CO₂ **2.Low carbon**

We signed the climate declaration – now what?
Lessons from counting carbon

Ben Gholam of Price & Myers shares his practice's experience of setting up a carbon-calculation tool and encourages other firms to take the plunge.

2019 was the year that the climate emergency finally got the headline exposure it deserved. As engineers, we are now becoming more aware of the impact of embodied carbon in our designs, and the significant contribution this makes to global emissions. Carbon calculations are becoming more commonplace, and the forthcoming IStructE guide, *How to calculate embodied carbon*, will greatly assist members in carrying these out.

However, these figures can be meaningless without context, and being able to make comparisons with other designs is crucial in assessing performance. This article outlines how we set up a carbon database from scratch, with the aim of demonstrating how simple it can be and the key lessons learned from the process.

Aim
A team from Price & Myers has been working alongside the University of Cambridge for four years on an Innovate UK-funded research project related to embodied carbon. We have established an excellent knowledge base for individual structural types and elements, but have lacked whole-building data on what our completed designs are actually achieving. This has prevented us from comparing current designs to any real-life benchmark and assessing relative efficiencies.

When Price & Myers signed the declaration of a Climate and Biodiversity Emergency in 2019, we wanted to ensure that these were not just empty words, and that we followed up with immediate and meaningful action on top of the work we were already doing.

There had always been an aim to set up a company-wide database, and the declaration gave us the impetus we needed. We decided to build a simple calculation tool and then use it to create a database of as many completed projects as possible.

Process
Counting carbon can be as straightforward as listing all materials and multiplying each by a carbon factor (a standardised value of carbon emitted per unit weight, measured in $kgCO_2e/kg$). It is, of course, possible to go into greater detail, so our first challenge was to minimise the amount of work for our busy engineers while still providing enough accuracy to be useful.

Materials
The solution was to move the emphasis away from the actual carbon and onto the materials. Inputs were restricted to 15, covering various types of steel, timber, concrete and masonry, selected to cover the vast majority of our work. For each of these, a fixed carbon value was assigned based on a secondary input (such as %GGBS) that would be consistent across all projects. This meant that engineers were essentially compiling material schedules – something that is simple enough to do but which we rarely ever do ourselves.

Carbon factors
Several data sources are available for carbon

TABLE 1: Extract from data collection spreadsheet

Job #	Sector	Type	GIFA (m²)	Storeys	Basement	Foundations	Ground floor	
1	Other	New build (brownfield)	4631	3	None	Piled ground beams	Suspended RC	
2	Residential	New build (brownfield)	4640	7	None	Mass pads/Strips	Suspended RC	
3	Cultural	New build (brownfield)	742	3	None	Mass pads/Strips	Suspended RC	
4	Residential	New build (greenfield)	1534	2	Partial footprint	Raft	Suspended RC	
5	Residential	New build (brownfield)	7284	6	None	Mass pads/Strips	Ground-bearing RC	
75	Commercial	New build (brownfield)	1163	1	None	Mass pads/Strips	Ground-bearing RC	
76	Other	New build (brownfield)	2575	4	Full footprint	Mass pads/Strips	Suspended RC	
77	Residential	New build (brownfield)	4787	6	None	Piled ground beams	Suspended RC	
78	Industrial	New build (greenfield)	3851	1	None	Mass pads/Strips	Ground-bearing RC	
79	Residential	New build (greenfield)	307	2	None	Mass pads/Strips	Ground-bearing RC	
80	Residential	New build (brownfield)	340	2	Partial footprint	Mass pads/Strips	Suspended RC	

NB The full spreadsheet is available to download at: www.pricemyers.com/news/embodied-carbon-data-for-building-structures-26

factors, but we find the Inventory of Carbon and Energy (ICE) database V3.0 Beta[1] to be the most comprehensive and useful (with care taken to ensure that appropriate values are used).

The database only covers the material-specific (cradle-to-gate) factors A1–A3, meaning no allowance is made for transportation to site or for site works themselves (factors A4 and A5).

