Multi-Span Installation Guide

Innovative Modular Bridge Systems

Award-Winning Innovation

Resilient Site-Cast Structures

InQuik

> We developed the InQuik bridge to keep communities connected, and we're so proud to be delivering robust and resilient bridges to regional areas across the country, which will serve the residents for the next 75 years or more.

Ben Mullaney,
CEO of InQuik.

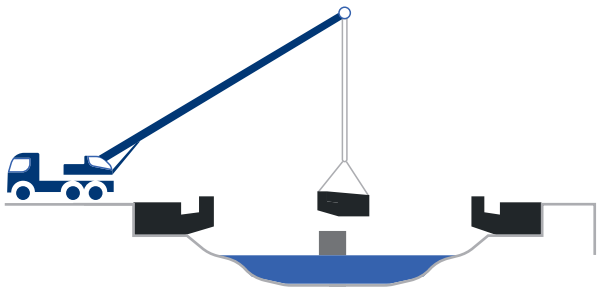
Contents

The InQuik Bridge

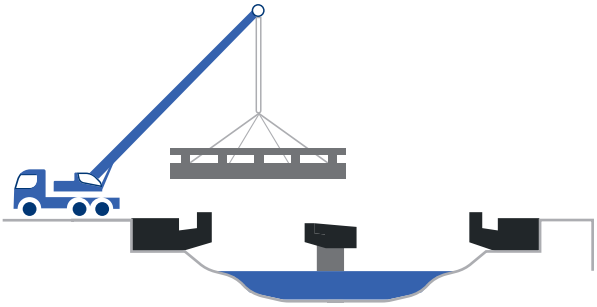
The InQuik® bridge is a semi-modular system, where the integrated steel formwork and reinforcing components are prefabricated off-site, then completed when concrete is poured on-site to form a single homogeneous mass.

The bridge panels are self-supporting, and the formwork is aesthetic and sacrificial, so beneath the steel form is a conventional in-situ poured reinforced concrete bridge, with all the benefits that provides. The InQuik product range includes abutments, wing walls, pier caps, blade piers and deck panels.

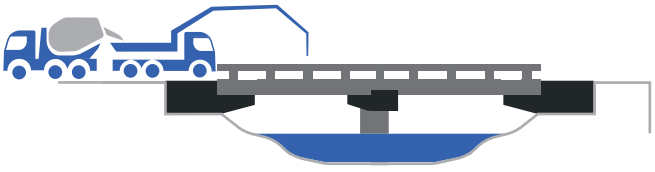
Installation process for a multi-span InQuik bridge:



Place abutments/pier caps and concrete



Install barriers and place decks



Deck concrete

Bridge complete

Key Attributes

- No temporary formwork support is needed.
- Bridge construction occurs from above, with minimal need to work under the bridge, improving worker safety and reducing environmental impact.
- The semi-modular deck panels are placed side by side to give the desired bridge width, and then concrete is poured to create a homogeneous slab.
- Can create multi-span bridge structures with pier/pier cap components.
- The InQuik bridge structure is designed for a minimum 75-year service life.
- InQuik abutments, wing walls, pier caps and wall piers are constructed using a similar semi-modular method as the deck.
- Single-span lengths range between 21-61ft, with engineering certified by ARUP to the AASHTO LRFD Bridge Design Specifications.
- Reduced long-term maintenance requirements when compared to other structures through eliminating longitudinal deck joints, and the integral design also removes tie-downs and bearings.

The InQuik Pier Cap

For multi-span InQuik bridges, our design team has developed a pier cap that is used as an intermediate support for the deck panels between the abutments. The pier cap can be either simply supporting, or integral with the deck spans. InQuik pier caps follow the same design principles of the deck and abutment structures and combine prefabricated reinforcement and formwork to create a self-supporting structure. These panels are relatively lightweight for ease of transport and installation, and concrete is poured into the pier caps on site. CMC can provide angle brackets and fixings to help locate the pier caps into the correct position relative to the piles on-site.

Pier Cap Design

The InQuik pier caps are designed using a similar philosophy to the other components of the modular InQuik bridge system. The pier cap has a standard height (39 3/8”) and width (47 1/4”), and the length of the pier cap is completely variable, but is ultimately determined by the width of the bridge.

Optional features like cambers and crossfalls are also available if required. Crowns and crossfalls are incorporated into the pier cap top surface, so that the base of the pier cap sits flat on top of the piles. Figure 1 shows an example of CAD model for a crowned pier cap which is used by the factory to fabricate the component. Figure 2 shows a completed single lane pier cap with formwork in the factory.

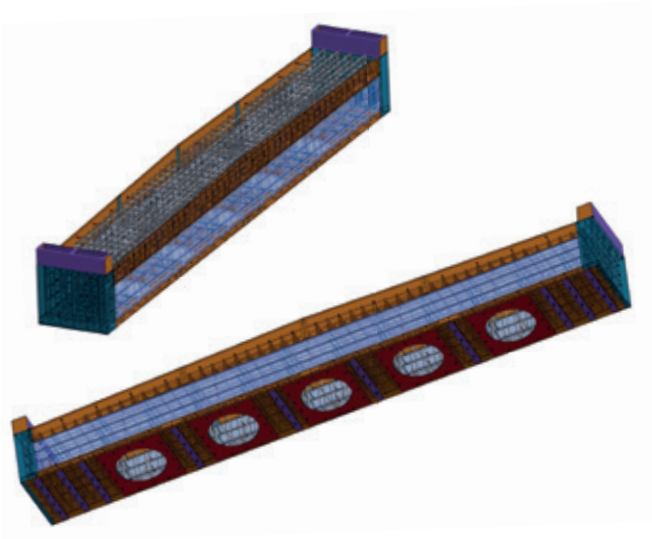


Figure 1. CAD model for a pier cap.

Figure 2. Completed single lane pier cap in the factory.

Figure 3. Pier cap installed on top of concrete encased H-piles.

Pier cap support during construction and placement of concrete

The InQuik pier cap is designed to be fully self-supporting and can be placed either directly on top of a flat concrete surface of the piles, or on top of pile collars fixed to piles which embed into the pier caps. In both cases, angle brackets and fixings are provided to secure the pier cap to its support and help to resist movement during construction.

