Service Carbon Footprint

Service Carbon Footprint: Life Cycle Assessment Report for Geobear

A comparison of the standard Geobear Geopolymer Injection service vs traditional Highways Concrete Bay Replacement

ORIGINAL FOUNDER OF URETEK SOLUTIONS

Carbon Footprint Ltd, Belvedere House, Basing View, Basingstoke, RG21 4HG, UK | +44 (0)1256 592 599 info@carbonfootprint.com | www.carbonfootprint.com

Executive Summary

This executive summary provides an overview analysis of the greenhouse gas emissions associated with the Geobear Geopolymer Injection service and a traditional Highways concrete bay replacement method. This assessment focuses on the embodied raw material emissions, the transport of these materials, the manufacture/processing, distribution and disposal of the two services. The Geobear method extends the lifetime of the existing asset, whereas the traditional replacement method, results in a brand-new asset.

The determined scenario for both services for this study is defined as:

<u>A UK Highway Concrete Bay project</u> [1]

Geobear aims to encourage its customers to be more sustainable when it comes to subsidence/settlement problems, Geopolymer injection below existing slabs/foundations to improve ground strength will avoid excavation and save emissions.

Geobear Infrastructure Ltd were contracted to treat sections of the carriageway to improve the strength of the road foundations of 39 concrete bays. Geobear Geopolymer Injection uses a two-part Geopolymer, and steel injection tubes to inject the Geopolymer[2]. The raw material transport is modelled based on an average supply distance by sea freight and truck to site. The emissions from the fuels used on site were calculated based on the typical machinery fuel consumption. This includes the transport to and from the site as well as the red diesel fuel use on-site. The two-part Geopolymer remains in-situ following the end of the project, however the steel is removed where possible and any Geopolymer wastage from testing is taken back to the depot for disposal.

A separate contract was let to a contractor employed to carry out bay replacement on the same number of bays at other sections of the highway. The comparable traditional method was modelled as using C40 Air Entrained Concrete and Type 1 sub-base, based on quantities provided by Geobear. All materials were modelled as supplied from a nearby depot (42km) by HGVs, with the number of HGVs based on the material quantities. The traditional method uses substantially more materials due to the need to replace the sub-base and the concrete bay. The emissions calculation also includes the waste generated when removing the existing materials.

For the case in question, the Geobear method is predicted to have extended the life of the highways concrete bays by around 9 years. In contrast, the traditional replacement method would result in brand new concrete bays with an anticipated life of 40 years. For the purposes of this assessment, 5 treatments will be compared to 1 replacement. It should be noted that after 40 years, it is likely that the concrete bays would need to be replaced due to degradation of the asset.

Two separate scenarios can be considered, one over a 40-year period and the other over an 80-year period. For the 40-year period, the traditional method of replacing the concrete bays can be compared with 5 treatments carried out by Geobear. For the 80-year period scenario, 2 replacements can be

[1] This covers a project completed by Geobear, with the comparison based on a nearby concrete bay replacement technique.

[2] Both the Geopolymer and Hardener formula and reagent are protected.

compared with 5 Geobear treatments, plus a replacement after 40 years (due to degradation of the asset).

The following table shows the percentage emissions breakdown for the assessed Geobear Geopolymer Injection service per treatment (Annex A):

Process	Emissions	
	$kgCO_2e$	Percentage
Raw materials - embodied	5,081.45	77.8%
Raw materials transport (excluding materials transported by the site team)	106.76	1.6%
Implementation Fuels	422.21	6.5%
Travel to and from site (including materials transported by the site team)	916.35	14.0%
Disposal	1.10	0.0%
Total emissions from the project	**6,527.88**	**100%**

The breakdown of life cycle carbon emissions for the Geobear Geopolymer Injection service and the comparison traditional method are shown in the following table:

Process	Traditional	Geobear (5 treatments over 40 years)
	$kgCO_2e$	$kgCO_2e$
Raw materials - embodied	121,018.83	25,407.27
Raw materials transport (excluding materials transported by the site team)	3,707.77	533.81
Implementation Fuels (Diesel)	9,458.61	2,111.05
Travel to and from site (including materials transported by the site team)	916.35	4,581.75
Disposal	1,027.29	5.52
Total	136,128.85	32,639.40

The Geobear Geopolymer Injection service produces less emissions than the traditional method. 5 Geobear treatments results in the avoidance of 76.02% of the modelled traditional method's emissions, this has an overall avoidance of 103,489.45 $kgCO_2e$.