Transport typically accounts for a minor proportion of the overall emissions in steel and concrete frames, but is more significant in timber-framed buildings. Due to a lack of data and to ensure simplicity, we also decided to omit factors relating to construction methods. The way the data were to be collected meant that there was scope to easily add these factors later if required.

We soon had a simple Excel-based tool that was ready to be rolled out across the practice. This was set up to provide a clean, graphical output that could be saved for each project **(Figure 1)** as a future reference point.

Data context
The next step was to provide context to the data – vital in establishing trends for future comparisons. We set up a second spreadsheet to collate all the data across the projects in a single place, allowing us to input a range of different datapoints on the structure in question **(Table 1)**. These included the substructure and superstructure type, typical spans, loads and storeys.

In total, there were over 40 datapoints collected for each project, the most important being the gross internal floor area (GIA), which allowed the amount of carbon to be rated in terms of the size of the structure. In order to ensure consistency, we restricted the collection to completed projects only, meaning that all data were collected from drawings or models from the final construction issue.

"WE HAD TO REGULARLY REMIND STAFF THAT PILE FOUNDATION VOLUMES ARE SIGNIFICANT

The tool was launched in October 2019. Take-up was slow at first, but staff responded well to a little friendly competition (being ranked weekly on a scale of 'Thunberg to Trump'), so a challenge between the nine structural teams to carry out the most calculations was well received. By the end of 2019, we had managed to complete the initial database for 80 projects, covering a wide range of sectors and materials.

Key lessons
To ensure consistency, we established rules on what should and shouldn't be included and what assumptions should be made. Some key lessons are presented here.

Understand quantities
Taking material schedules from building information models (provided they have been modelled correctly) is easy. However, problems frequently arose with contractor-designed items that are often not modelled – such as piles and staircases. We had to regularly remind staff that pile foundation volumes are significant and cannot be ignored (particularly in basements with contiguous walls!).

We also had to ensure that non-loadbearing facades were not included, but that lightweight proprietary roofs were, for consistency in comparisons.

We asked people to be as accurate as they could be – with a margin of around 10% being

acceptable. Any other allowances for materials not listed (e.g. connections) were left at the discretion of the engineer, as long as they were clearly noted in a comments section.

Agree scope
One of the crucial requirements in being able to compare trends is to set some limits in the data that can be entered. For each category, we forced a selection from a dropdown menu, which limited the engineers to a pre-set value but meant that sorting data and establishing trends was much easier.

For example, in the superstructure type input was limited to one of 12 categories, ensuring that we didn't end up with a wide range of subjective descriptions that would be difficult to analyse.

A notes column at the end allowed input of anything that was crucial to mention, and all categories contained an 'other' option for anything that didn't quite fit.

Check reinforcement
As all projects included were at the final construction/as-built stage, schedules were available for the reinforcement (as opposed to estimates). However, as there is often no need for running totals of quantities to be kept in house, this sometimes added significant time to the process.

As a simple check, we built a function into the tool to calculate an overall reinforcement rate – very useful as a means of spotting obvious mistakes. Again, piles proved to be a problem as the cages in these were rarely included and had to be manually calculated.
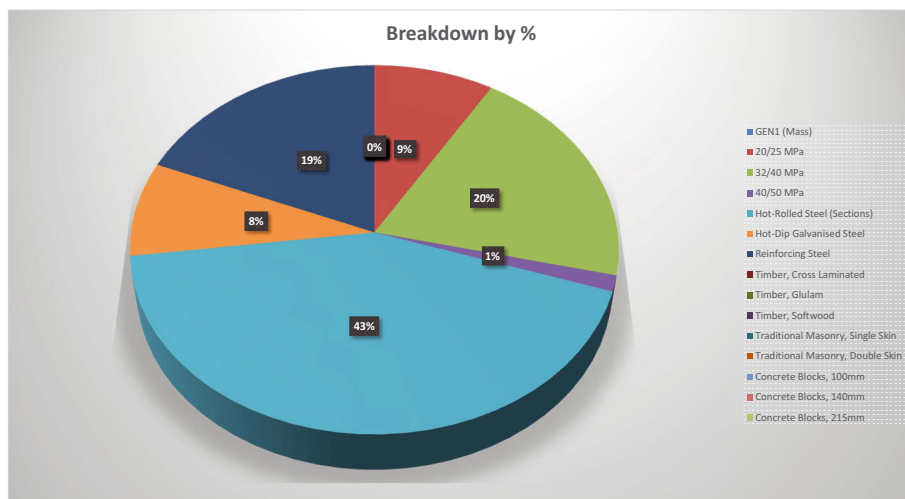
Areas are crucial
Rating the carbon totals by floor area is the best overall comparison method. However, in certain cases we struggled to decide whether this was

