

Green Siesta

Micropiles – The Green Choice?

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A Balfour Beatty Company

What is Sustainability?



The Challenge?

" Carbon Accounting is the future of Sustainable construction. With increasing Legislation being introduced it is imperative that companies keep looking to lesson their carbon Footprint"

Ground Engineering 2008

An Introduction to Green Siesta

Developed in-house by BBGE Acronym for Stent Integrated Estimating Application Drivers; Supply chain pressures **Balfour Beatty** Corporate responsibility Group Fuel costs Escalating landfill tax **Balfour Beatty** Planning conditions **Ground Engineering** Public/Customer awareness **Balfour Beatty Pennine Branlow** Testal Stent GeoEnvironmental

An Introduction to Green Siesta

| Stent Sie | sta | | | | | | | | | | |
|--------------|-----------------------------|---------------|--------------|----------------|-----------------|--------------|---|----------------------------------|--------|-------------------|----------------|
| LDP Estimate | LDP 11930/1/35 | Rev O | | 15:18 25 | 5 September 20 | 08 About 🤞 | Print | page 📇 Print Rej | port 🛐 | Notes 🎇 🛛 Calc | Close |
| | Scope | A | | B | <u>c</u> | | D | Ē | 1 | Summa | ry |
| | Description | | | | | Seca | nt wall | | | Max. rigs 3 | amme |
| scope | Type of pile | Bearing | Bea | iring | Bearing | Male | | Female | | Prog.duration 2. | .8 wks |
| 2 | Nominal Diameter (mm) | 600mm | 600 | mm | 650mm | 600m | m | 600mm | | Con | crete |
| Tasouroas | Number of piles | 40 | 10 | | 10 | 10 | | 9 | | Female 10N | £70.00 A |
| resources | Average bored length (m) | 22m | 22m | I | 11m | 22m | | 22m | | Guide wall | £65.00 |
| | Average concrete length (m) | 21.50m | 21.5 | 50m | 10.50m | 21.50 | m | 21.50m | | | × |
| timeline | Max bored length (m) | 22m | 22m | 1 | 11m | 22m | | 22m | | Total volume 50 |)4 m3 |
| | Total bored length (m) | 880m | 220 | m | 110m | 220m | | 198m | | Total cost E3 | 35,086 |
| materials | Avg cut-off level below ppl | 0.50m | 0.50 |)m | 0.50m | 0.50m | 1 | 0.50m | | Main | eel Hel/Lnk |
| | Total concrete length (m) | 860m | 215 | m | 105m | 215m | | 193.50m | | Tonnes 6.61t | 0.54t |
| 世特 | Design load (kN) | | | | 1.000.000.000.0 | | | | | Av.£/t £588 | 2585 |
| cages | + Temporary Casing (m) | 1m | 1m | | 1m | 1m | | 1m | | Total £3,887 | £317 |
| a | + Permanent Casing (m) | | 1 | | 1 | | ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | | | Cent.ba | ars Steel Col. |
| steel | Boring Dry / Wet | Wet | Dry | | Dry | Dry | 2 | Dry | | Tonnes U.UUt | |
| 800 | Overpour | 1.20m | 0.40 |)m | 0.40m | 0.40m | 1 | 0.40m | | AV.27(20 | 0 |
| 4 2 | + Under Ream | Г | | | П | Г | | Г | | | |
| subcontract | Theoretical Concrete Volume | 243m3 | 61m | 13 | 35m3 | 61m3 | | 55m3 | | Prod | uction |
| - T | ⊕ B | earing 💮 | Secant 💽 | Contig (1) | King Post (| Plg Col 🚷 (| Copy 🗙 De | lete K | 1 | Tot bored m | 9 |
| testing | Cages Allocated to pile A | (40 out of 40 | allocated) | | | | | | | Tot conc m 1 | ,588.50m |
| Ö | Cage Description Pil | e diameter To | al weight El | fective Length | Projection | Total Length | Quantity | ~ | | Piles/day 5 | .7 |
| summary | CT-11 60 | 0. 0. | 16t 9 | .2m | 0.8m | 10m - | 40 | Automatically update cage gua | intity | per day | |
| | | | | | | | | if the number of p | oiles | Current total val | ue |
| BOQ 🔽 | | | | | | | | Assign Cages | | £405,815 | 5.89 |
| | | | | | | | | | | A Balfour Be | atty Company |

