4.1 CROXLEY VIADUCT

4.1.1 Scheme Overview

The main justification for the spans (lengthening them in most cases) was to span both the river tributaries on the eastern side of the viaduct to avoid placing a pier in the middle of a natural habitat, infringing on open environmental spaces. Also, avoiding placing a pier in the middle of the roadway median so that during engineering hours when the replacement bored piles, in-situ pile caps, and in-situ piers are cast, they will not infringe as much on social environmental factors as civilians will not be forced to drive their automobiles right next to a 5-8 meter high concrete pier.

The choice to use precast pre-stressed concrete Box Girders came down to durability as concrete girder Life Spans are nearly twice that of steel, and thus maintenance costs will sharply decrease. Even though this is a fourth rail system, stray current is inevitable but will have less effect of corrosion on a concrete structure with reinforcement steel than that of a steel box girder.
Only fixed Piers to Girder connections will be placed in the middle of the Viaduct (Pier 4 to 5 and Pier 5 to 6) to account for deceleration forces and to make sure that the forces do not extend longer than they need to along the viaduct– thus the lengthening of piles to 25 meters on the central piers (4, 5, and 6) to counteract those forces in the middle section. For the other piers, expansion joints will be implemented to allow movement for expansion and contraction, and to account for inevitable creep in the concrete.
The Maximum radius of curvature on the viaduct is 300 meters and the Maximum speed is 75 km/h and Concrete Box Girders are structurally sound in Torsion.

The Aesthetics have been met; A uniformity of material and representation of "form follows function" that does not impede on the surroundings, or yell out for attention, but stands solid, its lines performing a structural duty.

4.1.2 Pier Location

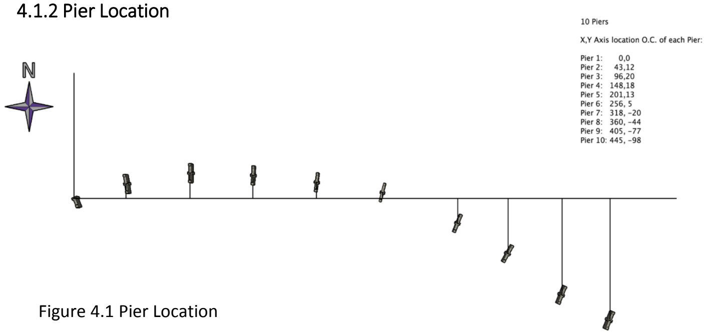
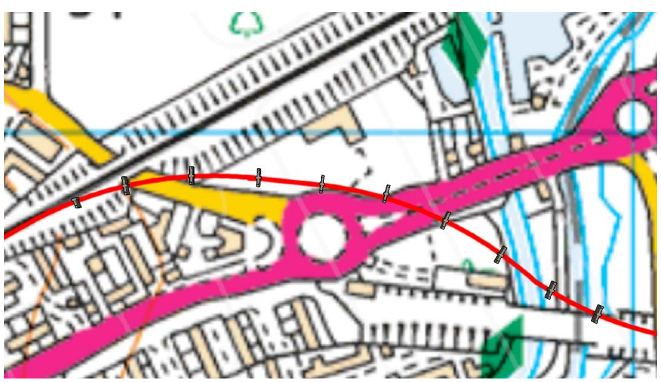


Figure 4.1 Pier Location



Benefits of slab track

Slab track offers the following advantages over traditional ballasted track:

- Very low maintenance requirements
- Shallow construction depth
- Reduced dead load
- Reduced structure gauge
- Higher speed operation
- Engineered noise and vibration performance
- Long design life
- Increased reliability
- Increased availability
- Low whole-life cost
- A sustainable solution

