Calculation of Carbon Footprint Values for masonry walls constructed using Wi System and HBP blocks compared with traditional windposts and standard blocks.

for

Wembley Innovation Ltd – Haughley Block Plant Ltd

Submitted by

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Quality Control Sheet

Proposal title

Calculation of Carbon Footprint Values for masonry walls constructed using Wi System and HBP blocks compared with traditional windposts and standard blocks.

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Abbreviations

Wembley Innovation	Wi
Wi Column	WiC
Wi Beam	WiB
Haughley Block Plant	HBP
Carbon footprint	CF
Carbon emissions	CE
Embodied carbon	EC
Life cycle analysis	LCA
Traditional windpost	TWP
Construction materials	CMs
Bill of Quantities	BoQ
Royal Institution of Chartered Surveyors	RICS

Executive summary

This report involves the updating of pre-existing carbon footprint (CF) calculations, supplied by the University of Greenwich in 2015. The key considerations of the study were to compare two types of blockwork wall panels (9 x 4m and 4 x 5m walls, referred to as Type 1 and Type 2, respectively) using traditional windposts (TWPs), Wi Columns, Wi Beams and Haughley Block Plant (HBP) blocks for their respective potential carbon footprints/savings. It is important to note the updated results may be used in support of an Environmental Product Declaration (EPD), and thus a robust and updated CF assessment process was required from this work.

Following changes in design, manufacturing process and construction of the two types of blockwork wall panel systems of interest, a new CF evaluation has been carried out using the Environment Agency (EA) Carbon Calculator.

The findings indicated significant environmental and economic benefits accrued by replacing TWPs and standard blocks with Wi System (Wi Columns and Wi Beams) and HBP blocks. The CF savings and reduction in carbon emissions using the Wi System and HBP blocks are highlighted in the report. Significant savings identified were ascribed to the reduction in the requirement of:

- Raw (construction) materials, e.g., stainless steel wind post, standard concrete blocks, fire boarding etc.
- Transportation (Wi System, windpost replacement blocks and Wi System Lintel replacement blocks can be delivered on the same vehicle as the HBP blocks, therefore significantly reducing the number of deliveries)
- Site activities (Emission from Plant and Equipment usage)
- Waste management (100% recycling achieved by HBP in Wi systems)
- Wi System (Wi Columns and Wi Beams) have shown better thermal performance over TWPs.

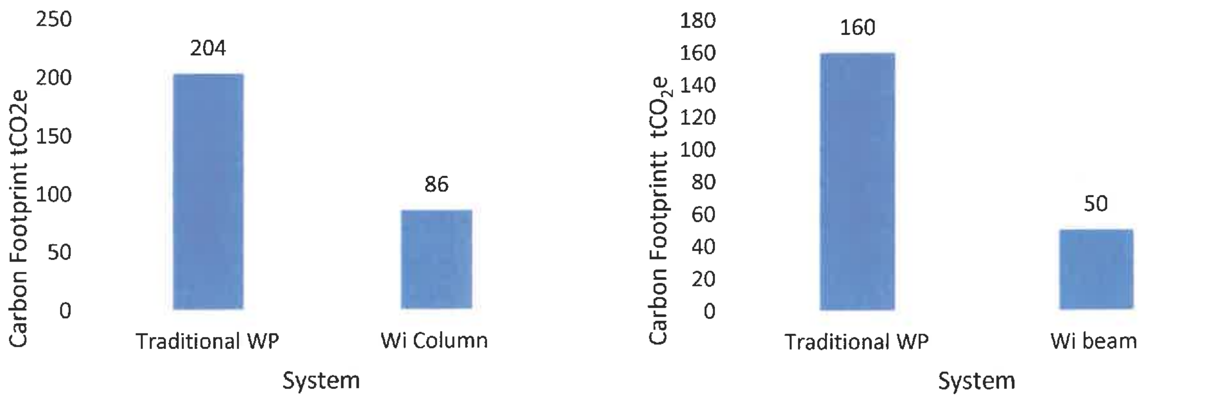
In terms of carbon savings, the Wi System / HBP blocks have shown significant advantages over TWPs and standard blocks. The key carbon savings are summarised below:

- There was a Carbon Footprint saving of 57.8% (1.18 tCO_2e) in the 9 x 4m blockwork wall panel incorporating Wi Columns and HBP blocks, compared to TWPs and standard blocks.
- There was a Carbon Footprint saving of 68.8% (1.10 tCO_2e) in the 4 x 5m blockwork wall panel incorporating Wi Beams and HBP blocks, compared to TWPs and standard blocks.
- In the case of Transportation, there was a carbon saving of 2.281 tCO_2e achieved by Wi Column and HBP blocks in 9 x 4m blockwork wall panel, and 1.322 tCO_2e achieved by Wi Beam and HBP blocks in 4 x 5m blockwork wall panel, compared to the CF of TWPs and standard blocks (based on 100 units).
- With the 100% recycling potential of HBP blocks in Wi systems, there is a significant reduction in the amount of tonnes disposed as landfilling compared to TWPs and standard blocks.
- Due to the reduction in site activities/equipment usage when constructing a wall utilising the Wi System and HBP blocks, there is a 2.969 tCO_2e reduction in Carbon Footprint, compared to a wall constructed using TWPs and standard blocks (based on 100 units).

Figure 1 shows a CF comparison of standard blockwork wall panels with TWP and:

(i) Wi Columns and HBP blocks

(ii) Wi Beams and HBP blocks.



(i) Wi Columns and HBP blocks (Type 1 wall) (ii) Wi Beams and HBP blocks (Type 2 Wall)

Figure 1: Comparison of CF (tCO2e) for standard blockwork wall panels with TWPs and blockwork wall panels with Wi System and HBP blocks (based on 100 units).

1.0 Background

In 2015, the University of Greenwich carried out an assessment of the carbon footprint for two blockwork panels incorporating either Wi Columns or Wi Beams in comparison with the same panels constructed with TWPs. The work identified Wi Beam and Wi Column systems having a significant carbon saving over TWPs, at 14% and 24%, respectively. In the intervening period, Wembley Innovation's (Wi) new supplier and sister company, Haughley Block Plant (HBP), built a new production facility, powered exclusively with sustainable green wind or solar energy and all ancillary machinery/equipment using lithium batteries. Further, Wembley Innovation have also upgraded their Wi Column and Wi Beam System.

The present work reviewed the CF of Wi's and HBP's upgraded offering in respect of the changes detailed above.

It is important to note that since 2015, significant changes have taken place in the requirement of CF analyses (as the life cycle analyses (LCA) evolved to incorporate various new factors/parameters). This report has incorporated these major factors in CF calculations.

Table A in Appendix A shows a comparison of the studies undertaken in 2015 and 2022, so the key differences are clear. The present work is more suited for third party certification of an Environmental Product Declaration (EPD).

1.1 Scope

The document details the CF values for standard blockwork wall panels incorporating TWPs compared to blockwork wall panels incorporating Wi Columns, Wi Beams and HBP blocks.

1.2 Blockwork wall panel design

Blockwork wall panels are generally designed to resist lateral loads (e.g., wind pressure, line loads, blast loads etc). Normally, blockwork wall panels need to be laterally supported by vertical posts at intermediate points along the length of the wall - these posts are referred to as traditional windposts (TWPs). TWPs allow the loads from the blockwork wall panel to be distributed back to the primary structure.

TWPs are normally manufactured from steel, and they are installed prior to the construction of the blockwork walls. The Wi Column is a reinforced concrete column constructed within a hollow block shell and is an alternative to using TWPs. The Wi Columns span vertically and are installed at the same time the blockwork walls are constructed.

The Wi Beam is a reinforced concrete beam constructed within a hollow block shell and can be used to provide lateral support to a blockwork wall panel. Wi Beams span horizontally and are installed at the same time the blockwork walls are constructed.

Wi Columns and Wi Beams are significantly stronger than TWPs, and therefore it is possible to reduce the quantity of lateral supports when using the Wi System compared to using TWPs.

2.0 Objectives

- To calculate the CF of blockwork wall panels constructed using standard blocks and TWPs.
- To calculate the CF of blockwork wall panels constructed using Wi Columns, Wi Beams and HBP blocks.
- To compare the CF of blockwork wall panels constructed using standard blocks and TWPs with walls constructed using Wi Columns, Wi Beams and HBP blocks.

3.0 Methodology

This study was conducted based on primary data supplied by Wi/HBP, verified by the University of Greenwich, and includes a review of the existing calculation model, supplied by the University of Greenwich in 2015. The CF was calculated using the Environment Agency (EA) Carbon Calculator.

For the CF analysis, different reinforcing systems were considered for calculation, as below:

- TWP and standard blocks
- Wi Column system and HBP blocks
- Wi Beam system and HBP blocks

It is important to note that the EA Carbon Calculator only considers values in tonnes, so inputting quantities for a single structure gives negligible values for CF. These values do not support conclusions related to CF. Therefore, calculations are based on 100 units to achieve the targeted objectives. If single unit assessment is required, the given values for CF need to be divided by 100.

3.1 Assessment type

The assessment included an examination of cradle-to-site boundary, incorporating the following elements for two types of blockwork panels, (i) 9 x 4m, and (ii) 4 x 5m containing TWPs with standard blocks or Wi System (Wi Columns and Wi Beams) with HBP blocks:

- Raw materials
- Transport of materials to site
- Waste Management (including the emission occurs due to waste transportation either to the recycling factory or landfill)
- Site Activities (Emission from Plant and Equipment)

For the calculation, three embedded modules or conditions are appropriate:

(i) The A1-A3 module: A1, A2 and A3 make up the product stage. The extraction, processing, transportation and manufacture of materials and products up to the point where they leave the factory gate to be taken to site. Embodied Carbon value of each material represents the product stage emission.

(ii) The A4 module: A4 module includes the CF resulting from the transportation of materials from the factory to site. Refer A3, A5, A7 and A9 in Appendix for transport distance for each material.