The 80-year scenario would produce 272,258 $kgCO_2e$ for the traditional method (consisting of 2 asset replacements), with the Geobear service (5 treatments) followed by a traditional replacement of the concrete bays (due to degradation of the asset), would produce 168,768 $kgCO_2e$. This means there is an overall carbon emissions avoidance of 38.01%.

Geobear has achieved **Carbon Assessed Standard** by completing this project. This assessment shows Geobear's service has lower carbon emissions than the traditional method. To provide additional environmental savings and benefits, Geobear could consider supporting carbon offset projects, to mitigate the services unavoidable emissions. This will also allow the use of our **Carbon Neutral Standard** in relation to its client's projects.

Table of Contents

Quality Control

Report issue number:	1.3
Date:	24 August 2022
Calculations completed by:	Myles Howard
Calculations reviewed by:	Rebecca Pattison
Report produced by:	Myles Howard
Report reviewed by:	Rebecca Pattison
Director:	Dr. Wendy Buckley

1. Introduction

1.1 Scope of this Assessment

The aim of this assessment is to demonstrate the carbon footprint of the Geobear Geopolymer Injection service undertaken at the highway in question and to compare it against a traditional method of replacing the highway concrete bays. This is the third assessment Geobear has completed and will be used to demonstrate to their clients the environmental credentials of their services and to differentiate their service in an increasingly competitive marketplace.

Carbon emissions for the service assessed in this report include those derived from the extraction and processing of virgin raw materials, transport of raw materials and on-site construction vehicles to the site, the fuels used on site by the construction vehicles, and disposal.

For the case in question, the Geobear method is predicted to have extended the life of the highways concrete bays by around 9 years. In contrast, the traditional replacement method would result in brand-new concrete bays with an anticipated life of 40 years. For the purposes of this assessment, 5 treatments will be compared to 1 replacement. It should be noted that after 40 years, it is likely that the concrete bays would need to be replaced due to degradation of the asset.

Two separate scenarios can be considered, one over a 40-year period and the other over a 80-year period. For the 40-year period, the traditional method of replacing the concrete bays can be compared with 5 treatments carried out by Geobear. For the 80-year period scenario, 2 replacements can be compared with 5 Geobear treatments, plus a replacement after 40 years (due to degradation of the asset).

1.2 What is a Service Life Cycle Assessment (LCA)?

Service LCA is the assessment of the environmental impacts of a service during its life cycle. It incorporates the analysis of raw materials, manufacture, transport and disposal. LCA can evaluate several environmental impacts (air pollution, ozone layer depletion, climate change, etc.) or focus on a single impact (e.g. climate change). When only climate change is considered, it is called service carbon footprint or carbon LCA.

The service carbon footprint detailed in this report is a *Cradle-to-Gate* carbon LCA.

1.3 How is the service carbon footprint calculated?

The service carbon footprint is derived from a combination of activity data provided by Geobear and from publicly available sources (primary data), and emission factors extracted from internationally recognised metrics Greenhouse gas (GHG), activity data is then multiplied by GHG emission factors to produce carbon metrics.

To guarantee transparency and reproducibility, the emission factors used in this report are shown in Annex 1 detailing the exact name of the emission factor as it appears on its respective database. Material emissions factors are sourced either from EcoInvent’s database (v3.7.1), ICE v3.0 (2019), the

UK Government (BEIS, 2020), or supplier sourced emissions factors. All EcoInvent factors account for all processes during the production of raw materials and all processes.

1.4 Abbreviations

CO_2e	Carbon Dioxide Equivalent
Defra	Department of Environment, Food and Rural Affairs
GHG	Greenhouse Gases
kg	Kilogrammes
km	Kilometres
kWh	Kilowatt Hours
LCA	Life Cycle Assessment
HGV	Heavy Good Vehicle

2. Service overview

2.1 Geobear Geopolymer Injection service

Geobear has teams and offices across the UK and Ireland. Geobear aims to encourage its customers to be more sustainable when it comes to highway concrete bay maintenance, through Geopolymer injection below existing bays to improve road foundation strength. This is an alternative to the traditional highway bay replacement method that requires a significant amount of concrete and stone which both have large CO_2e emissions and subsequent logistical, implementation and disposal emissions.

The Geopolymer Injection service provided by Geobear injects a two-part Geopolymer below the existing bay to enhance and improve the strength of the road foundation. This is injected through steel tubes below the existing bay slabs. The sourcing of the raw materials was all calculated based on the distance from the source of materials to the contractor's yard. From the contractors yard, an average return supply distance of 340.8km was used for the transport to site.

