Reinforced embankments for the causeway for Pont Briwet Project, Penrhyndeaudreath, North Wales, UK

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ABSTRACT: The Pont Briwet Project consisted in the replacement of an historic timber trestle bridge with a new 136m long concrete viaduct and the upgrade of the approach road to the north and south of the crossing. The site is set within the flood plain of the Afon Dwyryd in north Wales, with tidal levels up to 4.6m. A key challenge of the project was building the viaduct within the tidal estuary whilst meeting, at the same time, the requirements on flood risk and water quality within an Area of Conservation of Natural Resources. Reinforced earthwork embankments using Tenax Geogrids with specific granular material were used as a solution to construct the causeway allowing the installation to take place directly into open water. The height of the embankments ranged between 2.0m to 4.10m with slope angles of 1V:1.5H and 1V:2H. The causeway working platforms were required to support large tracked piling rigs and cranes, in addition to a 800 tonne mobile crane to lift the bridge beams into place. During the construction the causeway was completely submerged on various occasions yet needed to be back in use immediately after the tidal events. The design of reinforced working platforms used as "safe areas" on the ramp approaches, above the predicted flood levels, allowed the tracked plant to remain safe during these events. The project was finished in July 2015 and the new viaduct was open to the public in August 2015.

Keywords: Reinforced Soil Slopes, reinforced embankments, Geogrids, working platform, tidal events, causeway

1 INTRODUCTION

The Pont Briwet Project consisted in the replacement of an historic timber trestle bridge with a new 136m long concrete viaduct and the upgrade of the approach road to the north and south of the crossing. The site is set within the flood plain of the Afon Dwyryd, at the boundary of Snowdonia National Park, with tidal levels up to 4.6m. The existing 22-span wooden viaduct dated back to the 1860s and carried the single track Cambrian Coast Railway and a single lane road. It had served the area well for almost 150 years but was no longer suitable for modern transport requirements. The new viaduct provides a new wider rail and two lane road, as well as linking the local footway and cycleway networks either side of the estuary. A key challenge of the project was building the viaduct within the tidal estuary whilst meeting, at the same time, the requirements on flood risk and water quality within an Area of Conservation of Natural Resources Wales.

The new viaduct comprises seven 20 m integral spans, formed from pre-stressed beams supported on concrete crossheads and large diameter concrete piles installed into the estuarine sands and gravels. For the causeway and ramps it was necessary to find a solution to construct temporary embankments to gain access for the construction of the foundations of the viaduct within the river. The initial design considered permanent sheet pile retaining walls, however this solution would have required a large amount of work to take place within the tidal river and would have had a significant impact on the cost of the project.

As an alternative to the sheet pile walls, we proposed to construct reinforced earthwork embankments using Uniaxial Tenax Geogrids and a specific granular material for the embankments' starter layers to allow the installation to take place directly in open water. The temporary causeway was required to extend approx. 80m into the tidal estuary from the southern shore and approx. 20m from the north (See Figure 1. Causeway Construction North Access and Figure 2. Stage 1 and Stage 2 Causeway Construction Details).

