MICROPILES – THE GREEN CHOICE?

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ABSTRACT

To date the environmental credentials of micropiles have not been fully recognised. As a technical solution micropiles and high capacity micropiles can achieve significant loads for a relatively small volume of grout and steel installed by making the best use of the geotechnical design advantages that they can give.

In many instances the carbon footprint of a particular choice of piled foundation is dominated by the volume of concrete/grout and steel employed. Although micropiles typically have relatively high cement content mixes they are able to carry significant load when expressed as a load per carbon tonne.

Branlow as part of the Balfour Beatty Ground Engineering Group are part of an initiative known as Green Siesta. Green Siesta is a method of carbon costing piled foundation solutions and hence determining the best choice from an environmental perspective.

An example project is used to illustrate that micropiles can be the environmental choice when compared against other methods.

1. BACKGROUND

Branlow is a specialist in restricted access mini and micro piling solutions. Part of Balfour Beatty Ground Engineering (BBGE) it is expected to place the needs of the customer at the forefront of their operations. An understanding of the customers existing needs are not only required but also identifying their future needs.

To gain an understanding BBGE surveyed its customers to ask about the issues that were most important to them with a view to identifying what issues would be of significance to them in the future. An overwhelming response from the customers was the need for clarity about sustainability and an understanding of the environmental impact of foundations, particularly in terms of reducing carbon emissions.

With a common theme identified from our customers requirements it was decided a process was needed for judging carbon emissions as routinely as other environmental issues such as noise and vibration are considered.

BBGE already possessed an in-house estimating application called SIESTA. Put simply SIESTA uses a library of costs which are multiplied by material and production quantities to provide a cost.

It was reasoned that the same approach could be used to calculate the carbon emissions for the project; all that was required was a library of appropriate emission factors for the material and production elements.

A proposal was put forward to modify SIESTA to include a ‘carbon calculator’, a relatively simple task; the difficulty came in identifying and quantifying the carbon significant elements of site operations.

2. ESTIMATING CARBON EMMISSIONS

To identify and quantify the carbon significant elements BBGE employed NIFES (National Industrial Fuel Efficiency Limited), a specialist in measuring carbon emissions.

All aspects of site operations were considered this included different technique, rigs, material usage, concrete mix designs, steel weight, transport methods and typical transport distances for plants and materials.

Where standards or protocols for measuring carbon exist these were followed. During the collation of the carbon library it became evident that there are no set criteria as to how the construction industry should measure embedded carbon - that is the total amount of carbon dioxide emitted from every stage of its production and distribution, from source to end product.

Within the figures NIFES was able to obtain there was significant variation. In order to account for this variation it was felt prudent to use average UK market figures recommended by NIFES.

3. PRIMARY SOURCE OF EMMISSIONS

In very simple terms the more energy involved in a product or process the greater the carbon footprint. The vast majority of this energy comes from the burning of fossil fuels.

3.1 Concrete

Concrete is responsible for 60 – 70% of all the $C0_2$ constructing our foundations. The second largest contributor is steel at 10 – 30% with transport and fuel accounting for 10 – 15%.

The $C0_2$ of concrete is derived mainly from cement. The production of one tonne of cement produces on average 0.8 tonnes of $C0_2$. The method of manufacture can dramatically affect the amount of $C0_2$ produced.

3.2 Steel

Mining and processing ore into steel is an energy intensive process. Obtaining accurate figures from the steel industry is at present difficult.

Steel is traded on a world market and contains steel from sources difficult to trace with unknown amounts of recycled material. It is estimated that virgin steel produces 2.7 tonnes of $C0_2$ per tonne of product. If we were to consider recycled steel we would reduce this to 0.4 tonnes of $C0_2$ per tonne of product.

The figure used in SIESTA is a NIFES advised average of 1.820 tonnes of $C0_2$ per tonne of steel.

3.3 Transport and Fuel

Fuel has less impact than the construction materials but is still significant. Heavy plant is used to transport materials and plant to site. Site fuel usage is approximated from the anticipated duration of the project and the average fuel used per day for the appropriate rig.

With plant and material transport SIESTA takes into account distance, journey composition and a round trip to average out the emissions due to vehicles being heavily or lightly loaded.

