The 2009 PTA

POST-TENSIONED STRUCTURE

Awards

CLACKMANNANSHIRE BRIDGE

Upper Forth Crossing

Kincardine

CLACKMANNANSHIRE BRIDGE - Upper Forth Crossing - Kincardine

CLACKMANNANSHIRE BRIDGE - incrementally launched post-tensioned bridge

The Clackmannanshire Bridge, located 40km northwest of Edinburgh, is designed to alleviate traffic pressure on the Kincardine Bridge and surrounding area. It provides enhanced transport links between Clackmannanshire, Falkirk and Fife, improving road safety and opening up the wider area to economic benefits. Approximately 20,000 vehicles per day are predicted to use the new bridge. It took just over two years to complete the £120m scheme, which comprises the design and construction of this multi-span bridge and 5.2km of approach roads, the project finishing on time and to budget.

INITIAL CONCEPT

The bridge form was determined by the client’s engineer, Jacobs as a tender concept design. The client, Transport Scotland, sought a low impact appearance with a ‘ribbon like’ profile, while providing sufficient navigational clearance and span. Morgan-Vinci’s designer, Benaim, developed the detail of the bridge, piers and launch while maintaining the spirit of the client’s concept.

Benaim worked closely with Morgan-Vinci to consider a range of solutions including incremental launching, pre-cast segmental, steel-composite plate and box girders. A low-level, multi-span, three-cell concrete box-girder was found to be the optimum solution and the design was therefore developed with 26 spans, typically 45m. The 35,000t, 1.2km long bridge was launched from the north side of the estuary and is the world’s second longest bridge to be constructed by launching. This construction method minimised disruption to the more environmentally sensitive south bank, as well as providing a safe, factory area for the main deck construction.

ENVIRONMENTAL AND SUSTAINABILITY

The new bridge had to cross sensitive salt marshes and mud flats, which extend over almost the full length of the Forth. This habitat is protected under European law and international conventions due to its importance for migratory and wintering birds. Successful completion of the project demanded no adverse impact on the integrity of this habitat, and extensive environmental measures were thus integrated into the design. By incrementally launching the bridge from the disused power station on the north bank, the majority of construction activities were confined to a relatively small area and this also minimized disruption to the SSSI on the south bank. Also as part of the mitigation measures, part of the disused power station site was remediated and returned to wildlife.

Another noteworthy feature of the project was its use of recycled materials such as red blaze, colliery waste spoil and PFA from local power stations and mines as on-site fill.

BRIDGE LAUNCH AND CASTING TECHNIQUES

A launch and casting yard was established on the north bank. To improve production, work was done off-line (ie: outside the casting bed). Reinforcement was precisely pre-fabricated upon steel jigs then lifted into position, removing a time constraint from the casting bed. Likewise steel shutters were used, which were cleaned, adjusted and prepared away from the casting bed. Hydraulic actuators allowed the shutter to be positioned and closed quickly. The steel formwork allowed for the accuracy of shape and high surface finish.

The factor controlling the launch was concrete strength in the rearmost section of each launch span. The rear section was therefore cast early, attaching it to the span, later, as the intermediate sections were cast.

Temporary supports in the casting area reduced the effective span such that the post-tensioning need not be done until after the cast section had been launched forward onto the temporary supports, thus releasing the casting bed. The post-tensioning work then progressed, off the critical path, to be completed before the next launch cycle.

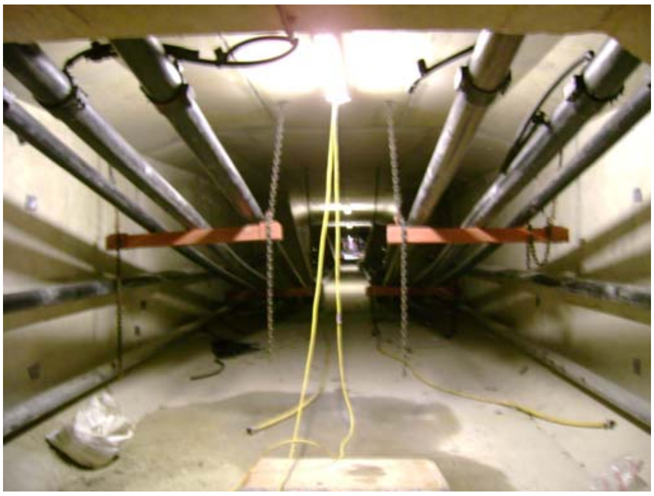
The doubly-curved soffit of the deck was created by using a three-cell concrete box girder. The main webs of the box were vertical and at 4 m centres, and the outer webs that form the soffit shape were fully utilised in all the structural actions. The 4 m spacing was chosen so as to create a good distance between the bearings and a good space within the central cell of the section. Both the launching bearings and the permanent bearings sat directly beneath the webs of the box to avoid any moments caused by eccentric reactions. The central cell incorporated the majority of the post-tensioning and thus had to be made wide enough to house most of the cables and anchorages.

