User Guide
Concept version 5: Cost and Carbon

The Concept spreadsheet compares conceptual designs to Eurocode 2 for a wide range of concrete frame options, then ranks them in order of cost, programme or embodied carbon. It is intended to be used for selecting the most appropriate scheme for a concrete frame, and for determining initial member sizes. Final working designs should be carried out via conventional means, such as by using The Concrete Centre's RC Spreadsheets.

For member sizing, database information from *Economic Concrete Frame Elements,* published by The Concrete Centre, is used. This data generally deals with spans of up to 12m (up to 16m for wide beams). Any solution with frame geometry falling outside the database range will produce a "no solution" result, in which case the designer should use other means to determine preliminary sizes and costs.

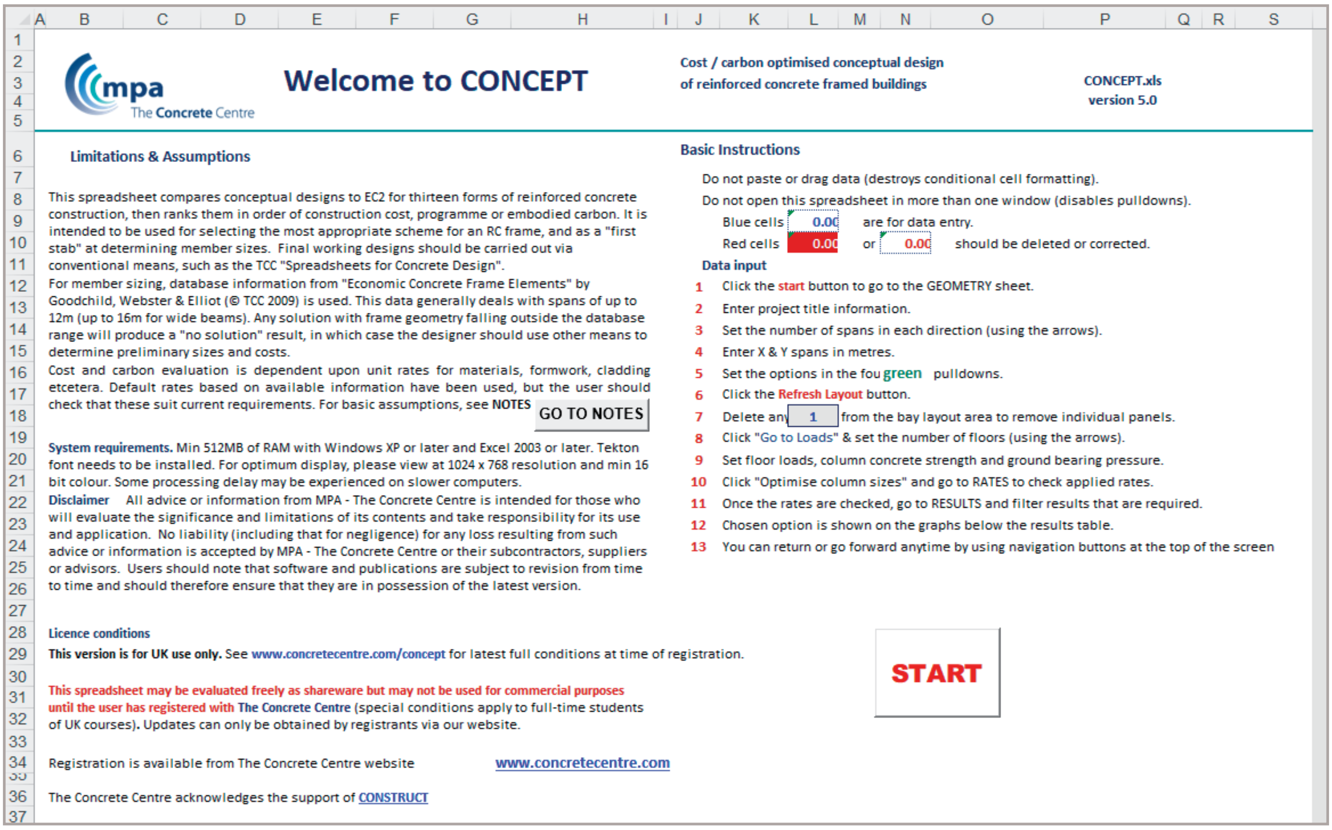
Cost and carbon evaluation is dependent upon unit rates for materials, formwork, cladding etc. Default rates based on available information have been used, but the user should check that these suit current requirements. For basic assumptions, see NOTES sheet.

This document provides guidance on how to use the Concept software, with screen shots to indicate the information generated from each stage of the process. The software itself can be downloaded from **www.concretecentre.com/concept**.

Key screens and how to use

Getting started

Open the .xls file using Microsoft Excel to view the 'Welcome' page and 'Enable content' when prompted - this will enable macros, which are required to run the tool. The welcome page gives an overview of how to use the software and assumptions and limitations of the spreadsheet. Users should note that cells with blue text are for data entry and cells with red text or with a red background indicate values to be deleted or corrected. It is important that cells are not copied and pasted as this may cause errors. From the welcome page, click 'START' to start entering the building geometry.