Once the materials and machinery are transported to site, the machinery is used to drill and inject the Geopolymer. The only waste materials are the steel and small amounts of Geopolymer used in testing which are returned to the depot with the site team. Table 1 below details the individual materials:

Table 1: Overview of all raw material used to produce a Geopolymer Injection service

Material ID	Material (kg) per treatment	Material (kg) for 5 treatments over 40 years	Percentage of total weight
Part A- Hardener	783	3,915	43.60%
Part B- Polymer	580	2,900	32.29%
Steel Injection Tubes	433	2,165	24.11%
Grand Total	**1,796**	**8,980**	**100%**

2.2 Traditional method (Highway Bay Replacement)

For the comparison, a traditional method for a highway bay replacement, for an equal area of carriageway, was used to compare and show carbon savings. The traditional method does not use any polymers, instead this method uses concrete and Type 1 sub-base. The bay and associated sub-base is excavated with a large quantity being removed as waste. This excavation requires significantly more fuel, as there is more time and machinery required. The excavated bay and associated sub-base is then replaced. Within this assessment, the emissions associated with the raw materials, transport, production and disposal of the traditional method is modelled based on standard distances and weights from Geobear's employee knowledge.

Due to a lack of actual data, the transport of the raw materials and the service distribution for the traditional method was modelled based on a nearby depot at an average distance of 42km, with the number of HGVs based on the material quantities.

Disposal of materials from the implementation state is modelled based on DEFRA emissions factors for the waste types.

Table 2 details the individual components and their materials used to produce the traditional method calculations.

Table 2: Overview of raw materials used to replace the highway bay slabs

Raw material	Material (kg)	Percentage
C40 Air Entrained Concrete	660,442	78.87%
Sub-base layer (Type 1 MOT - Series 800)	168,480	21.13%
Grand Total	797,472	**100%**

3. Accuracy of the carbon footprint LCA calculation

The accuracy of the overall carbon footprint calculations for the Geobear Geopolymer Injection service (Table 3) is very good as the majority of the data used in the calculation is primary data or modelled based on past experience and industry standards submitted by Geobear. The accuracy of the data for the comparison traditional method (Table 4) was modelled due to lack of primary data. Similar models were used for both service methods to avoid bias.

Table 3: Source data and calculation accuracy for the Geobear Geopolymer Injection service

Dataset	Source of data and comments	Accuracy
Raw materials Embodied material emissions and processes	Individual component weights and material types provided by Geobear, based on the amount of weight of material needed for the assessed project.	Very Good
Raw materials transport (excluding materials transported by the site team)	Calculated based on the supplier details provided by Geobear.	Very Good
Travel to and from site Transport (including materials transported by the site team)	Modelled based on average distance from Geobear depot to project site.	Modelled
Implementation Fuels (Red Diesel)	Calculated based on red diesel usage for a weeks' worth of projects apportioned to the active minutes recorded on technicians' timesheets.	Good
Disposal	Calculated based on the steel used and the percentage of typical Geopolymer offcuts.	Modelled

Table 4: Source data and calculation accuracy for the traditional method

Dataset	Source of data and comments	Accuracy
Raw materials Embodied material emissions and processes	Individual component weights and material types provided by Geobear based on industry experience.	Modelled
Raw materials transport (excluding materials transported by the site team)	Modelled based on industry standard practice and vehicle types.	Modelled
Travel to and from site Transport (including materials transported by the site team)	Modelled based on the same distance as Geobear's depot to project site, to ensure comparability.	Modelled
Implementation Fuels	Fuels and quantities provided by Geobear based on industry experience.	Modelled
Disposal	Calculated based on the expected material extraction needs, provided by Geobear.	Modelled

4. Carbon Footprint Service Results

4.1 Embodied emissions from raw materials

Embodied emissions have been calculated by multiplying the mass of each material by the correspondent carbon emission factor (Table 5). The emission factors used typically include, for each material: the extraction of the raw materials they are made of, their transportation, processing and distribution. The emissions from the Geopolymer and Hardener[3] (the two components which are combined to form the injected Geopolymer), have been apportioned based on the recorded combined weight and standard ratio. Geobear has provided material safety data sheet (MSDS) for both the Geopolymers and Hardeners, to allow for the verification of the emissions factors provided by Geobear's material supplier.