Figure 1. Pont Briwet: Historic Timber trestle bridge

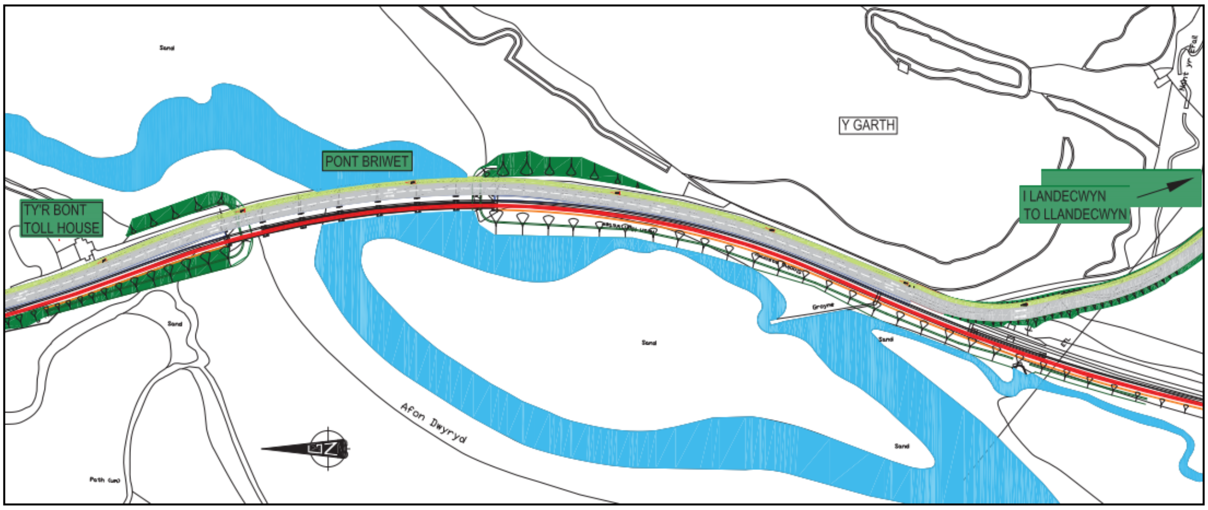
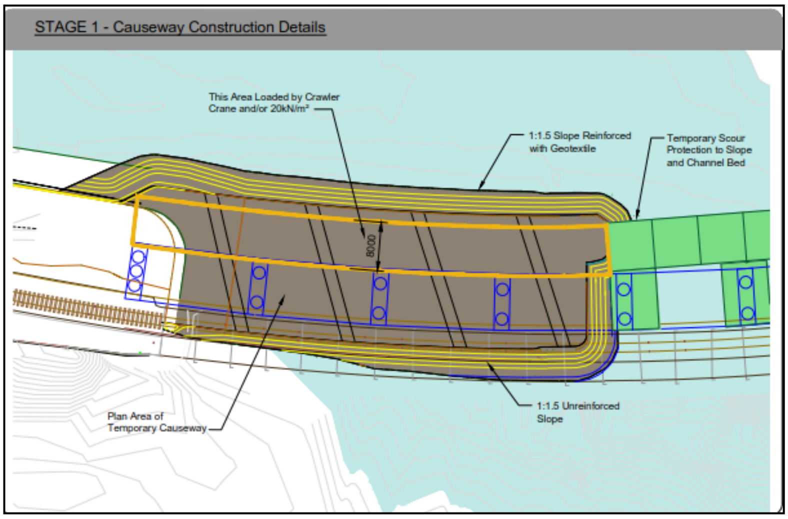


Figure 2. Plan view Bridge and approaches



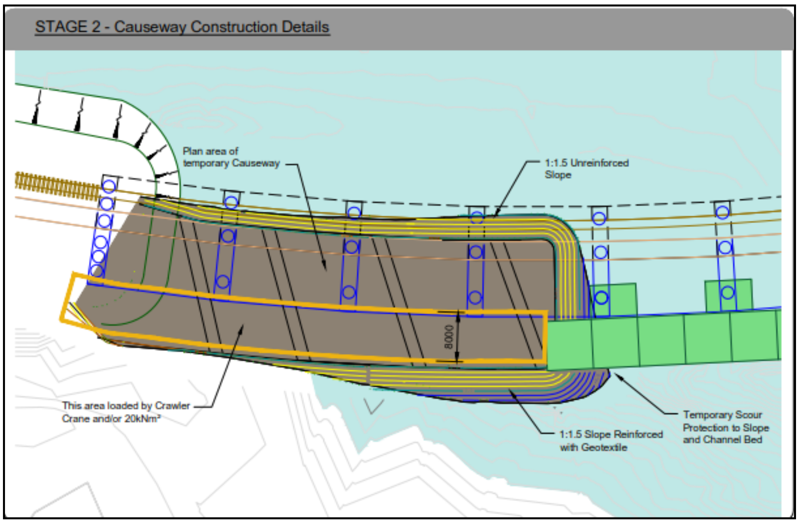


Figure 3. Stage 1 and Stage 2 Causeway Construction Details

2 DESIGN CONSIDERATIONS

2.1 *Design parameters*

Reinforced soil slopes with uniaxial Geogrids were designed to increase the stability of the slopes so that heavy plant could travel on the access roads, 1m away from the edge of the embankment.

