CASED HOLLOW BAR MICROPILE ARRAY FOUNDATIONS FOR BRIDGE REPLACEMENT PROJECTS IN NORTHERN NEW SOUTH WALES, AUSTRALIA

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ABSTRACT

As many existing rural timber bridges reach the end of their design life, it is a challenge for authorities to replace them within budgetary constraints, whilst meeting the current design standards. One regional council had the innovative solution of purchasing ex Army Surplus “Line of Command” bridges, also known as Bailey Bridges, for single clear spans of 30 to 50m. The original foundation design was bored or driven piles, with total abutment loads in the order of 3600kN vertical and 600kN lateral. After visiting the 5 (five) sites,and considering the access and construction limitations that each site presented, PCA, in conjunction with the Principal Contractor- SEE Civil, offered up an alternative foundation solution, consisting of an array of vertical and raked cased micropiles. After demonstrating their suitability, the proposal was accepted, the piles installed, the headstocks poured and all 5 bridges were successfully launched and landed.

BACKGROUND

The 5 bridge sites are located approximately 30 to 40km west of Byron Bay, in the hinterland on the eastern side of the Great Dividing Range. Formed during the Carboniferous Period, over 300 million years ago when Australia, New Zealand and South America were still part of the came land mass, the Great Dividing Range stretches 3500km along the Australia’s eastern seaboard- from the north of Queensland to western Victoria, in the nations south.

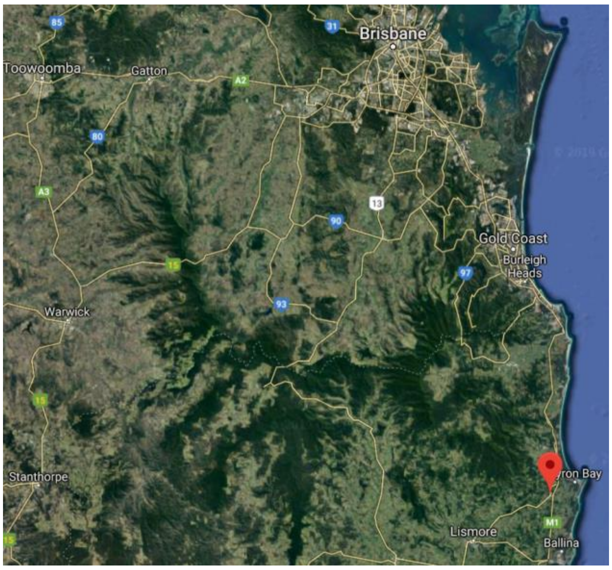

Figure 1

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The bridge sites are part of the upper reaches of the Wilsons River Catchment, which heads south and feeds into the Richmond River at Cobaki, before emptying into the Coral Sea at Ballina, some 600km from the southern tip of the Great Barrier Reef.

During the 4th and 5th of June 2016, there was an intense rain event estimated to be a 50 to 100 year ARI event. All 5 bridges were overtopped by approximately 1.6m. O' Meara's Bridge was the most adversely affected, and the resulting flood damage led to its permanent closure.

Figure 2

There are a large number of similar timber bridges remaining in rural Australia, which are being systematically replaced by local and state authorities.

As part of the NSW State Government and Byron Shire Council's "Bridges Renewal Programme", these 5 bridge sites were identified for replacement. The bridges were: Parkers and James Bridge over Byron Creek, and O'Meara's, Scarrabellotis and Booyong Bridge over the Wilsons River.

The original bridges were generally in poor condition, and had had load restrictions imposed upon them. Prior to its permanent closure, O'Meara's already had had a 5 tonne limit. Parkers had a 3 tonne limit, and Scarrabelottis a 10 tonne limit.

BRIDGE SUPER STRUCTURE

The proposed bridge superstructure for the sites were Bailey Bridges- modular truss type bridges, pioneered by the US Military in World War 2. They facilitate crossings from one side to the other, without any necessary landing on the far side before hand, by building a set of modules that are cantilevered out over the creek with increasing weight being added to the back span.

Indicative unfactored self weights of a typical 50m span bridge were of the order of 160 tonnes. During the launching process, factored point loads under the main rollers of 90 tonnes were determined.