The deck was launched using push-launch technology with a 1200 tonne thrust force. The deck segment ‘cast and launch’ cycle was initially 11 days but refinement and further planning quickly reduced this cycle time to 9 days (an 18% acceleration) with the launching finishing two months early.

THE POST-TENSIONING ARRANGEMENT

A major innovation was the use of partial prestressing in the bridge deck. By using external prestressing cables throughout, i.e. for both the continuity cables and the launching cables, it became possible to share loads between the prestressing and the longitudinal reinforcement in the deck; passive reinforcement that would otherwise be ignored. This approach highlighted inconsistencies in the concrete codes between BS 5400 Part 4, BD 24 and BD 58. A departure from standards was therefore sought to allow a crack width limit of 0.25 mm to be used during the launch condition. This was granted on the basis that the 0.25 mm limit would be adequate for reinforced concrete and the durability of the prestressing tendons would not be compromised because they were external.

All the post-tensioning was comprised of external replaceable tendons formed from bare strands within a grout-filled HDPE sheath.



The 94m long, straight **launching cables** were chosen to give an average axial stress on the section of 2.5 MN/m^2, which was about half the stress that would have been required to fully compress the section. This was provided by 8 No. Freyssinet 19C15 tendons, four in the centre cell and two in each of the outer cells. These tendons provided an axial stress only, which was necessary to accommodate the full moment range that every section experienced during the launch cycle. The length of the launching cables was chosen to have no more than 50% of the cables lapped at any pier diaphragm and to give a gradual increase in the axial compression as the bridge moved away from the Casting Area.

On completion of the launch, a further set of profiled **continuity cables** were installed, which consisted of 6 No. Freyssinet 19C15 tendons, all located in the centre cell. The continuity cables were typically 140m (three spans) long and installed with a very simple cable profile that used deviators at third points in the span. The longer spans around the centre of the bridge had more continuity prestressing, using up to 8 No. Freyssinet 37C15 tendons. All the continuity post-tensioning was installed within a period of 6 weeks. The details of these arrangements were developed through close working between Benaim, Morgan-Vinci and Freyssinet.

POST-TENSIONING ASSOCIATION



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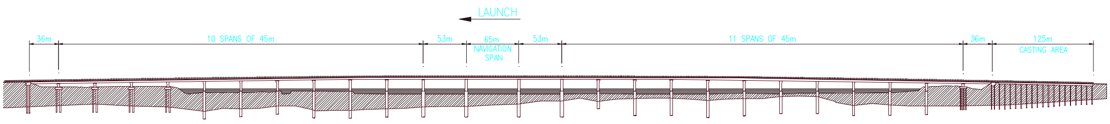
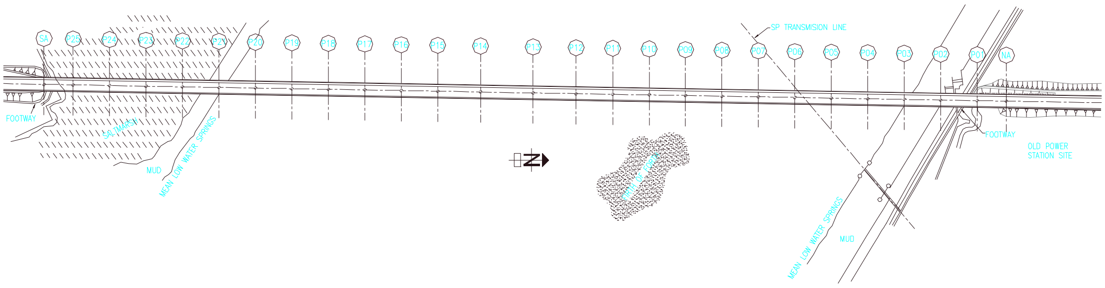
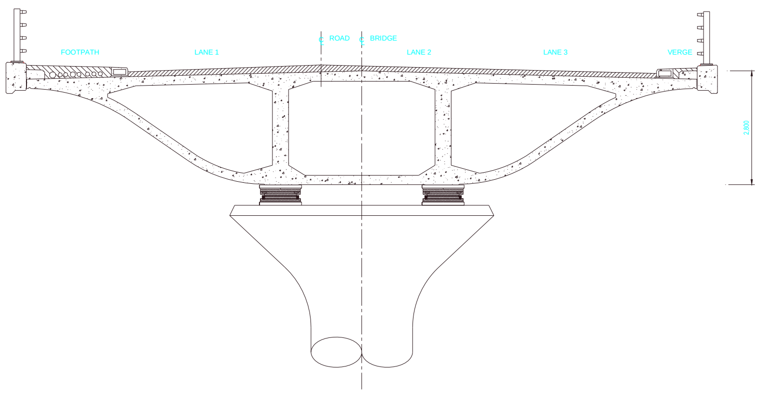
DRAWINGS