Superstructure	Typical span (m)	Typ Q_k (kN/m²)	Cladding	BREEAM rating	Calculated total tCO₂e	Calculated tCO₂e/m²
In situ RC	7.00	4.00	Masonry + SFS	Unknown	1179.8	0.255
CLT frame	4.00	2.50	Lightweight only	Unknown	881.9	0.190
Steel frame, precast	2.50	4.00	Masonry + SFS	Very good	149.6	0.202
Masonry, concrete	7.00	2.50	Stone + masonry	Unknown	424.5	0.277
In situ RC	7.50	2.50	Masonry + SFS	Unknown	1896.3	0.260
Steel frame, precast	6.24	5.50	Lightweight + SFS	Unknown	246.9	0.212
Steel frame, precast	7.50	4.00	Lightweight + SFS	Unknown	493.9	0.192
In situ RC	6.00	2.50	Masonry + SFS	Unknown	1169.0	0.244
Steel frame, composite	20.50	0.85	Lightweight + SFS	Unknown	727.8	0.189
Timber frame	4.00	1.50	Timber only	Unknown	51.0	0.166
In situ RC	6.50	2.50	Other	Unknown	70.1	0.206

		Basic Embodied Carbon Calculator						
		Total Embodied Carbon	1059029.2	kgCO2e				
		Total Embodied Carbon (rate)	382.0	kgCO2e/m2				
		Building Gross Internal Floor Area	2772	m2				
			Quantity Input	**Units**	**Material Selection**	**Value**	**Total CO2**	**Weighting**
CONCRETE		GEN1 (Mass)	0	kg	CEMI	0.097	0.0 kgCO2e	0.00%
		20/25 MPa	1049879	kg	40% PFA	0.088	92140.0 kgCO2e	8.70%
		32/40 MPa	1692400	kg	30% PFA	0.125	211774.3 kgCO2e	20.00%
		40/50 MPa	85032	kg	CEMI	0.172	14650.1 kgCO2e	1.38%
STEEL		Hot-Rolled Steel (Sections)	293000	kg	Short Term (A-C)	1.550	454150.0 kgCO2e	42.88%
		Hot-Dip Galvanised Steel	31780	kg	Short Term (A-C)	2.760	87712.8 kgCO2e	8.28%
		Reinforcing Steel	99800	kg	Short Term (A-C)	1.990	198602.0 kgCO2e	18.75%
TIMBER		Timber, Cross Laminated	0	kg	No Carbon Storage	0.437	0.0 kgCO2e	0.00%
		Timber, Glulam	0	kg	No Carbon Storage	0.512	0.0 kgCO2e	0.00%
		Timber, Softwood	0	kg	No Carbon Storage	0.263	0.0 kgCO2e	0.00%
MASONRY		Traditional Masonry, Single Skin	0	m2	1:1:6	37.305	0.0 kgCO2e	0.00%
		Traditional Masonry, Double Skin	0	m2	1:1:6	79.987	0.0 kgCO2e	0.00%
		Concrete Blocks, 100mm	0	m2	High Density	19.786	0.0 kgCO2e	0.00%
		Concrete Blocks, 140mm	0	m2	High Density	27.961	0.0 kgCO2e	0.00%
		Concrete Blocks, 215mm	0	m2	High Density	42.614	0.0 kgCO2e	0.00%

