SMART Portal 2D

Designing open sided building frames

Version: 1.0

GLOBAL CONSTRUCTION
SOFTWARE AND SERVICES

Revision history

Date	Version	Description	Author
26/01/2015	1.0	Initial version for review	RCH
02/02/2015	1.1	Initial publication	RCH

1 Introduction

The current versions of SMART Portal 2D and 3D are configured so as to ease the input of data for portal framed buildings with closed sides. In order to deal with open sided buildings the default wind pressure and suction coefficients must be edited and this requires careful thought. This guide aims to help with this by providing commentary on the relevant code clauses and worked examples. The guide has been written specifically for SMART Portal 2D but is equally applicable to the main frames in SMART Portal 3D. Further guidance or user interpretation may be required for application to the design of purlins, sheeting rails and end frames in SMART Portal 3D. This document may be superseded in due course by specific software support for buildings with open sides.

Pending the release of the Eurocode version of CADS SMART Portal software it is assumed that for the time being, users will refer to the design standards BS 5950-1:2000 and BS 6399-1, 2 and 3 and this temporary guide has been prepared accordingly.

This guide has been prepared with appropriate professional engineering logic and care but it has no official status and its interpretation and application is the responsibility of the user.

2 Relevant BS 6399-2 clauses and tables

The following cases of open sided portal framed buildings can be identified:

- One side open which may be a left, right, near or far side in the SMART Portal convention
- Two adjacent sides open – there are four possible configurations
- Two opposite sides open – two possible configurations
- Three sides open – four possible configurations
- Four sides open

BS 6399-2 treats the `four sides open' case as a canopy and in section 2.5.9.1 gives roof net pressure coefficients in Table 13 for monopitch canopies and table 14 for duopitch canopies. The tables include for fully open and blocked conditions. Multi-span canopies are treated by applying reduction factors to the coefficients for downwind spans according to Table 15.

BS 6399-2 section 2.6.3 requires the other cases of open sides to be treated as enclosed buildings in respect of external pressure coefficients but provides special internal pressure coefficients in Table 18.

A grandstand may fall into either of the above categories depending upon the configuration of its back and side walls if present ie whether they are they full or part height and whether they are supported by the main frames.

Rather than comment further on the text of BS 6399-2 it is proposed to consider some worked examples using SMART Portal in the following sections of this guide. Each example considers one configuration of open sides for a single span building. Common text is repeated between examples in order to avoid the need for cross referencing and interpretation. It is therefore necessary to read only the part of section 3 applicable to the configuration of interest.

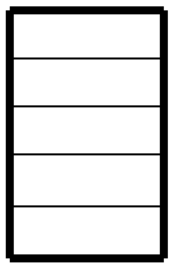
Note that it is not necessary for side cladding to be entirely absent for a side to be considered open. One normal sized open bay is more than sufficient to provide the requisite airflow. Smaller permanent or accidental openings may be worth considering as `dominant openings' under section 2.6.2 of BS 6399-2.

Where the whole side is not fully open but only some bays there are two design conditions to be addressed:

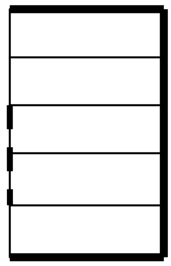
- Frames where the open side column is free standing thereby sustaining negligible direct wind load.
- Frames where the open side column supports attached cladding thereby sustaining direct wind load.

The 17 examples are listed and their wall configurations are shown diagrammatically in plan as follows:

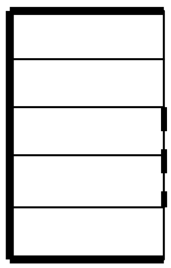
Example 1 All sides clad



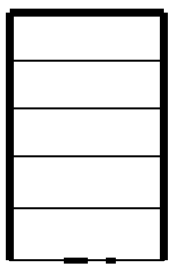
Example 2 Left side partly/fully open



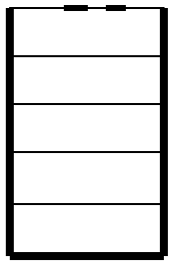
Example 3 Right side fully/partly open



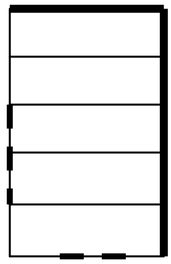
Example 4 Near side fully/partly open



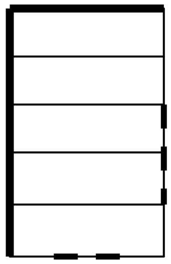
Example 5 Far side fully/partly open



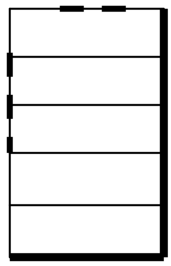
Example 6 Near and left sides fully/partly open



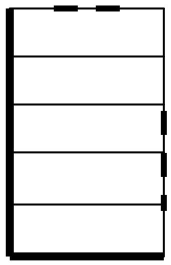
Example 7 Near and right sides fully/partly open



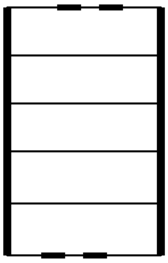
Example 8 Far and left sides fully/partly open



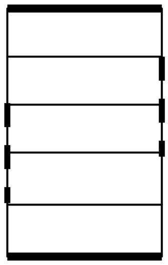
Example 9 Far and right sides fully/partly open



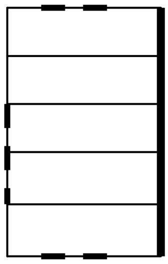
Example 10 Near and far sides fully/partly open