Although the pier cap doesn't need additional supportive scaffolding, safe working platforms and the associated scaffolding are still required throughout the entire installation process, so that the workers can safely pour the concrete and install any other parts required (such as bearings and retainer strips). Workers must also follow their local safety guidelines throughout the installation process. It is also possible to erect a scaffolding that has an additional function to help resist movement in the pier cap, which may be desirable depending on the size of the pier cap and the way that concrete is poured into the structure.

In addition to safety, the benefits of scaffolding under the pier cap include:

- If the pile tops are not located at the correct location and height. A properly set-out scaffolding can help to guide the pier cap installation on the piles, ensuring appropriate dimensions relative to the abutments.
- It acts as a secondary support for the pier cap in case it is hit by machinery during installation.
- Once secured to the pier cap, the scaffolding eliminates any possible movement of the pier cap from the centreline. It effectively acts as an installation jig for the pier cap.
- Properly erected and certified scaffolding could be used the remove the need for a 2-stage pour in the pier cap, improving the speed of construction.

There are different types of scaffolding and framework systems available. Below is a possible scaffolding system that can be used during the on-site installation process. In this example (Figure 4), the scaffold frames are built according to design standards, and consistent with site engineer advice.

Figure 4 shows formwork frames that are located on both sides of the support piles, and firmly supported at the base. Screw jacks are used to adjust the height of the supports. On the formwork frames, transverse cross beams / supports are installed so that it can resist any movement in this direction. As seen in Figure 5, these cross beams can also lock the scaffolding between the piles, and they can support both the pier cap and the working platform if required. Once the formwork frames are set, the Pier cap is placed on top of the piles and the cross beams are adjusted to the correct position. Refer to Figure 5 for completed scaffolding setup on-site.

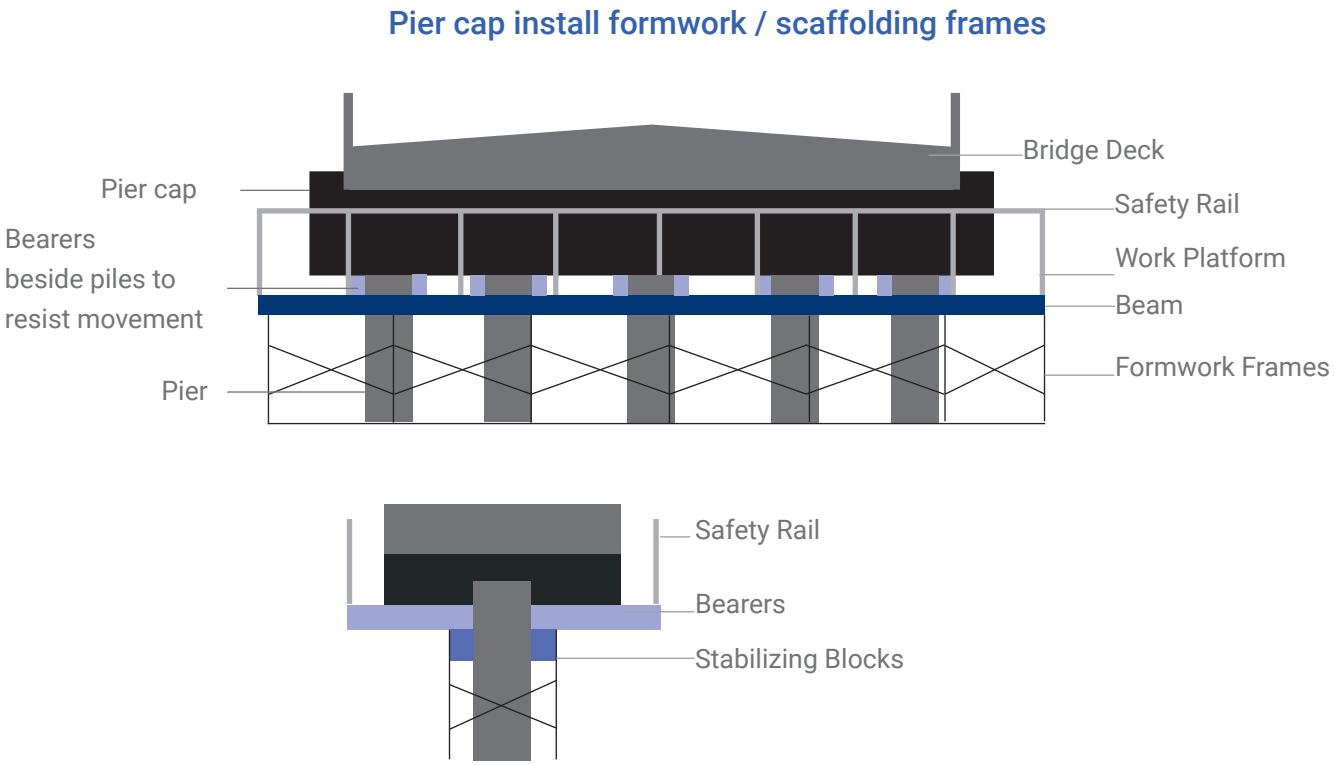


Figure 4. An example of a scaffolding system that can be used on-site during installation.

Figure 5. A close-up view of the formwork frame at one of the piles below the pier cap.

Types of Piles

A standard InQuik abutment is 47 1/4” wide with a flat deck shelf. If an approach slab is required, an 11 13/16” wide pocket is incorporated into the abutment, so the approach slab can be placed on top.

Certain projects may require a crossfall, which depending on the width of the bridge and the size of the crossfall, could be incorporated into the blinding layer (for a one-way crossfall), formed on-site by mounding up the deck concrete (for crowned crossfall), or incorporated into the abutment shelf.

Figure 6. H-pile is driven into the concrete on-site

Figure 7. Piles are cured and ready for pier cap installation.

Figure 8. Concrete pipe encasements are used to achieve the required level before the pier cap is installed on top.