4. HOW GREEN SIESTA WORKS

Once the estimator has undertaken the Bill of Quantities SIESTA then uses the library of carbon emission factors to calculate the total CO2 produced on site. This is broken down into key areas of concrete / grout, steel, spoil, fuel and mobilisation.

A ‘Carbon Bill of Quantities’ is produced for the Client this shows the breakdown both graphically and in tabular form.

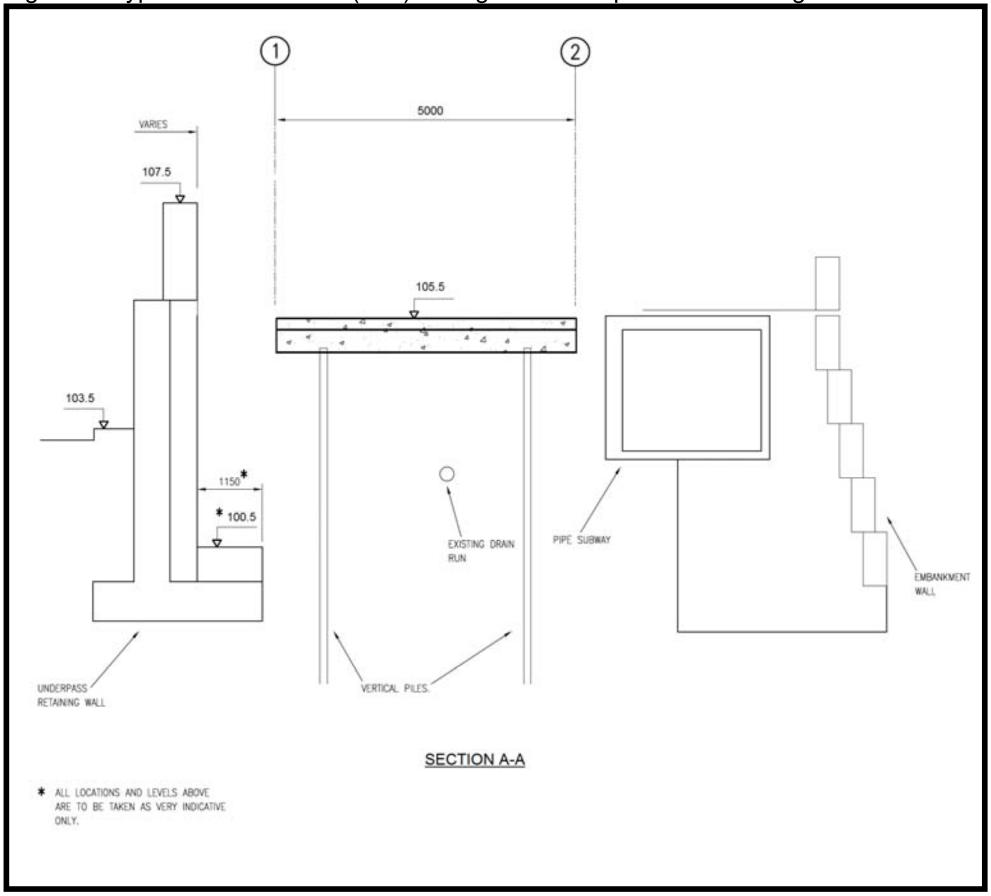
5. CASE STUDY

An exercise was performed to evaluate the relative carbon footprint produced for a micro pile project when compared against an equivalent bottom driven and auger bored solution

It should be noted that this exercise is solely for the comparison of carbon dioxide emissions for various restricted access piling methods.

The project consisted of a lightly loaded two storey structure to be constructed on an elevated section of walkway. Difficult site constraints were posed with an underpass directly north and service tunnel to the south (Figure 1).

Figure 1: Typical cross-section (N-S) through the example site exhibiting site constraints.



In addition to the site constraints the ground conditions were problematic due to the thickness and nature of the Made Ground. A typical geological profile is presented in Table 1.