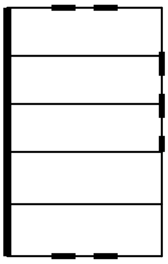
Example 11 Left and right sides fully/partly open



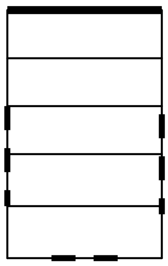
Example 12 Near, far and left sides fully/partly open



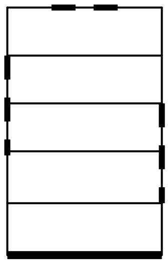
Example 13 Near, far and right sides fully/partly open



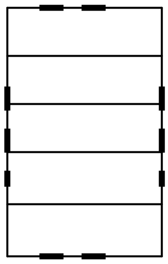
Example 14 Near, left and right sides fully/partly open



Example 15 Far, left and right sides fully/partly open



Example 16 All sides fully/partly open



Example 17 All sides fully open (canopy)

For instructions on editing the default wind parameters given in section 3.1 refer to the relevant section 3.2 ….3.17 below for the building proposed. It is not necessary to read the other sections. Note that the wind pressure coefficients given in the examples are for the given frame dimensions and different values of the external wind coefficients may result from interpolating in the relevant tables for a particular building design.

Finally it may be noted that for main frame design the most onerous wind condition arises when either the left or right side column supports cladding and the other column is freestanding.

3 Worked examples

3.1 Duopitch portal frame building with all sides clad

This example is the benchmark or reference frame against which open sided variations may be compared. It consists of a symmetrical single 20 m span building with 5 degree pitch roof and 5.0 m eaves height. There are 6 no 6.0 m bays. For simplicity the effective wind speed is taken as 35 m/s in all directions. This produces a wind–critical design for this building with closed sides and 10% fixity base connections whereas 30 m/s does not.

The following screenshots show the wind parameter input pages with default coefficients for the case of a building with closed sides.

Wind parameters - BS6399 pt2

Accept or edit the general parameters applicable for the entire building

Wind Blowing From	Left	Right	Near	Far
Effective Wind Speed (Ve)	35.000	35.000	35.000	35.000
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.739	0.739	0.739	0.739
Basic Pressure Coefficient	0.200	0.200	0.200	0.200
Factored Pressure Coefficient	0.152	0.152	0.152	0.152
Basic Suction Coefficient	-0.300	-0.300	-0.300	-0.300

Analysis Mode: Standard / Hybrid

Restore Current | Restore All

Fig 1.1 Internal surface coefficients

Wind Load - BS6399pt2-Span 1

Accept or edit the member wind loading parameters for the specific span.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

Fig 1.2 Left and right wall external surface coefficients

Wind Blowing From	Left	Right	Near	Far
Left Roof/Rafter				
Size Effect Factor Ca	0.936	0.936	0.936	0.936
Basic Main Zone Coefficient	-0.600	-0.400	-0.600	-0.500
Basic Edge Zone Coefficient	-1.800	-0.900	-0.600	-0.500
Edge Zone Width (m)	1.265	1.265	0.000	0.000
Reduction Factor	0.600	1.000	1.000	1.000
Factored Main Zone Coefficient	-0.347	-0.386	-0.579	-0.482
Factored Edge Zone Coefficient	-1.042	-0.868	-0.579	-0.482

Fig 1.3 Left roof slope external surface coefficients

Wind Blowing From	Left	Right	Near	Far
Right Roof/Rafter				
Size Effect Factor Ca	0.936	0.936	0.936	0.936
Basic Main Zone Coefficient	-0.400	-0.600	-0.600	-0.500
Basic Edge Zone Coefficient	-0.900	-1.800	-0.600	-0.500
Edge Zone Width (m)	1.265	1.265	0.000	0.000
Reduction Factor	1.000	0.600	1.000	1.000
Factored Main Zone Coefficient	-0.386	-0.347	-0.579	-0.482
Factored Edge Zone Coefficient	-0.868	-1.042	-0.579	-0.482

Fig 1.4 Right roof slope external surface coefficients

With 10 % base partial fixity for deflection only, limiting height/horizontal deflection ratio 200, grade S275 steel and 7.5% span haunch lengths, the sections produced by autodesign are:

Rafters: 356 x 171 UKB 45 Columns: 406 x 178 UKB 60 Steel weight per frame: 1717 kg

These sections were selected from the UKB preferred list.

3.2 Duopitch portal frame building with left side open

The following text explains the modifications to be made for an open left side. The procedure is the same but `handed' for an open right side but is given in full in section 3.3 to avoid cross referencing and interpretation. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2.

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60	–0.46	–0.57	–0.63
	+0.52	+0.67	+0.77	+0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension (a) for internal pressure is the diagonal dimension of the open face. In the present example if the whole left face is open the diagonal dimension is given with sufficient accuracy by:

$$a = \mathrm{Sqrt}\{36^2 + 5^2\} = 36.3 \quad \text{m}$$

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.85

If only one bay is open a = Sqrt{$6^2 + 5^2$} = 7.8 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.96

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1.1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

In BS 6399-2 Table 18, left wind equates to wind 0^o blowing into the open longer face for which Cpi = 0.80. Therefore edit the default internal surface coefficient from +0.20 to + 0.80.

There is no corresponding suction value for this wind direction so leave the default value – 0.30 unchanged.

Internal surface coefficients – wind blowing from right

This direction equates to 180^o in table 18 for which Cpi = -0.43. Therefore edit the default internal suction coefficient from -0.300 to -0.43.

There is no corresponding internal pressure value in table 18 for this wind direction so leave the default value + 0.200 unchanged.