Building geometry

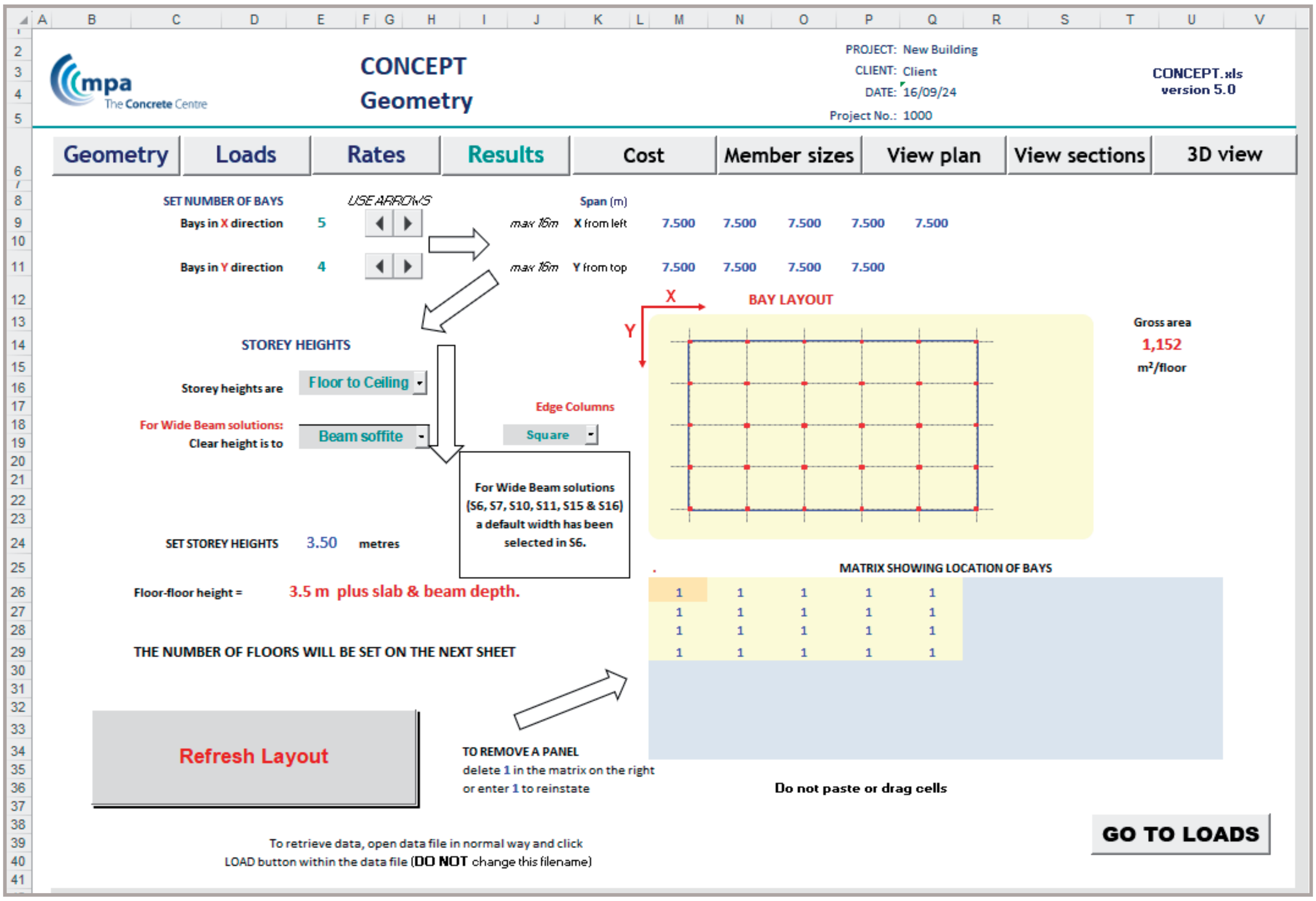
The tabs at the top of the spreadsheet can be used to navigate through the spreadsheet.

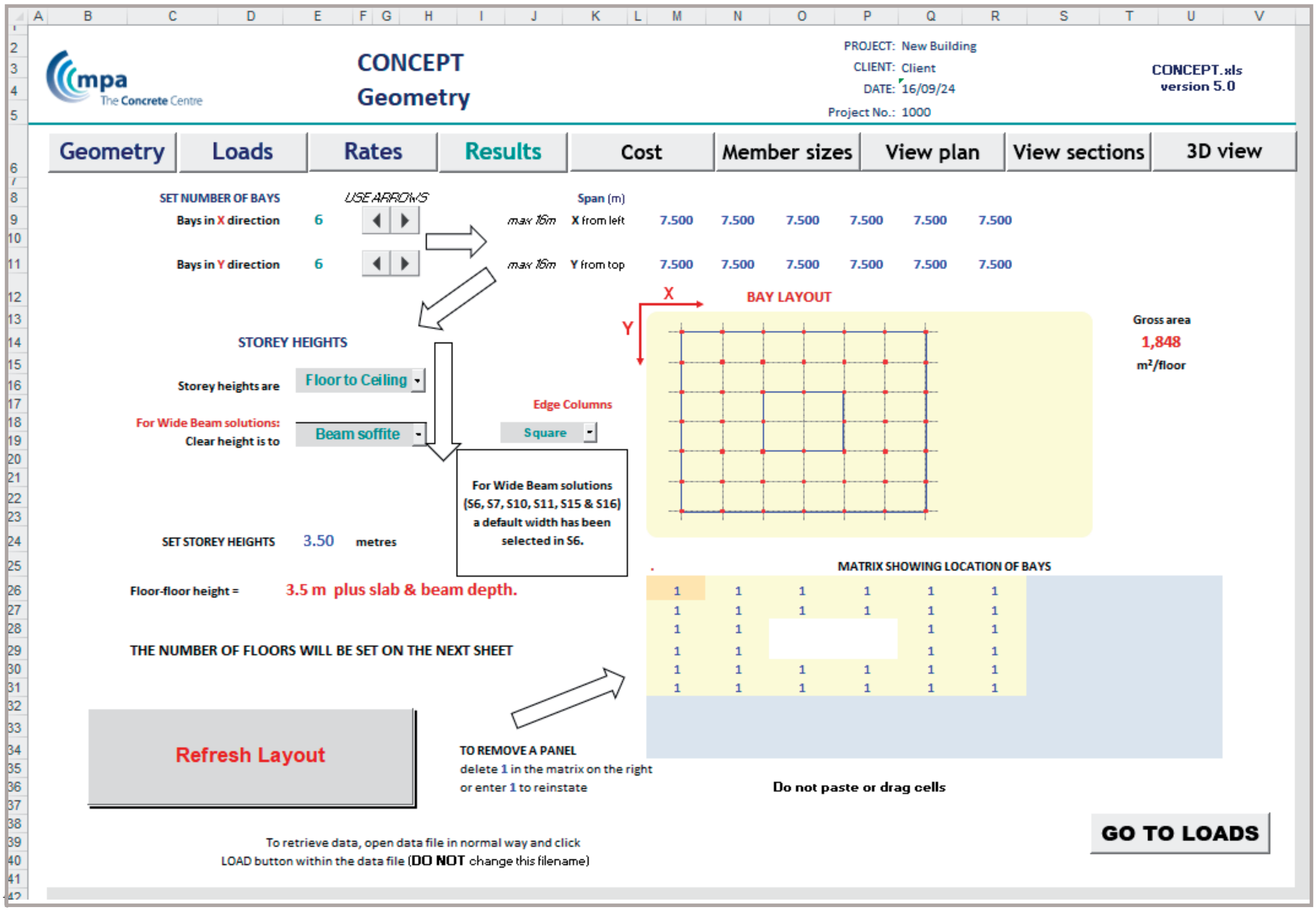
Start by setting the number of bays in each direction using arrows, then define the span lengths for each bay.