Available Techniques:

- CFA
- Pre-cast
- Sheet
- Rotary bored

In development:

- Micropile
- Bottom Driven

An Introduction to Green Siesta





Key issue identified from a 2007 survey of Clients:

'The need for clarity about sustainability and an understanding of the environmental impact of foundations, particularly in terms of reducing carbon emissions.'

It was decided a process was required that evaluated this aspect of our operations as easily as we assessed other environmental issues such as noise and vibration.

Green Siesta

How was this to be achieved?

- Already had Siesta which uses a library of costs.
- Which put simply:
- Unit Rate * Material Quantity * Productivity = Total Cost

Reasoned same approach could be used to calculate carbon emissions for a project.

Confident Siesta could be modified to include a 'carbon calculator'

Difficult task was to identify and quantify the carbon significant elements of site operations.

Green Siesta



Identifying CO2 Emissions

Consultant: **NIFES** National Industrial Fuel Efficiency Ltd

WBCSD World Business Council for Sustainable Development Green House Gas Protocol - a Corporate Accounting and Reporting Standard

The Carbon Trust UK







The Source of CO2 Emissions

ENERGY

- •Concrete (60-70%)
- Steel (10-30%)
- Fuel (10-15%)

Quantifying: Cement

Large variation - plant type, fuel, age etc.

Lafarge Cement UK

| Plant | Kg CO2/te |
|-------------------------|-----------|
| Aberthaw, S.Wales | 703 |
| Cauldron, Staffordshire | 740 |
| Hope, Derbyshire | 760 |
| Dunbar, East Lothian | 810 |
| Cookstown, N.Ireland | 820 |
| Northfleet, Kent | 960 |
| Westbury, Wiltshire | 970 |

Quantifying: Cement

Different types of Portland cement from the ICE report

| Method | Kg CO2/te |
|---------------|-----------|
| Wet kiln | 970 |
| Semi-wet kiln | 930 |
| Dry kiln | 740 |
| Semi-dry kiln | 840 |

Siesta uses a NIFES advised average of 777 kg CO2/te

| Replacement | Description | Kg CO2/te |
|----------------------|-----------------------------|-----------|
| Portland Ash cement | 25-30% fly ash | 585 |
| Portland Slag cement | 80-94% clinker, 8% slag | 755 |
| Portland Slag cement | 20-34% clinker, 64-73% slag | 279 |

Quantifying: Cement Replacement

London Concrete

| Material | Source: | CO ₂ from Transport | Embodied CO_2 | Total CO ₂ kg/te |
|----------|-------------|-----------------------------------|-----------------|--------------------------------|
| PFA | West Burton | 19.39 | 30 | 49.39 |
| GGBFS | Purfleet | 1.81 | 89 | 90.81 |

Civil and Marine: GGBFS 70 kg CO2/te UK Quality Ash Association: PFA 25 kg CO2/te

Siesta uses NIFES recommended figures of:

| Replacement | CO2 kg/te |
|-------------|-----------|
| GGBFS | 89 |
| PFA | 25 |

Quantifying: Sand, Aggregate & Water

Figures Collated by NIFES

| Material | kg CO ₂ /te | Data source |
|-----------------------|------------------------|--------------------------|
| Sand & gravel | 3.45 | from Tarmac (UK average) |
| Crushed rock | 3.23 | from Tarmac (UK average) |
| Aggregate | 3 | from Hanson (UK average) |
| Crushed stone | 3.40 | from London Concrete |
| Sand (marine dredged) | 7.79 | from London Concrete |
| Sand (land-based) | 3.49 | from London Concrete |