The A5 module: A5 module indicates the CF resulting from the site activities during the construction and the CF resulting from waste management (due to waste generated from construction activities and transportation of generated waste either into the landfill or recycling factor).

The summary plan of action undertaken in this work is shown in Figure 2.

Collection of relevant details for traditional wind posts (TWPs), Wi Columns (WiCs), Wi Beams (WiBs) and HBP blocks

↓

Identification of construction materials and design specifications of TWPs, WiCs, WiBs and HBP blocks

↓

Investigation of existing calculation methods/tools for the Cradle-to-site stage

↓

Construction of database for embodied carbon (EC) of construction materials and design specifications

↓

Construction of Bill of Quantities (BoQ) for TWPs, WiCs, WiBs and HBP blocks

↓

Calculation of Carbon Footprint (CF)

↓

Compilation and analysis of results

↓

Comparison of the CF of TWPs, WiCs, WiBs and HBP blocks

Figure 2: Steps involved in CF analysis of TWPs, Wi Columns, Wi Beams and HBP blocks.

3.2 Models

The comparison of CF was undertaken, as described in Table A (Appendix A). Two different blockwork panel sizes were reviewed:

(i) 9x4m – Type 1
(ii) 4x5m – Type 2

TWP with 140mm standard blocks and Wi System with 140mm HBP blocks were reviewed for both wall types, designed to a 1.0kPa wind load.

(i) Type 1 blockwork panel (9 x 4m)

Wall panel designs were completed for Type 1 blockwork wall panels constructed using TWPs with standard blocks and Wi Columns with HBP blocks. Figures 3 and 4 show the layout of the blockwork wall panels.

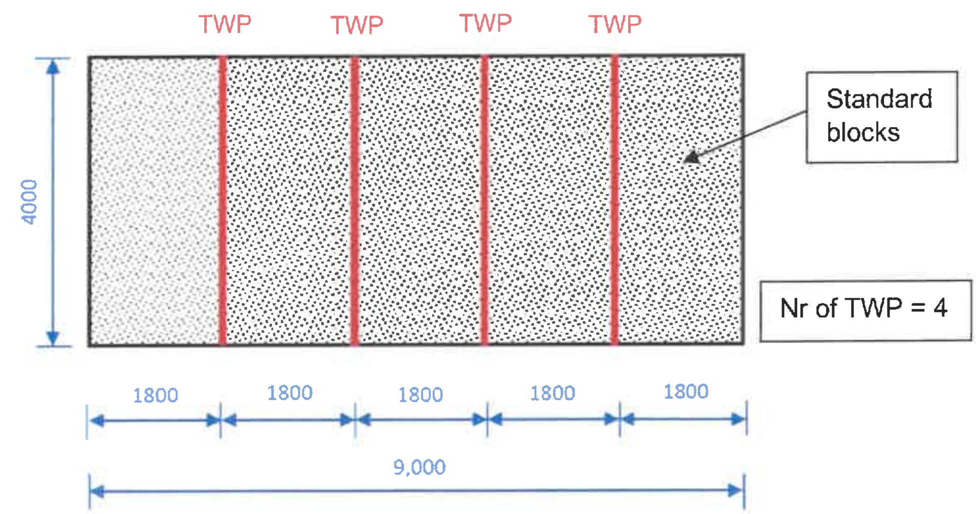


Figure 3: Type 1 wall panel designed with TWPs and standard blocks (Source: Wembley Innovation)

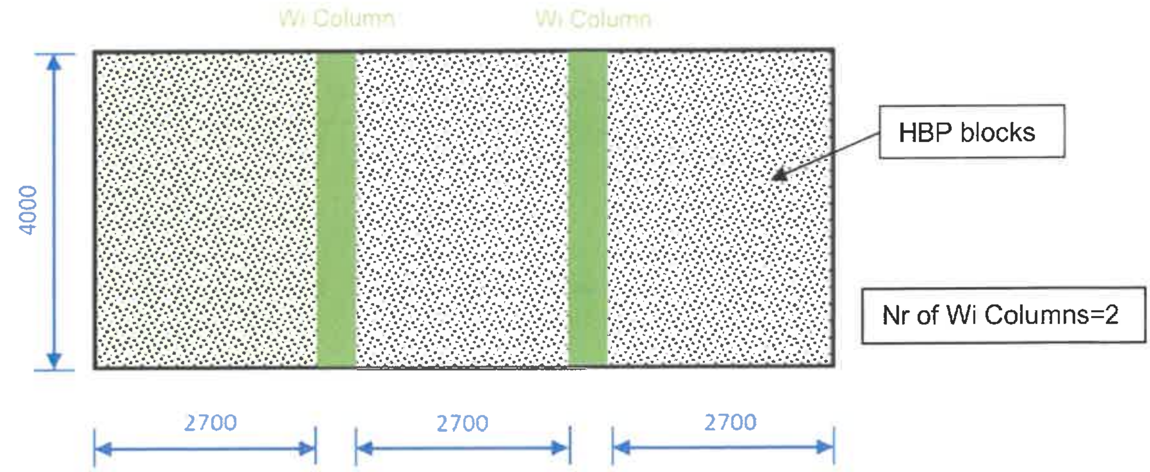


Figure 4: Type 1 wall panel designed with Wi Columns and HBP blocks (Source: Wembley Innovation)

(ii) Type 2 blockwork panel (4 x 5m)

Wall panel designs were completed for Type 2 blockwork wall panels constructed using TWPs with standard blocks and Wi Beam with HBP blocks. Figures 5 and 6 show the layout of blockwork wall panels.

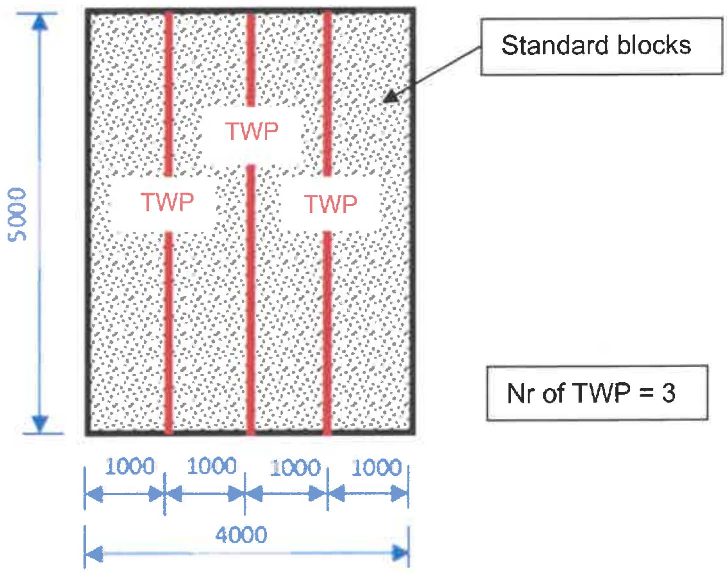


Figure 5: Type 2 wall panel designed with TWPs and standard blocks (Source: Wembley Innovation)

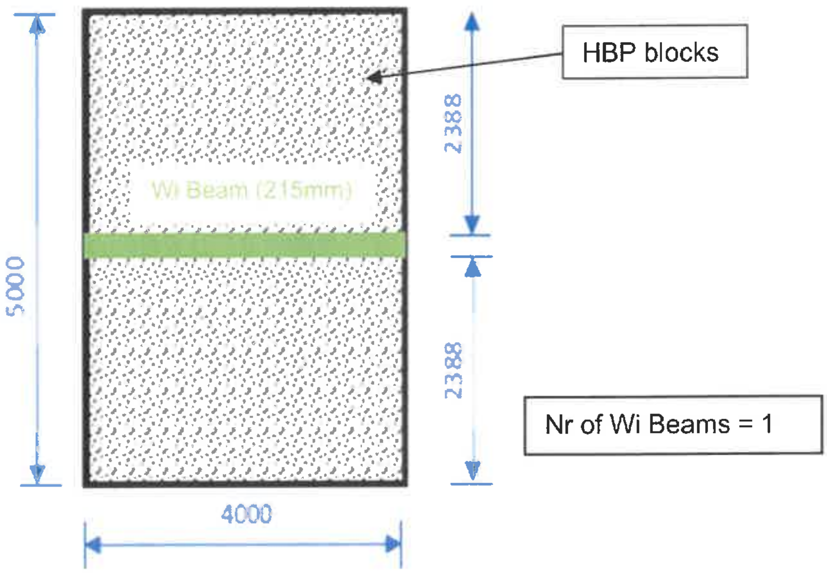


Figure 6: Type 2 wall panel designed with Wi Beam and HBP blocks. (Source: Wembley Innovation)

4.0 Results

4.1 Carbon footprint of traditional windposts, Wi System and HBP blocks

For the cradle-to-site CF assessments, the standard equation is upgraded with the CE resulting from transportation, site activities and waste removal as per Equation 1 shown below:

Carbon footprint	=	EC of CMs (A1-A3) x Quantity	+	CE due to material transportation (A4)	+	CE from site activities and waste removal (waste that is produced during production) (A5)

The analysis included a review of the design specifications and other relevant documents to identify the main CMs in both TWPs and Wi System (Wi Columns and Wi Beams) and HBP blocks. Table 1 summarises the EC for the cradle-to-site analysis.

