is secured for casting;
14. Crew preps the reinforcement cage, adds utility embeds, and completes post-tensioning components; **Figure 8** shows the precise reinforcement and post-tensioning layout requirements to produce excellent quality;
15. Surveyor completes final survey and releases form for casting;
16. QC staff reviews the wet-cast segment and releases for casting;
17. Concrete is received and tested;
18. Segment is cast and finished;
19. Cover segment and start concrete preset; and
20. After preset, begin the accelerated curing process.

BIDDING PROCESS

Contractor Relations

Determine the proper scope of work and risk assessment on each project. Pay special attention to inclusions and exclusions within the precast concrete bid, especially because construction updates during the bidding process will complicate matters. Negotiate an acceptable mobilization amount to cover casting production facility setup, equipment upgrades, and trucking options (Fig. 9), and clearly define the payment schedule criteria. Discuss any contract drawing modifications required to ensure overall quality and productivity enhancements. Notify the contractor of strategic milestones for material deliveries to avoid casting delays.

The contractor should verify that all embeds associated with the contract drawings are present on the shop drawings, including electrical embeds and fire-retardant fiberglass sleeves, scuppers, standpipes, and anchors for mechanical items. The contractor should also verify that all embeds required by the contract's "construction means



Photo courtesy of Parsons Brinckerhoff.

Fig. 9. Segment loaded on lowboy trailer ready for delivery.

and methods" are present on the shop drawings, including picking devices, erection sleeves, top slab access, and openings. Ensure that the following as-built elevation and detail verifications

are obtained before shop drawing submittals: adjacent closure pour adjustments, electrical pass-through conduit alignment, column and pintle placements, span length adjustments, and

New Precast Concrete Segmental Contract

The latest PCI-Certified Producer to enter precast concrete segmental bridge casting is Bethlehem Construction Co. Inc. (BCI) in Cashmere, Wash. BCI will fabricate over 2200 precast concrete segments for Sound Transit Authority's Central Link Light Rail Project in Seattle, Wash.

The decision to enter this specialized precast concrete market was made after BCI was approached by PCL Construction Services Inc. (PCL) in Bellevue, Wash., about the project. The company had previously supplied precast concrete beams, columns, girders, stadia, double tees, hollow-core, and precast concrete wall panel products to PCL on over a dozen other successful projects, and PCL Civil Division was an experienced segmental bridge constructor. The concept of using the combined strengths of each firm to bring an advantage to the project owner was developed over a period of several months prior to the bid date.

Bethlehem's PCI-Certified plant brought the benefits of an established precast concrete facility and precast concrete labor force, including a concrete batch plant less than 200 yards from the casting area, thereby ensuring a dedicated source of concrete with a level of control over the high-strength concrete production and delivery. This would not normally be possible from commercial concrete ready-mix plants. The use of BCI's existing casting beds for form and reinforcement jig setup, existing equipment, crane runways, shop and equip-

ment maintenance facilities. PCI-Certified QC personnel and concrete lab equipment, and the use of the BCI plant-established utilities systems for steam, electricity, and compressed air were strong benefits with value and reduced cost to the general contractor and owner over setting up a greenfield segmental casting site near the job. Precast concrete crews from BCI would staff the nontechnical production jobs, and PCL technical experts in precast concrete segmental bridge construction would supervise the technical aspects, engineering, geometry, casting, planning, and scheduling.

The BCI plant upgrades to prepare for the project included a batch plant upgrade to allow concrete production to meet the needs of the project when combined with other BCI precast concrete project volumes, a yard reorganization to dedicate the necessary area for segmental reinforcement jigs, segmental casting forms and handling areas, and the acquisition of additional storage area for segments waiting to be shipped (Fig. 10).

From a PCI-Certified Producer's perspective, this strategic partnership approach was an ideal situation to manage the risks associated with the new product that otherwise would not have been possible on a project of this scale. From the general contractors and owners' perspective, it allowed a lower bid price and cost savings to the project along with the many others benefits noted.

elevation and layout changes between projects. Inquire if the contractor will check post-tensioning jacking clearance at all interior anchorages, including longitudinal and future tendons.

Managerial Assessment

After conducting a thorough review of the precast concrete plant and equipment, scrutinize the existing managerial and production team expertise to handle a segmental operation. Determine if an outside consultant should be contracted to provide the needed expertise to properly plan the product line expansion. While a professional segmental engineering consultant is an added cost, remember that costly omissions or a slow start-up could cripple operations.