Water supply: 289 kg CO2 per 1 Million litres (from the trade body Water UK)

Quantifying: Steel Bar & Rod

| Туре | Typical (UK market) kg CO ₂ /te | Primary material kg CO ₂ /te | Recycled material kg CO ₂ /te |
|-------------|---|--|---|
| General | 1,820 | 2,820 | 450 |
| Bar and rod | 1,720 | 2,680 | 420 |

Problem: How to identify the source? How much is recycled?

Siesta uses the "typical" figure for auger bored and the "recycled" figure for Precast.

When considering steel for this exercise the typical value of 1,820kg CO_2 /te was taken.

Quantifying: Fuel

Diesel: 2.630 kg CO2/litres - excludes indirect emissions (from DEFRA)

- Fuel use on site
- Transport of materials
- Mobilisation/ Demobilisation
- Spoil removal

Siesta approximates site fuel use from the Net Sales Value & the total fuel use for each technique per year

Quantifying: Fuel

Transport of Materials

| Activity | Vehicle type | Load | Distance | Composition | Kg CO2 Per trip |
|--------------------------|-----------------|------|------------------------|--|--------------------|
| Readymix | Rigid HGV | 6m3 | 32km round trip | 100% urban | 17.23 |
| Steel & Precast piles | Artic. HGV | 24te | 480km round trip | 20% urban 40% rural 40% motorway | 493.20 |
| Reinforcement Cages | Artic. HGV | 8te | 480km round trip | 20% urban 40% rural 40% motorway | 493.20 |

Based on figures from National Atmospheric Emissions Inventory

Quantifying: Fuel

Mobilisation / Demobilisation & Spoil Removal

Calculated in similar way & depends on distance:

| Type of transport | Type of vehicle | Kg CO2 / km |
|---------------------------|---------------------|-------------|
| General transport to site | Light Goods Vehicle | 0.287 |
| Machine delivery | Articulated HGV | 1.022 |
| Spoil removal | Rigid HGV | 0.829 |

How Green Siesta calculates the CO2

| Stent Sie | esta | | | | | | |
|--------------|--|---------------------------------|----------------------------|--------------------------|--------------------------|---|-------------|
| CFA Estimate | CFA 22679/1/1 Rev 0 60 Lin m Secant wal | 26 CFA Load Bearing Piles | 15:57 27 June 2008 | About 📥 🛛 Pri | nt page 📇 Print Report | 😰 Notes 🕅 Calc 📰 🛛 Close | |
| details | Carbon Assessmer | nt | | | | Programme Ø No. rigs 1 | |
| | Concrete 126.87 te | Concrete Steel Spoil Fu | uel/Mob/Overhead | | | Mobilisation 0.40 wks | |
| scope | Steel 55.15 te | Source of Portland Cement | /erage | | • | Production 2.00 wks | |
| | Spoil 8.39 te | Aprox.dist.to batching plant | miles Average wag | gon load 5.5 m3 | (rigid HGV 100% urban) | 5 Total 2.40 wks Concrete Volume / Cost | |
| production | Fuel/Mob/OH | Mix | Male | Female | Guide wall | Male 776.51 m3 £88.00 Female 286.28 m3 £84.00 | Carbon |
| resources | | Strength Chemical class | DC-2 | C8/10 DC-1 | DC-1 | Total 1062.79 m3 | Calculation |
| | | Cementitious (kg/m3) | 415 kg | 300 kg | 305 kg | Main Hel/Lnk Cent | Screenshot |
| materials | | Туре | GGBFS | GGBFS | GGBFS | Total 31.74t | from CFA |
| | | Sand (kg/m3) | 845 kg Land-based | 950 kg Land-based | 852 kg Land-based | Av £/t £811.10 Weekly Plant & Labour | |
| A | Concrete 62% | Gravel/Aggregate (kg/m3) | 845 kg Crushod stopo | 975 kg Crushod stopo | 1075 kg Crushad stopa | Plant £8,255 Labour £9,098 | |
| U testing | Spoil 4% | Water | 210 kg | 172 kg | 165 kg | Total £17,353 | |
| Ò | | CO2 kg/m3 | 128.47 kg | 54.02 kg | 180.71 kg | Num piles 107 | |
| summary | | Transport CO2 | 973.04 kg | 358.73 kg | 71.05 kg | Av. conc len 13.77m Tot conc len 1473m | |
| | | Total CO2 (tonnes) | 100.73 te | 15.82 te | 10.32 te | Piles/day 10.7 | |
| | Print Carbon Assessment | NOTE: Emissions due to the tran | nsport of raw materials to | the batching plant are c | urrently unknown. | Max (av) m3 per day 121.0 (106.3) m3 | |
| carbon | Total CO2 203.06 te | Concrete | | Total CO2 | 2 126.87 te | £268,787.00 | |
| | | | | | | A Balfour Beatty Company | |