Table 1: EC in raw materials (per 100 units)

	Embodied Carbon (EC) (Cradle to site) tCo2e/t		
		Wi systems	
Element	**TWP**	**WiB**	**WiC**
TWP	6.15	N/A	N/A
Head Cleats	N/A	N/A	0.15
Top Cleats	6.15	N/A	N/A
Frame Cramp Ties	6.15	6.15	6.15
Masonry Ties	6.15	N/A	6.15
Bottom Cleats	0.32	N/A	N/A
End Cleats	N/A	0.32	N/A
Long Transfer rods	N/A	6.15	N/A
H16 Rebar	N/A	1.4	1.4
Fireboard	0.13	N/A	N/A
Wi Debonding Sleeve	N/A	3.31	N/A
Wi Column blocks	N/A	N/A	0.0917
Wi U Blocks	N/A	0.0917	N/A
Standard medium dense solid blocks	0.06	N/A	N/A
Standard Mortar	0.17	0.17	0.17
HBP medium dense slot block	N/A	0.06	0.06
C40 Wi Mortar	N/A	0.178	0.178
Stone Mineral Wool	1.86	1.86	1.86
310ml intumescent acoustic sealant	1.86	1.86	1.86

4.1.1 Carbon footprint calculation of traditional windposts with standard blocks

After identifying EC values of CMs from Table 1, the required material quantities for the analysis have been extracted from the BoQ presented in Tables 2 & 3 below.

When inputting the data for modules A4 and A5 to determine the CF (using Equation 1), the standard approach as outlined by the Royal Institution of Chartered Surveyors (RICS) was used in the calculation.

i. When determining the module A4, the default/standard values given in RICS (2017) were used. These values can be used in cases where no exact data is available. In the present study, Wembley Innovation confirmed that all the materials have been manufactured in the UK (Table A1 in Appendix A).

ii. To determine the CE resulting due to the waste removal (module A5), the RICS (2017) approach has been followed, which presumes 90% of any waste generated is recycled/reused, with the remaining 10% being landfilled. For certain materials, such as steel, the specific management ratio is shown in Table A2 (see Appendix A) and were used in this study. The CE associated with waste transport also have been considered.

i) Type 1 blockwork wall panel (9 x 4m) – TWPs with standard blocks

The required material quantities for the construction of a Type 1 blockwork wall panel (9 x 4m) constructed using TWPs with standard blocks are shown in Table 2 below:

Table 2: Material requirement of TWPs (Type 1) – per 100 units

Material	9 x 4m blockwork wall panel with 4 TWPs			Tonnes/ 100 Units (9 x 4m)
	Quantity	Description	Tonnes/ (9 x 4m unit)	
130x70x6mm stainless steel	4nr	16m (4m per TWP)	0.154	15.400
Bottom Cleat (150x150x6mm)	4nr	1nr cleat per WP	0.004	0.432
Top Cleat (220x70x6mm)	4nr	1nr cleat per WP	0.003	0.296
Fireboard (100x15mm)	16m	Fireboard to exposed TWP	0.031	3.120
Standard 140mm 7.3N medium dense solid block	360nr	Weight =19 kg/block	6.840	684.000
Standard mortar (1:1:6)	0.315m^3	10 mm thick mortar	0.693	69.300
200x20x2.5 Frame cramp ties @ 450 c/c spacing	88nr	Both sides of TWP and at end abutments	0.007	0.704
Stone mineral wool	40m	Filler material either side of each TWP and at end abutments	0.044	4.400
310ml intumescent acoustic sealant	32nr tubes	Mastic either side of TWP & abutments, both sides of wall	0.016	1.567

Tables A3 and A4 (see Appendix A) show the input data used for determining the modules A4 and A5 for TWPs Type 1. The CF results are as follows (calculated for 100 units):

A Type 1 blockwork wall panel (9 x 4m) constructed using TWPs with standard blocks emits 204 tCO_2e.

ii) Type 2 blockwork panel (4 x 5m) – TWPs with standard blocks

The required material quantities for the construction of a Type 2 blockwork wall panel (4 x 5m) constructed using TWPs with standard blocks are shown in Table 3 below:

Table 3: Material requirement of TWPs (Type 2) – per 100 units

Material	4 x 5m blockwork panel with 3 TWPs			Tonnes/ 100 Units (4 x 5m)
	Quantity	Description	Tonnes/ (4 x 5m unit)	
130 x 70 x 6 mm stainless steel	3nr	15m (5m per TWP)	0.144	14.400
Bottom Cleat (150x150x6mm)	3nr	1nr cleat per WP	0.003	0.324
Top Cleat (220x 70x6mm)	3nr	1nr cleat per WP	0.002	0.222
Fireboard (100x15mm)	15m	Fireboard to exposed TWP	0.029	2.936
Standard 140mm 7.3N medium dense solid block	200nr	Weight =19 kg/block	3.800	380.000
Standard mortar (1:1:6)	0.165m^3	10 mm thick mortar	0.363	36.300
200x20x2.5 Frame cramp ties @ 450 c/c spacing	88nr	Both sides of TWP and at end abutments	0.007	0.704
Stone mineral wool	40m	Filler material either side of each TWP & abutment	0.044	4.400
310ml intumescent acoustic sealant	32nr tubes	Mastic either side of TWP & abutments, both sides of wall panel	0.016	1.567

Tables A5 and A6 show the input data used for determining the modules A4 and A5 for TWPs Type 2. The CF results are as follows (calculated for 100 units):

A Type 2 blockwork wall panel (4 x 5m) constructed using TWPs with standard blocks emits 160 tCO_2e.

4.1.2 Carbon footprint calculation of Wi systems (Wi Column and Wi Beam) with HBP blocks

Similar to the methodology for TWPs, Equation 1 was used for the calculation of CF. The EC values of CMs presented in Table 1 were used for the calculation of CF for blockwork wall panels constructed using Wi Columns and Wi Beams with HBP blocks. The required material quantities for the analysis have been extracted from the BoQ presented in Tables 4 & 5 below.

All the materials were assumed to be obtained/sourced within 100 miles of the factory, when determining the module A4. Both fine and coarse aggregates were sourced from an Aggmax quarry located 3 miles (5 km) away from the factory. The cement used in the process was supplied by Cemex (Haughley/Tilbury- 76.5 miles distance).

In the module A5 scenario, all the waste at Haughley Block Plant is 100% recycled and for the rest of the materials, RICS (2017) approach has been followed.

i) Type 1 blockwork wall panel (9 x 4m) – Wi Column with HBP blocks

The required material quantities for the construction of a Type 1 blockwork wall panel (9 x 4m) constructed using Wi Columns with HBP blocks are shown in Table 4 below:

Table 4: Material requirement of Wi Column (Type 1) - per 100 units

Material	9 x 4m blockwork wall panel with 2 WiCs			Tonnes/ 100 Units (9x 4m)
	Quantity	Description	Tonnes/ (9 x 4m)	
140mm WiCs, 2nr @ 4m = 8m total				
140mm Wi Column blocks	36nr	WiC block weight = 11.4kg/block	0.431	43.100
Head Cleat (430x60x8mm)	2nr	Top of both WiCs	0.003	0.322
H16 rebar with socket	16m	4nr @ 4m length	0.025	2.500
C40 Wi mortar	480kg	8m x 60kg/m	0.480	48.000
HBP 140mm 7.3N medium Dense Slot Block	324nr	HBP Slot Block Weight = 17.8kg/block	5.767	576.720
Standard mortar (1:1:6)	0.266 m^3	10 mm thick mortar	0.585	58.520
200x20x2.5 Frame cramp ties @ 450 c/c spacing 225x19x3 masonry ties @450 c/c spacing	18nr 36nr	At end abutments Both sides of WiCs	0.001 0.004	0.120 0.369
Stone mineral wool	12m	Filler material either side of WiC and at end abutments	0.013	1.320
310ml intumescent acoustic sealant	12nr tubes	Mastic to end abutments and one side of 1nr WiC for MJ, both sides of wall panel	0.006	0.588

Tables A7 and A8 (see Appendix A) show the values used as the input data for determining the modules A4 and A5 for the cradle-to-site CF calculations for Wi Columns and HBP blocks. The CF results are as follows (calculated for 100 units):

A Type 1 blockwork wall panel (9 x 4m) constructed using Wi Columns with HBP blocks emits 86 tCO_2e.

ii) Type 2 blockwork wall panel (4 x 5m) – Wi Beam with HBP blocks

The required material quantities for the construction of a Type 2 blockwork wall panel (4 x 5m) constructed using a Wi Beam with HBP blocks are shown in Table 5 below:

Table 5: Material requirement of Wi Beam (Type 2) - per 100 units

Material	4 x 5m blockwork wall panel with 1 WiB			Tonnes/ 100 Units (4 x 5m)
	Quantity	Description	Tonnes/ (4 x 5m)	
140mm WiB, 1nr @ 4m = 4m total				
140mm Wi U blocks	9nr	WiB block Weight = 12.4kg/block	0.112	11.160
End Cleats Cleat (200x60x8mm)	2nr	Both ends of WiB	0.001	0.149
Wi Debonding sleeve (plastic) (0.029kg each)	4nr	2nr per end cleat	0.0001	0.012
H16 rebar no socket	10m	2nr @ 5m length	0.016	1.570
Long transfer rod (675x34x4mm)	5nr @ 0.712kg each	5m /900mm ccs	0.004	0.356
C40 Wi mortar	115kg	5m x 23kg/m	0.115	11.500
HBP 140mm 7.3N medium dense Slot Block	191nr	HBP Slot Block Weight = 17.8kg/block	3.399	339.900
Standard mortar (1:1:6)	0.162m³	10 mm thick mortar	0.3562	35.620
200x20x2.5 Frame cramp ties @ 450 c/c spacing	22nr	at end abutments	0.002	0.176
Stone mineral wool	10m	at end abutments	0.013	1.320
310ml intumescent acoustic sealant	10nr tubes	Mastic to end abutments both sides of wall panel	0.005	0.490

Tables A9 and A10 (see Appendix A), respectively show the input data used for the calculation and CF of a 4 x 5m blockwork wall panel with Wi Beams and HBP blocks. The CF results are as follows (calculated for 100 units):

A Type 2 blockwork wall panel (4 x 5m) constructed using a Wi Beam with HBP blocks emits 50 tCO_2e.

4.2 Discussion

4.2.1 Comparison between Wi Columns and traditional windposts

Figure 7 shows the comparison of CF for standard blockwork wall panels with TWPs and blockwork wall panels with Wi Columns and HBP blocks.