Final Estimate

Every precast concrete plant department must provide input for procurement needs, process, and procedures. This input will include not only individual cost items but a thorough presentation and assessment of problematic areas that have the potential to cause delays and cost overruns.



Photo courtesy of Parsons Brinckerhoff.

Fig. 11. Span-by-span precast concrete segmental construction using a launching gantry.

Post-Award

After being awarded the segmental contract, immediately open dialog with plant staff on enhancements and value engineering to ease forming restraints and speed productivity. The more emphasis placed on up-front analysis and

strategic planning, the greater chance of a successful venture.

CONCLUSIONS

In some respects, gearing up to handle precast concrete segmental bridge

by Bob Connelly, Area Manager/Project Manager, Bethlehem Construction, Cashmere, Wash.

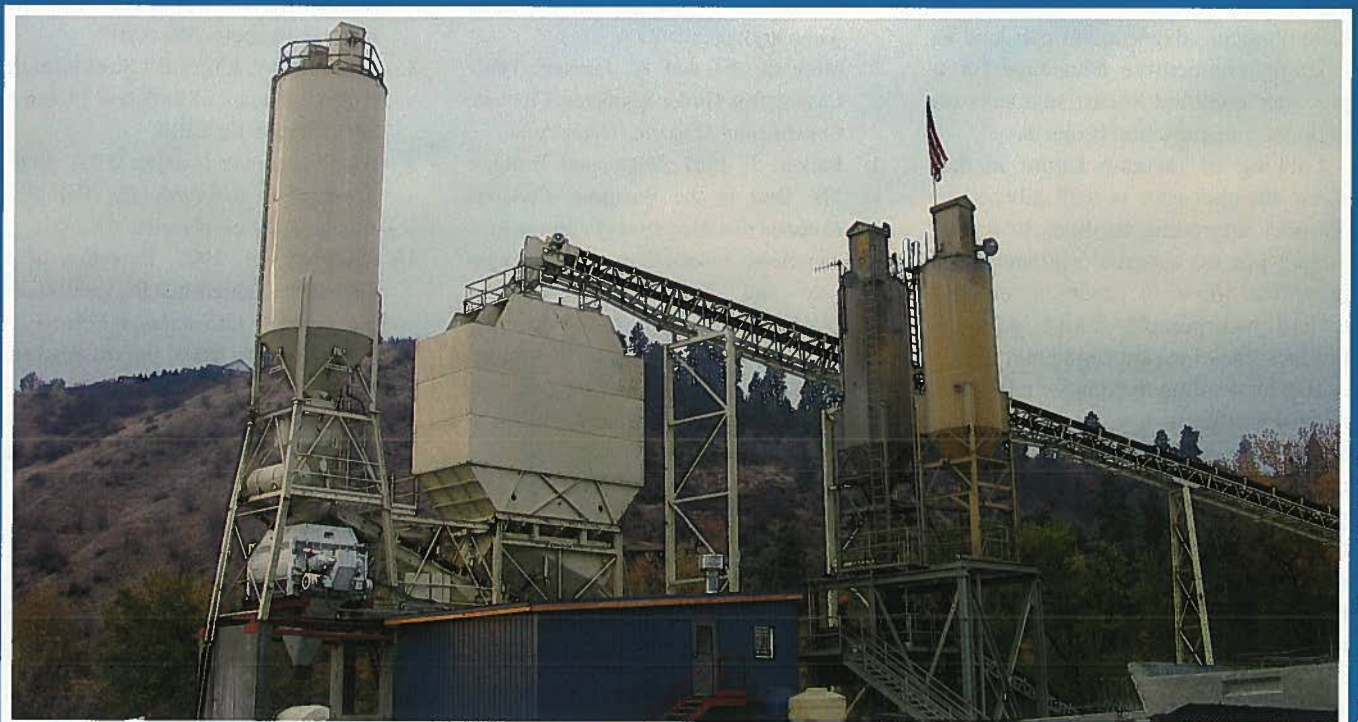


Photo courtesy of Parsons Brinckerhoff.

Fig. 10. Bethlehem Construction batch plant additions to increase production.