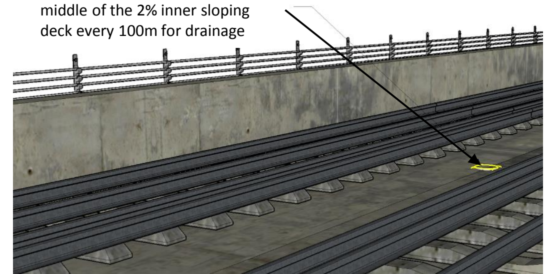
4.1.4 Expansion and Contraction Joint

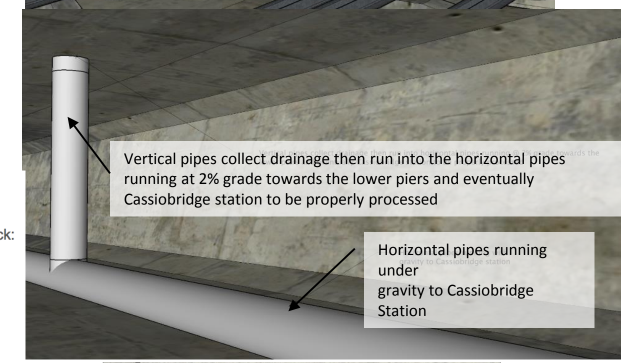
Expansion joints placed in-between each successive box girder to account expansion and contraction

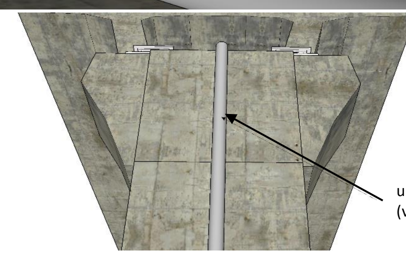
Figure 4.2 Expansion and Contraction Joint

4.1.3 Track Drainage

Vertical pipes run along the middle of the 2% inner sloping deck every 100m for drainage







upvc pipe (vertical)

Manhole cover every 100m along the centre of the deck to cut down the duration of maintenance time inside the concrete box girder

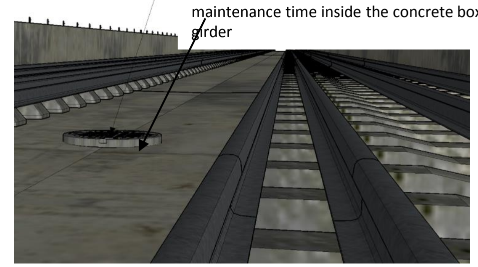
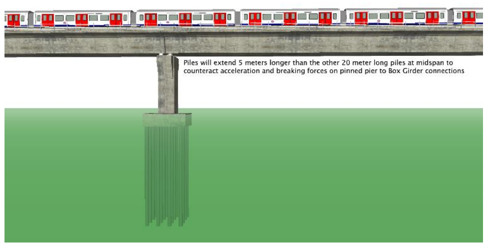
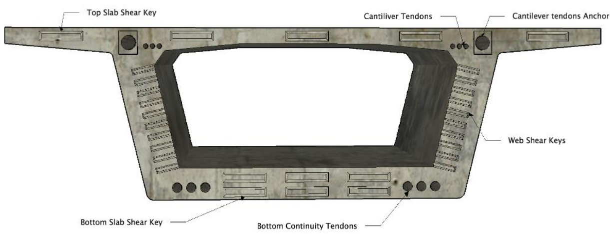