The height of the embankments ranged between 2.00m to 4.10m with slope angles of 1V:1.5H and 1V:2H. The causeway working platforms were required to support large tracked piling rigs and cranes, in addition to a 800 tonne mobile crane required to lift the bridge beams into place.

The top level of the temporary embankments was at +5.2m AOD (Above Ordnance Datum) and maximum water level was assumed at +4.25m AOD. For the causeway, Geogrids were used for the stability of the slopes and for the basal reinforcement of the working platform to support the pressures applied by the cranes and piling rigs.

The top level of the causeway was at +3.20 m AOD with sea bed varying from +1.0m AOD to -2.5m AOD and maximum water level assumed at +2.60m AOD. During the temporary works, a woven Geotextile (wrap-around) was used to protect the slopes from erosion and to prevent the fines being washed out with the constant changes of water level.

The main challenge for the design of the reinforced embankments was to keep the distance from slope edge for piling rigs and cranes to 1m, with a maximum slope angle of 1V: 1.5H. The variation of the water levels due to the tidal activity added a further complication. For the design it was considered that during the construction the causeway would be completely submerged on various occasions yet needed to be back in use immediately after the tidal events. In the design we included some “reinforced safe areas” on the ramp approaches, above the predicted flood levels, to allow the tracked plant to remain safe during these events.

2.2 *Scenarios Analysis*

For each section of the causeway, a stability analysis of the reinforced embankment was carried out considering the different pressures of the rigs and the cranes, the maximum water level in each case, and the minimum distance to the edge of the embankment. Based on the results, the slope angle for each section and the minimum distance was determined.

The maximum height of the embankment was 4.10m in section CH240 and the minimum height is 2.10m in section CH380. For both sections, CH240 and CH380, the global safety factor was less than 1.00 for the scenario with a slope angle of 1:1.5 and a distance of 1.0m from the edge. So the proposal for these sections was to increase the slope angle to 1:2 (26.56deg) and to maintain the distance of 1.0m to the edge of the embankment. Figures 4 and 5 show the illustrative cross-sections and the results of the stability analysis of the Section CH240- Embankment- Access Road and CH380 Temporary access road – Causeway.

RESULTS - ANALYSIS WITH RESSA

SECTION CH240	**Embankment - access road**				
				Distance to edge of emb D = 1.00m	
Loading	**Nominal value (kPa)**	**Factor**	**Track Length (m)**	**FS Slope 1:1.5**	**FS Slope 1:2**
Rig (1)	368	1.35	2.95	0.96	1.03
Rig (2)	368	1.35	0.80	1.11	
LR1100 (1)	258	1.35	4.30	1.06	
LR1100 (2)	258	1.35	0.90	1.28	
LTM 1750	NA	NA	NA		

Top level:	5.20 m OD
Toe level:	1.10 m OD
Height:	4.10m
Water level:	4.25 m OD
Distance: surcharge from slope face:	**1.00 m**
Slope:	1V:2H
Reinforcement:	3 layers Tenax HM3 @ 300mm ; L = 20m (tbc) 6 layers Tenax TT045 @ 500mm ; L = 10 m (tbc)
Assumed length:	50 m (CH190 - CH240) (tbc for quantities)

SECTION CH380 (CH380 - CH440)	**Temporary access road - causeway**				
				Distance to edge of emb D = 1.00m	
Loading	**Nominal value (kPa)**	**Factor**	**Track Length (m)**	**FS Slope 1:1.5**	**FS Slope 1:2**
Rig (1)	368	1.15	2.95	0.97	1.02
Rig (2)	368	1.15	0.80	1.12	
LR1100 (1)	258	1.15	4.30	1.07	
LR1100 (2)	258	1.15	0.90	1.31	
LTM 1750	NA	NA	NA		

Top level:	3.20 m OD
Toe level:	1.062 m OD
Height:	2.14 m
Water level:	2.36 m OD
Distance: surcharge from slope face:	**1.00 m**
Slope:	1V:2H
Reinforcement:	3 layers Tenax HM3 @ 300mm ; L = 20m (tbc) 3 layers Tenax TT045 @ 500mm ; L = 10 m (tbc)
Assumed length:	60 m (CH380 - CH440) (tbc for quantities)