Figures 9 and 10 show that concrete pipes can be used as formwork around the H-piles. If the concrete pile must be embedded into the pier cap, then a pile collar can be used to support the pier cap position - see Figure 11. The height of the piles is determined by the site engineer.

Figure 9. The piles are cured, and the pier cap can be installed.

Figure 10. Concrete pipes can be used for formwork around H-piles.

Figure 11. An example of a pile collar placed on top of the concrete pipe encasement.

Once the pile concrete is cured, the pier cap is ready to be installed on top of the piles. CMC provides brackets to secure the pier cap to the piles. See Figure 12 for a schematic view of how the brackets are installed.

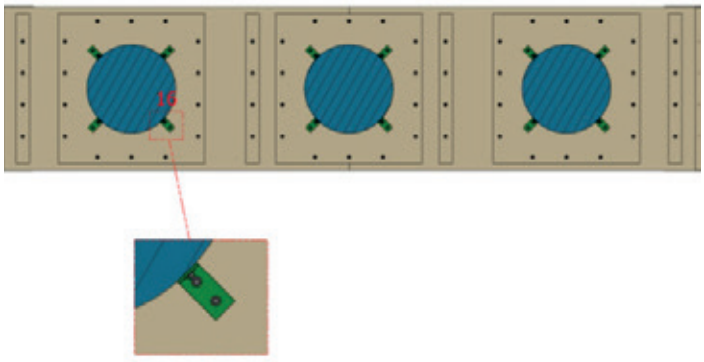


Figure 12. Brackets are installed to secure the pier cap to the piles.

In general, the brackets are connected to the pier cap and piles using screws/anchors. However, in the figure below, the brackets are welded to the pier cap support plate and the steel casing of the piles after the pier cap is placed on top of the piles. Note that these brackets can only be welded when there is steel casing on the piles. This method can provide a more secure way to ensure that the pier cap will not move during concrete pouring. The installer and customer should be aware that welding the brackets will result in long-term rusting along the weld seams.

Figure 13. A pier cap placed on top of piles.

Figure 14. Pier cap support plates and brackets are welded to the steel casing on the piles.

Installation Steps for the InQuik Pier Cap

The pier cap is prefabricated in the factory and delivered to site for installation and on-site pouring of concrete. If temporary shoring is not used to support the pier cap, the concrete is typically poured in two stages: the first pour is 24" high and is left to reach 3600 psi strength before the second stage is poured to the top of formwork. The top surface of the concrete is then screeded. Note that 3-inch slump concrete must be used, and wet low slump mixes are not suitable for this application. Optionally, as noted on page 7, properly designed and constructed scaffolding can be used to support the pier cap in such a way that a two-stage pour is not required. and the entire pier cap can be filled with concrete in a single pour.

Below are the steps for the installation of the InQuik pier cap:

I. Setup Safety Scaffold

After the piles are cured and ready for the pier cap placement, it is important to ensure that all appropriate safety measures are in place, including safe work scaffolding. Refer to Figure 15 and Figure 16 for an example of a working platform erected before the pier cap is installed.

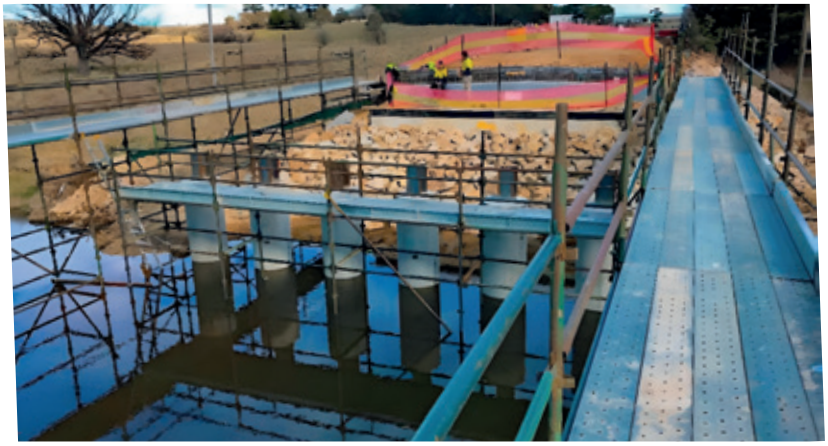


Figure 15. Safety rails and platform are erected on one side of the piles after the pile concrete is cured

As shown in the Figure 16, the safety rails and platform can be built only on one side of the piles. The workers can then only work from one side of the pier cap, which may require additional considerations to ensure that all workers follow appropriate safe working practises.

Figure 16. Safety rails and platform erected on one side of the piles.

II. Preparation of Piles

It is important to ensure that the pier cap is placed on a flat, clean surface, as this surface will be receiving the weight of the pier cap and concrete, and an uneven surface can create a risk of concrete seeping through. If a pile surface is uneven, it should be smoothed out before the pier cap is installed. Depending on how flat the pile surface is, it may be necessary to use propping and bracing during concrete placement.

The crossfall can be incorporated into the top of the pier cap

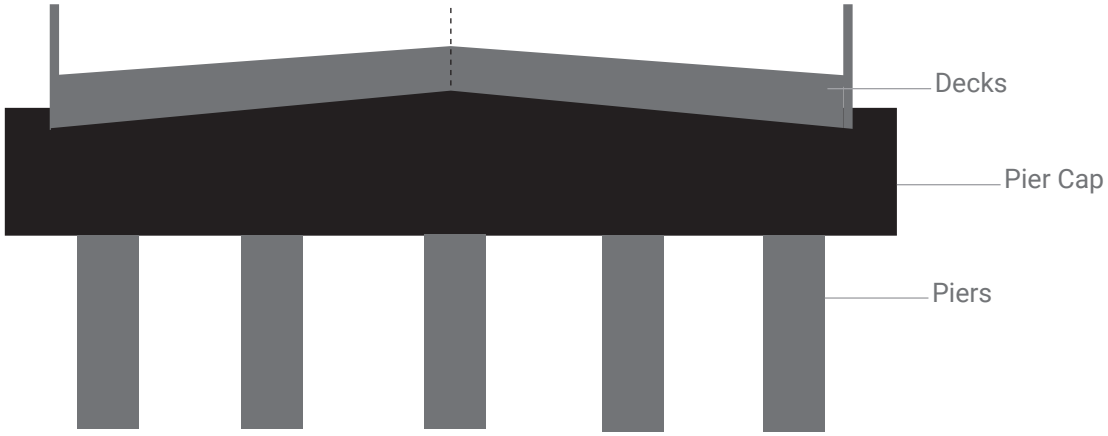


Figure 17. Flat bottom pier cap with crossfall incorporated into the top surface.

