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Precast Segmental Bridge Construction Part 2 - Span by Span Erection Method

by

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Introduction

The popularity of precast concrete segmental bridge construction has grown worldwide in the last few decades. A broader understanding of these structures and basic outline of the processes for Precast Manufacturing, Substructure Erection, Superstructure Erection – Span by Span Method, and Superstructure Erection – Balanced Cantilever Method are detailed in the SunCam course; ***Precast Segmental Bridge Construction – An Introduction***. This course gives a more specific look at the Span by Span Method of superstructure erection. Some of the material from the referenced Introduction course is repeated within this course as background information to allow this document to be read as an individual subject. However, as the subsequent courses are added (Precast Substructures, Balanced Cantilever Erection, Segment Casting and Storage, Stressing and Grouting, etc.), each one should be complementary to provide the full scope of this type of construction. The course will be broken down into four basic sections: Erection Equipment, Lifting and Transporting Segments, Truss Placement, Erection Geometry, Span Erection, and Stressing and Grouting.

Precast Concrete Segmental Bridges offer many benefits to owners like reduced costs, reduced construction time, reduced environmental impacts, and reduced maintenance of traffic. These benefits can be achieved while utilizing local labor and materials, better means of quality control, and with minimum requirements for future maintenance. They also offer additional structural advantages of durability, fire resistance, deflection control, better rider serviceability, insensitivity to fatigue, and other redundancies. These bridges can accommodate highways, railways, and rapid transit, in both urban and rural environments. They can be straight or curved alignments, and can provide long spans for difficult obstructions and terrain. The Span by Span erection method is the most common procedure for constructing this type of bridge superstructure.

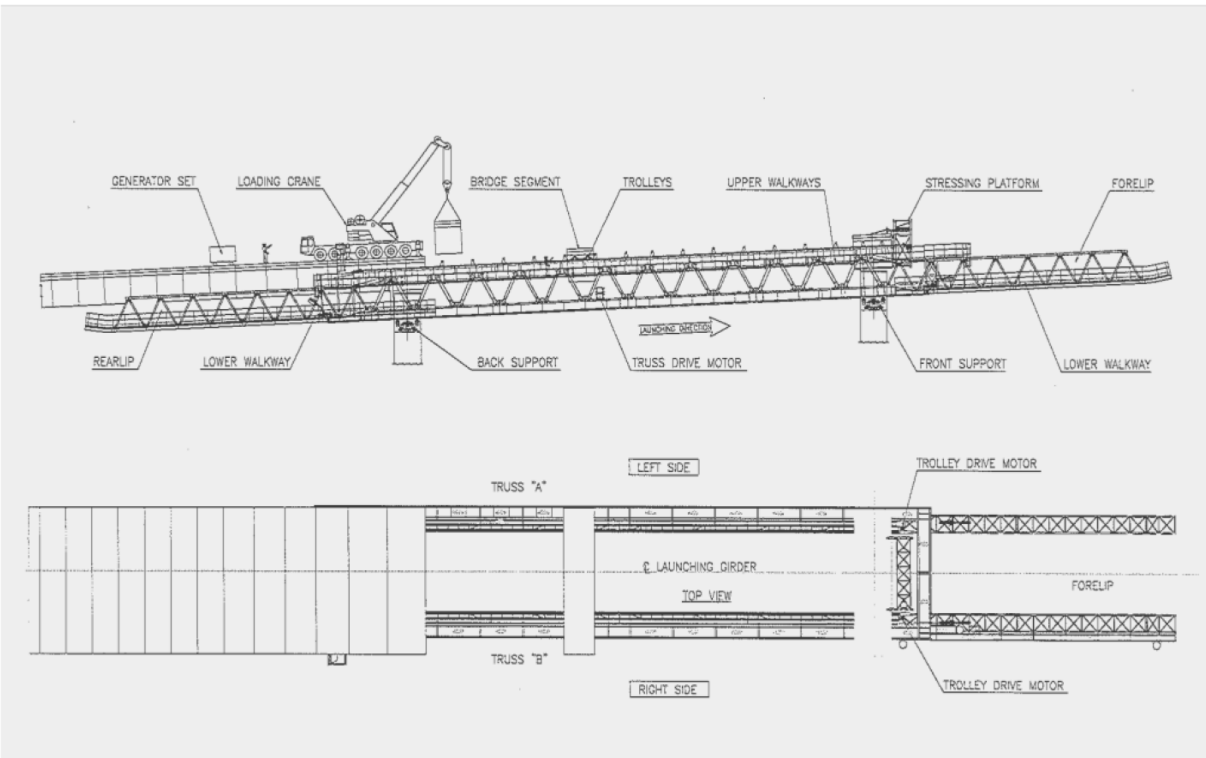
The span by span superstructure erection method of construction is where the span elements are temporarily held in place until they are self-supporting and once capable of self-support the erection procedure advances to the subsequent span. The completion of one span at a time is the defining character for which the name “span-by-span” is derived from. This method is very repetitive and can be economical for spans ranging from 80 to 180 feet (150 ft spans are generally accepted as the most economical span length based on typical substructure types vs. typical truss). Efficiency is gained due to the repetitive assembly line nature of the work. Items that can affect productivity include: variations in span length and especially span height, the terrain being spanned (land vs. water, urban or industrial vs. open areas), and changes in alignment (curves and transitions).