Internal surface coefficients – wind blowing on near end

This direction equates to wind 90^o in table 18 for which Cpi = + 0.67 or -0.46. These values actually correspond to wind directions slightly oblique to 90^o. The positive pressure value occurs when the inclination directs the wind into the building whilst the negative suction value occurs when the inclination directs the wind away from the building. Therefore edit the default values +0.20 and -0.30 to +0.67 and -0.46 respectively.

Internal surface coefficients – wind blowing on far end

The internal coefficient values apply equally to far and near end wind.

After editing the internal surface coefficients should appear as shown in fig 5 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.800	0.200	0.670	0.670
Factored Pressure Coefficient	0.742	0.186	0.622	0.622
Basic Suction Coefficient	-0.300	-0.430	-0.460	-0.460
Factored Suction Coefficient	-0.278	-0.399	-0.427	-0.427

Fig 2.1 Internal surface coefficients after editing for open left side.

External surface coefficients

The external surface coefficients for main frames are unchanged except for the open left side. The coefficients for the left side depend on the situation at the frame being considered for design. As previously noted (in section 2), the whole of the left side may be unclad or the opening may be restricted to one or more bays. In this latter case there are clearly two or more wind loading conditions which need to be considered and, if necessary, justified.

In the current version of SMART Portal 2D it is necessary to run these cases separately.

For the case where the left column has cladding attached both sides (the opening being one or more bays distant), the treatment is simple because the external pressure or suction can co-exist with either internal pressure or suction. The problem reduces to the normal `all sides clad' case with enhanced internal pressures and suctions and no further editing is required. We will refer to this as case 1. Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This represents a 5% increase over the design for the equivalent closed sided building. In other circumstances the difference could be lesser or greater.

At the other extreme a left column may have no cladding attached in which case it will attract only negligible wind force. Although this results in lesser direct wind force on the column, the overall effect on the frame and the column stability may be critical. We will refer to this as case 2. In principle this case may be modelled by applying left external surface coefficients equal and opposite to the internal surface coefficients. Unfortunately the current versions of SMART Portal provide only one set of external surface coefficients per wind direction which are combined with the two sets of internal coefficients. Forthcoming versions of the software will provide two sets of external coefficients which will also cater for the cases where the wind code provides alternative + and – coefficients for the windward roof slopes. In the meantime it is necessary to exercise some engineering judgement and approximations in order to use the software safely and economically. Alternatively two versions of the frame can be run:-

- Case 2a: with the left column subject to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic coeff = 0.742/(1.031 x 0.963) = 0.747.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.747	0.187	0.626	0.626
Factored Pressure Coefficient	0.742	0.186	0.622	0.622
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

  Fig 2.2 Edited external surface coefficients for case 2a.

  Autodesign produces the following sections for this case:

  Rafters: 406 x 178 UKB 54 Columns: 533 x 210 UKB 82 Steel weight per frame: 2182 kg

  This represents a 27% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2b: with the left column subject to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind right basic coeff = 0.399/(1.031 x 0.963) = 0.402.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.280	-0.402	-0.430	-0.430
Factored Pressure Coefficient	-0.278	-0.399	-0.427	-0.427
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

Fig 2.3 shows the edited external surface coefficients for case 2b.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 457 x 191 UKB 74 Steel weight per frame: 2089 kg

This represents a 22% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater. The internal pressure case 2a therefore governs the design

3.3 Duopitch portal frame building with right side open

The following text explains the modifications to be made for an open right side. The procedure is the same but `handed' for an open left side but is given in full in section 3.2 to avoid cross referencing. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60	–0.46	–0.57	–0.63
	+0.52	+0.67	+0.77	+0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole left face is open the diagonal dimension is given with sufficient accuracy by:

a = Sqrt{$36^2 + 5^2$} = 36.3 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.85

If only one bay is open a = Sqrt{$6^2 + 5^2$} = 7.8 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.96

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1.1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

This direction equates to 180° in table 18 for which Cpi = -0.43. Therefore edit the default internal suction coefficient from -0.300 to -0.43.

There is no corresponding internal pressure value in table 18 for this wind direction so leave the default value + 0.200 unchanged.

Internal surface coefficients – wind blowing from right

In BS 6399-2 Table 18, right wind equates to wind 0° blowing into the open longer face for which Cpi = 0.80. Therefore edit the default internal pressure coefficient from +0.20 to + 0.80.

There is no corresponding suction value for this wind direction so leave the default value – 0.30 unchanged.

Internal surface coefficients – wind blowing on near end

This direction equates to wind 90° in table 18 for which Cpi = + 0.67 or -0.46. These values actually correspond to wind directions slightly oblique to 90°. The positive pressure value occurs when the inclination directs the wind into the building whilst the negative suction value occurs when the inclination directs the wind away from the building. Therefore edit the default values +0.20 and -0.30 to +0.67 and -0.46 respectively.

Internal surface coefficients – wind blowing on far end

The internal coefficient values apply equally to far and near end wind.

After editing the internal surface coefficients should appear as shown in fig 3.1 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.200	0.800	0.670	0.670
Factored Pressure Coefficient	0.186	0.742	0.622	0.622
Basic Suction Coefficient	-0.430	-0.300	-0.460	-0.460
Factored Suction Coefficient	-0.399	-0.278	-0.427	-0.427

Fig 3.1 Internal surface coefficients after editing for open right side.

External surface coefficients

The external surface coefficients for main frames are unchanged except for the open right side. The coefficients for the right side depend on the situation at the frame being considered for design. As previously noted (in section 2), the whole of the right side may be unclad or the opening may be restricted to one or more bays. In this latter case there are clearly two or more wind loading conditions which need to be considered and if necessary justified.

In the current version of SMART Portal 2D it is necessary to run these cases separately.