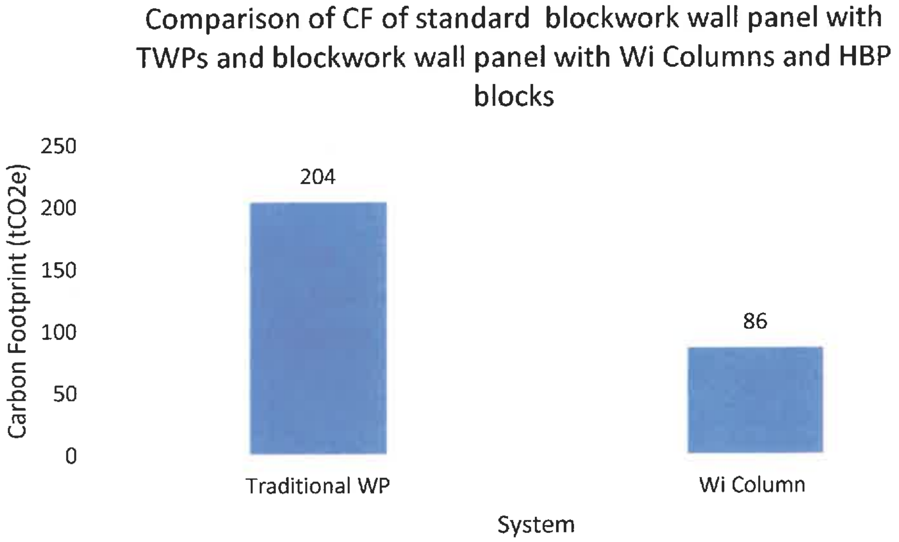


Figure 7: Comparison of CF of standard blockwork wall panel with TWPs (from Figure 3) and blockwork wall panel with Wi Columns and HBP blocks (from Figure 4) (Based on 100 units)

The contribution of each material component towards the CF is shown in Tables A4 and A8 and (see Appendix A) and is given below:

Design specification

The Type 1 (9 x 4m) blockwork wall panel constructed using TWPs and standard blocks requires 4nr TWPs. Whereas, using Wi Columns and HBP blocks requires 2nr Wi Columns. Figure 7 shows there is a major CF saving of 118 tCO_2e (204 – 86 tCO_2e) when using Wi Columns and HBP blocks in place of TWPs and standard blocks.

Comparison of CE of raw materials

- **Minimum use of metals; steel:** Stainless steel is the main type of metal used in TWPs. The highest CE value was contributed by the steel component in TWPs (103.517 tCO_2e of CE). Due to the replacement of steel in Wi Columns, the CE was reduced to 6.555 tCO_2e (3.5 + 3.007+ 0.048 tCO_2e), leading to a saving of carbon by 96.962 tCO_2e (see Tables A4 and A8 in Appendix A).

- **Reduced use of concrete blocks:** In the walls constructed using standard blocks and TWPs, the second-highest CE arose from use of standard solid concrete blocks. Using HBP blocks and Wi Columns to construct blockwork walls resulted in a saving of 2.807 tCO_2e. (see Tables A4 and A8 in Appendix A).

- **Eliminating fire boarding:** Unlike standard blockwork wall panels with TWPs, blockwork wall panels constructed using Wi Columns and HBP blocks do not require fire boarding. This results in a reduction in CE due to manufacturing, transportation, installation and waste materials.

Transportation

- **Reduced CF from material transport** Table A4 (see Appendix A) shows a CF of 18.230 tCO_2e arising from material transportation, associated with production of 9 x 4m standard blockwork wall panel (Type 1) with TWPs (x 100 units). In contrast, only 16.475 tCO_2e of CF was associated with blockwork wall panel with Wi Columns and HBP blocks.

  Among the other material, transportation of standard blocks has the highest contribution as per the Table 4 in Appendix. In fact, it has a CF of 12.190 tCO_2e and with the replacement of HBP blocks, it has reduced to 9.909 tCO_2e resulting a reduction of 2.281 tCO_2e saving.

Waste removal

In terms of waste removal, industrial waste such as concrete blocks, landfilling has resulted in the highest CF contribution of 14.162 tCO_2e to the total CF of walls constructed using standard blocks and TWPs. Due to the 100% recycling potential of HBP blocks the CF for walls constructed with HBP blocks and Wi Columns has majorly reduced to 0.920 tCO_2e resulting in a 13.242 tCO_2e saving. (Table A11 and A12 in Appendix).

There is a significant reduction in the amount of waste landfilling with Wi System and HBP blocks. According to the Table A3 and A7 in Appendix, standard blockwork wall panels (Type 1) with TWPs (x 100 units) resulted in 76.912 tonnes to landfill, when blockwork wall panel with Wi Columns and HBP blocks only produced 15.285 tonnes of waste landfilling.

Site activities

- **Minimum site activities and equipment use:** As expressed in Table A4, the site activities undertaken in TWP installation produced CE of 5.937 tCO_2e. The Wi System is a single trade installation, with no steel erector or fireboard installation operative required, resulting in considerably less work on site, less manpower and journey/transport. CE of 2.968 tCO_2e were produced by site activities associated with the construction of a blockwork wall using HBP blocks and Wi Columns. (Table A11 and A12 in appendix).

Also, the fact that the HBP blocks are manufactured at Haughley Block Plant (HBP), which is powered exclusively by sustainable green wind or solar energy and with all ancillary machinery/equipment using lithium batteries has a major effect on reducing the CF.

Thermal properties

Wi Columns are designed to have improved thermal performance compared to TWPs. With the installation of Wi Columns, heat dispersion and cold bridging are minimised, resulting in an energy-efficient alternative to TWPs.

4.2.2 Comparison between Wi Beams and traditional windposts

Figure 8 shows the comparison of CF for standard blockwork wall panels with TWPs and blockwork wall panels with a Wi Beam and HBP blocks.

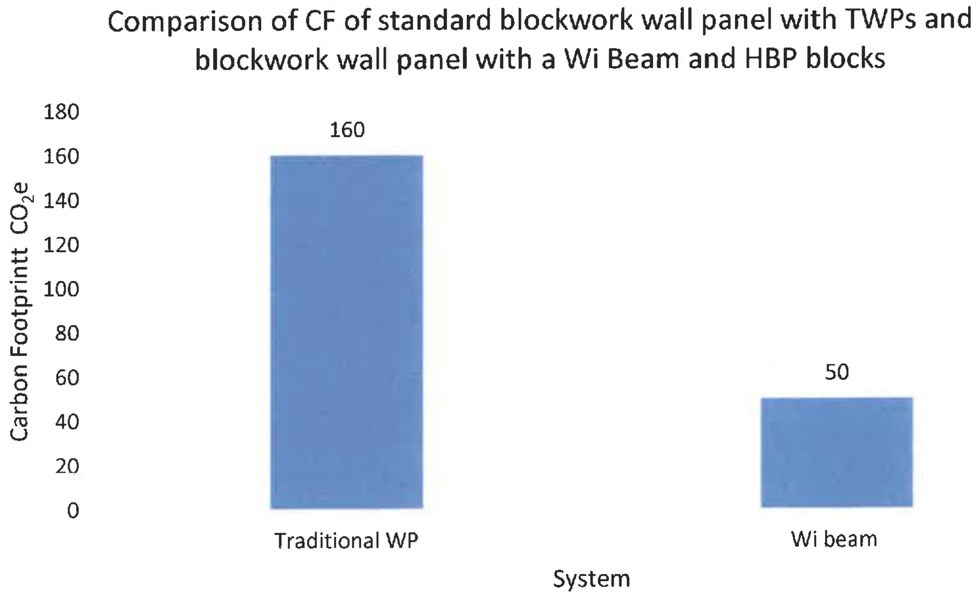


Figure 8: Comparison of CF of standard blockwork wall panel with TWPs (from Figure 5) and blockwork wall panel with a Wi Beam and HBP blocks (from Figure 6) (Based on 100 units)

The contribution of each material component towards the CF is shown in Tables A6 and A10 (see Appendix A) and is given below:

Design specifications

The Type 2 (4 x 5m) blockwork wall panel constructed using TWPs and standard blocks requires 3 nr TWPs. However, using the Wi System and HBP blocks only requires 1 nr Wi beam. Figure 8 shows there is a major CF saving of 110 tCO_2e (160 – 50 tCO_2e) resulting from using a Wi Beam and HBP blocks in place of TWPs and standard blocks.

Comparison of CE of raw materials

- **Minimum of metals: steel:** Tables A4 and A10 (see Appendix A) show that the CE associated with steel in standard blockwork wall panels with TWPs is much higher (96.248 tCO_2e), in comparison to blockwork wall panels with a Wi Beam and HBP blocks (5.492 tCO_2e). The carbon saving of 90.756 tCO_2e is due to the reduced metal/steel requirement of Wi Beams.

- **Eliminating fire boarding:** Unlike standard blockwork wall panels with TWPs, blockwork wall panels constructed using a Wi Beam and HBP blocks do not require fire boarding. This results in a reduction in CE due to manufacturing, transportation, installation, and waste materials.

Transportation

- **Reduced CF from material transport:** As shown in Table A4 and A10 (Appendix A), the material transport for standard blockwork wall panels with TWPs and blockwork wall panels with a Wi Beam and HBP blocks resulted in a CE of 10.38 tCO_2e and 9.058 tCO_2e, respectively. Blockwork wall panels constructed using Wi Beam and HBP blocks reduce the CF associated with transportation of materials by 1.322 tCO_2e.

Waste removal

In terms of waste removal, industrial waste such as standard concrete blocks, landfilling has resulted in the highest CF contribution of 7.947 tCO_2e to the total CF of walls constructed using standard blocks and TWPs. Due to the 100% recycling potential of HBP blocks the CF for walls constructed with HBP blocks and Wi Beams has majorly reduced to 0.265 tCO_2e (Table A11 and A12 in Appendix) resulting a reduction of 7.682 tCO_2e (Table A13 and A14 in Appendix).