Erection Equipment

In order to make this erection method as efficient as the name “span by span” would imply, the operations have been simplified to become repetitive. This however is aided/accomplished with some very specialized equipment. First the segments of the span must be temporarily held in place until they are self-supporting.   Common temporary structures used for this function are: individual shoring towers, underslung carrying devises like trusses or box beams (these can support the segments under the soffit or under the wing (only if the segments are designed with a cantilever wing support condition)), the trusses can be supported from erected towers or brackets at the piers, or an overhead gantry can hang the segments from above. Second the segments must be lifted into position on the temporary supports. Where access permits, ground based or barged cranes can be used to lift the segments. Excessive heights or height restrictions may limit the use of cranes so specialized gantry transports have also been used. Lastly, rollers, jacks, winches, cable pushers and tuggers, stressing platforms, and C-brackets are a partial listing of miscellaneous equipment and fabrications that need to be procured prior to beginning the erection.

TEMPORARY SUPPORT EQUIPMENT

Underslung Trusses: Underslung trusses are a very stable and versatile choice for temporary support. The truss frames are well suited for walkways and access scaffolds. They can provide for lateral and longitudinal movements of individual segments as well as the entire span. They can be self-launching or picked and placed by cranes. Downfalls are they are harder to maneuver through curves because the segments interfere with the truss chords, they restrict clearance under the bridge, and underbridge obstructions may interfere with their use.



Overhead Gantries: Overhead Gantries are less stable than underslung trusses but provide more versatility. They are usually self-launching and since they set above the construction and the terrain they can navigate through curves and congestion better than underslung trusses. The gantries can be loaded by delivering the segment from the previously constructed spans or lifted from below. Usually this system is the most expensive option of temporary support.

<u>Individual Shoring Towers and Carrier Beams</u>: If schedule allows, individual shoring towers can be used to support the segments. The towers can be placed under each segment (either under soffit or underwing) or a combination of towers and carrier beams can be used for multiple segments. Each tower will be located horizontally and vertically for the bridge alignment and there is less ability for adjustment of the span after the segments are set. Also, pour ground bearing capacity, excessive span heights, and difficult terrain and obstructions will limit this option. However, shoring towers are the most readily available materials and usually the cheapest system to purchase.

SEGMENT PLACING EQUIPMENT

Cranes: Where access allows, cranes can be used to place segments in the temporary supports. Excessive heights, excessive weights, congested sites, or difficult terrain may limit this option. Each crane manufacturer and type will have specific load charts that will details the crane capacity at various boom lengths and swing radii. Allowable soil bearing capacity is a significant factor when selecting this placement method, unstable foundations can fail causing reduced crane capacity.