Figure 17 shows a schematic illustration of a pier cap on top of piles. This figure shows that the connecting surface between the base of the pier cap and the piles is flat, and the top of the pier cap incorporates any crossfall required for the bridge. Having a flat bottom surface allows the workers on-site to install the pier cap onto the piles much faster and safer, compared to if the base of the pier cap followed a crossfall as well.

In certain cases where the piles have a larger diameter than the opening in the pier cap, the pile cages will need to reduce to have a smaller diameter, so that it can be fitted inside the pier cap reinforcement cage. Figure 18 shows a detail view of the pile cage design where the pile cage diameter is reduced before entering the pier cap.

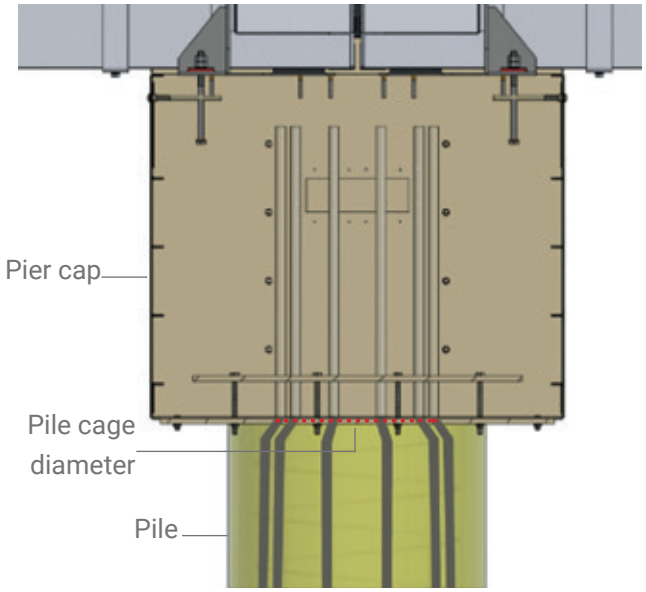


Figure 18. The pile cage diameter can be reduced to insert into the pier cap more easily.

III. Place Pier Cap

If required, pile collars are installed and fixed into the piles. The pier cap is then lowered into position and fixed to the piles using brackets. Figure 19 shows a pier cap installed with the appropriate scaffolding, and Figure 20 shows a view of the pile inside the pier cap after it is positioned.

Figure 19. The pier cap must be installed with appropriate scaffolding.

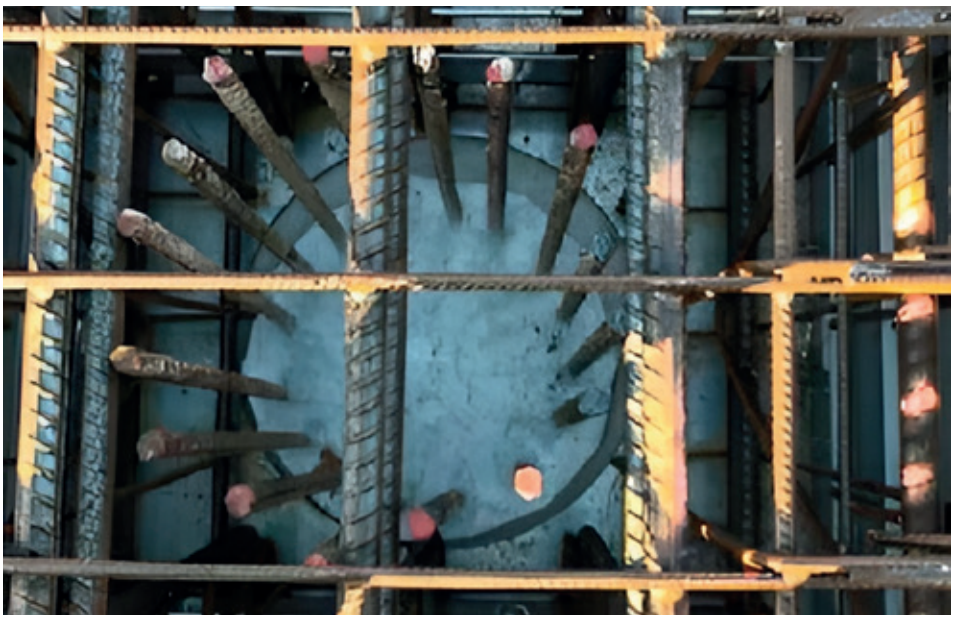


Figure 20. The pier cap is placed on top of the piles before concrete is poured.

IV. First concrete pour (24 in.)

Once the pier cap is installed on top of the piles, the pier cap can be filled with concrete. The concrete is poured in two stages. The first 24” pour starts by placing concrete around the piles, then the rest of the pier cap is initially filled with concrete up to 12”. This will allow the concrete to stiffen up slightly which will provide a strong base before finishing off the first stage pour.

After the initial pier cap pour, the workers can then start on the abutment concrete while the pier cap concrete stiffens, before continuing to fill up the pier cap to a total 24” height. If the ambient temperature is hot, we advise that the whole 24” pour is done without breaking the pour, as the concrete is likely to set more quickly.

The first stage of the pier cap concrete pour secures it in position before the second pour, which helps to ensure safe construction, and avoids overloading the pier cap with wet concrete.

Figure 21 shows the first pour of concrete into the pier cap, over the piles. For this first stage, it is important that the pipe is lowered toward the bottom of the pier cap and is placed over the middle of the pile before starting the pour. This avoids concrete and aggregate from setting on the upper rebar, which can compromise the effectiveness of the second pour stage. A concrete vibrator is also used to ensure that the concrete is evenly distributed, and air pockets are removed.