Then define the storey heights – either clear height (floor to ceiling) or floor to floor. There are also options for wide beam solutions (measuring height to slab or beam soffit) and a choice of square or rectangular edge columns.

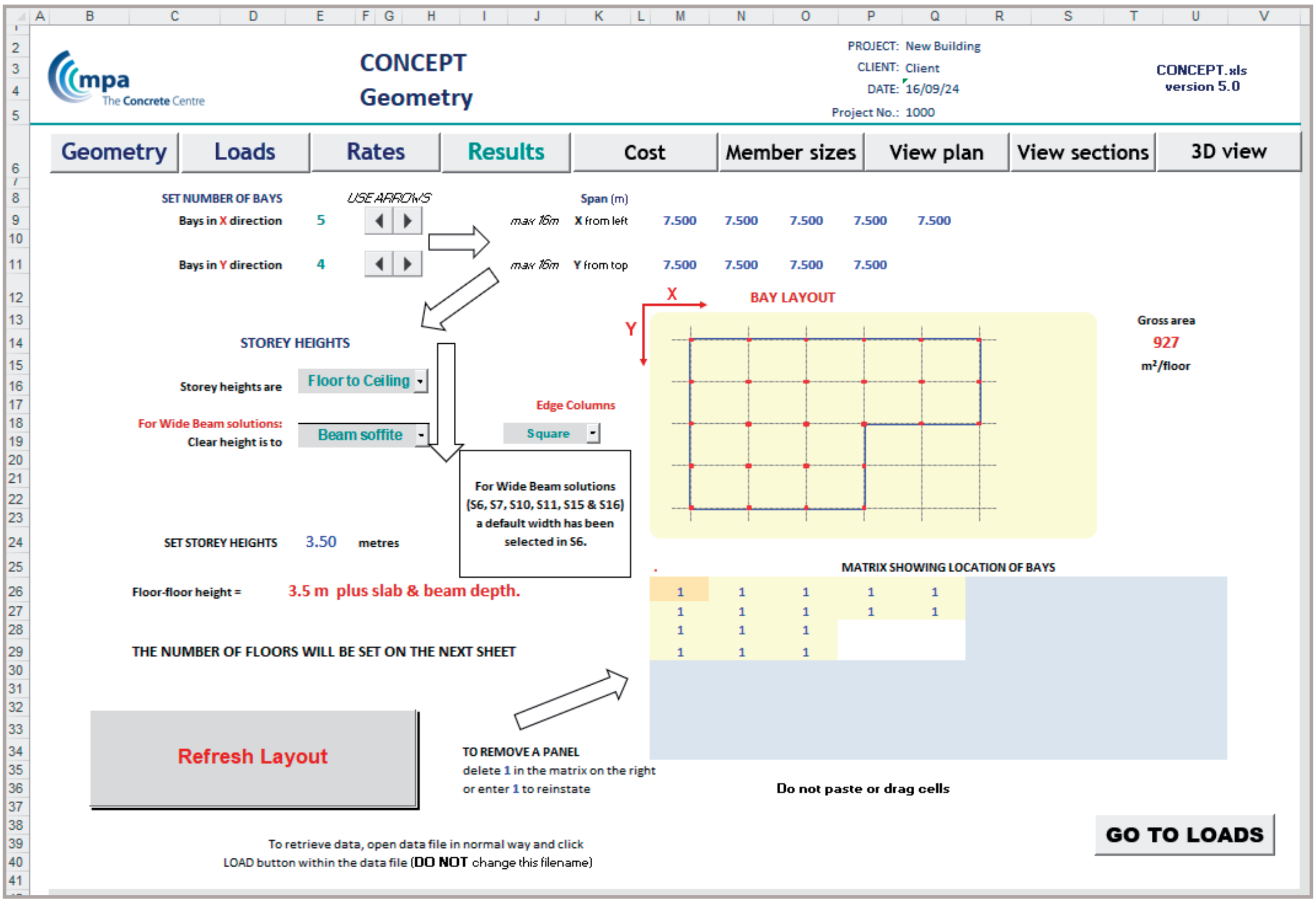
You can add and remove panels (for example if you had an L-shaped building or a central atrium) by deleting or adding "1" to the relevant cell in the matrix below the Bay Layout diagram.

If you experience issues with the 'Refresh Layout' button, ensure you are using Concept on your primary screen - rather than a separate monitor.