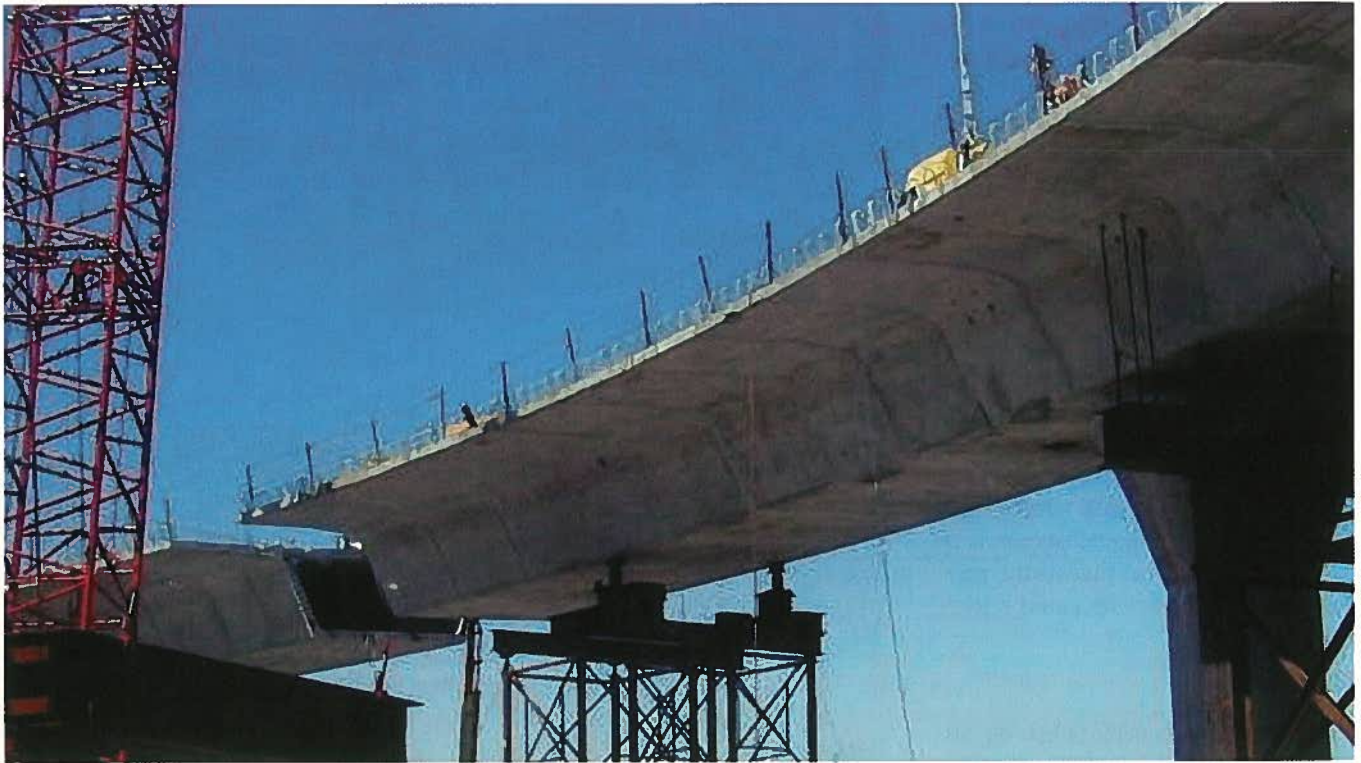


Photo courtesy of Parsons Brinckerhoff.

Fig. 12. Precast segment erection using balanced cantilever construction.

production is just another product line to augment a precaster's bottom line (Fig. 11). It is important to bear in mind, however, that segmental technology is still evolving in both design and construction/erection techniques (Fig. 12). There are at present a number of engineering and erection issues that need refinement, and this potential for technological advancement can lead to a strong competitive advantage for a precaster qualified to cast segments on regional transportation projects.

Looking to increase future market share, the precaster is well advised to consider upgrading facilities to manufacture precast concrete segments as a propitious move to ensure a foothold toward incorporating future complex product lines beyond segmental bridges. Understanding the quality initiatives needed and geometry control aspects of segmental construction is an ideal business opportunity to comprehensively prepare the precaster in competition for the pending high-speed rail projects and specialty bridges. Precasters are advised to promote AASHTO/ASBI/PCI precast concrete segmental standards in their respective regions because standardization will help ensure that purchased segmental casting machines will be adaptable

for future projects. ASBI is an excellent resource for developing contacts in the precast concrete segmental industry.

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This article is presented for informational use only as an introduction to casting segmental bridge components. The intent is to promote an understanding of casting yard considerations and does not cover all situations or particular project specifications and plan requirements.

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