Figure 21. The pier cap is placed on top of the piles before concrete is poured.

V. Construction Joint

Where multiple concrete pour stages are required, then a construction joint must be properly prepared to ensure a secure concrete bond. For a multi-span bridge, in addition to the construction joints for integral abutments and the 53-61ft deck spans, there is also a construction joint in the pier cap, unless the single-pour method us done utilizing adequate scaffolding supports.

All the surfaces of the construction joints must be prepared properly to ensure proper performance of the joint. Surfaces of hardened concrete must be cleaned of laitance, dirt, and contaminants, exposing coarse aggregate but leaving it firmly embedded in the mortar matrix. Immediately before new concrete is placed, construction joints shall be prewetted and standing water removed. This can be achieved by using the methods outlined in ACI 318, which are replicated in the standard InQuik Installation guide.

To assist with preparing the construction joint in a pier cap, the CMC | InQuik design team has included a wash-out hole in the side of the pier cap to allow the slurry of laitance and surface mortar to be easily removed. This hole is located above the first concrete pour level. During this wash-out process, slurry must be captured and disposed of properly, instead of washed into the waterway or surrounding environment.

To capture the slurry during the wash out process, we recommend that a catchment drum (such as an IBC container) is used, with an appropriate funnel or other draining tool attached between the wash-out hole and the drum. The catchment drum could be craned into position using standard lifting equipment.

Once the slurry is removed, a cover plate is placed over the hole and screwed into position before the second concrete pour, as shown in the figure below. The cover plate must be sealed using silicone or similar, to prevent concrete leakage. The slurry must be disposed of responsibly.

Don't forget that the concrete surface of a construction joint must be dampened before the next pour, to prevent moisture from the new concrete being sucked into the lower layer, which affects the curing of the new concrete.

Figure 22. A wash-out hole is included on the side of the pier cap.
A small patch up plate is used to cover the hole before the next concrete pour.

VI. Final concrete pour

Once the first concrete pour has hardened, the second pour fills up the remainder of the pier cap. If tie-down brackets are required for a simply supported span, the bolts are generally embedded into the concrete, so before the second concrete pour, workers will have to ensure that the fixing bolts are held securely using a positioning frame (such as plywood) before the concrete is poured.

This template ensures that the bolts are accurately positioned and embedded and avoid reinforcing steel in the pier cap. After the bolts are positioned, the second concrete pour can proceed. Figure 23 shows the screeded concrete surface after the second concrete pour, and Figure 24 shows the same pier cap in position between the abutments.

Figure 23. The surface is screeded after the second concrete pour, and the restraint blocks on the pier cap sides are filled with concrete and levelled.

Figure 24. The concrete cures before the deck panels are installed.

Simply Supported Pier Cap

InQuik pier caps can be connected to the deck spans in 2 distinct ways: simply supported or integral. This section describes how the simply supported connection is made between the pier cap and the deck panels.

A simply supported arrangement means that the superstructure and substructure are constructed as individual separated sections, and then assembled together to form the bridge structure. Rubber bearings are used to cushion and transfer loads between the elements, and tie-down brackets are used when there is a risk of superstructure lateral movement, usually from high flood loads.

I. Install bearings

After the pier cap concrete is set, then the tie-down brackets, bearing retainer strips and bearings can be installed onto the top surface. Figure 25 shows the elastomeric bearing strips that InQuik uses for most simply supported designs. Some designs, particularly with longer deck spans, will use laminated bearing pads instead.

Figure 25. Elastomeric bearing strips.

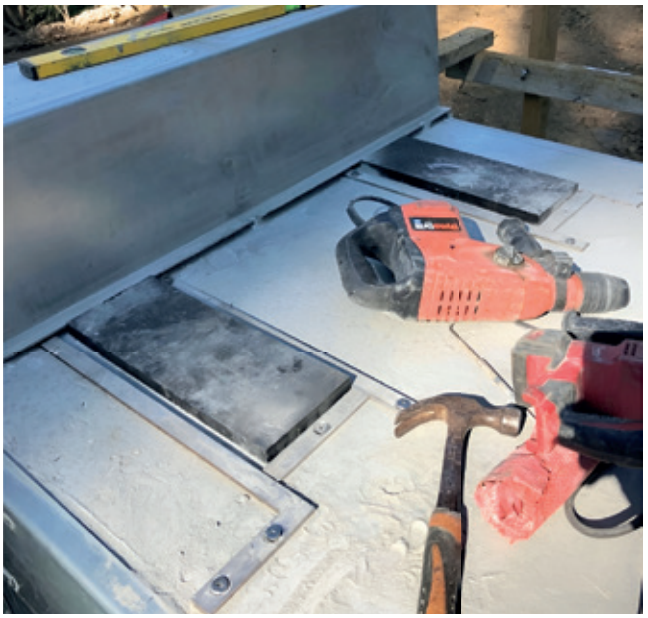


Figure 26. The bearings and retainer strips are installed on the pier cap.

II. Position bearings

Before the bearing pad is placed, the first retainer strip is installed and the bearing pad is placed against this retainer strip, before the second retainer strip is installed using the bearing pad position as a guide.

III. Bearing Distribution

The bearings are installed in a grid pattern across the top of the pier cap to support each of the bridge spans – see Figure 28. Figure 27 shows the schematic of the bearing positions, and Figure 29 shows a photo of the same bearing pad arrangement.

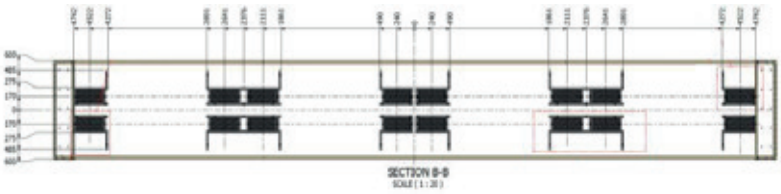


Figure 27. Top view of the pier cap.