Figure 4.3 Drainage

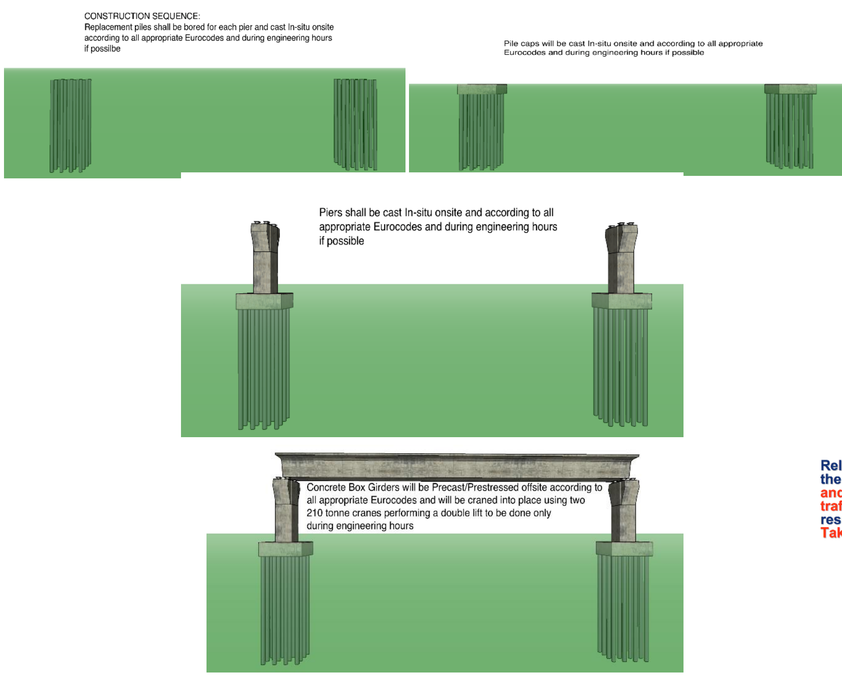
4.1.5 Piles at Midspan



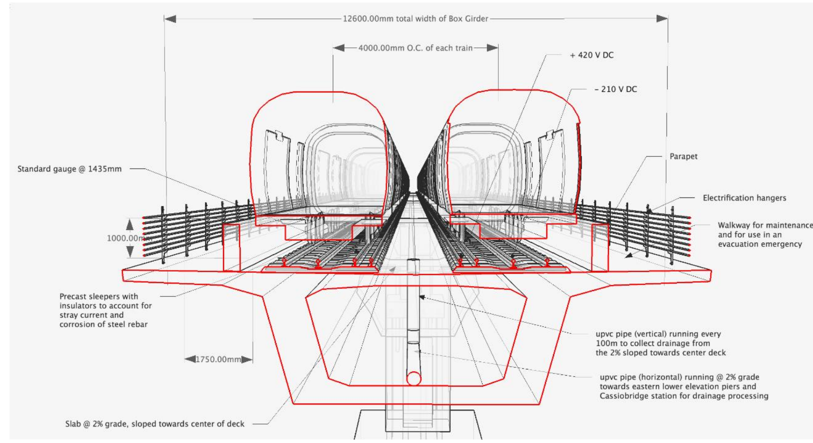
4.1.6 Deck Cross-section



4.1.7 Construction Plan



4.1.8 Kinematic Envelope



BASIC STRUCTURAL ANALYSIS OF THE LONGEST SPAN Box Girder @ 55 METERS (no radius)
Dead Load: Box Girder: 4000kN Electrification/pipes/utilities: 100kN Slab Track 300 kN Rails: 100 kN Parapet: 500 kN. Total Dead Load = 5000kN • 1.3 (ULS) = 6500 kN. Live Load: 8 carriage train has a tare weight of 246.6 tonnes/8 (each carriage) = 30.775 tonnes ≈ 303 kN. Conservative passenger mass estimate is 70kg • 1218 (crush capacity of passengers[1])/8 carriages ∴ 152.25 • 70 kg = 10657.5 kg/1000 = 10.66 tonnes or ≈ 105 kN passengers' force per carriage ∴ 303 kN + 105 kN = 408 • 55 meters/16.7 meters (length of each carriage) is: 408 • 3.3 ≈ 1347 kN • 2 (rail tracks) = 2694 kN • 1.5 (ULS) = 4041 kN Live Load.