Table 1: Typical Geological Profile

Stratum	Level of Top of Stratum AOD	Level of Top of Stratum mBGL	Typical Thickness m	Typical Description
Made Ground	104.7	Ground Level	9.2	Brown and grey sandy fine to coarse angular and subangular gravel sized fragments of sandstone, siltstone, brick, chert, quartz and concrete.
River Terrace Gravels	95.5	9.2	4.0	Medium Dense brown fine to coarse SAND and fine to coarse angular to rounded GRAVEL of chert, quartz., sandstone and siltstone. Occasional cobbles.
London Clay	91.5	13.2	Proven to 16.8m	Stiff brown slightly sandy CLAY.

Groundwater was recorded at 100.0mAOD (approximately 5.0mBGL)

Three design options (Table 2) were considered for the carbon assessment comparison of which the geotechnical design was undertaken by Terrain Geotechnical Limited.

Table 2: Design Considerations

Type	Diameter mm	Length m	F.O.S.	Safe Working Load kN	Testing
Micropile	40/16 hollow bar with 175mm clay bit	13.0	2	250.0	Non working pile test
Bottom Driven	220mm	11.0	2.5	250.0	Dynamic pile test
Auger Bored	300mm	20.5	3	250.0	None

It should be noted a micropile solution for this project was chosen based on the following advantages - programme, limited spoil generation and the ability to overcome the anticipated obstructions in the Made Ground.

A Bill of Quantities was produced for each of the solutions. The break down of the bill of quantities is presented in Table 3.

Table 3: Quantities and Outputs for Micropile, Bottom Driven and Auger Bored Piles

Type	Grout / Cement	Steel kg	Spoil m3	Fuel litres	Mobilisation	Productivity
Micropile	Ordinary Portland Cement – 1.02t or 0.735m^3 grout (overbreak 230%)	110.00	0.4	23	Rigid HGV: 1 No. Approx mobilisation distance: 220 miles	120m per day. Approx 9 per day.
Bottom Driven	Readymix Concrete – 1.2t or 0.50m^3	215.00 for casing + 23.50 for cages (4 no. t12 bars x 6.0m	None	28.5	Rigid HGV: 1 No. Approx mobilisation distance: 220 miles (352km)	45.5m per day. Approx 3.5 per day.
Auger Bored	Ordinary Portland Cement 2.5t or 1.80m^3 grout (overbreak 125%)	23.5 for cages (4 no. t12 bars x 6.0m)	1.8	150	Articulated HGV: 1 No. Approx mobilisation distance: 220 miles Rigid HGV: 1 No. Approx mobilisation distance: 220 miles	20-25m per day. Approx 1 per day.

On completion of the Bill of Quantities using the figures derived from Siesta the total CO2 for the project was calculated based on each piling technique. The results of which are presented in Figure 2 and Table 4.

Figure 2: Percentage of carbon dioxide embedded and emitted for each piling technique

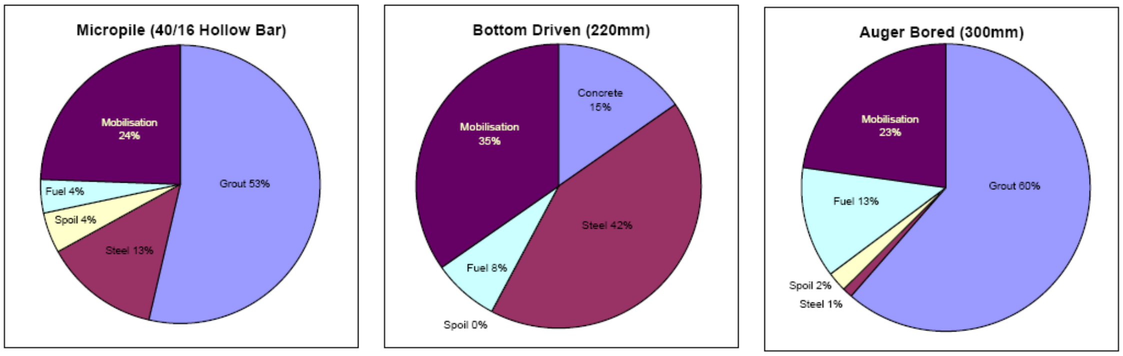


Table 4: Total carbon dioxide embedded and emitted for each piling technique

Type	Grout[1] / Cement[2]	Steel[3]	Spoil[4]	Fuel[5]	Mobilisation[6]	Total
Micropile	0.79te	0.20te	0.066	0.06	0.36	1.59te
Bottom Driven	0.16 te	0.44te	None	0.08	0.36	1.13te
Auger Bored	1.94te	0.04te	0.066	0.4	0.72	2.91te