Example CO2 Bills of Quantities

Concrete 62 %

Fuel & Mob 6 %

Steel 27%

Spoil 4%

Stent CFA Carbon Assessment

Head Office & Southern Office PavillionC2,AshwoodPatk, AshwoodWay,Basingstoke RG238BG Tel01256400200 Fax01256400201

Summary

Approximate tonnes of carbon dioxide embedded and emitted:

| Concrete | 126.87 te | (includestransport) | |
|-----------------------|-----------|----------------------|---|
| Steel | 55.15 te | (includes transport) | (|
| Spoil | 8.39 te | (transportonly) | 1 |
| Fuel & Mob. | 12.65 te | | |
| Total CO ₂ | 203.06 te | | |
| | 80 | | × |

Breakdown

Concrete

| Concrete Mix | Strength/Class | Replacement | CO2Kq/m3 | Volume | Transport CO2 | Total CO |
|--------------|----------------|-------------|-----------|-----------|---------------|-----------|
| Male | C28/35 DC-2 | 70% GGBFS | 128.47 kg | 776.51 m3 | 973.04 kg | 100.73 te |
| Female | C8/10 DC-1 | 90% GGBFS | 54.02 kg | 286.28 m3 | 358.73 kg | 15.82 te |
| Guide wall | C20/25 DC-1 | 30% GGBFS | 180.71 kg | 56.7 m3 | 71.05 kg | 10.32 te |

Estimate: 22679/1/1-CRA

Ireparel: 27/06/2008

Project:

Tender:

GrosvenorWaterside,BlockA,London,SW1W8QN

60 LinmSecantwall & 26 CFA LoadBearing Piles

Transport carbon is based on the batching plant being approximately 4 miles from site with an average load of 5.5 m3 perwagon. Round trips are assumed by a rigid HGV and 100 % urban driving.

Steel

| Reinforcement | Embedded CO2 | No.cages | Transport CO2 | Total CO2 |
|---------------|--------------|----------|---------------|-----------|
| 31.74 te | 54.6 te | 67 | 0.55 te | 55.15 te |

Embedded carbonis based on a UKmarket average for steel bar and rod of 1,20 C 0.4gAe Transport carbonis based on age Athonican being approximately 60m lass from site with an average load of 20 cages perwagon. Round trips are assumed by an articulated HCV with 40 % urban, 40 % rural and 20 % motorway driving. Carbon emissions from the fabriculation of the cages are not included.

Spoil

| Total Spoil | Av.m3 per wagon | Av haulage distance | Total CO2 |
|-------------|-----------------|---------------------|-----------|
| 924.86 m3 | 9.5 m3 | 50 miles | 8.39 te |

Round trips are assumed by a rigid HGV/with 50 % rual and 50 % urban driving.