Once Statically Determinant: Max Moment of the Box Girder is calculated @ 6500 kN + 4041 kN = 10541 kN / 55 meters @ Wl^2/8 ∴ 837kN/m • (55m)^2/8 = 316500 kNm... In the scheme stage of design, still using a conservative span/depth ratio of L/20 @ 2.75 meters in depth though due to breaking and acceleration forces; breaking controls @ Live-Load F = ma where F = 4041kN • 1.5 (deceleration) = 6062 kN of horizontal force(s) to determine that the depth of the box girder and its second moment of area (moment of inertia) ∴ Max Fb= Max Moment • Distance from neutral axis to outer fiber/ I (second moment of area) which for this Box Girder can be calculated by finding the Centroid (center of mass) then ¥ = ∑ ad/∑A then locating the second moment of area (I) of the cross section with the Parallel Axis Theorem: ∑ (Ii + Aidi^2) ∴ finding the Maximum bending stress of Box Girder can fit appropriate steel rebar sizes and the concrete strength to be used @ a minimum of RC 30 (minimum compressive strength for reinforced concrete) with an Modulus of elasticity (E) of 30 Gpa.[2] Max Shear of the Box Girder is calculated @ 6500 kN (Dead-Load) + 4041 kN (live-Load) = 10541 kN/55 meters @ WL/2 ∴ 837kN/m • 55m/2 = 23017.5 kN and for Max shear stress for this particular section use: Fv = VQ/Ib where V= interior shear force, Q = moment about neutral axis for area above or below plane where stress is to be calculated or (a' • y), I = moment of inertia, b = width of section. [3] Deflection calculated with Δ Max@ center = 5WL^4/384EI or for extreme breaking using a model of a beam according to Eurocode LM71.

Pier design for stocky column members: span/depth or H/20 as the tallest pier is 8 meters on the western end of the viaduct and stocky columns need only be designed for the maximum design moment about one axis ∴ design moment ≈ axial load of 10541 kN • .8 = 8444 kNm.[4] Reinforcement estimates: Box Girder 250 kg/m^3, Piers, 300 kg/m^3, Pile caps 115kg/m^3 included in total load for the design of piles in limestone chalk.

Total Load on the piles: Dead Load 5000 kN + Piers (1500 kN) + Pile caps (1500 kN) = 8000 kN • 1.3 (ULS) = 10400 kN + Live- Load @ 4041 kN = 14441 Total Load on piles. Bored concrete replacement piles @ 600 mm diameter ∴ Design piles @ 14441 kN/16 piles @ 20 meters long acting as both end bearing/shear piles ≈ 900 kN per pile.[5] As for the pile caps, scheme design calls for pile diameter @ 600 mm ∴ pile cap depth 1400 mm and each piles shall be spaces at least 3 diameters or 1800 mm center to center.

Maximum percentages of reinforcing steel: Box Girder As Max = 4% Ac, Columns (horizontal cast in-situ) As Max = 6% Ac– if rebar increases on further checks for breaking resistances, then Fck of concrete must increase potentially changing the design mix to suit the specifications.

The larges radius of curvature of the viaduct is 300 meters as noted which will approximately cover 3 Girders, conservatively making one Girder have a radius of curvature of 900 meters to account for Torsion thus we apply $T/J = \tau/r = G\o/L$ where T is the applied torque, J is the polar moment of inertia, τ is the torsional shear stress, r is the radius, ø is the angle of twist, G is the shear modulus of elasticity and L is the length of the member.[6]

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[1] Neil (2015)
[2] Grynuik (2013)
[3] Grynuik (2013)
[4] Cobb (2015)
[5] Cobb (2015)
[6] Cobb (2015

Relative displacements of the track and of the bridge, caused by the combination of the effects of thermal variations, train braking and traction forces, as well as deflection of the deck under vertical traffic loads (LM 71), lead to the track/bridge phenomenon that results in additional stresses to the bridge and the track.
Take LM 71 with α = 1.00 (even if α > 1.00 for ULS)!