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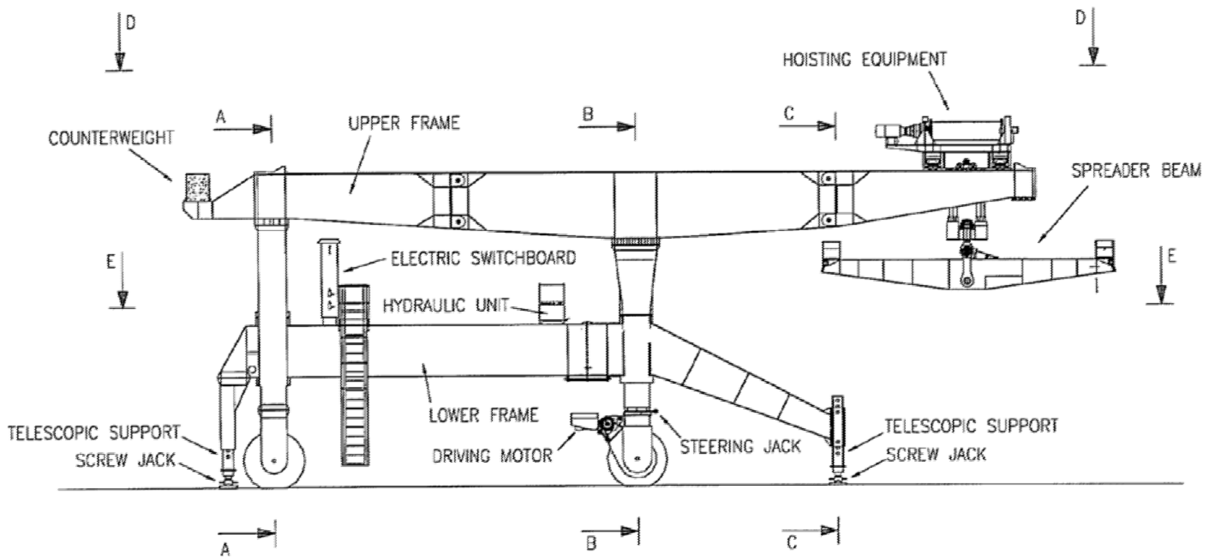
Segment Loaders: Project size and schedule may allow for the design and purchase of specialized erection equipment. Segment loaders are specifically manufactured to lift and place segments. These pieces are usually project specific and will require manufacturing time and upfront money, but through economy of scale they can more than pay for themselves.