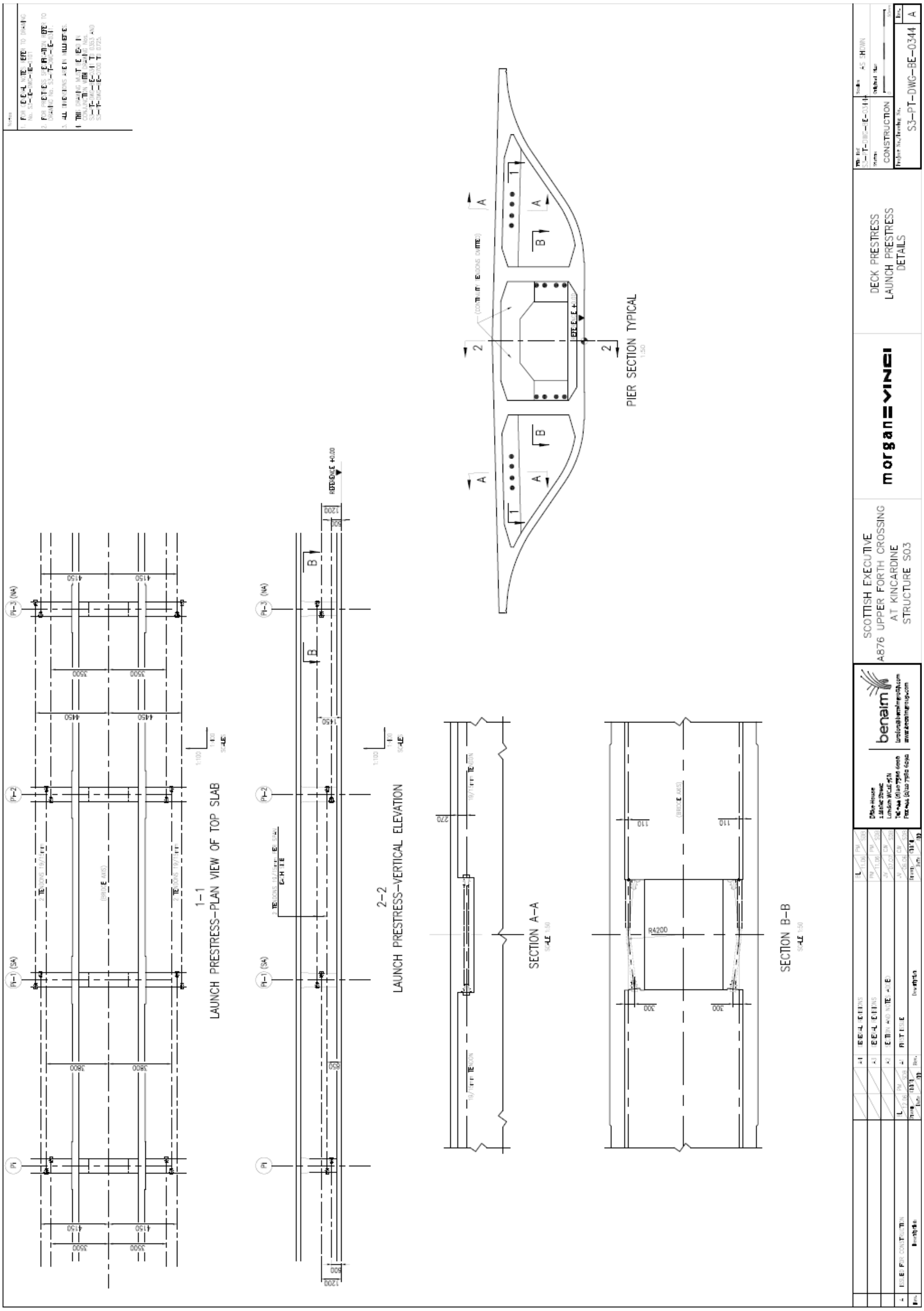
Drawings courtesy of Benaim.