For the case where the right column has cladding attached both sides (the opening being one or more bays distant), the treatment is simple because the external pressure or suction can co-exist with either internal pressure or suction. The problem reduces to the normal `all sides clad' case with enhanced internal pressures and suctions and no further editing is required. We will refer to this as case 1. Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This represents a 5% increase over the design for a closed sided building. In other circumstances the difference would be lesser or greater.

At the other extreme a right column may have no cladding attached in which case it will attract only negligible wind force. Although this results in lesser direct wind force on the column, the overall effect on the frame and the stability of the column may be critical. We will refer to this as case 2. In principle this case may be modelled by applying right side external surface coefficients equal and opposite to the internal coefficients. Unfortunately the current versions of SMART Portal provide only one set of external surface coefficients per wind direction which are combined with the two sets of internal coefficients. Forthcoming versions of the software will provide two sets of external coefficients which will also cater for the cases where the wind code provides alternative + and – coefficients for the windward roof slopes. In the meantime it is necessary to exercise some engineering judgement and approximations in order to use the software safely and economically. Alternatively two versions of the frame can be run:-

- Case 2a: with the right column subject to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind right basic coeff = 0.742/(1.031 x 0.963) = 0.747.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.187	0.747	0.626	0.626
Factored Pressure Coefficient	0.186	0.742	0.622	0.622

Fig 3.2 Edited external surface coefficients for case 2a.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 533 x 210 UKB 82 Steel weight per frame: 2182 kg

This represents a 27% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2b with the right column subject to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind right basic coeff = -0.399/(1.031 x 0.963) = -0.402.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.280	-0.402	-0.430	-0.430
Factored Pressure Coefficient	-0.278	-0.399	-0.427	-0.427

Fig 3.3 Edited external surface coefficients for case 2b

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 457 x 191 UKB 74 Steel weight per frame: 2089 kg

This represents a 22% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater. The internal pressure case 2a therefore governs the design

3.4 Duopitch portal building with near side open

The following text explains the modifications to be made for an open near side. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60	–0.46	–0.57	–0.63
	+0.52	+0.67	+0.77	+0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole near face is open the diagonal dimension is given with sufficient accuracy by:

$$a = \text{Sqrt}\{20^2 + 5^2\} = 20.6 \text{ m}$$

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.89

If only a quarter of the side is open $a = \text{Sqrt}\{5^2 + 5^2\} = 7.1$ m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.98

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1.1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

This direction equates to 90^{o} in table 18 for which Cpi = -0.60 and +0.52. These values actually correspond to wind directions slightly oblique to 90^{o}. The positive pressure value occurs when the inclination directs the wind into the building whilst the negative suction value occurs when the inclination directs the wind away from the building. Therefore edit the default internal coefficients from -0.300 and +0.20 to -0.60 and +0.52.

Internal surface coefficients – wind blowing from right

This direction equates to 90^{o} in table 18 for which Cpi = -0.60 and +0.52. The positive pressure value occurs when the inclination directs the wind into the building whilst the negative suction value occurs when the inclination directs the wind away from the building. Therefore edit the default internal coefficients from -0.300 and +0.20 to -0.60 and +0.52.

Internal surface coefficients – wind blowing on near end

This direction equates to 0^{o} in table 18 for which Cpi = +0.85. There is no corresponding suction value so leave the default -0.30 unchanged.

Internal surface coefficients – wind blowing on far end

This direction equates to 180^{o} in table 18 for which Cpi = -0.39 There is no corresponding pressure value so leave the default +0.20 unchanged.

After editing, the internal surface coefficients should appear as shown in fig 4.1 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.520	0.520	0.850	0.200
Factored Pressure Coefficient	0.483	0.483	0.789	0.186
Basic Suction Coefficient	-0.600	-0.600	-0.300	-0.390
Factored Suction Coefficient	-0.557	-0.557	-0.278	-0.362

Fig 4.1 Internal surface coefficients after editing for open near side.

External surface coefficients

The external surface coefficients for main frames are unchanged from the default values for a building with closed sides.

Autodesign produces the following sections for this example:

Rafters: 356 x 171 UKB 51   Columns: 406 x 178 UKB 60   Steel weight per frame: 1854 kg

This represents a 8% increase over the design for a closed sided building. In other circumstances the difference would be lesser or greater.

3.5 Duopitch portal building with far side open

The following text explains the modifications to be made for an open far side. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60 +0.52	–0.46 +0.67	–0.57 +0.77	–0.63 +0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole near face is open the diagonal dimension is given with sufficient accuracy by:

a = Sqrt{$20^2 + 5^2$} = 20.6 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.89

If only a quarter of the side is open a = Sqrt{$5^2 + 5^2$} = 7.1 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.98

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1.1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

This direction equates to 90° in table 18 for which Cpi = -0.60 and +0.52. These values actually correspond to wind directions slightly oblique to 90°. The positive pressure value occurs when the inclination directs the wind into the building whilst the negative suction value occurs when the inclination directs the wind away from the building.Therefore edit the default internal coefficients from -0.300 and +0.20 to -0.60 and +0.52.

Internal surface coefficients – wind blowing from right

This direction equates to 90° in table 18 for which Cpi = -0.60 and +0.52. The positive pressure value occurs when the inclination directs the wind into the building whilst the negative suction value occurs when the inclination directs the wind away from the building. Therefore edit the default internal coefficients from -0.300 and +0.20 to -0.60 and +0.52.

Internal surface coefficients – wind blowing on near end

This direction equates to 180° in table 18 for which Cpi = -0.39 There is no corresponding pressure value so leave the default +0.20 unchanged.