MISCELLANEOUS EQUIPMENT

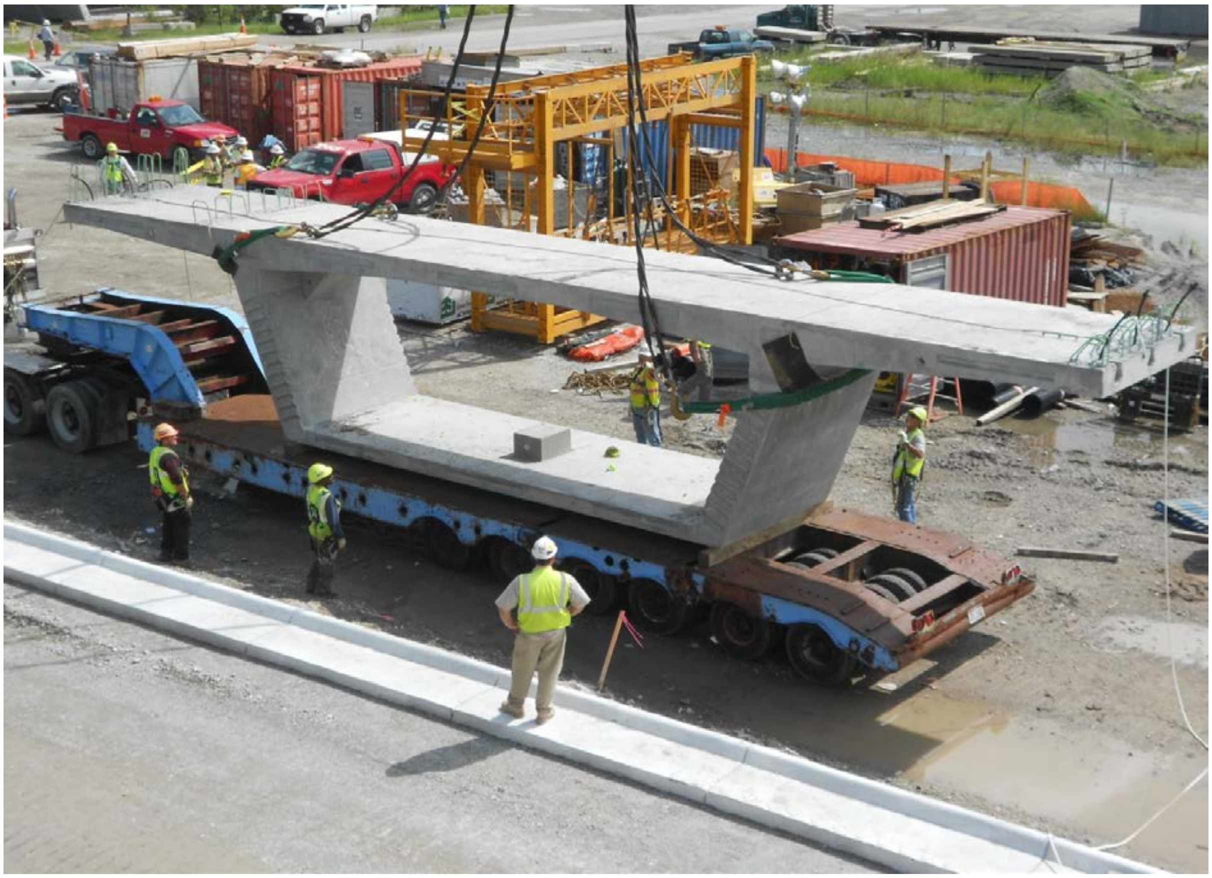
Under Soffit and Under Wing Jacks

Stressing Platforms

Rollers

C-Hooks

Lifting and Transporting Segments



Depending on the location of the storage area to the bridge erection site, the method of transportation will differ. Whether it is by trucks (on and off road), rail, or barge, several factors apply to all: hauling restrictions – time and weight, permits, environmental and noise ordinances, and distance. The most direct routes might not be the most cost effective or available. A necessary decision will also include whether to purchase, rent, or subcontract the loading and transporting. The lifting and handling of these large castings is specialized work and any errors can be catastrophic therefore, the services of professionally experienced subcontractors are advised.
Note: the segments must be transported to the bridge for erection in the same relation as they were cast.

Crane lifting segments using picking frames and picking beams with anchors or sleeves cast into the top deck of the segment