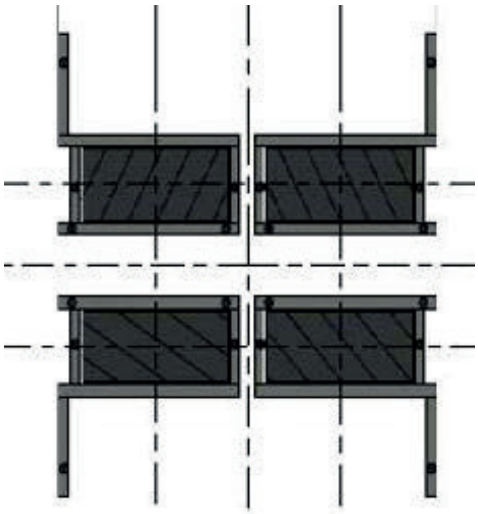


Figure 28. Schematic of the bearing pads and retainer plates installed on top of the pier cap.

Figure 29. Bearing pads are installed onto the pier cap.

IV. Placement of deck panels

When the concrete for the abutment and the pier caps has reached a minimum strength of 3600 psi, the deck panels can be installed and filled with concrete. Ensuring the substructure concrete is of sufficient strength before installing the decks is necessary for the bridge to retain its engineering certification. The first deck panel is lifted by a crane and positioned according to the supplied layout drawing, refer to Figure 30 for an example.

Figure 30. Deck panels are lowered onto the pier cap.

V. Bearing pads between deck spans

Once the deck panels for the first span are installed onto the abutment and pier cap, bearing pads are installed at the end of each beam as shown in Figure 31. It is important to install this component before the next span is installed, as the bearing pad acts as a spacer and expansion joint between the spans.

Figure 31. Bearing pads are installed at the end of the deck spans before the next span is installed.

VI. Through-Bolt

When deck panels for both spans are installed on top of the pier cap, the next step is to connect them together, so they are secured in position before the next stage of the deck installation continues. A “through-bolt” is installed through the end beams of adjacent deck panels over the pier cap. This connector is used to transfer lateral loads between the deck spans, and to connect tie-down brackets to the deck, so the deck panels will be firmly secured on the pier cap. Figure 32 shows a schematic view of the connection method between deck panels to the pier cap.

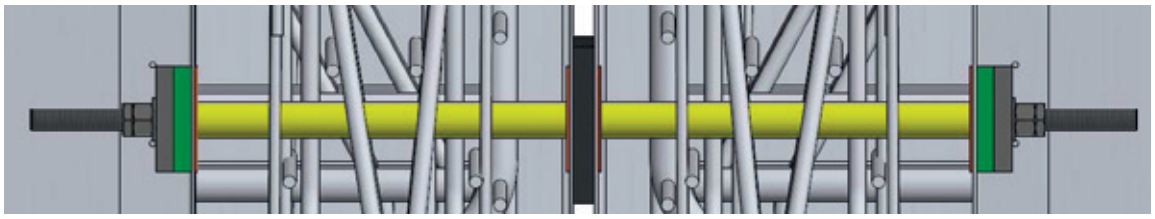


Figure 32. Through-bolt passes through two panels, and it is fastened to the tie-down bracket.

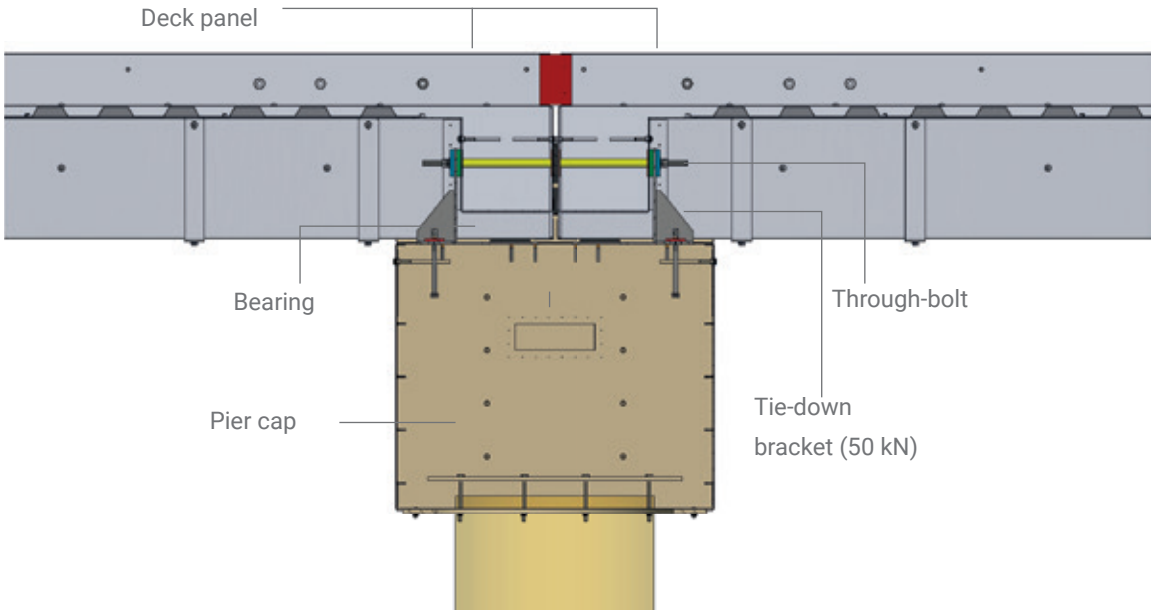


Figure 33. The through-bolt assembly links together adjacent deck spans.

Figure 33 shows an example of a deck panel secured to the pier cap using tie-down brackets. The through-bolts are placed through two deck panels and are fastened to the tie-down brackets using nuts (Figure 34).

Figure 34. Tie down brackets are used to secure the deck to the pier cap.

VII. Install tie-downs

Figures 35 and 36 show detailed views of installed tie-down brackets. These brackets connect the deck panels to the Pier cap and are designed to resist vertical loads from flood waters. These tie-down brackets are only required where a bridge has a risk of experiencing flood loads.

Figure 35. Tie-down brackets connect the deck panel and the pier cap.

Figure 36. A complete installation of a tie down bracket connecting the deck panel and the pier cap.