Internal surface coefficients – wind blowing on far end

This direction equates to 0° in table 18 for which Cpi = +0.85. There is no corresponding suction value so leave the default -0.30 unchanged.

After editing the internal surface coefficients should appear as shown in fig 5.1 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.520	0.520	0.200	0.850
Factored Pressure Coefficient	0.483	0.483	0.186	0.789
Basic Suction Coefficient	-0.600	-0.600	-0.390	-0.300
Factored Suction Coefficient	-0.557	-0.557	-0.362	-0.278

Fig 5.1 Internal surface coefficients after editing for open far side.

External surface coefficients

The external surface coefficients for main frames are unchanged from the default values for a building with closed sides.

Autodesign produces the following sections for this example:

Autodesign produces the following sections for this example:

Rafters: 356 x 171 UKB 51   Columns: 406 x 178 UKB 60   Steel weight per frame: 1854 kg

This represents a 8% increase over the design for a closed sided building. In other circumstances the difference would be lesser or greater.

3.6 Duopitch portal building with near and left sides open

The following text explains the modifications to be made for two adjacent sides open. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2:

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60	–0.46	–0.57	–0.63
	+0.52	+0.67	+0.77	+0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole left face is open the diagonal dimension is given with sufficient accuracy by:

a = Sqrt{36^2 + 5^2} = 36.3 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.85

If only one bay is open a = Sqrt{6^2 + 5^2} = 7.8 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.96

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

In BS 6399-2 Table 18, left wind equates to wind 0° blowing into the open side face for which Cpi = 0.77. Therefore edit the default internal pressure coefficient from +0.20 to + 0.77.

There is no corresponding suction value for this wind direction so leave the default value – 0.30 unchanged.

Internal surface coefficients – wind blowing from right

This direction equates to 180° in table 18 for which Cpi = -0.60. Therefore edit the default internal suction coefficient from -0.300 to -0.60.

There is no corresponding internal pressure value in table 18 for this wind direction so leave the default value + 0.200 unchanged.

Internal surface coefficients – wind blowing on near end

This direction equates to wind 90° in table 18 for which Cpi = + 0.77 or -0.57. The positive coefficient corresponds to wind blowing into the open near end. Therefore edit the default values +0.20 and -0.30 to +0.77 and -0.30 respectively.

Internal surface coefficients – wind blowing on far end

This direction equates to wind 90° in table 18 for which Cpi = + 0.77 or -0.57. The negative coefficient corresponds to wind blowing onto the closed far end. Therefore edit the default values +0.20 and -0.30 to +0.20 and -0.57 respectively.

After editing the internal surface coefficients should appear as shown in fig 6.1 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.770	0.200	0.770	0.200
Factored Pressure Coefficient	0.715	0.186	0.715	0.186
Basic Suction Coefficient	-0.300	-0.600	-0.300	-0.570
Factored Suction Coefficient	-0.278	-0.557	-0.278	-0.529

Fig 6.1 Internal surface coefficients after editing for open left and near sides.

External surface coefficients

The external surface coefficients for main frames are unchanged except for the open left side. The coefficients for the left side depend on the situation at the frame being considered for design. As previously noted (in section 2), the whole of the left side may be unclad or the opening may be restricted to one or more bays. In this latter case there are clearly two or more wind loading conditions which need to be considered and if necessary justified.

In the current version of SMART Portal 2D it is necessary to run these cases separately.

For the case where the left column has cladding attached both sides (the opening being one or more bays distant), the treatment is simple because the external pressure or suction can co-exist with either internal pressure or suction. The problem reduces to the normal `all sides clad' case with enhanced internal pressures and suctions and no further editing is required. We will refer to this as case 1. Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This solution is the same as left or right side open only and represents a 5% weight increase over the design for a closed sided building. In other circumstances the difference would be lesser or greater.

At the other extreme a left column may have no cladding attached in which case it will attract only negligible wind force. Although this results in lesser direct wind force on the column, the overall effect on the frame and the column stability may be critical. We will refer to this as case 2. In principle this case may be modelled by applying left external surface coefficients equal and opposite to the internal surface coefficients. Unfortunately the current versions of SMART Portal provide only one set of external surface coefficients per wind direction which are combined with the two sets of internal coefficients. Forthcoming versions of the software will provide two sets of external coefficients which will also cater for the cases where the wind code provides alternative + and – coefficients for the windward roof slopes. In the meantime it is necessary to exercise some engineering judgement and approximations in order to use the software safely and economically. Alternatively two versions of the frame can be run:-

- Case 2a: with the left column subject to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic coeff = 0.715/(1.031 x 0.963) = 0.720.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.720	0.187	0.720	0.187
Factored Pressure Coefficient	0.715	0.186	0.715	0.186
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

Fig 6.2 Edited external surface coefficients for case 6a

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 60 Columns: 533 x 210 UKB 82 Steel weight per frame: 2319 kg

This represents a 35% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2b with the left column subject to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind right basic coefficient = -0.557/(1.031 x 0.963) = 0.561.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.280	-0.561	-0.280	-0.574
Factored Pressure Coefficient	-0.278	-0.557	-0.278	-0.570
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

Fig 6.3 Edited external surface coefficients for case 6b

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 533 x 210 UKB 82 Steel weight per frame: 2182 kg

This represents a 27% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater. The internal pressure case 2a therefore governs the design

3.7 Duopitch portal building with near and right sides open

The following text explains the modifications to be made for two adjacent sides open. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2:

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60 +0.52	–0.46 +0.67	–0.57 +0.77	–0.63 +0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole left face is open the diagonal dimension is given with sufficient accuracy by:

a = Sqrt{$36^2 + 5^2$} = 36.3 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.85

If only one bay is open a = Sqrt{$6^2 + 5^2$} = 7.8 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.96

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

This direction equates to 180^{o} in table 18 for which Cpi = -0.60. Therefore edit the default internal suction coefficient from -0.300 to -0.60.