There is a significant reduction in the amount of waste landfilling in Wi System and HBP blocks. According to the Table A5 and A9 in Appendix, standard blockwork wall panels (Type 1) with TWPs (x 100 units) resulted in 43.146 tonnes of waste to landfill, when blockwork wall panels with Wi Beam and HBP blocks only produced 6.087 tonnes of waste landfilling.

Site activities

- **Minimum site activities and equipment use:** There are fewer site activities/equipment/services used with Wi System construction, compared to TWPs, resulting in a CF reduction of 2.969 tCO_2e (Table A 13 and A14 in Appendix) compared to Standard blockwork wall panel with TWPs (x 100 units).

- Also, the fact that the HBP blocks are manufactured at Haughley Block Plant (HBP), which is powered exclusively sustainable green wind or solar energy and with all ancillary machinery/equipment using lithium batteries has a major effect on reducing the CF of site activities in Wi systems.

- **Single trade installation with reduced manpower:** TWP production and installation activities are energy intensive, involving various machines and manpower. However, the Wi System is a single trade installation, negating the need for a steel erector, fireboard installation, etc.

Thermal properties

Wi Beams are designed to have improved thermal performance compared to TWPs. With the installation of Wi beam, heat dispersion and cold bridging are minimised, resulting in an energy-efficient alternative to TWPs.

5.0 Summary and conclusions

This study presents the carbon emission savings comparing standard blockwork wall panels with TWPs and blockwork wall panels with the Wi System (Wi Columns and Wi Beams) and HBP blocks.

The key considerations were to compare the construction material quantities of two blockwork wall panels (Type 1 and 2 walls), constructed with standard blocks and TWPs or Wi System and HBP blocks, regarding their respective carbon footprints (x100 units). The results are summarised in the Tables S1 below:

Table S1: Comparison of the CF and subsequent savings of blockwork wall panels comprising TWPs, Wi Columns, Wi Beams and HBP blocks.

	CF of standard blockwork wall panels with TWPs*		CF of blockwork wall panels with WiCs and HBP blocks*	
9 x 4m blockwork wall panel	204 tCO_2e	4nr TWPs	86 tCO_2e	2nr WiCs
	CF of standard blockwork wall panels with TWPs*		**CF of blockwork wall panels with WiBs and HBP blocks***	
4 x 5m blockwork wall panel	160 tCO_2e	3nr TWPs	50 tCO_2e	1nr WiBs

*** per x100 units**

The key concluding environmental and economic benefits of the Wi System and HBP blocks over TWPs and standard blocks are:

- The major reduction in raw materials achieved by adopting Wi Columns and Wi Beams over TWPs.
- In standard blockwork wall panels with TWPs, the highest (single material component) CE resulted from steel. With the reduction in metal content in the Wi system, significant reductions in CE are achieved.
- The carbon emission arising from transportation of Wi Columns, Wi Beams and HBP blocks are lower, when compared to TWPs.

	CF of standard blockwork wall panels with TWPs*	CF of blockwork wall panels with WiCs and HBP blocks*
CE resulting from Transportation	18.230 tCO_2e	16.475 tCO_2e
	CF of standard blockwork wall panels with TWPs*	**CF of blockwork wall panels with WiBs and HBP blocks***
CE resulting from Transportation	10.38 tCO_2e	9.058 tCO_2e

*** per x100 units**

- There is a significant reduction in the amount of waste disposed to landfill in walls constructed with HBP blocks and Wi system in comparison to walls constructed with standard blocks and TWPs. It has a significant contribution towards reducing the total CF. This was mainly due to the 100% recycling potential of HBP blocks.

Type 1			
	CF of standard blockwork wall panels with TWPs*	**CF of blockwork wall panels with WiCs and HBP blocks***	**Saving**
Amount of waste dispose in to Landfill (tonnes)	76.912	15.285	61.627
Type 2			
	CF of standard blockwork wall panels with TWPs*	**CF of blockwork wall panels with WiBs and HBP blocks***	**Saving**
Amount of waste dispose in to Landfill (tonnes)	43.146	6.087	37.059

- The CE of site activities during the Wi System construction process is significantly less due to the reduction in manpower and equipment usage. TWPs have significantly higher CE associated with their installation.

	Standard blockwork wall panel with TWPs	**Blockwork wall panels with WiCs/WiBs and HBP block**
Grid Electricity Usage	5.937 tCO2e from 10,000kWh	2.968 tCO2e from 5,000 kWh

- Also, the HBP block production at Haughley Block Plant Ltd with the use of Green Energy, New Machinery etc has a significant effect on reducing the CE resulting from site activities.
- As per the design specification, both Wi Columns and Wi Beams have improved thermal performance compared to TWPs.

Appendix A

Table A: Comparison of the methods used in the University of Greenwich 2015 and 2022 reports

Method used in 2015 work	Method used in present work (2022)
Step 1 - Identification of construction materials and design specifications of following structures: • 9 x 4m standard wall with x4 TWPs • 9 x 4m standard wall with x2 Wi Beams • 9 x 4m standard wall with x2 Wi Columns **Step 2** – Determining the quantities of each (main) CM **Step 3** – Gathering EC values for each CMs; Transport emission and equipment use from databases such as ICE, Eco invent database, Carbon Trust etc. **Step 4** – After gathering the required data, CF calculation was performed manually multiplying the CE value by the quantity. i. Following assumptions have been made during the calculation. o Vehicle lifetime performance: 0.283kg CO_2/tonne/mile o Unit value is 1 kilogram o Distance for readily available materials: 10 miles **Step 5** – As the last step, the CFs of traditional and Wi systems (Wi Beams and Wi Columns) were compared.	**Step 1** - The design specification and CMs of Wi Beam/Wi Column and TWPs were identified: • Design specifications and materials used were supplied by Wembley Innovation and Haughley Block Plant, incl. the 'Wi System User Manual', Wi System and HBP product datasheets (Properties, Performance and Reduction, 2019) (Properties, Performance and Reduction, 2021). • Design specification for TWP was obtained from Ancon ('Windposts and We are one team . We are Leviat', 2021). **Step 2** - Review existing CF tools for the cradle-to-site boundary. For CF, the Environment Agency Carbon Calculator was used to: (i) Identify boundaries and limitations, and (ii) Data analysis and interpretation. **Step 3** – Constructing the database (EC of each CM used) (Table 1) **Step 4** – To obtain CFs the Bill of Quantities (BoQ) for the following were prepared: • 9 x 4m, Type 1 wall panel designed with x4 TWPs and standard blocks (Table 2) • 9 x 4m, Type 1 wall panel designed with x2 Wi Columns and HBP blocks (Table 4) • 4 x 5m, Type 2 wall panel designed with x3 TWPs and standard blocks (Table 3) • 4 x 5m, Type 2 wall panel designed with x1 Wi Beam and HBP blocks (Table 5) **Step 5** - The cradle-to-site boundary assessment, incorporated the following: • EC of raw materials in (tCO_2e/tonne) • CE from material transportation (factory to the site, incl. distance and mode) • Waste transportation distance to landfill or/and recycling facility • CE from electricity usage. **Step 6** - Input data to the CF calculation tool to generate a CF for given blockwork wall panels. **Step 7** – A simple comparison of Wi Systems with TWPs was undertaken (in x100 units) for: • 9 x 4m standard blockwork wall panel (Type 1) with x4 TWPs (Figure 3) vs. 9 x 4m blockwork wall panel with x2 Wi Columns and HBP blocks (Figure 4). • 4 x 5m standard blockwork wall panel (Type 2) with x3 TWPs (Figure 5) vs 4 x 5m blockwork wall panel with x1 Wi Beam and HBP blocks (Figure 6).

Table A1: Default values to estimate the transport emissions for UK projects (RICS, 2017)

Transport method	Transport distance by road (km)	Transport distance by sea (km)
Locally manufactured,	50	
Nationally manufactured	300	
European manufactured	1500	
Globally manufactured	2000	10 000

Table A2: Standard principle for the rates of recovery and disposal for different materials (as described in RICS)

Construction material	Percent (%) recovery (Recycling or reuse)	Percent (%) of disposal to landfill
Steel	96	4
For any other material	90	10

Table A3: Input data used for A4 and A5 modules in the CF calculation of TWP (9 x 4m)

Construction material		A4		A5				
		Transportation distance (km)	Mode	Recycling (t)	Landfill (t)	Transport distance and mode (km)	Site activities (kWh)	
Metals	Top Cleat (220x 70x6mm)	270	Road	0.284	0.012	50 km by road	Electricity	10,000
	Frame ties @450 c/c spacing	270	Road	0.676	0.028	50 km by road		
	Bottom Cleat (150x150x6mm)	270	Road	0.415	0.017	50 km by road		
	Stainless steel (130 x 70 x 6mm)	270	Road	14.784	0.616	50 km by road		
Firestopping	Fireboard	167	Road	2.808	0.312	50 km by road		
Standard Blocks	7.3N/mm^2 compressive strength	167	Road	615.600	68.400	50 km by road		
Standard Mortar	1:1:6 cement: lime: sand mix	167	Road	62.370	6.930	50 km by road		
Wool	Stone mineral wool	167	Road	3.960	0.440	50 km by road		
Mastic	310ml intumescent acoustic sealant	167	Road	1.411	0.157	50 km by road		

Table A4: Detailed CF calculation of 9 x 4m standard blockwork wall panels with TWPs

Carbon footprint (tCO_2e)			
Construction material	**Embodied carbon of raw materials (A1-A3)**	**Transport (A4)**	**Sum**
Top Cleat (220x 70x6mm) Bottom Cleat (150x150x6mm) Frame ties @450 c/c spacing Stainless steel (130 x 70 x 6mm)	103.517	0.485	104.002
Standard dense solid block	43.092	12.190	55.282
Standard Mortar (1:1:6 Cement: lime: sand mix)	12.058	1.235	13.293
Firestopping – Fire boarding	0.406	0.056	0.461
Mineral Wool Mastic	11.099	0.106	11.205