Figure 4. Results: Stability analysis Section CH240 and CH380

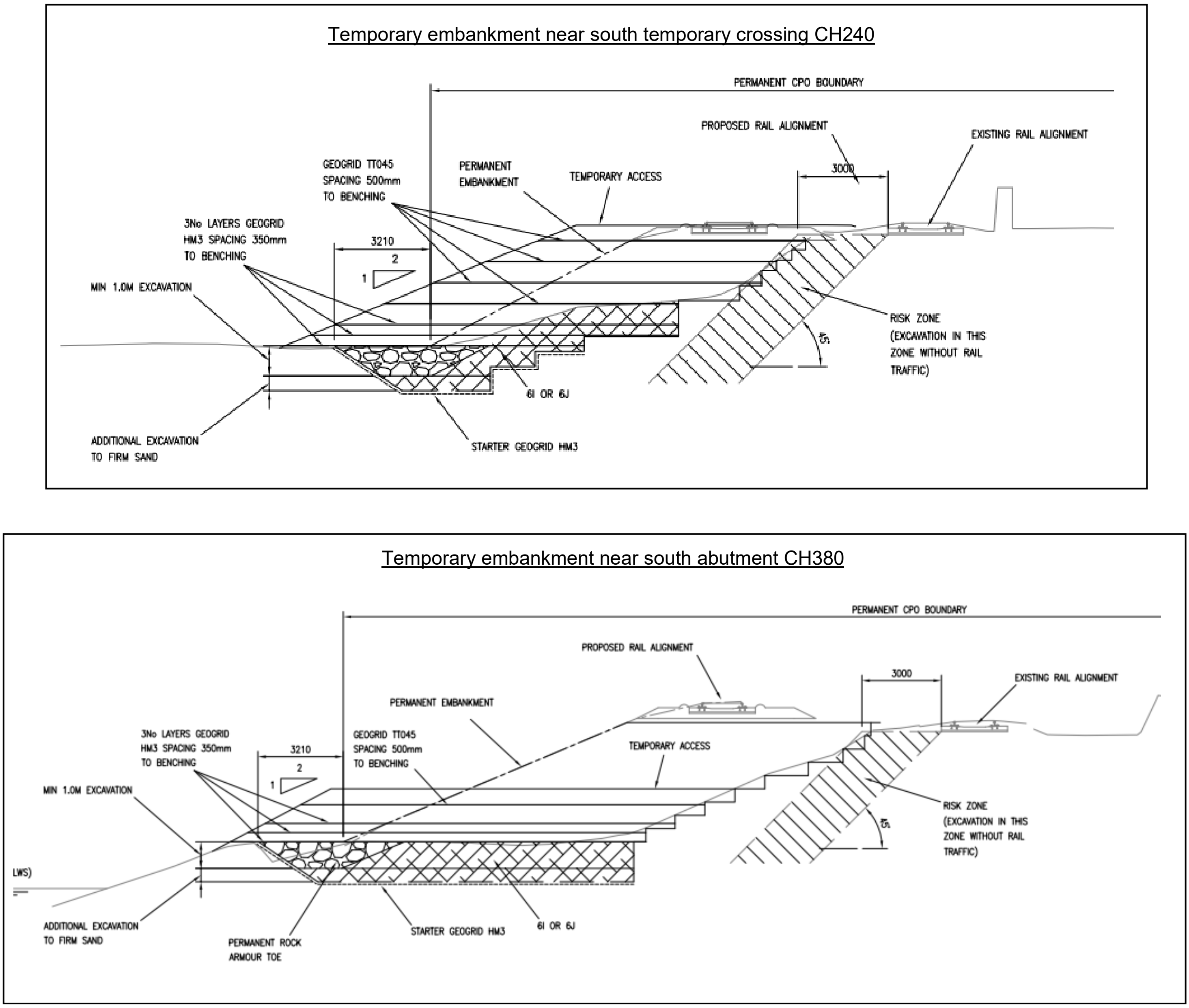


Figure 5. Illustrative cross-sections CH240 and CH380

2.3 *Soil Properties*

For the fill material it was very important to consider the use of local resources, to provide environmental and cost benefits to the project.

The starter layer was specified with a granular material Class 6B with no fines and the embankment fill was designed with a locally modified Class 6N material (classifications according to the Specifications for Highways Works, Series 600).