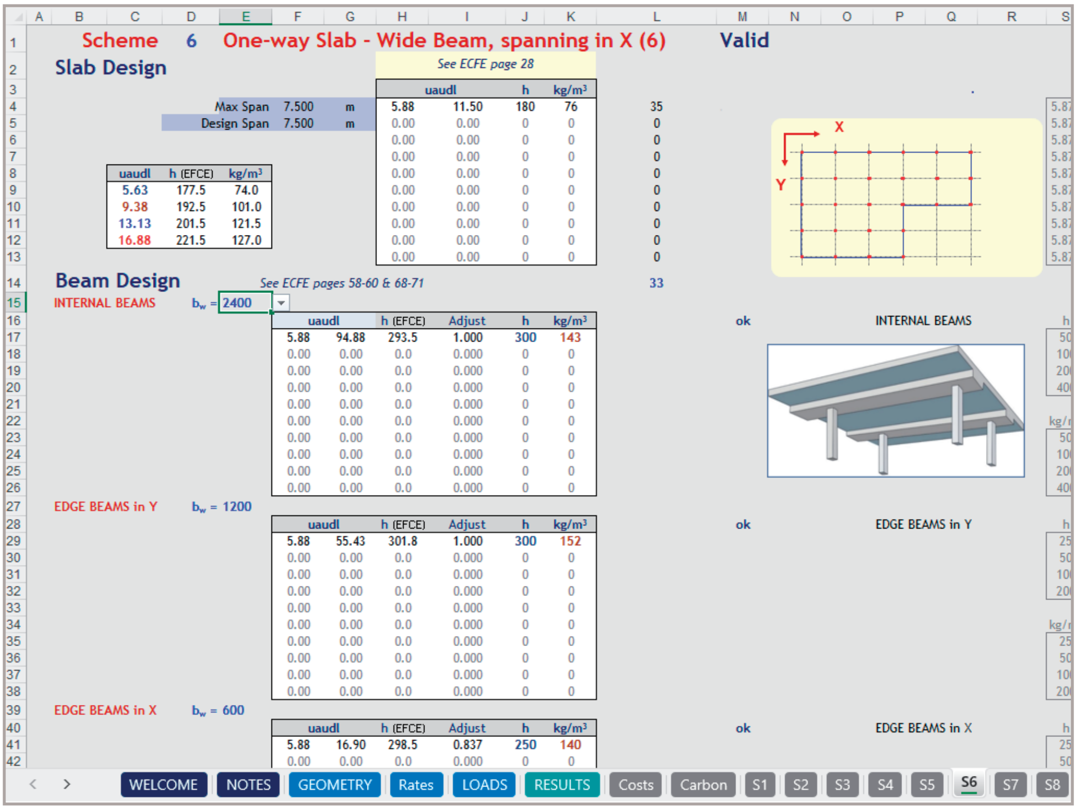


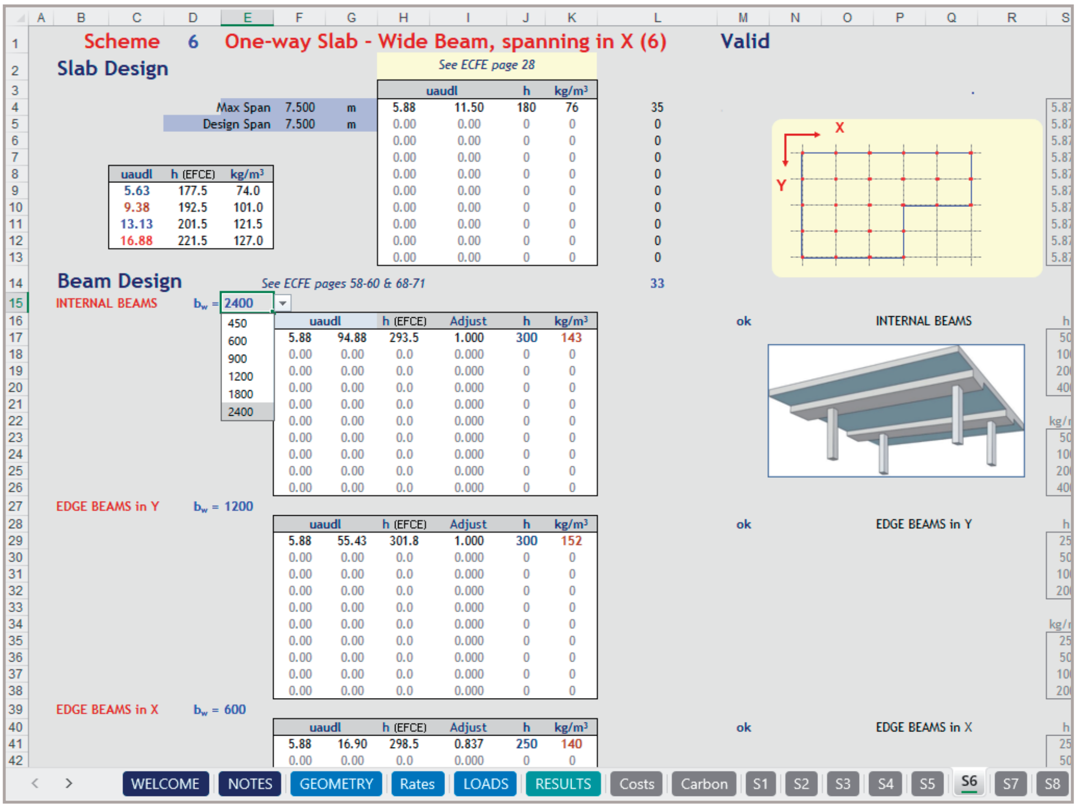


Once geometry has been entered, click 'Refresh Layout' and the image showing the bay layout will update. If you decide to make further changes, click 'Refresh Layout' again. Once you are happy with the geometry, click 'GO TO LOADS'.



For wide beam solutions (for one way slabs, ribbed slabs and troughed slabs), a default beam width is provided in Concept. Users may select an alternative width using the drop down in sheet S6 - this will change the width for all wide beam solutions (on sheets S7, S10, S11, S15 and S16).





Loading

On the loading page, first set the number of storeys using the arrows. Note that level 1 is the first suspended slab above ground floor.