Breakdown by %

- GEN1 (Mass)
- 20/25 MPa
- 32/40 MPa
- 40/50 MPa
- Hot-Rolled Steel (Sections)
- Hot-Dip Galvanised Steel
- Reinforcing Steel
- Timber, Cross Laminated
- Timber, Glulam
- Timber, Softwood
- Traditional Masonry, Single Skin
- Traditional Masonry, Double Skin
- Concrete Blocks, 100mm
- Concrete Blocks, 140mm
- Concrete Blocks, 215mm

☝ **FIGURE 1:**
Excel-based simple calculation tool

actually a fair comparison – the most common being podium slabs over unheated spaces, such as car parks. In these cases, it could be argued that a roof was not necessary, and therefore the slab was constructed to provide the additional space.

Spaces with increased heights (industrial facilities and sports halls) presented another question. These buildings have extended floor-to-floor heights and often require large amounts of material for lateral stiffness, meaning a volumetric measurement would feel more appropriate.

We were unable to resolve these questions during the construction of the database, and the architectural GIA was used wherever possible for consistency.

Think long-term
While collecting material data is definitive, the selection of the appropriate carbon factor still requires a lot of educated judgment. Despite our experience, there were a few values we were not fully confident with.

We wanted to ensure that the data collected had long-term flexibility, and this required it to be broken down in as detailed and transparent a way as possible. The collection spreadsheet lists every material type separately, with the carbon factors extracted and customisable.

As the factors are independent from the material totals, we can adjust them as we wish. If

we decide that the recycled content of our steel is unrealistic, we can increase the rate. Similarly, if we decide that we should allow for timber sequestration (which was ignored as it was still a grey area at the time), we can easily do so. It also means that additional figures (such as the A4 and A5 factors) can be added later.

Representation of the data in a format such as this also makes it easier for external parties to break it down, analyse and compare with other projects on a like-for-like basis.

Look for trends
The data we collected have enabled us to start trying to establish trends across building types and materials. Price & Myers' work covers an unusually wide variety of building types and scales and, while all main building types and materials are covered, trends are only clearly visible once enough projects of each type are entered.

While it is great to have as many buildings included as possible, it is also wise to pick carefully if time is restricted to ensure an even balance. Any trends are also heavily dependent on the specific carbon factors used (especially when comparing materials).

At present, we are still researching the degree to which we are satisfied with our inputs before we can confidently state what we have found. We will be hoping to take this work further over the

course of this year, as well as aiming to increase the number of projects included.

Closing thoughts
Databases such as these will be essential in the drive to reduce embodied carbon. They will be needed to set targets and to benchmark designs. There has been great work by organisations such as the London Energy Transformation Initiative (LETI) to provide some initial industry-wide benchmarks, and as more real data become freely available, these can be further refined and tightened.

The forthcoming IStructE guide will be a valuable resource for those not experienced in the field and we would encourage every practice to have a go, regardless of size.

It does involve a time commitment – we had initially hoped that the calculations would take no more than half an hour to complete per project – but some took several hours. However, it is worth stressing that getting engineers to think about material quantities in this way has benefits that go beyond the scope of embodied carbon, so in no way was it wasted time.

As one of the key requirements of signing the declaration was to share information, the dataset we created is freely available on the Price & Myers website[2] with the aim of assisting cross-industry collaboration. We encourage anyone who is interested to download and use it to help create their own for further sharing across the industry.

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REFERENCES

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2) Price & Myers (2020) *Embodied Carbon Data for Building Structures* [Online] Available at: www.pricemyers.com/news/embodied-carbon-data-for-building-structures-26 (Accessed: June 2020)