There is no corresponding internal pressure value in table 18 for this wind direction so leave the default value + 0.200 unchanged.

Internal surface coefficients – wind blowing from right

In BS 6399-2 Table 18, right wind equates to wind 0^{o} blowing into the open side face for which Cpi = 0.77. Therefore edit the default internal pressure coefficient from +0.20 to + 0.77.

There is no corresponding suction value for this wind direction so leave the default value – 0.30 unchanged.

Internal surface coefficients – wind blowing on near end

This direction equates to wind 90^{o} in table 18 for which Cpi = + 0.77 or -0.57. The positive coefficient corresponds to wind blowing into the open near end. Therefore edit the default values +0.20 and -0.30 to +0.77 and -0.30 respectively.

Internal surface coefficients – wind blowing on far end

This direction equates to wind 90^{o} in table 18 for which Cpi = + 0.77 or -0.57. The negative coefficient corresponds to wind blowing onto the closed far end. Therefore edit the default values +0.20 and -0.30 to +0.20 and -0.57 respectively.

After editing the internal surface coefficients should appear as shown in fig 7.1 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.200	0.770	0.770	0.200
Factored Pressure Coefficient	0.186	0.715	0.715	0.186
Basic Suction Coefficient	-0.600	-0.300	-0.300	-0.570
Factored Suction Coefficient	-0.557	-0.278	-0.278	-0.529

Fig 7.1 Internal surface coefficients after editing for open near and right sides.

External surface coefficients

The external surface coefficients for main frames are unchanged except for the open right side. The coefficients for the right side depend on the situation at the frame being considered for design. As previously noted (in section 2), the whole of the right side may be unclad or the opening may be restricted to one or more bays. In this latter case there are clearly two or more wind loading conditions which need to be considered and if necessary justified.

In the current version of SMART Portal 2D it is necessary to run these cases separately.

For the case where the right column has cladding attached both sides (the opening being one or more bays distant), the treatment is simple because the external pressure or suction can co-exist with either internal pressure or suction. The problem reduces to the normal `all sides clad' case with enhanced internal pressures and suctions and no further editing is required. We will refer to this as case 1. Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This solution is the same as left or right side open only and represents a 5% weight increase over the design for a closed sided building. In other circumstances the difference would be lesser or greater.

At the other extreme a right column may have no cladding attached in which case it will attract only negligible wind force. Although this results in lesser direct wind force on the column, the overall effect on the frame and the column stability may be critical. We will refer to this as case 2. In principle this case may be modelled by applying right side external surface coefficients equal and opposite to the internal pressure coefficients. Unfortunately the current versions of SMART Portal provide only one set of external surface coefficients per wind direction which are combined with the two sets of internal coefficients. Forthcoming versions of the software will provide two sets of external coefficients which will also cater for the cases where the wind code provides alternative + and – coefficients for the windward roof slopes. In the meantime it is necessary to exercise some engineering judgement and approximations in order to use the software safely and economically. Alternatively two versions of the frame can be run:-

- Case 2a: with the right column subject to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to \`ignore'. Note that it is the \`factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind right basic coeff = 0.715/(1.031 x 0.963) = 0.720.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.720	0.187	0.720	0.187
Factored Pressure Coefficient	0.715	0.186	0.715	0.186

  Fig 7.2 Edited external surface coefficients for case 2a

  Autodesign produces the following sections for this case:

  Rafters: 406 x 178 UKB 60 Columns: 533 x 210 UKB 82 Steel weight per frame: 2319 kg

  This represents a 35% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2b with the right column subject to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to \`ignore'. Note that it is the \`factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind right basic coefficient = -0.557/(1.031 x 0.963) = 0.561.

Wind Blowing From	Left	Right	Near	Far
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.280	-0.561	-0.280	-0.561
Factored Pressure Coefficient	-0.278	-0.557	-0.278	-0.557
Left Roof/Rafter				

Fig 7.3 Edited external surface coefficients for case 2b

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 457 x 191 UKB 67 Steel weight per frame: 2007 kg

This represents a 17% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater. The internal pressure case 2a therefore governs the design

3.8 Duopitch portal building with far and left sides open

The following text explains the modifications to be made for two adjacent sides open. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2:

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60	–0.46	–0.57	–0.63
	+0.52	+0.67	+0.77	+0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole left face is open the diagonal dimension is given with sufficient accuracy by:

a = Sqrt{$36^2 + 5^2$} = 36.3 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.85

If only one bay is open a = Sqrt{$6^2 + 5^2$} = 7.8 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.96

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

In BS 6399-2 Table 18, left wind equates to wind 0^{o} blowing into the open side face for which Cpi = 0.77. Therefore edit the default internal pressure coefficient from +0.20 to + 0.77.

There is no corresponding suction value for this wind direction so leave the default value – 0.30 unchanged.

Internal surface coefficients – wind blowing from right

This direction equates to 180^{o} in table 18 for which Cpi = -0.60. Therefore edit the default internal suction coefficient from -0.300 to -0.60.

There is no corresponding internal pressure value in table 18 for this wind direction so leave the default value + 0.200 unchanged.

Internal surface coefficients – wind blowing on near end

This direction equates to wind 90^{o} in table 18 for which Cpi = + 0.77 or -0.57. The negative coefficient corresponds to wind blowing onto the closed near end. Therefore edit the default values +0.20 and -0.30 to +0.20 and -0.57 respectively.