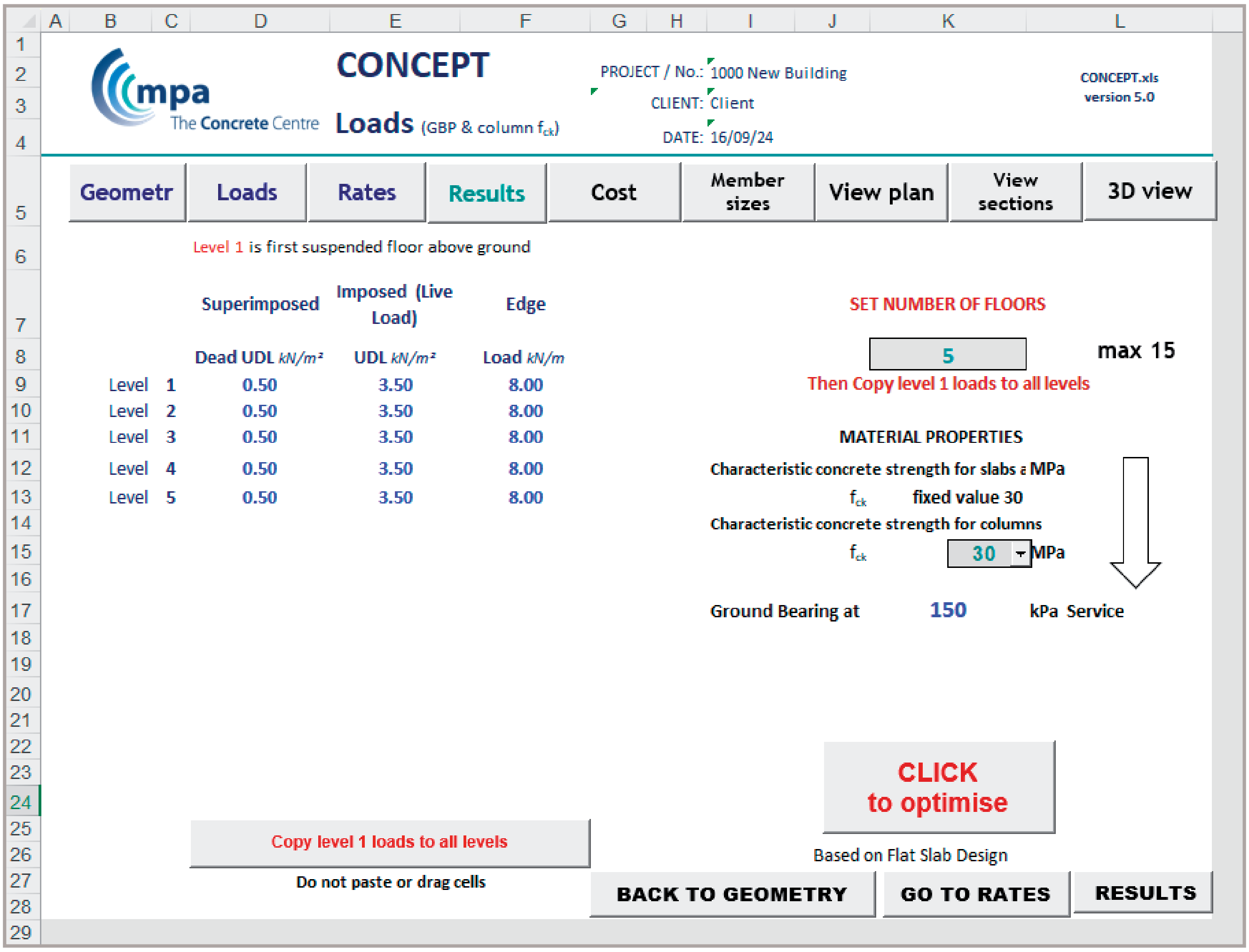
Then set the material properties – the concrete strength for slabs and beams is a fixed value but the column strength may be increased. You can also input the ground bearing pressure if this is known – alternatively leave this as the default value.

Next input floor loading and then use the button below to copy the loading at level 1 to all levels - be careful not to copy and paste or drag cells as this will affect the running of the spreadsheet. You can then modify individual floor loading as required, for example roof loading.

Typical loads are provided for different buildings types within Concept – these loads are for information only and loading should be agreed with the client for each project.

Then 'CLICK to optimise'. Once complete, click 'GO TO RESULTS'.

You can also go to the rates page from here if you want to alter the default values.



Rates

The rates page includes information on unit costs, embodied carbon per cubic metre and programme data. Recommended values are provided – these are based on information from industry and are the default values within the spreadsheet. Users can input their own values based on information available from the project team such as the contractor or quantity surveyor.

The embodied carbon values can be changed depending on the proposed concrete specification. The recommended values given are based on a concrete using CEM IIB cement. This is typical in the industry for designated concretes, but the values are very dependent on the specification of the concrete. CEM IIIA and CEM IIIB cements will give significantly lower results for embodied concrete, but may affect setting times.

EMBODIED CARBON VALUES

Concrete density:	2,380	kg/m^3
Steel density:	7,850	kg/m^3

EMBODIED CARBON VALUES - 'cradle-to-gate'

	Material	A1-A3		A1-A3	
	Concrete				
30	C30/37	230	$kgCO_{2e}/m$	97	$kgCO_{2e}/t$
32	C32/40	240	$kgCO_{2e}/m$	101	$kgCO_{2e}/t$
35	C35/45	250	$kgCO_{2e}/m$	105	$kgCO_{2e}/t$
40	C40/50	260	$kgCO_{2e}/m$	109	$kgCO_{2e}/t$
45	C45/55	270	$kgCO_{2e}/m$	113	$kgCO_{2e}/t$
50	C50/60	280	$kgCO_{2e}/m$	118	$kgCO_{2e}/t$
	Hollowcore				
	150	50	$kgCO_{2e}/m$	335	$kgCO_{2e}/m^3$
	200	57	$kgCO_{2e}/m$	285	$kgCO_{2e}/m^3$
	250	65	$kgCO_{2e}/m$	261	$kgCO_{2e}/m^3$
	300	75	$kgCO_{2e}/m$	251	$kgCO_{2e}/m^3$
	350	85	$kgCO_{2e}/m$	244	$kgCO_{2e}/m^3$
	400	95	$kgCO_{2e}/m$	238	$kgCO_{2e}/m^3$
	450	105	$kgCO_{2e}/m$	234	$kgCO_{2e}/m^3$
	Reinforcement				
	f_{yk} = 500 N/mm²	5,652	$kgCO_{2e}/m$	720	$kgCO_{2e}/t$
	Tendons				
	f_{pk} = 1860 MPa	7,850	$kgCO_{2e}/m$	1,000	$kgCO_{2e}/t$