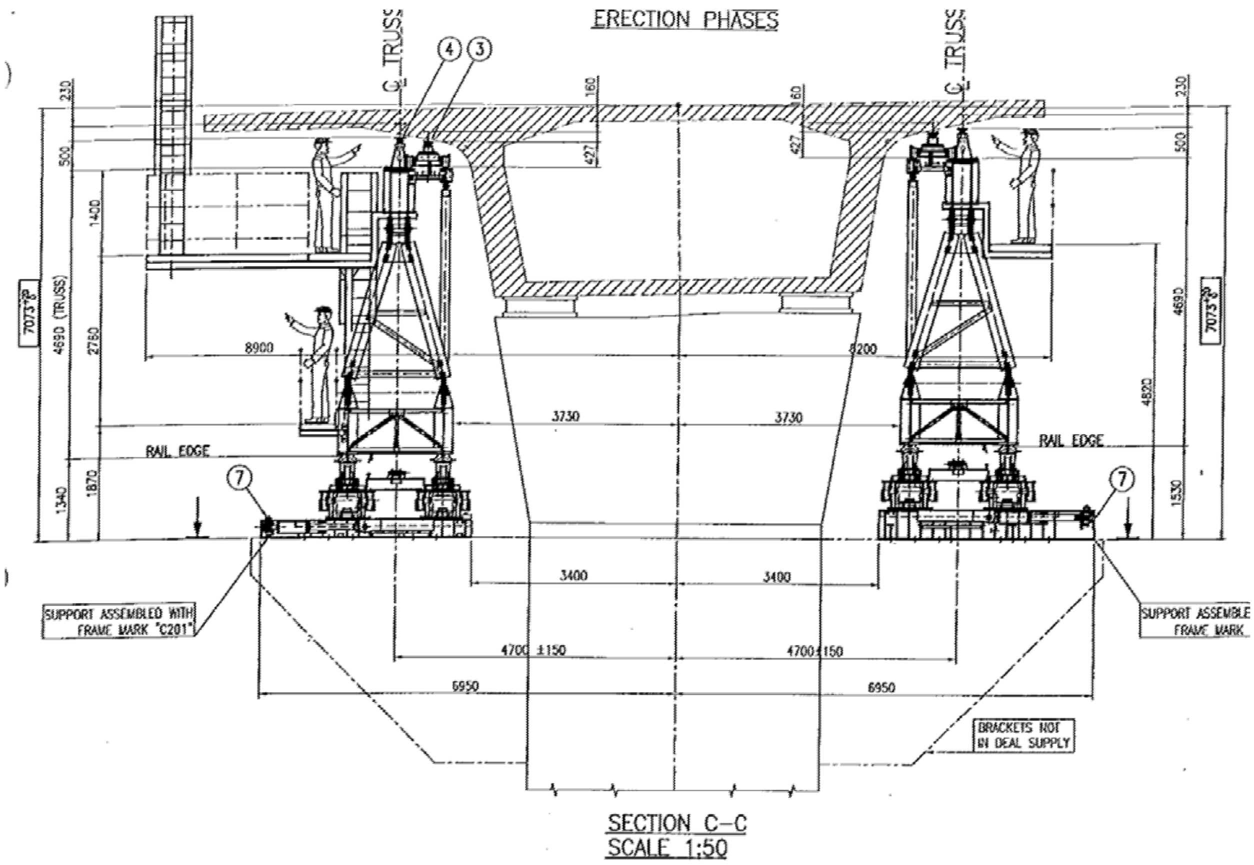
Gantries lifting segments using under wing straps with softeners at the concrete edges

Specialized multi-axle trailers will be needed for hauling the segments, as well as, a tractor with enough horse-power to tow the load. The above trailer is adequate for non-permit loads for hauling onsite or at the casting yard. Multi-axle dollies will be needed for legal permit loads on public roadways. If the trailers are used to deliver segments over the previously constructed portions of the bridge, the engineer will need to check that the wheel and axle loads are allowable. If manufacturing details for the tractor and trailer are available, the engineer can determine the optimal location for placing each segment on the trailer to distribute the loading acceptably to each axle. Alternately, portable truck scales can be used to measure the actual axle loads and through a series of “trial-and-error” segment placements, an optimal location can also be determined.

Truss Placement

To begin erection, the support structures must be erected. If individual shoring towers are used, the ground must have a suitable bearing capacity, if not, stabilize with stone and/or use crane mats, then erect the towers to the bridge alignment and height. If an underslung truss or overhead gantry is used, erect supports at piers and place truss to the correct line and grade off the pier supports. The length of the underslung or overhead trusses will need to be a minimum twice the structure's span length if they are to be self-launching, otherwise they can be shorter if a crane will be used to pick and set them in place at each span.

Given a known truss/gantry width and height, the supports can be set relatively close to grade, but the support system should have some adjustability to complement the geometry controls of the truss/gantry frames. This is especially true for bridge structures with significant horizontal and vertical curves. The geometry controls of the frames need as a minimum, sufficient ability to adjust the support of the segments to the bridge alignment but may not be enough to clear bridge curvatures for the erection of the subsequent spans. For sharp horizontal curves, the frames will need to rotate through the curve in chords until they can be set in position for the next span. For the sag and crest portions of vertical curves, as well as, changes in superelevations for sharp horizontal curves, the frames will similarly traverse through the curves in chords and may lose clearance. Each position of the erection support structures will require a thorough evaluation of the bridge geometry to determine the most efficient locations for each span erection.



Once the locations of the supports and frames are determined, and the erection of the temporary supports are at the required line and grade, a complete inspection of the structure is necessary to ensure the placement of the segments are ready to proceed. The construction engineer and the support structure manufacturer should provide a checklist of safety and maintenance items to be reviewed at each setup. After a final survey to confirm all dimensions are correct, the mechanical systems used for erection adjustments should be locked down to prevent any accidental changes in alignment from occurring.