Internal surface coefficients – wind blowing on far end

This direction equates to wind 90^{o} in table 18 for which Cpi = + 0.77 or -0.57. The positive coefficient corresponds to wind blowing into the open far end. Therefore edit the default values +0.20 and -0.30 to +0.77 and -0.30 respectively.

After editing the internal surface coefficients should appear as shown in fig 8.1 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.770	0.200	0.200	0.770
Factored Pressure Coefficient	0.715	0.186	0.186	0.715
Basic Suction Coefficient	-0.300	-0.600	-0.570	-0.300
Factored Suction Coefficient	-0.278	-0.557	-0.529	-0.278

Fig 8.1 Internal surface coefficients after editing for open left and far sides.

External surface coefficients

The external surface coefficients for main frames are unchanged except for the open left side. The coefficients for the left side depend on the situation at the frame being considered for design. As previously noted (in section 2), the whole of the left side may be unclad or the opening may be restricted to one or more bays. In this latter case there are clearly two or more wind loading conditions which need to be considered and if necessary justified.

In the current version of SMART Portal 2D it is necessary to run these cases separately.

For the case where the left column has cladding attached both sides (the opening being one or more bays distant), the treatment is simple because the external pressure or suction can co-exist with either internal pressure or suction. The problem reduces to the normal `all sides clad' case with enhanced internal pressures and suctions and no further editing is required. We will refer to this as case 1. Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This solution is the same as left or right side open only and represents a 5% weight increase over the design for a closed sided building. In other circumstances the difference would be lesser or greater.

At the other extreme a left column may have no cladding attached in which case it will attract only negligible wind force. Although this results in lesser direct wind force on the column, the overall effect on the frame and the column stability may be critical. We will refer to this as case 2. In principle this case may be modelled by applying left external surface coefficients equal and opposite to the internal surface coefficients. Unfortunately the current versions of SMART Portal provide only one set of external surface coefficients per wind direction which are combined with the two sets of internal coefficients. Forthcoming versions of the software will provide two sets of external coefficients which will also cater for the cases where the wind code provides alternative + and – coefficients for the windward roof slopes. In the meantime it is necessary to exercise some engineering judgement and approximations in order to use the software safely and economically. Alternatively two versions of the frame can be run:-

- Case 2a: with the left column subject to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic coeff = 0.715/(1.031 x 0.963) = 0.720.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.720	0.187	0.187	0.720
Factored Pressure Coefficient	0.715	0.186	0.186	0.715
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

  Fig 8.2 Edited external surface coefficients for case 2a

  Autodesign produces the following sections for this case:

  Rafters: 406 x 178 UKB 54 Columns: 457 x 191 UKB 74 Steel weight per frame: 2089 kg

  This represents a 22% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2b with the left column subject to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind right basic coefficient = -0.557/(1.031 x 0.963) = 0.561.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.280	-0.561	-0.533	-0.280
Factored Pressure Coefficient	-0.278	-0.557	-0.530	-0.278
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

Fig 8.3 Edited external surface coefficients for case 2b

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 533 x 210 UKB 82 Steel weight per frame: 2182 kg

This represents a 27% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater. The internal suction case 2b therefore governs the design

3.9 Duopitch portal building with far and right sides open

The following text explains the modifications to be made for two adjacent sides open. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2:

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60	–0.46	–0.57	–0.63
	+0.52	+0.67	+0.77	+0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole right face is open the diagonal dimension is given with sufficient accuracy by:

a = Sqrt{$36^2 + 5^2$} = 36.3 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.85

If only one bay is open a = Sqrt{$6^2 + 5^2$} = 7.8 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.96

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

This direction equates to 180° in table 18 for which Cpi = -0.60. Therefore edit the default internal suction coefficient from -0.300 to -0.60.

There is no corresponding internal pressure value in table 18 for this wind direction so leave the default value + 0.200 unchanged.

Internal surface coefficients – wind blowing from right

In BS 6399-2 Table 18, right wind equates to wind 0° blowing into the open side face for which Cpi = 0.77. Therefore edit the default internal pressure coefficient from +0.20 to + 0.77.

There is no corresponding suction value for this wind direction so leave the default value – 0.30 unchanged.

Internal surface coefficients – wind blowing on near end

This direction equates to wind 90° in table 18 for which Cpi = + 0.77 or -0.57. The negative coefficient corresponds to wind blowing onto the closed near end. Therefore edit the default values +0.20 and -0.30 to +0.20 and -0.57 respectively.

Internal surface coefficients – wind blowing on far end

This direction equates to wind 90° in table 18 for which Cpi = + 0.77 or -0.57. The positive coefficient corresponds to wind blowing into the open far end. Therefore edit the default values +0.20 and -0.30 to +0.77 and -0.30 respectively.

After editing the internal surface coefficients should appear as shown in fig 9.1 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.200	0.770	0.200	0.770
Factored Pressure Coefficient	0.186	0.715	0.186	0.715
Basic Suction Coefficient	-0.600	-0.300	-0.570	-0.300
Factored Suction Coefficient	-0.557	-0.278	-0.529	-0.278

Fig 9.1 Internal surface coefficients after editing for open far and right sides.

External surface coefficients

The external surface coefficients for main frames are unchanged except for the open right side. The coefficients for the right side depend on the situation at the frame being considered for design. As previously noted (in section 2), the whole of the right side may be unclad or the opening may be restricted to one or more bays. In this latter case there are clearly two or more wind loading conditions which need to be considered and if necessary justified.

In the current version of SMART Portal 2D it is necessary to run these cases separately.