Fuel

Estimated diesel use: 4,808 litres Direct CO2 emission = 12.65 te Based on DEFRAdata which currently excludes emissions from the manufacture of the fuel itself

Mobilisation

No.articulated HGV's: 0 No.rigid HGV's: 0 Approx.mob.distance: 150 miles Transport CO₂= 0 te Round trips are assumed by an articulated HGV with 40 % urban, 40 % rural and 20 % motorway driving.



Stent Procast

Head Office & Southern Office ParillionC2, AstwoodPath, AstwoodWayBasingstoke RG238BG Tel01256400200 Fax01256400201
 Brinnarie
 22741/1/1PRE

 Brojett:
 25-27RoseKihLane,Reading,Benkshire

 Tender:
 275sepilesingrave1

 Bregared:
 27/06/2008

Summary

Approximate tonnes of carbon dioxide embedded and emitted:



Breakdown

Concrete

| Strength | /Class | Replac | ement | CO 2Kq/m 3 | Volume | Total CO 2 |
|-----------|-----------|--------------|-------------|------------------------|------------------------|-------------------|
| C45/20 | DC-3 | 25% | PFA | 291.24 | 204.84m3 | 59.66 t |
| Transport | oftherawr | naterials fo | or the conc | rete to the precast fa | actory are included in | n the calculation |

Steel

| | Total weight | CO 2Kate | Embedded CO2 |
|---------------|--------------|----------|--------------|
| Reinforcement | 19.8t | 420 | 8.31 t |
| Pile joints | Ot | 420 | Ot |

Embedded oarbon is based on steel bar and rod manufactured in the UK from sorap steel" at 420 C0, kgAe Carbon emissions from the fabrication of the joints and cages are not included.

Pile Transport

Number of wagons: 20 Approx.transport.distance: 150 miles Transport CO₂= 9.86 t Round trips are assumed by an articulated HGV with 40 % urban, 40 %

Fuel

Estimated diesel use: 1,709 litres Direct CO2 emission = 4.49 t Based on DEF RAdatawhich currently excludes emissions from the manufacture of the fuelitself.

Mobilisation

No.articulated HGV's: No.rigid HGV's: Approx.mob.distance: 150 miles Transport CO₂=0 t Round tripsare assumed with 40 % urban, 40 % rural and 20 % motorway driving



Calculations are based on figures provided for Stent by Nifes Consulting Group www.nifes.co.uk

- Proposed construction of a lightly loaded two storey structure on an elevated section of walkway.
- Particularly difficult site constraints underpass immediately north and embankment to south.
- Ground Conditions Thickness of Made Ground and likely occurrence of obstructions
- Column Loads of 250kN

Balfour Beatty Ground Engineering



 ALL LOCATIONS AND LEVELS ABOVE ARE TO BE TAKEN AS VERY INDICATIVE ONLY.

Typical Geological Model:

| Stratum | Level of Top of Stratum mAOD | Level of Top of Stratum mBGL | Typical Thickness m | Typical Description |
|-----------------------------|---------------------------------------|---------------------------------------|---------------------------|--|
| Made Ground | 104.7 | Ground Level | 8.5 | Brown and grey sandy fine to coarse angular and subangular gravel sized fragments of sandstone, siltstone, brick, chert, quartz and concrete. |
| River Terrace Gravels | 96.2 | 8.5 | 4.7 | 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)

Design Profiles Vs Elevation:

Made Ground







London Clay



Design Considerations

• Three options considered for carbon assessment comparison:

| Туре | Diameter | Diameter Length F.O.S. | | S.W.L | Testing |
|------------------|---|------------------------|-----|-------|-----------------------------|
| | mm | m | | kN | |
| Micropile | 40/16 hollow bar with 175mm clay bit | 13.3 | 2 | 250 | Non working pile test |
| Bottom Driven | 220 | 11.0 | 2.5 | 250 | Dynamic pile test |
| Auger Bored | 300mm | 20.5 | 3 | 250 | None |

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

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.