GEOLOGY/ GEOTECHNICAL PROFILE

The sites are located within a 10km radius, and each shares a differing but similar profile, As indicated in the 1:100,000 Coastal Quaternary Geological Map of New South Wales, the sites are underlain by Basalt derived from volcanic lava flows in the Miocene epoch (5 to 25 million years ago) and subsequently overtopped by flood plain alluvial deposits of silts, clays, sands and gravels. The strength of the rock at depth

varied from very low strength to fresh, high strength rock, which was another contributing factor in the decision to adopt a micropile solution.
A typical soil profile (1) (Parkers) was as follows:

Unit 1	Fill	Road pavement
Unit 2	Alluvial Soil	Silty to Gravelly Clay
Unit 3	Alluvial Gravels	Medium dense to very dense clayey gravels
Unit 4	Ex Weathered Basalt	Stiff to very stiff to hard residual soil
Unit 5	Slightly Weathered to Fresh Basalt	

The depth to the high strength rock varied both from bridge to bridge and from abutment to abutment. The borehole at Parkers northern abutment indicated 13m, while the southern abutment indicated 25m.

Forces to the abutments resulting from the self weight of the superstructure, traffic loading from a T44 truck travelling at 80km/h, and estimated flood loadings of typically 2.6m/s (ARI 100) and 3.1m/s (ARI 2000) gave typical pile loads as follows:

			Load per pile		
		No piles/ abutment	Vertical kN	Lateral kN	Bending kNm
Scarrabelotti	Bored Pile	2	1580	300	480
	Driven	4	800	150	240

Table 1

The soils report and the original design drawings nominated conventional solutions for the construction of bridge foundations. Bored piers and driven precast pile designs were provided. Each had advantages and disadvantages.

WHY MICROPILES?

The primary issue for conventional piled solutions was the requirement to penetrate the very hard fresh basalt in order to provide the necessary rock socket, both for vertical and lateral capacity. With regards to driven piles, it was simply unfeasible given the hardness of the rock. That left bored piers as a solution, however, the necessary size of piling rig required (nominally 60 tonne) was problematic and cost prohibitive.

Scarrabelottis Bridge in particular presented the problem of access of the piling rig given that is was only accessible from one direction and required equipment to be mobilised across the nearby James Bridge which had a 15T load limit. Scarrabelottis Bridge itself was also load limited which meant that any large piling equipment would need to make a 20 kilometre trip by road and across private farmland to reach the abutment on the far side of the river.

In contrast, the micropile rig chosen for both Scarrabelottis Bridge and James Bridge was an 8 tonne track mounted rig that could be mobilised across the existing bridges to install the micropiles without costly detours or temporary works.

Common to all five sites was the environmentally sensitive nature of their location directly adjacent to pristine waterways and fertile farm land. In order for a large bored pile drill rig to operate, a significant amount of temporary works would need to have been undertaken to support the rig during the drilling operation. This would have also required considerable measures to control sediment from water runoff from the piling platforms and the material required to construct the platforms would risk introducing foreign weeds and noxious plants to adjacent farm land.

By utilising micropiles, the local road network was also saved from additional heavy vehicle traffic required to remove spoil from the drilling operation and to deliver the large steel cages and concrete to each site.

In summary, the major advantages of a micropiled solution were

1- A Cased Hollow Bar Micropile Array Foundation can be installed by relatively light weight plant. The piling rig utilised to install the micropiles at Scarrabelottis was an 8 tonne track mounted drill rig, which was able to traverse the existing bridge. The other sites utilised excavator mounted drill equipment that could reach down into the excavated abutment areas without the need for significant temporary platforms and other controls.
2- The required earthworks preparation and working platforms for piling rig access were significantly reduced by adopting a micropile solution.
3- The ability of the hollowbar system to advance into high strength rock was a significant time saver
4- The reduced head height of the piling rigs, due to the hollowbars being installed in 3m lengths, meant that the risks involved with the over head power lines could be mitigated on a number of the sites.
5- The potential impacts of variable ground conditions could be reduced, with the method of installation allowing for monitoring of drilling feedback to cross check the adopted design parameters were against the design parameters, allowing for final pile lengths to be extended or reduced to suit the specific site conditions.
6- Significant “de-risking” of the project in terms of cost and program due to the reduced potential for impacts from latent conditions when utilising micropiles as opposed to traditional bored piles.