Table 5: Embodied GHG emissions per 40-year timeframe

Method	Raw material	Material including offcuts (kg)	Embodied ($kgCO_2e$)
Geopolymer	Part A- Hardener	3,915	10,805.40
	Part B- Polymer	2,900	9,990.50
	Steel Injection Tubes	2,165	4,611.37
Total		8,980	25,407.27
Traditional	C40 Air Entrained Concrete	660,442	105,010.21
	Sub-base layer (Type 1 MOT - Series 800)	168,480	16,008.62
Total		828,922	121,018.83

4.2 Emissions from transport of raw materials (excluding materials transported by the site team)

The emissions associated with transport reflect the mass of each component, the mode of transport and the distance travelled. These were calculated based on Geobear's supplier locations. All material for the traditional method were modelled as supplied from a nearby depot (42km) by HGVs, with an assumed 44 journeys for the concrete and 9 journeys for the Type 1 sub-base, based on material quantities.

[3] Geopolymer and hardener are protected.

4.3 Emissions from travel to and from site (including materials transported by the site team)

Includes one HGV and two vans, calculated to include transport to and from site twice for Geobear's scenario. These carry the materials that are coming from the construction site, the technicians and the welfare facilities.

In terms of the traditional method, an equivalent distance to Geobear's travel was assumed with two site team vans, one welfare van, one supervisor van and two HGVs (to account for the excavator and roller). Due to data and site trips not being available for the traditional project, it should be noted, the traditional method could take 20 shifts of 8 hours to remove and replace the bays and associated Type 1 sub-base. This will therefore mean the traditional project is likely to have higher emissions due to the site team transport.

4.4 Implementation fuel use

The fuel use is significantly higher over the 40-year timeframe for the traditional method due to the need to remove the existing concrete bays and sub-base. The Geopolymer emissions are significantly less as a result of the Geopolymer injection project taking only 52 hours of working time over two weekends of nighttime working, for each treatment and does not result in any excavations.

Geobear has calculated the average diesel litres per minute for their generator (0.0616 L/minute) based on the fuel usage and time of active minutes recorded by their time sheet.

The traditional method has been calculated based on litres of fuel for the project size, provided by Geobear.

Table 6: GHG emissions per implementation machinery per 40-year timeframe

Method	Process	Diesel (litres)	Embodied ($kgCO_2e$)
Geopolymer	Generators	785	2,111.05
Geopolymer Total		785	2,111.05
Traditional	Preparing replacement concrete	763	2,050.84
	Break up existing concrete	676	1,817.00
	Excavate existing concrete	1,183	3,179.75
	Carting away existing concrete	832	2,236.31
	Preparation to sub-base layer	65	174.71
Traditional Total		3,519	9,458.61

4.5 Emissions from Disposal

The disposal emissions of the steel and offcuts from the Geopolymer Injection services is accounted for in the project, using the DEFRA material waste emissions factors. With the traditional method, the DEFRA factors have also been applied with the disposal quantities provided by Geobear for the existing removed materials and material offcuts. The Geobear calculations also include the treatment emissions from inert material landfill. The modelled quantities for both can be seen in the below table.

Table 7: GHG emissions for disposal per 40-year timeframe

Method	Raw material	Weight (kg)	Embodied ($kgCO_2e$)
Geopolymer	Part A	392	2.06
	Part B	290	1.53
	Steel Tubes	216	1.93
Geopolymer Total		898	5.52
Traditional	Pre cast concrete	660,442	818.49
	Type 1 sub-base	168,480	208.80
Traditional Total		828,922	1,027.294

4.6 Summary of results

This report provides an analysis of the greenhouse gas (GHG) emissions associated with a Geobear Geopolymer Injection service compared against a traditional service. The total ***cradle to gate*** service life cycle carbon emissions for both services are shown in the following table, split by lifecycle stage.

Table 8: GHG emissions per service

Process	Traditional	Geobear (5 treatments over 40 years)
	$kgCO_2e$	$kgCO_2e$
Raw materials - embodied	121,018.83	25,407.27
Raw materials transport (excluding materials transported by the site team)	3,707.77	533.81
Implementation Fuels (Diesel)	9,458.61	2,111.05
Travel to and from site (including materials transported by the site team)	916.35	4,581.75
Disposal	1,027.29	5.52
Total	136,128.85	32,639.40

As Table 8 shows, based on the agreed 40-year scenario, overall, the Geobear Geopolymer Injection has significantly lower emissions when compared to the traditional method. **5 Geobear treatments results in the avoidance of 76.02% of the modelled traditional method's emissions, this has an overall avoidance of 103,489.45 $kgCO_2e$.**

The 80-year scenario would produce 272,258 $kgCO_2e$ for the traditional method (consisting of 2 asset replacements), with the Geobear service (5 treatments) followed by a traditional replacement of the concrete bays (due to degradation of the asset), would produce produce 168,768 $kgCO_2e$. This means there is an overall carbon emissions avoidance of 38.01%.