DECK SECTION



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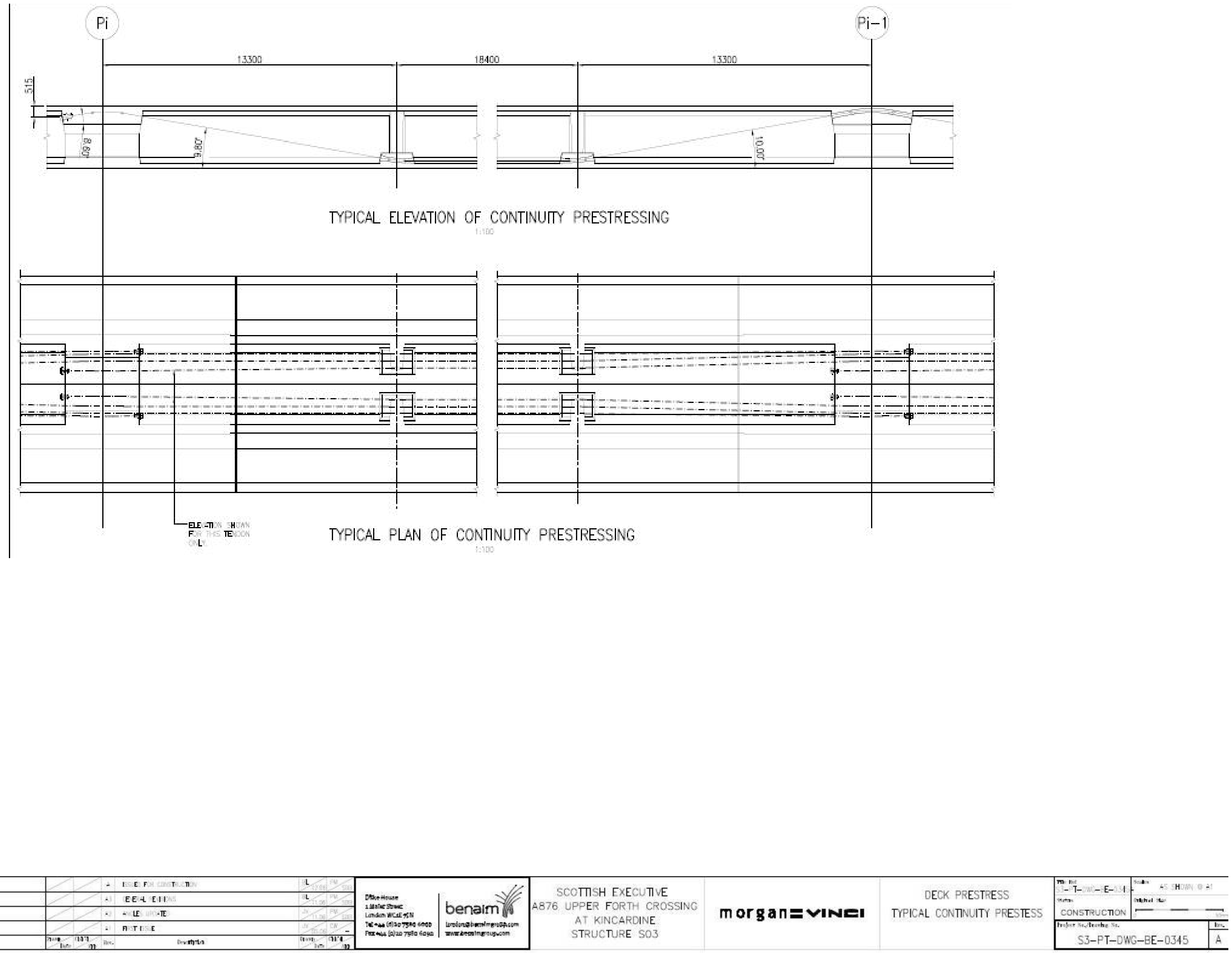
Pi
Pi–1
13300
18400
13300
515
8.60°
9.80°
10.00°
TYPICAL ELEVATION OF CONTINUITY PRESTRESSING
1:100
TYPICAL PLAN OF CONTINUITY PRESTRESSING
1:100
ELEVATION SHOWN FOR THIS TENDON ONLY
benaim
SCOTTISH EXECUTIVE
A876 UPPER FORTH CROSSING
AT KINCARDINE
STRUCTURE S03
morgan=VINCI
DECK PRESTRESS
TYPICAL CONTINUITY PRESTESS
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S3–PT–DWG–BE–0345
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