CASED MICROPILE FOUNDATION- DESIGN PROCESS

Having established that a micropile solution would address many of the key construction challenges this project presented, the next step was to carry out preliminary designs for tender purposes.

Abutment loads were assessed initially by back calculation and first principles, and a suitable arrangement determined, costed and presented to the Client. After positive feedback, the detailed design stage began, with site specific loads and load combinations provided by the Engineer (2,3).

Each abutment consists of 2 rows of micropiles, with the inner piles vertical and the outer piles raked at 10 to 20 degrees to counteract lateral/ longitudinal loads arising from flood and braking loads respectively.

Each micropile consists of an upper section with a 168 x 11 (350) CHS (circular hollow section) sleeve, 3m long, embedded into the abutment to develop fixity. For this project, an additional inner 114 x 6 (350) sleeve x 4m long has been provided for 2 purposes. 1) to increase the bending capacity of the section and 2) provide additional toe/ passive resistance due to the scour condition.

Beyond the underside of the CHS, the bending becomes negligible, and the axial load is resisted by a central hollow bar, nominally 40mm in outside diameter, 16mm internal. The hollow bar is installed through the CHS casing, and advanced by rotary percussion whilst being flushed with a drilling grout (0.8 water cement ratio) which is continuously pumped through the inner annulus of the hollow bar, maintaining a positive hole pressure and grout return to the surface. Once the target depth has been achieved, the sacrificial drill bit and hollow bar are left in place and a richer grout (0.45 w/c) is flushed through the pile. The grout acts as both the means of developing the piles capacity in skin friction (end bearing is ignored) and provides the durability cover to the hollow bar. Drilling with continuous grout results in higher skin friction capacities, as the grout permeates the surrounding soil, forming a soil/ grout matrix, increasing the effective diameter of the pile.

DURABILITY

The grout cover provides the durability requirements for the hollow bar, and a uniform section loss is applied to the upper CHS sleeve section for the combined axial load and bending checks.

Reference is made to the exposure classifications nominated in the Coffey's reports, with a 'mild' exposure to buried steel elements being reported.

AS2159 Section 6.5 Table 6.5.3 states that for a mild exposure classification, the uniform section loss allowance is from 0.01 to 0.02mm/ year.

AS5100.3 Section 4.4 (b) states that "rates of corrosion for unprotected steel surface shall be 0.025mm per year ", which was adopted as the sacrificial section loss for the combined axial load and bending checks calculation.

LOADS/ LOAD COMBINATIONS

As discussed above, site specific loads and load combinations were provided, and are summarised below:

Number	ULS/ SLS	Description
LC 20	ULS	Max PE + 2 x live (no braking) (no flood)
LC21	ULS	Max PE + 2 x live (inc braking) + 1 x deck level stream force
LC22	ULS	Max PE + 1 x live (inc braking) + 1.3 x deck level stream force
LC23	ULS	Max PE + ARI_{2000} stream force
LC21.1	ULS	Min PE + 2 x live (inc braking) + 1 x deck level stream force
LC22.1	ULS	Min PE + 1 x live (inc braking) + 1.3 x deck level stream force
LC23.1	ULS	Min PE + ARI_{2000} stream force
LC31	ULS	Max PE + min lateral restraint
LC31.1	ULS	Min PE + min lateral restraint
LC120	SLS	Max PE + 1 x live
LC123	SLS	Max PE + 1 x deck level stream force
LC124	SLS	Max PE + 1 x live (inc braking)

Table 2

The worst case load combination (with respect to both maximum axial load and combined axial load and pile bending) was determined as:
LC21- max dead/ super dead + 2.0 x live load (including braking)+ 1.0 x stream force at deck level