Erection Geometry

Geometry Control for the erection process is necessary to ensure that the segments of the spans are oriented in the correct horizontal and vertical alignments, as well as, control for cross slope super-elevations and bridge deck camber. The segments are surveyed and placed in their as-cast alignment, then adjusted for any field conditions that deviate. The erection should follow the values as-cast. Minor deviations should be expected and are easily adjusted. More severe adjustments may occur and should be addressed by the engineer on a case-by-case basis.

In order to understand the geometry control for erection, a brief overview of the casting geometry is necessary (for further detail a subsequent course will detail the casting geometry more in-depth). For this course the precast segments will be short-line match-cast. This means the segments are cast sequentially in a single stationary form system where subsequent segments are cast against their predecessor creating a matching pair. The exact bridge geometry is established between the matched pairs such that the segment is unique to a singular place in the structure. The controlled setting of the precast yard allows production similar to an assembly line environment with the goal of completing a segment each day per cell.

After casting a segment, the previous day's production is asbuilt by the survey crews to ensure the geometry was maintained while the concrete set. If the asbuilt survey shows any deviation from the plan geometry, adjustments will be made in the subsequent castings the correct the error (minor deviations can be corrected in the next segment while more severe differences may take several segments to span the adjustment or may ultimately result in rejection of the segment making a re-cast necessary). The segment is rolled out of the forms and then set in the match-cast position for the next placement. The forms are tightened around the match-cast segment, embedded materials are placed, and the new geometry is surveyed to make the segment ready for concrete. The procedure is repeated with the match-cast segment rolled out to storage, the casting rolled out to be the new match-cast, and the cell prepared for a new casting. The as-cast survey is recorded to be given to the field surveyors at the erection site for controlling the erection alignment.

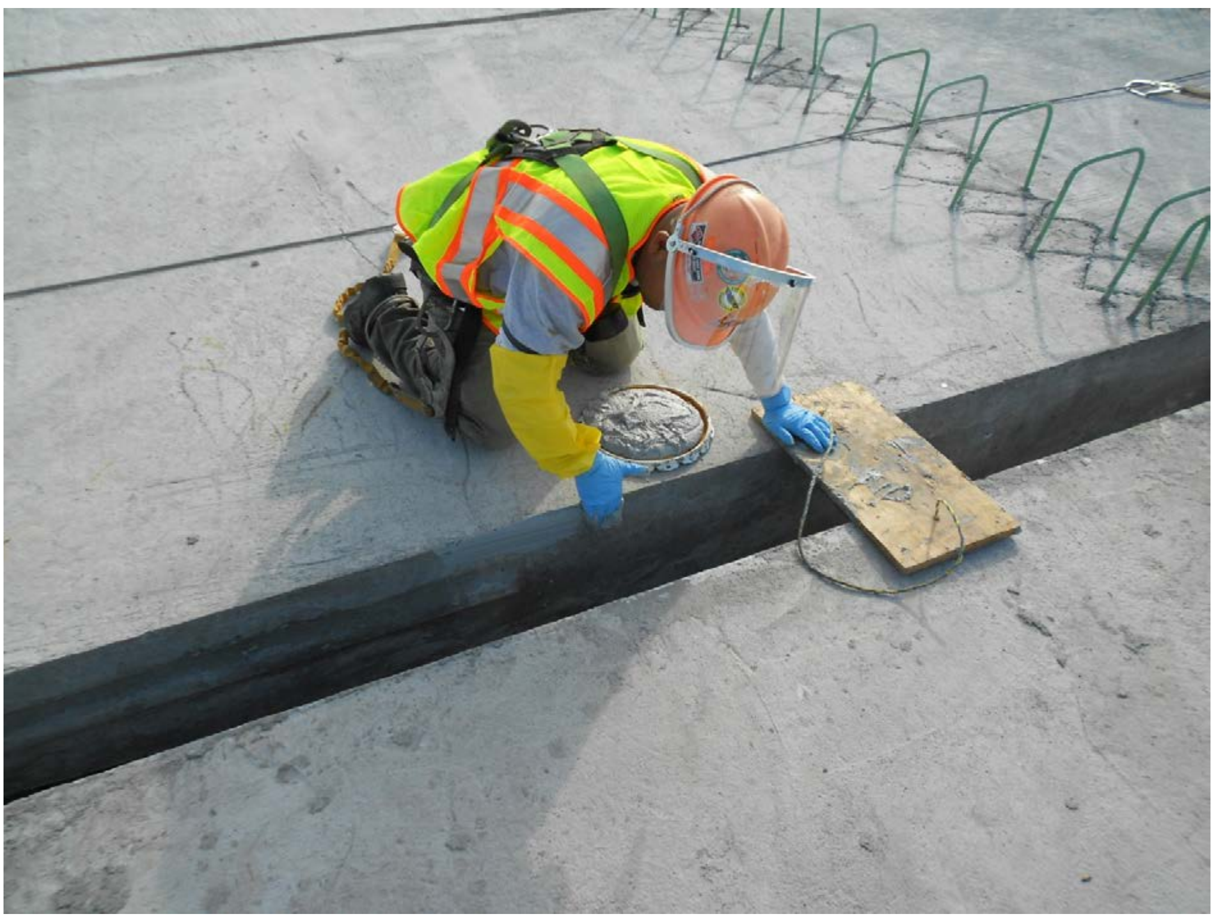
At erection the individual segments are surveyed as they are placed in the supports then the deck is re-surveyed as a unit to confirm the alignment was maintained through the erection process. Utilizing the survey control points cast into the segment, the first segment will be set in the required location and the following segments will be surveyed as they are placed to aid the "fitting up" of the matching pairs. The geometry will be monitored with each segment placed and compared to the recorded data from the casting. Through the erection process minor changes due to field tolerances will occur. This can be controlled by adding cast-in-place closure pours between segments (usually at planned locations at the beginning and end segments of the span). Since the closures are cast-in-place, the geometry can be adjusted horizontally and vertically to accommodate transverse and longitudinal changes.