1) Siesta uses a NIFES advised average of 777kg CO2/te
2) Siesta uses a calculated average of 328kg CO2/m^3
3) Siesta uses a NIFES advised average of 1,820kg CO2/te
4) Transport only. Based on 50 mile trip, 50% urban and 50% rural
5) Based on DEFRA recommendation of 2.630kg CO2/litre
6) Round trips are assumed by an articulated HGV with 40% urban, 40% rural and 20% motorway driving

6. DISCUSSION

Of the carbon areas considered the carbon content calculated for spoil, fuel and mobilisation are similar in comparison and hence the following sections concentrate on the materials contribution to total carbon content.

6.1 Micropile

The total embedded and emitted carbon produced for the micropile was 1.59 tonnes. When comparing the carbon produced against the three piling techniques the micro pile placed second behind the bottom driven pile. Although the micropile grout quantities are less than the other methods, of the carbon areas considered the majority of the carbon is attributed to the use of cement for the grout.

6.2 Bottom Driven

The total embedded and emitted carbon produced for the bottom driven pile was 1.13 tonnes. When comparing the carbon produced against the three piling techniques the bottom driven pile placed first. Of the carbon areas considered the majority of the carbon is attributed to the use of steel for the permanent casing and reinforcement. When considering the use of concrete, although there was more volume than the grout used for the micropile, in this instance it was the lesser of two ‘carbon evils’. By using cement grout the micropile and auger bored methods produced 5 and 12 times, respectively, as much carbon dioxide per pile for grout cement.

Due to the bottom driven pile being a displacement pile there was no additional carbon generated for the removal of the spoil.

6.3 Auger Bored

The total embedded and emitted carbon produced for the auger bored pile was 2.91 tonnes. This is 2.5 times more carbon than the bottom driven and 1.8 times more carbon than the micropile. Auger bored is therefore the ‘worst offender’ for carbon embedment and emitted this is due to the (relatively) inefficient design. Where as the bottom driven and micropile derive the bearing capacity from the gravels the auger bored requires the clay. Therefore, the longer pile length requires greater materials (particularly grout) and hence greater carbon content.

It should also be noted that the additional transport required delivering the casings and flights to site for the auger bored method, although not significantly, contributed to greater total carbon content.

6.4 General

From the research conducted for this paper it is clear there is a large potential for variation in reference data and more work is required to determine the accuracy of these figures.

For instance if the figures published for recycled steel are utilised this would have a dramatic reduction in carbon content. Traceability can be problematic when considering steel as the source or percentage of recyclable material can not always be identified.

Furthermore it is evident that the design mix for the concrete/grout mix can have a significant impact on the outcome of the total carbon produced e.g. use of PFA.

If the correct testing is undertaken at an early stage in the project the design efficiency can be improved which will reduce the amount of materials (and carbon content) required.

7. CONCLUSIONS

From the data and results it is clear that although not definitive the approach gives a reasonable approximation of the carbon content produced for the considered piling techniques. Therefore the exercise is primarily a tool for comparison which enables the Client the choice of a lower carbon alternative.

In this instance the lowest carbon content was the bottom driven which interestingly would have been the lowest cost. The message to spread to our Clients is that the sustainable option can be affordable.

Where possible, consideration should be given to the use of cement replacement materials (i.e. PFA) to further minimise carbon content.

Consideration should be given to achieving a lower factor of safety by adopting a suitable testing programme.

When considering micropiles as a green choice further research is required in refining the carbon figures published for the materials and also in the choice of materials. If this is undertaken correctly micropiles are a strong candidate for a green solution.

8. ACKNOWLEDGEMENTS

The author would like to thank Stuart Bradshaw of Terrain Geotechnical for undertaking the design elements of the paper, my Branlow Colleagues including Mark Hinton for supplying data and advice and finally Nirmal Tiwari and Viv Troughton of Stent Foundations for their assistance and guidance with SIESTA.

9. REFERENCES

Ground Engineering, December 2008. Siesta Time

Various Internal BBGE / Branlow Technical Publications