Emissions due to waste removal and site activities (A5)				
Construction material	**Waste treatment method**	**Embodied Carbon of wasted materials**	**Transport**	**Sum**
Standard Mortar	Recycling	-	0.333	-
	Re-use	-	0.037	-
Top Cleat, Bottom Cleat, Frame ties and Stainless steel (130 x 70 x 6mm)	Recycling	-	0.086	-
	Re-use	0.013	0.004	0.017
Fire boarding, Mastic, Mineral Wool and Standard dense solid block	Recycling	-	3.328	-
	Re-use	13.792	0.370	14.162
Emissions from site activities (emission from plant and equipment)				
	kWh	**Embodied**		**Sum**
Grid electricity	10,000	5.937		5.937
	SUM		**18.230**	**= 204**

Table A5: Input data used for CF calculation of TWP (4 x 5m)

Construction material		A4 Transportation distance (km)	A4 Mode	A5 Recycling (t)	A5 Landfill (t)	A5 Transport distance and mode (km)	A5 Site activities (kWh)	
Metals	Top Cleat (220x 70x6mm)	270	Road	0.213	0.009	50 km by road	Electricity	10,000
	Bottom Cleat (150x150x6mm)			0.311	0.013			
	Frame ties @450 c/c spacing	270	Road	0.676	0.028	50 km by road		
	Stainless steel (130 x 70 x 6mm)	270	Road	13.824	0.576	50 km by road		
Firestopping	Fireboard	167	Road	2.642	0.294	50 km by road		
Concrete blocks	7.3N/mm^2 compressive strength	167	Road	342.000	38.000	50 km by road		
Mortar	1:1:6 cement: lime: sand mix	167	Road	32.670	3.630	50 km by road		
Mineral wool	Stone mineral wool	167	Road	3.960	0.440	50 km by road		
Mastic	310ml intumescent acoustic sealant	167	Road	1.411	0.157	50 km by road		

Table A6: Detailed CF calculation of 4 x 5m standard blockwork wall panel with TWPs

Carbon footprint (tCO_2e)

Construction material	**Embodied carbon of raw materials (A1-A3)**	**Transport (A4)**	**Sum**
Top Cleat (220x 70x6mm) Bottom Cleat (150x150x6mm)	96.248	0.451	96.698
Frame ties @450 c/c spacing			
Stainless steel (130 x 70 x 6mm)			
Standard dense solid block	23.940	6.772	30.712
Standard Mortar (1:1:6 Cement: lime: sand mix)	6.316	0.647	6.963
Firestopping - Fire boarding	0.382	0.052	0.434
Mineral wool	11.099	0.106	11.205
Mastic			

Emissions due to waste removal and site activities (A5)				
Construction material	**Waste treatment method**	**Embodied Carbon of wasted materials**	**Transport**	**Sum**
Standard Mortar	Recycling	-	0.174	-
	Re-use	-	0.019	-
Top Cleat, Bottom Cleat, Frame ties and Stainless steel (130 x 70 x 6mm)	Recycling	-	0.080	-
	Re-use	0.013	0.003	0.016
Stone Mineral wool, Mastic, Fireboarding and Standard Dense solid blocks	Recycling	-	1.868	-
	Re-use	7.739	0.208	7.947
Emissions from site activities (Emission from plant and equipment)				
	kWh	**Embodied**		**Sum**
Grid electricity	10,000	5.937		5.937
	SUM		**10.38**	**= 160**

Table A7: The input data used for determining the A4 and A5 modules for the cradle-to-site CF calculation for Wi Columns and HBP blocks.

Construction material		A4		A5			
		Transport distance (km)	Mode	Recycling (t)	Landfill (t)	Transport distance (km) and mode	Site activities
Steel	H16 rebar	161	Road	2.400	0.100	50 km by road	5,000 kWh
Stainless Steel	Frame Cramp Ties @450 c/c spacing (200x20x2.5)	161	Road	0.469	0.019	50 km by road	
	Masonry Ties @450 c/c spacing (225x19x3)	161	Road				
Standard Mortar	1:1:6 cement: lime: sand mix	161	Road	52.668	5.852	50 km by road	
Wi Mortar	C40 Wi Mortar	161	Road	43.200	4.800	50 km by road	
HBP blocks	HBP 140mm 7.3N medium dense slot block	161	Road	576.720	0	50 km by road	
Wi Column block	140 mm Wi Column Blocks	161	Road	38.79	4.31	50 km by road	
Mild Steel	Head Cleat (430x60x8 mm)	161	Road	0.309	0.013	50 km by road	
Wool	Mineral Stone wool	161	Road	1.188	0.132	50 km by road	
intumescent acoustic sealant	Mastic	161	Road	0.529	0.059	50 km by road	

Table A8: Detailed CF calculation of 9 x 4m blockwork wall panel with Wi Columns and HBP blocks

Carbon footprint (tCO_2e)

Construction material		**Embodied carbon of raw materials (A1-A3)**	**CE from Transport (A4)**	**Sum**
Steel	H16 rebar	3.500	0.043	3.543
Stainless steel	Frame Cramp Ties @450 c/c spacing (200x20x2.5)	3.007	0.008	3.016
	Masonry Ties @450 c/c spacing (225x19x3)			
Standard Mortar	1:1:6 cement: lime: sand mix	10.182	1.005	11.188
Wi Mortar	C40 Wi mortar	8.544	0.825	9.369
HBP Block	HBP 140mm 7.3N medium dense slot block	36.333	9.909	46.243
Mild Steel	Head Cleat (430x60x8 mm)	0.048	0.006	0.054
Wi Column block	140 mm Wi Column blocks	3.952	0.741	4.693
Wool	Mineral Stone Wool	3.549	0.033	3.582
Mastic	Intumescent Acoustic Sealant			

Emissions due to waste removal and site activities (A5)

Construction material	**Waste treatment method**	**Embodied carbon of wasted materials**	**Transport**	**Sum**
Wi Mortar & Standard Mortar	Recycling	-	0.512	-
	Reuse	-	0.057	-
Frame Cramp Ties, Masonry Ties, H16 rebar & Mild Steel	Recycling	-	0.017	-
	Reuse	0.003	0.001	0.003
Mineral Stone Wool, Intumescent Acoustic Sealant,	Recycling	-	3.294	-
	Reuse	0.896	0.024	0.920

Wi Column Blocks and HBP Block				
Emissions from site activities (emission from plant and equipment)				
	kWh	**Embodied**		**Sum**
Grid electricity	5,000	2.968		2.968
		SUM	**16.475**	**86**

Table A9: The input data used when determining the A4 and A5 modules for the cradle-to-site CF calculation for Wi Beams and HBP blocks.

Construction material		A4		A5			
		Transport distance (km)	Mode	Recycling (t)	Landfill (t)	Transport distance (km) and mode	Site activities
Plastic	Wi Debonding sleeve	161	Road	0.010	0.001	50 km by road	5000 kWh
Wi Mortar	C40 Wi Mortar	161	Road	10.350	1.150	50 km by road	
Standard Mortar	1:1:6 cement: lime: sand mix	161	Road	32.058	3.562		
Steel	H16 rebar	161	Road	1.507	0.063	50 km by road	
Mild Steel	End Cleats (200x60x8 mm)	161	Road	0.143	0.006	50 km by road	
Stainless Steel	Long transfer rod (675x34x4mm)	161	Road	0.342	0.014	50 km by road	
	Frame cramp ties @ 450 c/c spacing (200x20x2.5 mm)	161	Road	0.169	0.007	50 km by road	
HBP Blocks	HBP 140mm 7.3N medium dense slot block	161	Road	339.900	0	50 km by road	
Wi U block	140 mm Wi U block	161	Road	10.044	1.116	50 km by road	
Wool	Mineral Stone Wool	161	Road	1.188	0.119	50 km by road	
intumescent acoustic sealant	Mastic	161	Road	0.441	0.049	50 km by road	

Table A10: Detailed CF calculation of 4 x 5m blockwork wall panel with Wi Beams and HBP blocks

Carbon footprint (tCO_2e)				
Construction material		**Embodied carbon of raw materials (A1-A3)**	**CE from Transport (A4)**	**Sum**
Steel	H16 rebar	2.198	0.027	2.225
Mild Steel	End Cleats (200x60x8 mm)	0.022	0.003	0.025
Plastic	Wi Debonding sleeve	0.040	0.000	0.040
Stainless Steel	Long transfer rod (675x34x4mm)	3.272	0.009	3.281
	Frame ties @450 c/c spacing. (200x20x2.5 mm)			
Standard Mortar	1:1:6 cement: lime: sand mix	6.198	0.612	6.810
HBP Blocks	HBP 140mm 7.3N medium dense slot block	21.414	5.840	27.254
Wi Mortar	C40 Wi Mortar	2.047	0.198	2.245
Wi U Block	140 mm Wi U Block	1.023	0.192	1.215
Wool	Mineral Stone Wool	3.367	0.031	3.398
Mastic	Intumescent acoustic sealant			
Emissions due to waste removal and site activities (A5)				
Construction material	**Waste treatment method**	**Embodied carbon of wasted materials**	**Transport**	**Sum**
Wi Mortar & Standard Mortar	Recycling	-	0.226	-
	Reuse	-	0.025	-
End Cleats, Long transfer rod, Frame	Recycling	-	0.012	-
	Reuse	0.002	0.000	0.002

ties and H16 rebar				
Plastic	Recycling	-	0.000	
	Reuse	0.000	0.000	0.000
HBP Blocks, Wi U block, Wool and Mastic	Recycling	-	1.876	-
	Reuse	0.258	0.007	0.265
Emissions from site activities (emission from plant and equipment)				
	kWh	**Embodied**		**Sum**
Grid electricity	5000	2.968		2.968
		Sum	**9.058**	**50**

Table A11: Summary table showing the top contributions towards the total CF of 9 x 4m standard blockwork wall panel (Type 1) with TWPs.