Quantity of Materials Per Pile for Each Method:

| Туре | Grout / Concrete | Steel | Spoil | Fuel | Mobilisation |
|------------------|------------------|-------|-------|--------|---|
| | te | te | m³ | litres | |
| Micropile | 1.02 Grout | 0.1 | 0.4 | 23 | 1 No. Rigid HGV |
| | | | | | Approximate mobilisation distance 352 km |
| Bottom Driven | 1.2 Readymix | 0.24 | none | 28.5 | 1 No. Rigid HGV |
| | | | | | Approximate mobilisation distance 352km |
| Auger | 2.50 Grout | 0.024 | 1.8 | 150 | 1 No. Articulated HGV |
| Bored | | | | | 1 no. Rigid HGV |
| | | | | | Approximate mobilisation distance 352km |

Micropile (40/16 Hollow Bar) Bottom Driven (220mm) Auger Bored (300mm) Concrete 15% Mobilisation Mobilisation Mobilisation 23% 24% 35% Grout 53% Grout 60% Fuel 4% Fuel 13% Spoil 4% Steel 42% Steel 13% Fuel 8% Spoil 2% Steel 1% Spoil 0%

Summary Approximate Tonnes of Carbon Dioxide Embedded and Emmited:

Summary

Approximate Tonnes of Carbon Dioxide Embedded and Emmited:

| Туре | Grout ¹ / Concrete ² | Steel ³ | Spoil ⁴ | Fuel ⁵ | Mobilisation ⁶ | Total |
|------------------|---|--------------------|--------------------|--------------------|---------------------------|--------------------|
| | te C0 ₂ | te C0 ₂ | te C0 ₂ | te C0 ₂ | te C0 ₂ | te C0 ₂ |
| Micropile | 0.79 | 0.2 | 0.066 | 0.06 | 0.36 | 1.48 |
| Bottom Driven | 0.16 | 0.44 | None | 0.08 | 0.36 | 1.04 |
| Auger Bored | 1.94 | 0.04 | 0.066 | 0.4 | 0.72 | 3.17 |

1) Siesta uses a NIFES advised average of 777kg CO₂/te

- Siesta uses a calculated average of 328kg CO₂/m³
- 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

Discussion – Bottom Driven

Bottom Driven produced least carbon emissions.

- Why?
- Although large amount of steel used there was not a great volume of concrete.

In this instance concrete was the lesser of two 'carbon evils'. Both the micropile and auger bored methods used a cement grout which produces three to four times as much carbon per tonne.

No spoil and therefore no carbon emissions.

Discussion – Micropile and Auger Bored

Micropile close second – Main factor was the use of cement

If a cement replacement was used e.g. PFA or a lower strength grout (0.4 w/c ratio was used) this would significantly reduce the amount of carbon emissions produced.

And lastly Auger Bored;

Worst Offender – Least design efficient i.e. longer pile length = greater materials.

Discussion – General

- Mobilisation ratios and fuel similar in comparison
- If steel is considered 'recycled' it has a dramatic effect
- Varying ratios in steel:grout/concrete for different methods
- F.O.S lower the more testing is undertaken = Lower CO_2
- Big potential for variation due to;
 - Reference data
 - Use of grout Vs. Concrete
 - Use of cement replacement (PFA) Vs. OPC
 - Use of recycled Steel Vs. General (Confidence in Source / Traceability)

High variability in published figures

More work is required to determine the accuracy of the figures

Therefore Siesta is primarily a tool for COMPARISON

As such Siesta does give clients choice.



•Lowest C0₂ is nearly always lowest cost.

•Therefore SUSTAINABLE = AFFORDABLE

•With the correct choice of materials;

'Micropiles are the <u>GREEN</u> choice'

Dziękują Dankeschön Grazie ¡Gracias! Merci Tak for lån Takk Thankyou

A Balfour Beatty Company