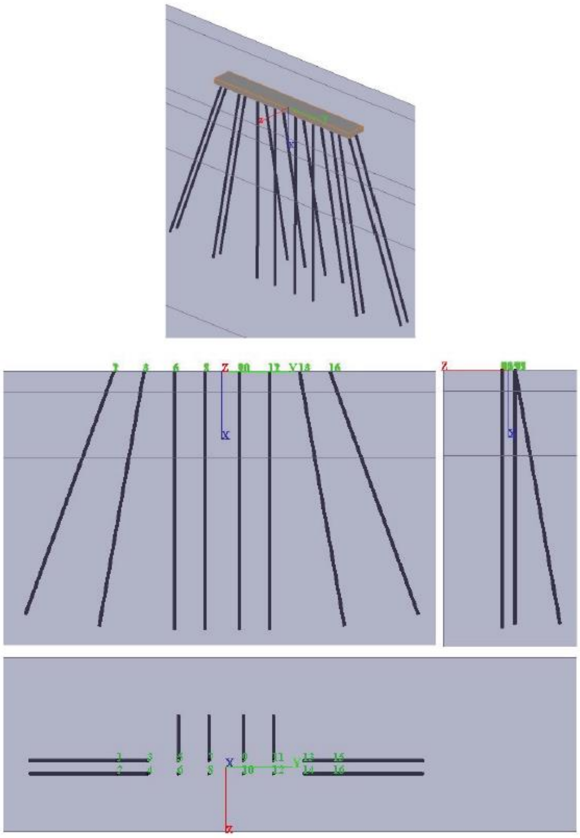
i.e. the design traffic loading braking suddenly as the bridge is just over topped by flood waters, with the design scour depth applied.
The table below lists the worst case design actions to the abutment, applied at top of head stock level, for each bridge, and the design scour depth.

		LC21		
	Scour Depth (m)	Fx (kN) Vertical	Fy (kN) (Lateral/ Flood)	Fz (kN) (Long'nal/ braking)
O'Meara's	1.8	2995	330	750
Scarrabelotti's	1.6	3021	240	750
Booyong	1.6	2995	210	750
Parkers	1.4	2803	170	750
James	1.4	2364	170	750

Table 3

METHODOLOGY

The commercially available GROUP 2016 was used to model the load/ pile arrangement, and the resulting axial and bi axial bending moments checked for combined axial load and bending using an in house excel spread sheet.



Typical Pile Configuration (GROUP model)

(Scarrabelotti, Booyong, Parkers, James)

Figure 4

The axial geotechnical capacity of the micropiles (hence the pile length) was calculated using in house design spreadsheets with an appraisal of the soil profile at each abutment location.
The geotechnical capacity and design parameters was verified by 1 (one) static load test at each abutment. A production pile was tension tested to a minimum of 75% of the ULS axial load.

SUMMARY OF PILE FORCES

The maximum compression and tension axial forces in an individual pile were identified as 425kN compression and 325kN tension, with a combined axial and bending utilisation of 86%, with a 40-16 hollowbar adopted with a yield of 525kN.

SUMMARY OF PILE SPECIFICATION

	Number of piles per abutment	CHS size	Hollow Bar	Drill Bit dia	Max Micropile Axial load	Micropile length
Typical	16	168 x 11 x 3m (350) (outer) + 114 x 6 x 4m (350) (inner)	40/ 16 (40OD-16ID) (Fsy=525kN)	115	425kN (C) 325kN (T)	From 15m to 24m

Table 4

CONCLUSION

Piling works commenced on Booyong Bridge on 21st May, 2018, followed by Parkers Bridge in July, Scarrabelottis and O’Mearas in August and concluding with James in October.

Excluding periods of bad weather, on average it took 1 to 2 days to install the 16 casings, and 3 days to install the hollowbars, at a rate of approximately 100 lineal metres per day.

The Bailey Bridges were subsequently launched and landed, accompanying civil works completed and the bridges are now operational.

REFERENCES

1 Coffey's Geotechnical Reports

GEOTALST	036988AA-AB_R1	O'Meara's
	754-LSY-GE-197810-E_Rev1	Scarrabelotti
	754-LSY-GE-197810-D_Rev 1	James
	754-LSY-GE-197810-F_Rev1	Parkers
	754-LSY-GE-197810-C_Rev1	Booyong

2 Loads as per Bridge Design Letter ref B1701-L-04 dated 09/01/2018

3 Load Combinations as per email correspondence between Bridge Design and PCA titled "11655- 5 Bridges for Byron Shire" circa 11/08/2018