Span Erection

After the temporary supports are set to grade, inspected, and locked in their fixed position, the span is ready to start erecting segments. The first step is to load segments on to the supports (assume underslung truss for narrative) starting from one location and launch them longitudinally to their approximate location. Typically the segments are set from the downstation end and are rolled up the truss (using Hillman rollers or alternate methods of launching) so the span segments need to be delivered in reverse order (last span segment first…first span segment last). Fully load the truss with all of the span segments prior to surveying to allow the truss deflection to occur. Survey and align segments for line and grade making sure chord offsets are correct for curved structures.

Next the segments will be aligned to the bridge geometry and joined. Sometimes it is helpful to dry fit the segments together before epoxy joining, especially if the epoxy is a rapid set type. This is usually an unnecessary step if adequate survey control was used in the casting yard during the match casting. A gap should be left between the segments over the piers and the mid segments of the span. This gap will be closed with cast-in-place concrete as a closure pour to correct any unaccounted field conditions. This will help ensure that errors won't be cumulative through the structure but rather each span will start as corrected to the proper line and grade. The bearing assemblies of the bridge will be set as part of the substructure activities. Various types of bearing assemblies can be designed for use on span by span segmental bridges (plain and steel reinforced elastomeric pads, pot bearings, spherical bearings, etc.). To accommodate for design cross-slopes and longitudinal geometry, as well as, construction tolerances, cast in place pedestals may be required under the pier segments. Since these pedestals are cast during the erection process, high strength rapid set grouts are normally used to maintain the span by span schedule.

Epoxy is then applied to the match cast faces, pressure is applied with temporary high strength rods for an "epoxy squeeze" to seal the joints (the epoxy is used as a lubricant/sealant to aid construction and increase long term durability of the structure).



If the span is over live traffic, private property, or environmentally sensitive areas, it is a good idea to drape netting below each joint to catch the epoxy that drips from the "squeeze" so it won't damage anything below while it hardens (once hardened it is inert and based on owners criteria, can be left behind). If the underside of the bridge has an architectural requirement, the drips will need to be cleaned off each joint or they will harden into unwanted jagged stalactites. If too much epoxy is used on the joints, excessive amounts will squeeze out as the joints are pulled tightly together. This will affect the amount of epoxy purchased, handled, and cleaned up. If too little epoxy is used, the joints will leak which will require epoxy pressure injection sealing to repair the integrity of the corrosion/freeze/thaw protection systems. The optimal amount of epoxy per joint will be fine-tuned by experience as spans are completed.