VALUES RECOMMENDED BY TCC

EMBODIED CARBON VALUES

Material	A1-A3		A1-A3		
Concrete					
C30/37	230	$kgCO_{2e}/m^3$	97	$kgCO_{2e}/t$	Source: BRMCA (2020). Based on a typically available CEMII mix
C32/40	240	$kgCO_{2e}/m^3$	101	$kgCO_{2e}/t$	
C35/45	250	$kgCO_{2e}/m^3$	105	$kgCO_{2e}/t$	
C40/50	260	$kgCO_{2e}/m^3$	109	$kgCO_{2e}/t$	
C45/55	270	$kgCO_{2e}/m^3$	113	$kgCO_{2e}/t$	
C50/60	280	$kgCO_{2e}/m^3$	118	$kgCO_{2e}/t$	
Hollowcore					
150	50	$kgCO_{2e}/m^2$	335	$kgCO_{2e}/m$	Source: EPD (for 150mm, 200-450mm – recalculated according to UK Precast Concrete Hollowcore Flooring) [http://bit.ly/2GSX6cr]
200	57	$kgCO_{2e}/m^2$	285	$kgCO_{2e}/m$	
250	65	$kgCO_{2e}/m^2$	261	$kgCO_{2e}/m$	
300	75	$kgCO_{2e}/m^2$	251	$kgCO_{2e}/m$	
350	85	$kgCO_{2e}/m^2$	244	$kgCO_{2e}/m$	
400	95	$kgCO_{2e}/m^2$	238	$kgCO_{2e}/m$	
450	105	$kgCO_{2e}/m^2$	234	$kgCO_{2e}/m$	
Reinforcement					Source: UK CARES (2024). Understanding UK average embodied carbon emissions for steel reinforcing bar. [https://shorturl.at/qfP6h]
f_{yk} = 500 N/mm²	5,652	$kgCO_{2e}/m^3$	720	$kgCO_{2e}/t$	
Tendons					
f_{pk} = 1860 MPa	7,850	$kgCO_{2e}/m^3$	1,000	$kgCO_{2e}/t$	

Results

When you reach the results page – first check if there are any actions. If there are, you can click the buttons below to go back to the relevant pages and address them.

At the top of the table, you can click to rank the options based on different parameters – cost, programme and embodied carbon – this will then sort the schemes based on this parameter – a traffic light systems shows you how the different parameters compare.

Below the table there are notes explaining what each parameter is based on and which elements are included.

mpa The Concrete Centre

CONCEPT Results (summary)

PROJECT / No.: 1000 New Building
CLIENT: Client
DATE: 16/09/24

CONCEPT.xls version 5.0

Geometry | Loads | Rates | Results | Cost summary | Member sizes | View plan | View sections | 3D view

Click on RANK to Select the Leading Lowest Cost Category

Gross Internal Floor Area = 4,636 m^2

Solution	SCHEME	Solution	Construction cost £k (RANK)	Cost per m2 GIFA £/m²	Construction time Days (RANK)	Total cost cost £k (RANK)	Total cost m2 GIFA £/m²	Structure Cost £k (RANK)	Structure m2 GIFA £/m²	Structure ISEC tCO_2e (RANK)	Structure ISEC per GIFA $kgCO_2/m^2$
14	S14	Waffle Slab (14)	£5,433k	£1,172	105.5	£5,482k	£1,183	£321k	£69	397	85.7
2	S2	Two-way Slab (2)	£5,137k	£1,108	105.5	£5,186k	£1,119	£326k	£70	398	85.8
9	S9	Ribbed Slab, spanning in Y (9)	£5,732k	£1,236	105.5	£5,781k	£1,247	£357k	£77	419	90.3
8	S8	Ribbed Slab, spanning in X (8)	£5,739k	£1,238	105.5	£5,788k	£1,249	£359k	£77	420	90.7
11	S11	Ribbed Slab - Wide Beam, spanning in Y (11)	£5,458k	£1,177	105.5	£5,507k	£1,188	£352k	£76	428	92.4
10	S10	Ribbed Slab - Wide Beam, spanning in X (10)	£5,466k	£1,179	105.5	£5,516k	£1,190	£355k	£76	431	93.0
3	S3	Post-tensioned flat slab (3)	£5,296k	£1,142	80.5	£5,283k	£1,140	£426k	£92	459	99.0
7	S7	One-way Slab - Wide Beam, spanning in Y (7)	£5,185k	£1,118	95.5	£5,209k	£1,124	£371k	£80	461	99.4
6	S6	One-way Slab - Wide Beam, spanning in X (6)	£5,193k	£1,120	95.5	£5,217k	£1,125	£371k	£80	462	99.6
16	S16	Trough Slab - spanning in Y (16)	£5,588k	£1,205	105.5	£5,637k	£1,216	£387k	£83	474	102.2
15	S15	Trough Slab - spanning in X (15)	£5,589k	£1,206	105.5	£5,638k	£1,216	£389k	£84	476	102.7
13	S13	Hollowcore, spanning in Y (13)	£5,287k	£1,140	90.5	£5,299k	£1,143	£470k	£101	482	103.9
12	S12	Hollowcore, spanning in X (12)	£5,310k	£1,145	90.5	£5,322k	£1,148	£473k	£102	485	104.6
5	S5	One-way Slab, spanning in Y (5)	£5,412k	£1,167	95.5	£5,437k	£1,173	£391k	£84	486	104.8
4	S4	One-way Slab, spanning in X (4)	£5,419k	£1,169	95.5	£5,444k	£1,174	£392k	£85	487	105.0
1	S1	Flat Slab (1)	£5,196k	£1,121	85.5	£5,196k	£1,121	£460k	£99	494	106.6