In both the Geobear and traditional services the embodied emissions attributed to the raw material account for the majority of the total emissions. However, as the Geobear method uses the Geopolymer to undertake their work, no concrete is needed, as seen in Table 5. This lack of significant concrete and stone required results in significantly lower embodied emissions associated with the raw material, for the Geopolymer Injection service compared to the traditional.

Table 5 also provides a breakdown of the weight of the raw materials used in both methods and the associated embodied emissions. It can be seen that despite the embodied emissions for the Geopolymer being high, the overall emissions are lower due to fewer materials required.

Significant savings can also be seen in the fuel required to complete the project. This is due to the Geopolymer only requiring 52 hours of working time over two weekends of nighttime working, for each treatment, rather than the fuels and machinery needed to break up the existing bays and replace the materials.

The raw materials transport (excluding materials transported by the site team) emissions from the Geopolymer Injection service is significantly low due to the Geopolymer's considerably lower material weight. However, the emissions resulting from site visits is higher than the traditional method, as both scenarios are modelled using the distance from Geobear's depot to site (to ensure comparability), with Geobear carrying out 5 treatments over the 40-year timeframe.

The disposal emissions are substantially less for the Geopolymer Injection service, due to the waste quantities being significantly less (Table 7).

5. Carbon Footprint Standard

5.1 Brand endorsement

Geobear has achieved **Carbon Assessed Standard** by completing this project. This assessment shows Geobear's service has lower carbon emissions than the traditional method. To provide additional environmental savings and benefits, Geobear could consider supporting carbon offset projects, to mitigate the services unavoidable emissions. This will also allow the use of our **Carbon Neutral Standard** in relation to its client's projects.

The Carbon Footprint Standard is in recognition of your organization's commitment to managing your services' carbon emissions.

6. References

1. EcoInvent database v3.7.1 2021, available at http://www.Ecoinvent.org/
2. Guidelines to Defra's Greenhouse Gas (GHG) Conversion Factors for Company Reporting – annexes (June 2013)
3. UK Government GHG Conversion Factors for Company Reporting (August 2020)
4. ICE Database V3.0 – 10 Nov 2019- Inventory of Carbon & Energy (ICE) database

Annex A: Emission Factors

The following table shows the emission factors used for the calculations contained in this report.

Table 8 Emission factors sources

Element	Emissions factor	Comments	Unit	Database /Source
Raw Materials (embodied)				
Part A - Hardener	2.76	Supplier specific emissions factor	$kgCO_2e$ per kg material	Eco-Profile 2021
Part B - Polymer	3.455	Supplier specific emissions factor		Ecochain 2022
Tubes – Steel Injection Tubes	2.13	ICE v3.0 (2019) -Steel, global seamless tube		EcoInvent v3.7.1 + ICE v3.0 (2019)
C40 Air Entrained Concrete	0.16	ICE v3.0 (2019) -40MPa Concrete		
Sub-base layer (Type 1 - Series 800)	**See Footnote**	ICE v3.0 (2019)/EcoInvent 3.7.1- Limestone and Crushing		
Transport				
Container ship	0.0161	Transport of raw materials	$kgCO_2e$ per tonne.km	DEFRA UK 2020
ALL HGVs (average)	0.1065	Transport of raw materials	$kgCO_2e$ per tonne.km	
All HGVs - Average laden	0.86407	Transport to and from site	$kgCO_2e$ per km	
Rail (Freight)	0.02556	Transport of raw materials	$kgCO_2e$ per tonne.km	
Implementation				
Diesel (Retail)	2.68787	UK Govt – Defra/BEIS 2020	$kgCO_2e$ per litre	Defra/BEIS 2020
Disposal				
All HGVs - Average laden	0.86407	Transport of raw materials	$kgCO_2e$ per km	DEFRA UK 2020

Please note – In accordance with IEA and EcoInvent's End User License Agreement (EULA) emissions factors cannot be presented in the report. A full emissions factor reference has been provided which will allow users with an active EcoInvent account to search for the emissions factor. Please see http://www.Ecoinvent.org/ for further details and to search for factors.