VIII. Buffer Bracket

In addition to vertical tie-down brackets, CMC can also provide a buffer bracket to provide lateral restraint if required due to heavy flood loads. This bracket is bolted into the pier cap next to the intersection of the two deck spans (thus resisting lateral movement for both spans at once). Refer to Figure 37 for an example.

Once the positions of the tie-down brackets are confirmed and correct, they can be removed and reinstalled after the deck panels are placed in position.

Figure 37. A buffer bracket is bolted into the pier cap, next to the intersection of two deck spans.

IX. Completed Assembly

Once the through-bolts from the end beams are secured to the tie-down brackets, the installation of the deck panels to the Pier caps are completed. Once all other deck installation work is completed (e.g. splice bars), concrete can be poured into the deck panels. Figure 38 shows a completed installation for an InQuik bridge before the concrete is poured.

Figure 38. A completed InQuik bridge installation before concrete is poured.

Integral Pier Cap Articulation

The Integral pier cap is an innovative product in InQuik's modular bridge range and has a number of advantages over the simply supported pier cap design, if site conditions allow for a fully integral structure.

An integral bridge has structural continuity between the superstructure and substructure. This eliminates the need for external connecting elements such as bearings, bolts, and tie-downs, which typically require maintenance and replacement over the bridge design life. The integral connection reduces the bending moment in the span, creating a stronger load-carrying structure.

The InQuik Integral pier cap allows multi-span bridges to be fully integral, by directly connecting the deck panels and the pier caps to create a monolithic structure. The resulting bridge is incredibly robust to external loads, and able to withstand high flood loads and impacts, and extreme weather events. However, the major benefit of an integral bridge compared to a simply supported bridge is removing the need to replace bearings, which requires the deck panel units to be lifted using synchronised hydraulic jacks, which is a costly and risky exercise.

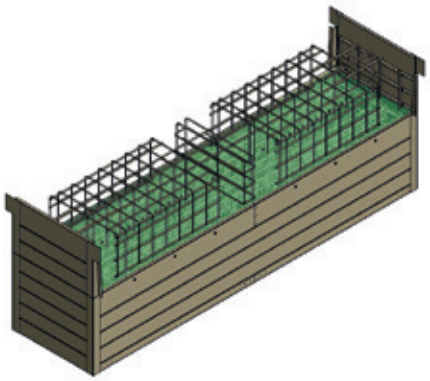
Figure 39. Comparison of simply supporting (left) and integral (right) pier caps.

It has been well established that there are many performance and durability benefits with integral bridges. An integral pier cap adds to the overall durability and resilience, and the stiffness of the connection results in small deformations, and thus minimizes potential for damage.

Integration is achieved by lapping reinforcing bars between the pier cap and deck panels. This allows the controlled transfer of force between the structural elements. The integration has been designed to create a link slab, so that there is no moment continuity through the pier. Because the link slab acts as a separate component, this reduces the risk of damage or undue strain at the pier cap/pier connection. Due to thermal effects, there will be a maximum fully integral bridge length before an expansion joint is required between spans, though this depends on site conditions and foundation design.

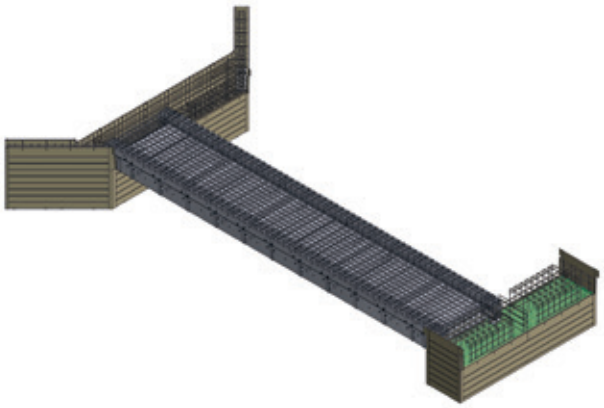
I. Pier Cap Shelf

The pier cap concrete and deck shelf surface are completed in the same manner to the simply supporting design, except there are a series of starter bars protruding up from the pier cap surface. It is important to ensure the surface where the deck beams will be placed is at the appropriate level, and has a flat, even surface where the beam feet will be placed.



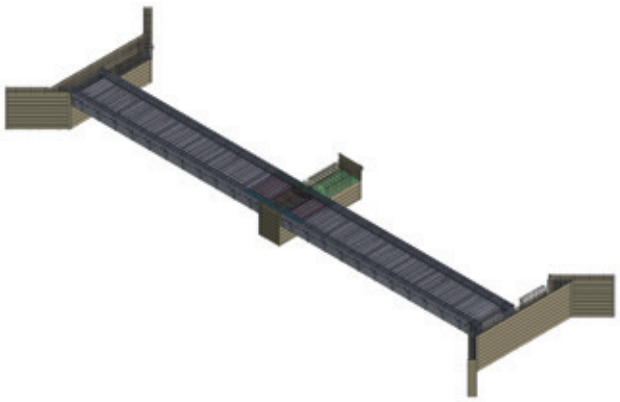
II. Place Decks of First Span

The deck panels for one span are placed into position on top of the pier cap concrete surface. The transverse integration tie-bars are placed into position, and the longitudinal overlap bars are fed through the deck panels far enough that they will not interfere with the placement of the deck panels for the other span.



III. Place Decks of Second Span

The deck panels for the other span are placed into position on top of the pier cap concrete surface. The transverse integration tie-bars are placed into position, and the longitudinal bars previously fed into the first deck span are threaded through the second deck span, such that the appropriate overlap lengths are achieved.