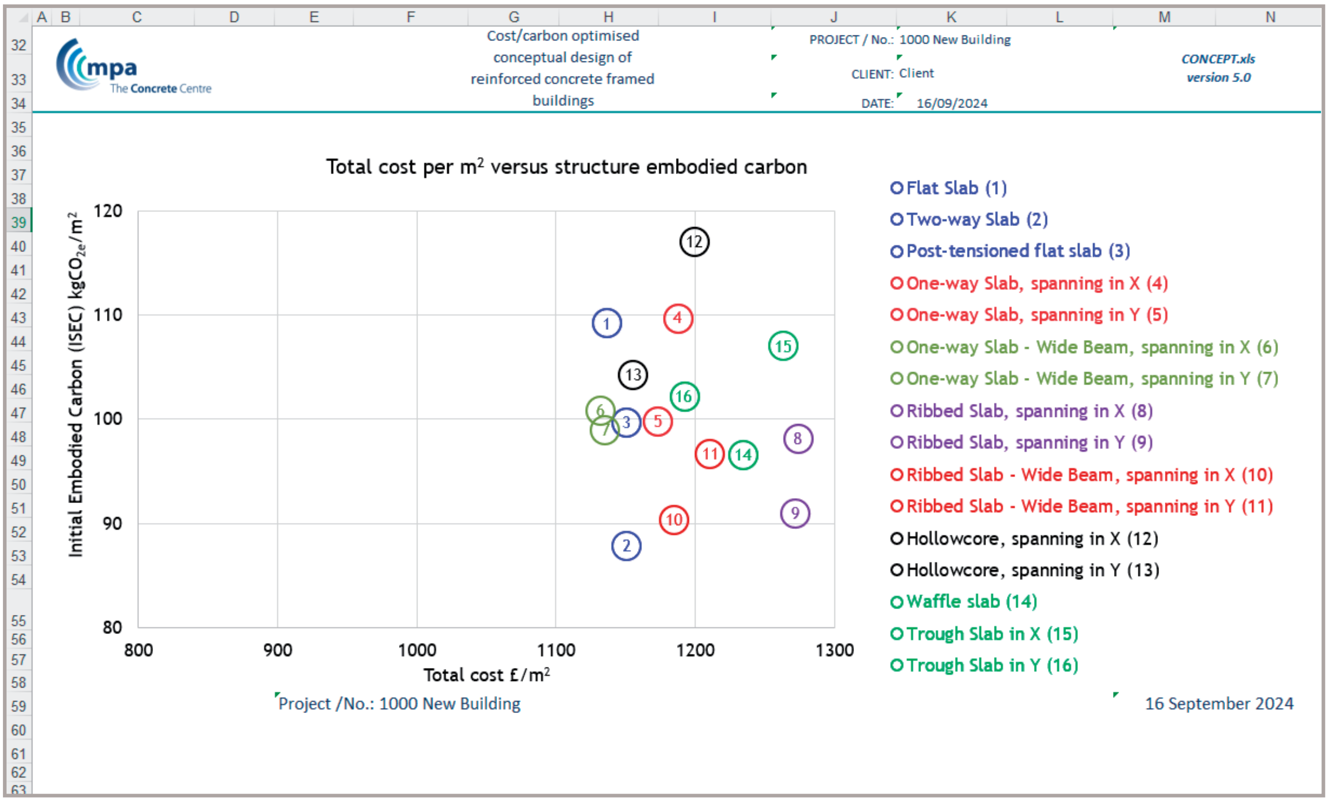
See if actions required:

Notes CONSTRUCTION COST includes ALL COST (material, construction, prelims & external works, mechanical & electrical, cladding, & allows for stairs, shear walls) - see Cost Summary
TOTAL COST includes CONSTRUCTION COSTS + COST OF TIME DIFFERENCE
STRUCTURE COST includes SLAB, BEAMS, COLUMNS, GROUND FLOOR SLAB, FOUNDATIONS
ISEC - Initial Structure Embodied Carbon (A1-A3) - includes SLAB, BEAMS, COLUMNS, GROUND FLOOR SLAB & FOUNDATIONS

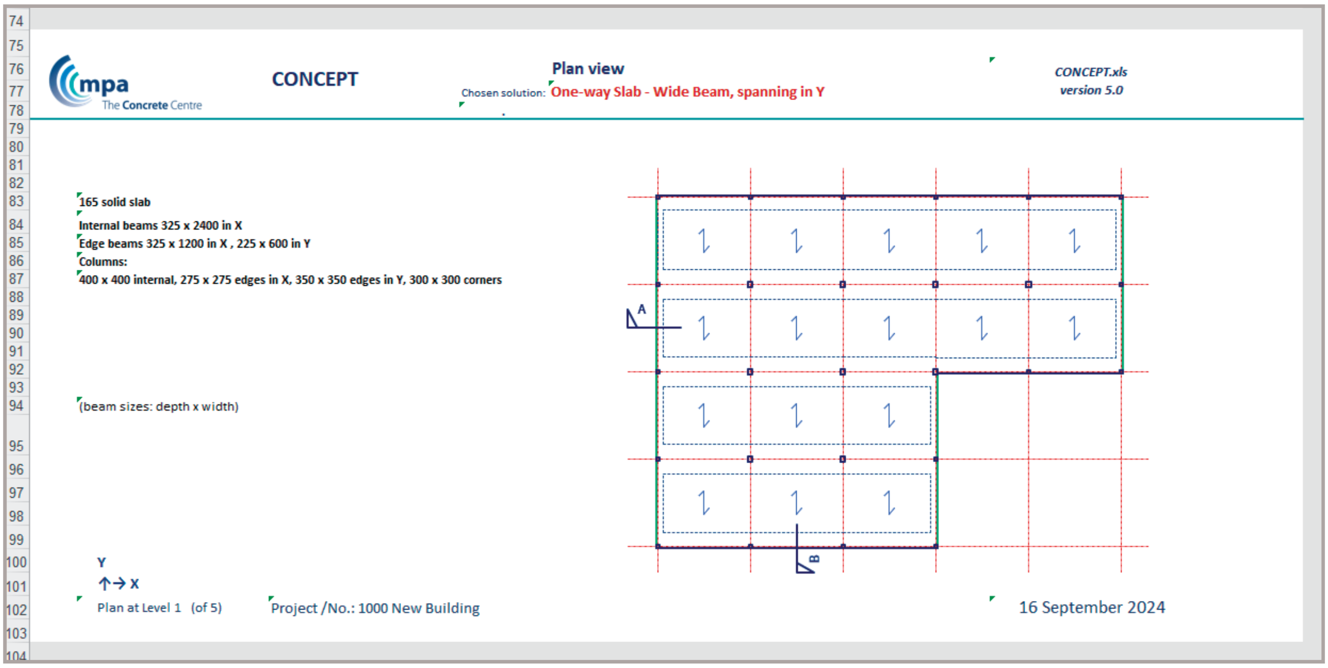
See if actions required:
Column sizes not optimised
Re-optimise for changes

Return to column optimisation | Change the strength of concrete for columns

The graph below is provided further down the results page and is another way to identify the optimum solution for your project.