Significant materials (figures include transport to site)	
Steel: Stainless	**104.002 tonnes CO2e**
Block - 8MPa Compressive Strength	**55.282 tonnes CO2e**
Waste removal - Mixed commercial and industrial waste - Lanfill	**14.162 tonnes CO2e**
Mortar (1:1:6 cement:lime:sand mix)	**13.293 tonnes CO2e**
Insulation: general	**11.205 tonnes CO2e**
Plant and equipment - Grid electricity	5.937 tonnes CO2e
Plaster: general (Gypsum)	0.461 tonnes CO2e
Waste removal - Metal: Scrap Metal - Landfill	0.017 tonnes CO2e

Table A12: Summary table showing the top contributions towards the total CF of 9 x 4m blockwork wall panels with Wi Columns and HBP blocks.

Significant materials (figures include transport to site)	
Block - 8MPa Compressive Strength	**46.243 tonnes CO2e**
Mortar (1:1:6 cement:lime:sand mix)	**11.188 tonnes CO2e**
C40 Concrete Mortar	**9.369 tonnes CO2e**
140 mm thick - Wi Column Block	**4.693 tonnes CO2e**
Insulation: general	3.582 tonnes CO2e
Steel: Bar & rod - UK (EU) Average Recycled Content	3.543 tonnes CO2e
Steel: Stainless	3.016 tonnes CO2e
Plant and equipment - Grid electricity	2.968 tonnes CO2e
Waste removal - Mixed commercial and industrial waste - Lanfill	0.920 tonnes CO2e
Mild Steel (Low Carbon Steel)	0.054 tonnes CO2e
Waste removal - Metal: Scrap Metal - Landfill	0.003 tonnes CO2e

Table A13: Summary table showing the top contributions towards the total CF of 4 x 5m standard blockwork wall panel (Type 2) with TWPs.

Significant materials (figures include transport to site)	
Steel: Stainless	**96.698 tonnes CO2e**
Block - 8MPa Compressive Strength	**30.712 tonnes CO2e**
Insulation: general	**11.205 tonnes CO2e**
Waste removal - Mixed commercial and industrial waste - Lanfill	7 947 tonnes CO2e
Mortar (1:1:6 cement:lime:sand mix)	6 963 tonnes CO2e
Plant and equipment - Grid electricity	5 937 tonnes CO2e
Plaster: general (Gypsum)	0 434 tonnes CO2e
Waste removal - Metal: Scrap Metal - Landfill	0.016 tonnes CO2e

Table A14: Summary table showing the contribution of each material and component towards the CF of 4 x 5m blockwork wall panel (Type 2) with Wi Beam and HBP blocks.

Significant materials (figures include transport to site)	
Block - 8MPa Compressive Strength	**27.254 tonnes CO2e**
Mortar (1:1:6 cement:lime:sand mix)	**6.810 tonnes CO2e**
Insulation: general	**3.398 tonnes CO2e**
Steel: Stainless	**3.281 tonnes CO2e**
Plant and equipment - Grid electricity	**2.968 tonnes CO2e**
C40 Concrete Mortar	2 245 tonnes CO2e
Steel: Bar & rod - UK (EU) Average Recycled Content	2 225 tonnes CO2e
140 mm thick U block	1 215 tonnes CO2e
Waste removal - Mixed commercial and industrial waste - Lanfill	0 265 tonnes CO2e
Plastics: general	0 040 tonnes CO2e
Mild Steel (Low Carbon Steel)	0 025 tonnes CO2e
Waste removal - Metal: Scrap Metal - Landfill	0 002 tonnes CO2e
Waste removal - Plastics: Average plastics - Landfill	0 000 tonnes CO2e

Appendix B

Calculation for TWPs and standard blocks

9 x 4m standard blockwork wall panel (Type 1) with TWPs (x100 units)

Metals	Steel Sections - UK (EU) Average Recycled Content	7 8 tonnes/m3	1 53							
	Steel Wire - Virgin	7 8 tonnes/m3	3 02							
	Steel Stainless	8 tonnes/m3	6 15	17	270	Road		103 517	0 485	104 002
	Steel Reused steel	7 8 tonnes/m3	0 15							
Miscellaneous	Glass Reinforced Plastic - GRP - Fibreglass	1 74 tonnes/m3	8 10							
	Insulation general	0 04 tonnes/m3	1 86	6	167	Road		11 099	0 106	11 205
	Insulation fibreglass (glasswool)	0 045 tonnes/m3	1 35							
	Insulation polystyrene	0 037 tonnes/m3	3 43							
	Insulation polyurethane	0 03 tonnes/m3	4 84							
	Plaster general (Gypsum)	1 3 tonnes/m3	0 13	3	167	Road	Reset	0 406	0 056	0 461
	Plasterboard	0 92 tonnes/m3	0 39							
Concrete blocks	Block - 8MPa Compressive Strength	1 05 tonnes/m3	0 06	684	167	Road	n/a	43 092	12 190	55 282
	Block - 10 Mpa Compressive Strength	1 15 tonnes/m3	0 08				n/a			
	Block - 12 Mpa Compressive Strength	1 25 tonnes/m3	0 09				n/a			
Mortars	Mortar (1 6 cement sand mix)	2 2 tonnes/m3	0 14							
	Mortar (1 ½ 4½ cement lime sand mix)	2 2 tonnes/m3	0 21							
	Mortar (1 1 6 cement lime sand mix)	2 2 tonnes/m3	0 17	69	167	Road		12 058	1 235	13 293

Type of waste	Waste treatment method	Tonnage	Distance (km)	Mode	Embodied	Transport	Sum
Aggregates (Rubble)	Reuse / Recycling*	62.37	50	Road	-	0 333	
	Landfill	6.93	50	Road	-	0 037	
	Landfill (potential aggregate)				-		
Batteries (Post Consumer Non Automotive)	Reuse / Recycling*				-		
	Landfill						
Glass	Reuse / Recycling*				-		
	Landfill						
	Landfill (potential aggregate)						
Metal: Scrap Metal	Reuse / Recycling*	16.159	50	Road	-	0 086	
	Landfill	0.673	50	Road	0 013	0 004	0 017
Mineral Oil	Reuse / Recycling*				-		
	Landfill				-		
Mixed commercial and industrial waste	Reuse / Recycling*	623.779	50	Road	-	3 328	
	Landfill	69.309	50	Road	13 792	0 370	14 162

		Input unit	tCO_2e/unit	Units	Distance	Mode			
Emissions from plant and equipment	Diesel	litres	0 0031761						
	Biodiesel	litres	0 0013674						
	Gas oil	litres	0 0035865						
	Grid electricity	kWh	0 00059368	10000			5 937	n/a	5 937
	Gas	m3	0 002217					n/a	
	Water	litres	0 00000034					n/a	

4 x 5m standard blockwork wall panel (Type 2) with TWPs (x 100 units)

Metals	Steel Plate- UK (EU) Average Recycled Content	7 8 tonnes/m3	1 66						
	Steel Sections - UK (EU) Average Recycled Content	7 8 tonnes/m3	1 53						
	Steel Wire - Virgin	7 8 tonnes/m3	3 02						
	Steel Stainless	8 tonnes/m3	6 15	16	270	Road	96 248	0 451	96.698
	[illegible]	[illegible]	[illegible]						

Miscellaneous	Glass Reinforced Plastic - GRP - Fibreglass	1 74 tonnes/m3	8 10							
	Insulation general	0 04 tonnes/m3	1 86	6	167	Road		11 099	0 106	11 205
	Insulation fibreglass (glasswool)	0 045 tonnes/m3	1 35							
	Insulation polystyrene	0 037 tonnes/m3	3 43							
	Insulation polyurethane	0 03 tonnes/m3	4 84							
	Plaster general (Gypsum)	1 3 tonnes/m3	0 13	3	167	Road		0 382	0 052	0 434
	Plasterboard	0 92 tonnes/m3	0 39							
Concrete blocks	Block - 8MPa Compressive Strength	1 05 tonnes/m3	0 06	380	167	Road	n/a	23 940	6 772	30 712
	Block - 10 Mpa Compressive Strength	1 15 tonnes/m3	0 08				n/a			
	Block - 12 Mpa Compressive Strength	1 25 tonnes/m3	0 09				n/a			
Mortars	Mortar (1 6 cement sand mix)	2 2 tonnes/m3	0 14							
	Mortar (1 ½ 4½ cement lime sand mix)	2 2 tonnes/m3	0 21							
	Mortar (1 1 6 cement lime sand mix)	2 2 tonnes/m3	0 17	36	167	Road		6 316	0 647	6 963

Type of waste	Waste treatment method	Tonnage	Distance (km)	Mode	Embodied	Transport	Sum
Aggregates (Rubble)	Reuse / Recycling*	32.67	50	Road	-	0 174	
	Landfill	3.63	50	Road	-	0 019	
	Landfill (potential aggregate)				-		
Batteries (Post Consumer Non Automotive)	Reuse / Recycling*				-		
	Landfill						
Glass	Reuse / Recycling*				-		
	Landfill						
	Landfill (potential aggregate)						
Metal: Scrap Metal	Reuse / Recycling*	15.024	50	Road	-	0 080	
	Landfill	0.626	50	Road	0 013	0 003	0 016
Mineral Oil	Reuse / Recycling*				-		
	Landfill				-		
Mixed commercial and industrial waste	Reuse / Recycling*	350.013	50	Road	-	1 868	
	Landfill	38.89	50	Road	7 739	0 208	7 947
	Landfill (potential aggregate)						

		Input unit	tCO_2e/unit	Units	Distance	Mode			
Emissions from plant and equipment	Diesel	litres	0 0031761						
	Biodiesel	litres	0 0013674						
	Gas oil	litres	0 0035865						
	Grid electricity	kWh	0 00059368	**10000**			5 937	n/a	5 937
	Gas	m3	0.002217					n/a	
	Water	litres	0 00000034					n/a	