- Reinforced Fill properties:
  - Class 6B: Selected coarse granular material use for starter layer, with no fines
    - Particle sizes: 300mm to 125mm
  - Class 6N: Selected well graded granular material use for embankment fill
  - Friction angle ϕ' = 40deg,
  - Unit weight γ = 20kN/m3,
  - Cohesion C' = 0 kPa

Ground conditions in the estuary comprised deep loose sands over dense gravels incorporating cobbles overlying rock.

- Foundation soil properties:
  - MD Sand
  - Friction angle ϕ' = 33deg,
  - Unit weight γ = 19kN/m3,

3 REINFORCED EMBANKMENTS

3.1 *Design standards*

The reinforced embankments were designed based on the Limit Equilibriun analysis in accordance with BS8006-2010 for the internal stability and Eurocode 7 (BS EN 1997-1) for the global stability. We used the method from Rowe and Soderman to estimate the stability of a reinforcement embankment for bearing capacity and the methods of reinforcement proposed by Giroud and Ah-Line-Bonaparte (1985), modified here in conjunction with the properties of Tenax Geogrids.

For the working platforms we used the BRE470 guidance with a modified method based on bearing capacity and loading distribution to incorporate the biaxial geogrids for reinforcement.

The new bridge was constructed in two phases to keep the existing railway line in service during the construction works. The design of the causeway needed to consider effects on the existing and new bridge and the final design was checked to meet Network Rail design requirements for working adjacent to a live rail line.

3.2 *Reinforced Embankment solution*

The final design included the results for each section in the south and north areas of the causeway, considering all the scenarios described above. The results for the embankment section with the maximum height and the maximum slope angle are described below. Figures 5 and 6 show the cross-section of the reinforced embankments in CH240 and CH380.

- **Reinforced embankment:**
  - Maximum height: 4.10m
  - Slope angle: 1V:2H
  - Minimum distance to the edge: 1.0m
  - Basal reinforcement: 3 layers of Biaxial Tenax Geogrid of 30kN/m, spacing 300mm, reinforcement length 20m
  - Slope reinforcement: 6 layers of Uniaxial Tenax Geogrid of 45kN/m, spacing 500mm, reinforcement length 10m
  - Face protection: Woven Geotextile wrap-around each layer (“C” shape with 1.5m at the bottom and top of each layer + layer thickness)

During the construction period the causeway was completely submerged by tidal activity on several occasions and back in use for construction activity within hours of the tidal event. To account for these events, we extended some areas of the embankments to include some “safe areas” on the ramped approaches, above the anticipated flood levels, allowing space for the tracked plant.

Figure 6. Construction process temporary embankments and permanent causeways

4 CONCLUSIONS

The use of reinforced earthworks embankments with Tenax Geogrids and granular material class 6B and class 6N allowed the construction of the causeway and access roads for the new bridge, keeping the existing timber viaduct in service during the construction works.

The main challenge for the design of the reinforced embankments was to keep the distance from slope edge for piling rigs and cranes to only 1m, with a maximum slope angle of 1V: 1.5H whilst coping with the variation of the water levels due to tidal activity. Tidal levels varied by up to 4.6m with very high spring tides experienced during the construction phase. In addition two periods of major storms and flooding occurred during the construction works and no damage occurred to the causeway or embankments.

The reinforcement of the embankments and access roads using geogrids also allowed the construction of working platforms and "safe areas" for the heavy plant to operate under all the conditions, even the most extreme tidal conditions. One of the major benefits was that even though the platforms were submerged on a regular basis, very little, or almost no, remedial work was required after each tidal event in order to bring them back into operation. Without the reinforced working platform solution, the project deliverables would have been impossible to achieve within the spatial constraints imposed by the scheme land boundary and zone of influence of the operational railway.

A very detailed and careful construction plan was produced to integrate the permanent embankment construction with the temporary works and also to ensure that the existing railway line could stay operational during the construction works. The project was successfully constructed in an efficient and cost-effective way, overcoming all the environmental and operational constraints of the scheme.

The project was constructed in two phases, with the completion date of the temporary earthworks in May 2015 and permanent earthworks in July 2015. The new viaduct was open to the public in August 2015.

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