For each option, you can export different views: plan, section and 3D view. The scheme displayed is selected using the drop down menu.



The costs all include pad foundations. These are sized for the flat slab scheme and the same cost per kN of load is used in the other cases. An internal column load is provided to allow designers to do their own foundation designs, for example using The Concrete Centre spreadsheets for pile caps. If the designer adopts this approach, the foundation cost can be set to zero in the rates page.

How the scheme designs are developed

Concept is based on The Concrete Centre's *Economic Framed Elements (ECFE)* publication and the following assumptions. ECFE contains charts and data that present economic sizes for many types of concrete elements over a range of common loadings and spans. In producing the charts and data, many assumptions have been made. These are more fully described in Section 7 of the ECFE handbook.

Material grades

C30/37 grade concrete and rebar with f_{yk} = 500 N/mm^2 are assumed for all beams and slabs, except post-tensioned flat slabs where concrete grade is assumed as C32/40.

Concrete for columns may be set at grades between C30/37 and C50/60 via the drop-down menu on the LOADS sheet.

Slab design

Concept uses the data provided in the ECFE tables to determine the required slab depth and reinforcement rate based on the span and applied ultimate distributed load (audl) inputs. These will be based on the maximum span and maximum applied load and interpolation is used for spans and loads which are not listed in the tables.

The calculated slab depth required is rounded up to the nearest 5mm and the reinforcement rate is rounded up to the nearest 1kg/m^3.

Beam design

The beam (web) width is determined first by checking the minimum width having a viable solution based on the tables in ECFE. Tables are provided for rectangular, L-beams and T-beams of different widths, typically at 300mm intervals. Users may wish to refer to these for further information. Note: for wide beam solutions, the user may select the beam width on sheet S6.

Beam depths are determined in the same way as slab depths, with the following adjustments:

- when audl < 50 kN/m, the value determined from ECFE is multiplied by $\sqrt{(audl/50)}$
- beam depth must be greater than slab depth + 50mm

The calculated beam depth is rounded up to the nearest 25mm and the reinforcement rate is reduced by a factor of $\sqrt{(h_{requd}/h_{actual})}$.

Additional assumptions for two-way slab solutions

Internal X and Y beams are assumed to have the same web width.

Edge X and Y beams are assumed to have the same web width.

Column design

Internal and corner columns are assumed to be square. The user may select square or rectangular edge columns - for rectangular columns, the larger dimension will be the same as the internal column dimension and the smaller dimension will be reduced.

The maximum reinforcement percentage in any column is assumed to be approximately 4%.

Internal columns are sized assuming the axial load, $N = N_{uz}$ and using a reinforcement percentage of 3.5% (i.e. the columns are designed for the minimum moment).

Edge columns are initially sized using a reinforcement percentage of 4% and by estimating N_{max} (using $N_{max} = N_{bal} + 0.85(N_{uz} - N_{bal})(n-1)/7$, where n = number of storeys supported). Tabulated values of N_{max} are then looked up from a database to match $N_{applied}$.

An algorithm for derivation of rebar simplifies design by adopting a linear interpolation between N_{uz} and N_{bal}.

Final sizes of edge and corner columns are then optimised by operating a macro button.

Foundation design

Pad foundations are assumed in the design. They are sized for the flat slab scheme and a cost per kN is calculated. This is then used to calculate the cost of the foundations for the other schemes.

The depth of the pad is calculated as 0.195 x plan dimension (assumed square) and the reinforcement rate is taken as 50kg/m^3.

The assumed net ground bearing pressure = ground bearing pressure (GBP) - 6 (ground slab) - 0.006 x pad depth.

If other foundations types are proposed, the unit cost may be overridden on the 'Rates' sheet.

How the rates are calculated

The rates for the cost calculations are taken from industry averages in June 2020. Costs can and do change, but normally the relative costs between elements is similar over time, so the recommended rates may still be used for comparison purposes. All the cost rates can be changed to reflect the costs at a particular time and location. The carbon rates given in the table of recommended values are based on industry data and commentary and further information on data sources is provided within the tool. These rates will change over time and are highly dependent on the type of cement chosen for the concrete and the source of the reinforcing and prestressing steel.

Cost calculations

The costs are calculated from the unit rates multiplied by the quantities of formwork, reinforcement, strand and concrete worked out for the different scheme designs. The cost of the foundations are calculated from sizing pad footings for the flat slab scheme, converting this to a cost per kN carried and then applying this to the other options. The costs of the other works are calculated on the basis of a percentage of the total. These percentages can be changed in the Rates section.

Costs for each solution include cladding and an allowance for stairs, shear walls and ground slab, preliminaries, finishes and M&E. Differential costs of construction time are also calculated.

Concept allows the user to rank the different schemes according to construction cost, construction time, total cost, structural cost and superstructure embodied carbon. A traffic light system enables users to compare multiple parameters visually to identify the optimum solution for their project.

Construction time

Times for the construction of each floor are calculated from floor area and rates.

To the construction time for all floors, the following are then added:

- A mobilisation period of 10 days.
- A lead-in time for the first group of nine columns.
- A lead-out time for curing and striking the last sector.
- A demobilisation period of five days.

Construction time is calculated directly only for the flat slab solution, and fixed time differentials per floor are added for other forms of construction.

Carbon calculations

Concrete calculations are based on material quantities calculated as described in the previous section.

Carbon calculations cover cradle-to-gate (A1-A3) impact for all materials, for the superstructure (does not include foundations, but does include ground floor slab). Users can set carbon values for the concrete to be used, however recommended values are included on the Rates sheet.

Cradle-to-gate carbon impact is equivalent to the A1-A3 module outlined in BS EN 15978:2011 and BS EN 15804:2012+A2:2019.

Concept Version 5 can be downloaded for free at www.concretecentre.com/concept.

The *Economic Concrete Frame Elements* publication, upon which the Concept software is based, can be purchased from www.concretecentre.com/publications.

If you have any queries on the use of Concept, or on the results it generates, please send your enquiry to info@concretecentre.com.

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