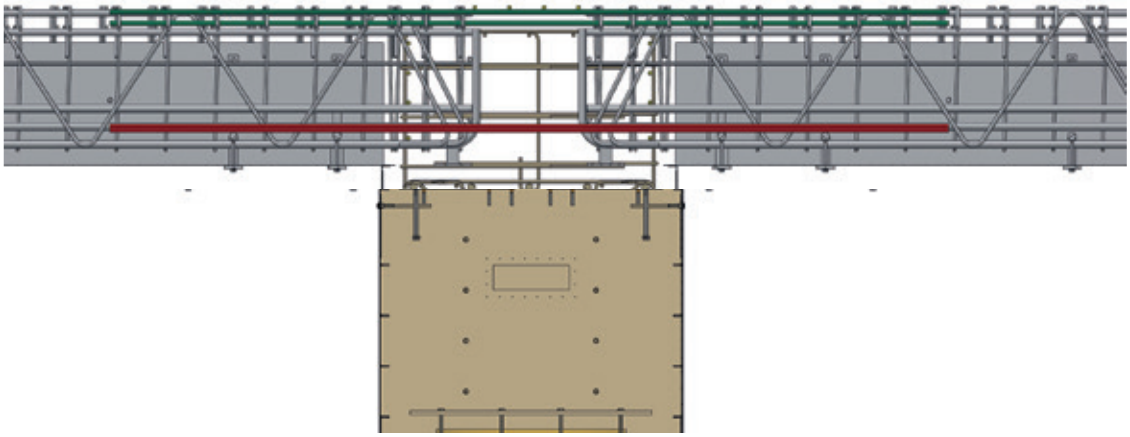
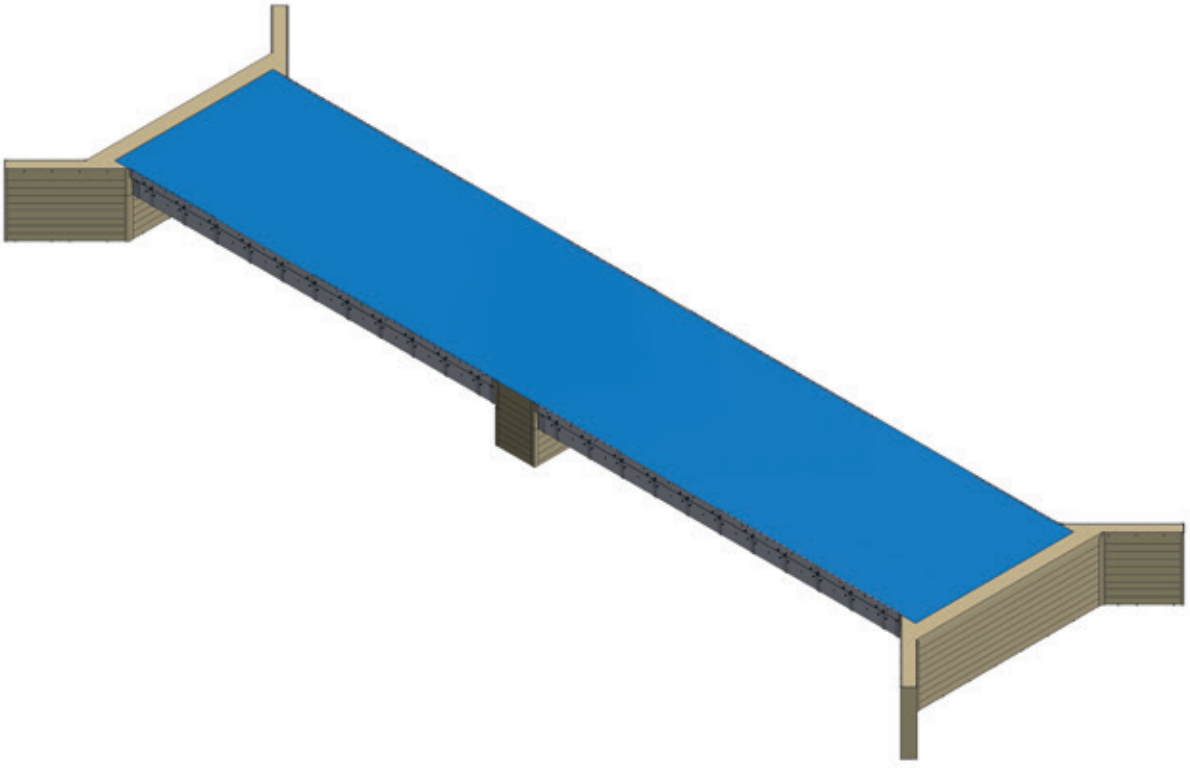


Figure 40. Tie-bars connect the deck spans longitudinally over the integral pier cap.

IV. Completed Assembly

Any final formwork pieces on the sides and underneath the bridge are placed into position and sealed using foam tape and/or silicone. The sealing is important to prevent concrete from seeping through the gaps between formwork sections.



InQuik Project Timeline

Customer	InQuik
Design Basis report - project scope Design will typically require Geotechnical report, flood study, traffic volume data, survey detail and environmental impact report. Global bridge design details the bridge foundation and scour protection required. REF - Review of Environmental Factors - Safety in Design assessment Ensure all necessary Council and DPI Fisheries approvals have been submitted and approval time-frame known.	
	Quote sent to customer
Global Design/Structural Plans	
Accept quote, give purchase order	
	Send sales contract and deposit (50%) invoice
Sign contract, pay deposit	Counter-sign contract, initiate production
Arrange site preparation works (earthmoving, foundations, etc.)	
	Liaise with customer for estimated delivery date
Pier caps/abutments/wing walls installed, and concrete poured **(~1-3 days)**	Pier caps/abutments/wing walls delivered
Deck panels installed **(~2-5 days)**	Deck panels delivered Final invoice sent
1st deck concrete pour	
2nd deck concrete pour [only for some deck designs]	
Light traffic after deck concrete reaches 4000 psi **(~7 days)**	
Unrestricted traffic after deck concrete reaches design strength (usually 5000 psi) (**~28 days after concrete pour**)	
	Upon project completion, supply Material Data Records (MDR)

InQuik® bridges have exceptional resilience to impacts caused by severe weather events and require minimal to no structural maintenance over their 75-year design. We have manufactured and delivered over 200 bridges across Australia, Pacific and USA. We provide environmentally friendly long-lasting solutions for communities, and enable the use of local resources, on-site labor, plant, and materials.

For more information, contact CMC Bridge Systems,
the authorized provider of InQuik® Bridges in the United States.

Website: cmc.com/bridgesystems

Phone: 866.249.9661

Email: bridgesystems@cmc.com

Address: 6565 N. MacArthur Blvd, Irving, TX 75039

it's what's **inside** that counts