CF calculation for Wi System and HBP blocks

9 x 4m blockwork wall panels with (Type 1) Wi Columns and HBP blocks (x100 units)

		Conversion	tCO_2e/t or unit	Tonnage or unit	Distance	Mode			
Metals	Copper EU Tube & Sheet	8 9 tonnes/m3	2 71						
	Copper Reused copper	8 9 tonnes/m3	0 27						
	Iron	7 87 tonnes/m3	2 03						
	Lead	11 34 tonnes/m3	1 67						
	Steel General - UK (EU) Average Recycled Content	7 8 tonnes/m3	1 46						
	Steel Bar & rod - UK (EU) Average Recycled Content	7 8 tonnes/m3	1 40	**3**	**161**	**Road**	3 500	0 043	3 543
	Steel Plate- UK (EU) Average Recycled Content	7 8 tonnes/m3	1 66						
	Steel Sections - UK (EU) Average Recycled Content	7 8 tonnes/m3	1 53						
	Steel Wire - Virgin	7 8 tonnes/m3	3 02						
	Steel Stainless	8 tonnes/m3	6.15	**0**	**161**	**Road**	3 007	0 008	3 016
Miscellaneous	Damp Proof Course/Membrane	0 0009 tonnes/m2	4 20						
	Rubber	1 5 tonnes/m3	2 85						
	Grit	2 tonnes/m3	0.01						
	Ground limestone	0 94508933879664	0 03						
	Glass Reinforced Plastic - GRP - Fibreglass	1 74 tonnes/m3	8 10						
	Insulation general	0 04 tonnes/m3	1.86	**2**	**161**	**road**	3 549	0 033	3 582

Concrete blocks	Block - 8MPa Compressive Strength	1 05 tonnes/m3	0 06	**577**	**161**	**Road**	n/a	36 333	9 909	46 243
	Block - 10 Mpa Compressive Strength	1 15 tonnes/m3	0.08				n/a			
	Block - 12 Mpa Compressive Strength	1 25 tonnes/m3	0 09				n/a			
Mortars	Mortar (1 5 cement sand mix)	2 2 tonnes/m3	0 16							
	Mortar (1 6 cement sand mix)	2 2 tonnes/m3	0 14							
	Mortar (1 ½ 4½ cement lime sand mix)	2 2 tonnes/m3	0 21							
	Mortar (1 1 6 cement lime sand mix)	2 2 tonnes/m3	0 17	59	161	Road		10 182	1 005	11 188

Enter name of material	tCO_2e/t for material	Tonnage	Distance	Mode	Choose category	Results (figures will be added to sub-totals above)		
C40 Concrete Mortar	0 178	48	161	Road		8 544	0 825	9 369
140 mm thick - Wi Column Block	0 0917	43.1	161	Road		3 952	0 741	4 693
Mild Steel (Low Carbon Steel)	0 15	0.322	161	Road		0 048	0 006	0 054

Type of waste	Waste treatment method	Tonnage	Distance (km)	Mode	Embodied	Transport	Sum
Aggregates (Rubble)	Reuse / Recycling*	95.868	50	Road	-	0 512	
	Landfill	10.652	50	Road	-	0 057	
	Landfill (potential aggregate)				-		
Batteries (Post Consumer Non Automotive)	Reuse / Recycling*				-		
	Landfill						
Glass	Reuse / Recycling*				-		
	Landfill						
	Landfill (potential aggregate)						
Metal: Scrap Metal	Reuse / Recycling*	3.179	50	Road	-	0 017	
	Landfill	0.133	50	Road	0 003	0 001	0 003
Mineral Oil	Reuse / Recycling*				-		
	Landfill				-		
Mixed commercial and industrial waste	Reuse / Recycling*	617.227	50	Road	-	3 294	
	Landfill	4.501	50	Road	0 896	0 024	0 920
	Landfill (potential aggregate)						

		Input unit	tCO_2e/unit	Units	Distance	Mode			
Emissions from plant and equipment	Diesel	litres	0 0031761						
	Biodiesel	litres	0 0013674						
	Gas oil	litres	0 0035865						
	Grid electricity	kWh	0 00059368	5000			2 968	n/a	2 968
	Gas	m3	0 002217					n/a	
	Water	litres	0 00000034					n/a	

4 x 5m blockwork wall panel (Type 2) with Wi Beam and HBP blocks (x100 units)

		Conversion	tCO_2e/t or unit	Tonnage or unit	Distance	Mode			
Metals	Copper EU Tube & Sheet	8.9 tonnes/m3	2.71						
	Copper: Reused copper	8.9 tonnes/m3	0.27						
	Iron	7.87 tonnes/m3	2.03						
	Lead	11.34 tonnes/m3	1.67						
	Steel: General - UK (EU) Average Recycled Content	7.8 tonnes/m3	1.46						
	Steel Bar & rod - UK (EU) Average Recycled Content	7.8 tonnes/m3	1.40	2	161	Road	2 198	0.027	2.225
	Steel: Coil (Sheet), Galvanised - UK (EU) Average Recycled Content	7.8 tonnes/m3	1.54						
	Steel: Engineering steel - Recycled	7.8 tonnes/m3	0.72						
	Steel: Pipe- UK (EU) Average Recycled Content	7.8 tonnes/m3	1.45						
	Steel: Plate- UK (EU) Average Recycled Content	7.8 tonnes/m3	1.66						
	Steel: Sections - UK (EU) Average Recycled Content	7.8 tonnes/m3	1.53						
	Steel: Wire - Virgin	7.8 tonnes/m3	3.02						
	Steel Stainless	8 tonnes/m3	6.15	1	161	Road	3.272	0.009	3.281

Plastics	Plastics general	0.96 tonnes/m3	3.31	0	161	Road	0.040	0.000	0.040
	Polyethylene, general	1.05 tonnes/m3	2.54						
	High Density Polyethylene (HDPE) Resin	1.05 tonnes/m3	1.93						
	HDPE Pipe	1.05 tonnes/m3	2.52						
	Expanded Polystyrene	1.05 tonnes/m3	3.29						

Miscellaneous	Damp Proof Course/Membrane	0.0009 tonnes/m2	4.20						
	Rubber	1.5 tonnes/m3	2.85						
	Grit	2 tonnes/m3	0.01						
	Ground limestone	0.9450893387966	0.03						
	Glass Reinforced Plastic - GRP - Fibreglass	1.74 tonnes/m3	8.10						
	Insulation: general	0.04 tonnes/m3	1.86	2	161	Road	3.367	0.031	3.398
	Insulation: fibreglass (glasswool)	0.045 tonnes/m3	1.35						

		Conversion	tCO_2e/t or unit	Tonnage or unit	Distance	Mode	Cement type			
Concrete blocks	Block - 8MPa Compressive Strength	1.05 tonnes/m3	0.06	340	161	Road	n/a	21.414	5.840	27.254
	Block - 10 Mpa Compressive Strength	1.15 tonnes/m3	0.08				n/a			
	Block - 12 Mpa Compressive Strength	1.25 tonnes/m3	0.09				n/a			
	Block - 13 Mpa Compressive Strength	1.35 tonnes/m3	0.11				n/a			
Mortars	Mortar (1:5 cement:sand mix)	2.2 tonnes/m3	0.16							
	Mortar (1:6 cement:sand mix)	2.2 tonnes/m3	0.14							
	Mortar (1:½:4½ cement:lime:sand mix)	2.2 tonnes/m3	0.21							
	Mortar (1:1:6 cement:lime:sand mix)	2.2 tonnes/m3	0.17	36	161	Road		6.198	0.612	6.810
	Mortar (1 2:9 cement:lime:sand	[illegible]	[illegible]							

	Enter name of material	tCO_2e/t for material	Tonnage	Distance	Mode	Choose category	Results (figures will be added to sub-totals above)		
	C40 Concrete Mortar	0.178	11.5	161	Road		2.047	0.198	2.245
	140 mm thick U block	0.0917	11.16	161	Road		1.023	0.192	1.215
	Mild Steel (Low Carbon Steel)	0.15	0.149	161	Road		0.022	0.003	0.025

Type of waste	Waste treatment method	Tonnage	Distance (km)	Mode	Footprint (tonnes fossil CO_2e) Embodied	Transport	Sum
Aggregates (Rubble)	Reuse / Recycling*	42.408	50	Road	-	0.226	
	Landfill	4.712	50	Road	-	0.025	
	Landfill (potential aggregate)				-		
Batteries (Post Consumer Non Automotive)	Reuse / Recycling*				-		
	Landfill						
Glass	Reuse / Recycling*				-		
	Landfill						
	Landfill (potential aggregate)						
Metal: Scrap Metal	Reuse / Recycling*	2.161	50	Road	-	0.012	
	Landfill	0.09	50	Road	0.002	0.000	0.002
Mineral Oil	Reuse / Recycling*				-		
	Landfill				-		
Mixed commercial and industrial waste	Reuse / Recycling*	351.573	50	Road	-	1.876	
	Landfill	1.297	50	Road	0.258	0.007	0.265
	Landfill (potential aggregate)						
Mixed municipal waste	Reuse / Recycling*				-		
	Landfill						
Organic Waste: Garden Waste	Reuse / Recycling*				-		
	Landfill						
Paper and board: Board (Av. board: 78% corrugate, 22% cartonboard)	Reuse / Recycling*				-		
	Landfill						
Plasterboard	Reuse / Recycling*				-		
	Landfill						
Plastics: Average plastics	Reuse / Recycling*	0.01	50	Road	-	0.000	
	Landfill	0.001	50	Road	0.000	0.000	0.000

		Input unit	tCO_2e/unit	Units	Distance	Mode	Embodied	Transport	Sum
Emissions from plant and equipment	Diesel	litres	0.0031761						
	Biodiesel	litres	0.0013674						
	Gas oil	litres	0.0035865						
	Grid electricity	kWh	0.00059368	5000			2.968	n/a	2.968
	Gas	m3	0.002217					n/a	
	Water	litres	0.00000034					n/a	