To align the entire span, a tensioning load must be applied through all segments to lock them together as a single unit. Permanent internal and external tensioning materials are installed through the spans usually in protective ductwork sheaths. To maintain the gaps needed for the closure pours while this load is applied, small concrete blocks are poured at the closure pour gaps using high strength rapid set grout to act as spacers. Once a minimum strength has been obtained, the permanent tensioning strands and rods are tightened to lock the segments together prior to final stressing and grouting operations. The closure pour is then completed to make the span continuous. The two closure pours should be equal and less than 12" wide each. At this width they usually do not need reinforcing steel. They may need to be adjusted when alignment corrections of the span dictate, reinforcing steel should be added if widths exceed 12". Simple formwork elements are hung between the two segments and held in place will all-thread rods for a tight seal. High Early concrete is usually used when making a closure pour to minimize curing time to obtain the minimum compressive strength and continue operations.

Spreading epoxy lubricant/sealer between segments prior to tensioning

Forming span closure pours from interior of segment box

Stressing and Grouting

After the setting and joining of the span is complete, the post-tensioning operations will begin. Install permanent internal and external post-tensioning strand and rod longitudinally through the span. The number of strands per duct and the number of ducts per span will vary and a stressing sequence will be provided in order to transfer a uniform load. The strand is stressed using high strength hydraulic jacks. When the

jacks reach the required pressure (compressive loads will be calculated in terms of hydraulic pressure in the jacks) the strands will be anchored in places with wedges to retain the loaded energy. The stresses applied to the strand will stretch the steel. Elongations will be measured to ensure the stresses occurred over the entire length of the strand (a shortened elongation will mean the strand is pinched somewhere along its length and repairs may be necessary). The ducts are then pressure grouted to both protect the strand from corrosion and to permanently contain the stresses from the jacks. Concrete is then poured around the anchor blocks for further corrosion protection.

After post-tensioning, the span is self-supportive and complete. The trusses and other support devices are advanced to the next span to be erected and the process is repeated. Trusses can be advanced with cranes using a “pick, move, & place” method or can be self-launching using a “launch, slide, & pivot” method. Note: Design and maneuvering of trusses through curved spans takes tremendous consideration and potential losses in time and efficiency are significant if not properly planned.

Once each span is complete it will be capable of being open to traffic for the design loading. No matter how accurate the geometry control is with casting and erecting the superstructure elements, the riding surface will be constructed by the individual segments and will reflect any imperfections across each segment joint. This will not matter for railway bridges or other structures where the segments are not the final riding surface. For bridges with rideability requirements, a longitudinal grinding is recommended to eliminate these imperfections and a transverse grooving can be added to improve skid resistance.

Summary Conclusion

This course is gives a more specific look at the Span by Span Method of superstructure erection for precast segmental bridges, broader information can be found in the Suncam course ***Precast Segmental Bridge Construction – An Introduction***. This construction is very specialized and no matter how in-depth the courses are written there is no substitute for experience. Many specialty subcontractors and suppliers offer onsite consulting services as a supplement to the construction staffing. To organize a new construction project, managers should strongly consider these additions as well as the support of an experienced construction engineering firm. The consulting experience will help train the project personnel, troubleshoot problems, and give confidence to the owner. Additionally, a well-structured quality control program is a must. From design to casting to erection, unaccounted errors can have significant impacts to cost, schedule, and **SAFETY**.

Lastly, safety must be a constant focus of every operation. Because of the versatility of these bridges (mostly described in the opening paragraphs of the course) they are often chosen to be constructed in some of the most adverse and inaccessible areas imaginable. Working with extreme weights at excessive heights requires safety diligence from every stakeholder. A comment from a past superintendent demanding patience about an operation; "we're not just throwing pillows around", sounds lighthearted considering the critical nature of these operations but served as a rallying cry for the safety of an entire project that completed without any OSHA recordable or lost-time incidents. Please be safe.