For the case where the right column has cladding attached both sides (the opening being one or more bays distant), the treatment is simple because the external pressure or suction can co-exist with either internal pressure or suction. The problem reduces to the normal `all sides clad' case with enhanced internal pressures and suctions and no further editing is required. We will refer to this as case 1. Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This solution is the same as left or right side open only and represents a 5% weight increase over the design for a closed sided building. In other circumstances the difference would be lesser or greater.

At the other extreme a right column may have no cladding attached in which case it will attract only negligible wind force. Although this results in lesser direct wind force on the column, the overall effect on the frame and the column stability may be critical. We will refer to this as case 2. In principle this case may be modelled by applying right side external surface coefficients equal and opposite to the internal surface coefficients. Unfortunately the current versions of SMART Portal provide only one set of external surface coefficients per wind direction which are combined with the two sets of internal coefficients. Forthcoming versions of the software will provide two sets of external coefficients which will also cater for the cases where the wind code provides alternative + and – coefficients for the windward roof slopes. In the meantime it is necessary to exercise some engineering judgement and approximations in order to use the software safely and economically. Alternatively two versions of the frame can be run:-

- Case 2a: with the right column subject to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind right basic coeff = 0.715/(1.031 x 0.963) = 0.720.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.187	0.720	0.187	0.720
Factored Pressure Coefficient	0.186	0.715	0.186	0.715

  Fig 9.2 Edited external surface coefficients for case 2a

  Autodesign produces the following sections for this case:

  Rafters: 406 x 178 UKB 54 Columns: 457 x 191 UKB 74 Steel weight per frame: 2089 kg

  This represents a 22% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2b with the right column subject to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind right basic coefficient = -0.557/(1.031 x 0.963) = 0.561.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.561	-0.280	-0.280	-0.533
Factored Pressure Coefficient	-0.557	-0.278	-0.278	-0.530

Fig 9.3 Edited external surface coefficients for case 2b

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 533 x 210 UKB 82 Steel weight per frame: 2182 kg

This represents a 27% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater. The internal suction case 2b therefore governs the design

3.10 Duopitch portal building with near and far sides open

The following text suggests modifications that might be made to the default wind coefficients to cater for open near and far sides. This condition is not covered by Table 18 of BS 6399-2. Section 2.6.3.2 briefly discusses the condition and refers to *The designer's guide to wind loading of building structures Part 2 sections 18.6.3 and 20.9.2.4*[1] for more detail. The latter reveals that experimental evidence is only available for overall force effects and attention is drawn to the case of wind blowing at 45 degrees to the main axes with the suggestion that an overall force coefficient of 2.2 could be divided between the clad sides. This could be modelled by changing the surface coefficients for the left and right walls under `left' wind to +1.1 and -1.1 respectively. Obviously the right wind coefficients would be -1.1 and +1.1. There is no information relating to internal surface pressures, however referring to Table 18 it seems unlikely that the range Cpi = -0.67 to +0.85 would be exceeded. The following text is based on the foregoing tentative interpretation and should be followed only at readers own discretion.

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60	–0.46	–0.57	–0.63
	+0.52	+0.67	+0.77	+0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole near face is open the diagonal dimension is given with sufficient accuracy by:

$$a = \mathrm{Sqrt}\{20^2 + 5^2\} = 20.6 \text{ m}$$

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.89

If only a quarter of the side is open a = Sqrt{$5^2 + 5^2$} = 7.1 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.98

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1.1 above from 0.739 to 0.90.

Internal surface coefficients

From the above discussion it is suggested that the internal pressure and suction coefficients are unlikely to be worse than + 0.85 and -0.67. These values actually correspond to wind directions oblique to the X (left – right) axis. The positive pressure value occurs when the inclination directs the wind into the building whilst the negative suction value occurs when the inclination directs the wind away from the building. This will happen at different frames. Therefore edit the default internal coefficients from -0.300 and +0.20 to -0.65 and +0.85.

After editing, the internal surface coefficients should appear as shown in fig 10.1 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.850	0.850	0.850	0.850
Factored Pressure Coefficient	0.789	0.789	0.789	0.789
Basic Suction Coefficient	-0.670	-0.670	-0.670	-0.670
Factored Suction Coefficient	-0.622	-0.622	-0.622	-0.622

Fig 10.1 Internal surface coefficients after editing for open near and far sides.

External surface coefficients

The external surface coefficients for main frames are only changed from the default values for a building with closed sides in respect of the left and right walls with wind blowing from left or right. As explained above the changes in fact model wind acting obliquely. After editing the external surface coefficients should appear as shown in fig 10.2 below.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	1.100	-1.100	-0.800	-0.500
Factored Pressure Coefficient	1.093	-1.093	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-1.100	1.100	-0.800	-0.500
Factored Pressure Coefficient	-1.093	1.093	-0.795	-0.497

Fig 10.2 External surface coefficients after editing for open near and far sides.

Note that the external coeficients for the roof surfaces are unchanged from the default values for a closed sided building.

Autodesign produces the following sections for this example:

Rafters: 406 x 178 UKB 60 Columns: 533 x 210 UKB 82 Steel weight per frame: 2319 kg

This represents a 35 % increase over the design for a closed sided building. In other circumstances the difference would be lesser or greater.

3.11 Duopitch portal building with left and right sides open

The following text suggests modifications that might be made to the default wind coefficients to cater for open left and right sides. This condition is not covered by Table 18 of BS 6399-2. Section 2.6.3.2 briefly discusses the condition and refers to *The designer's guide to wind loading of building structures Part 2 by NJ Cook sections 18.6.3 and 20.9.2.4*[1] for more detail. The latter reveals that experimental evidence is only available for overall force effects and attention is drawn to the case of wind blowing at 45 degrees to the main axes with the suggestion that an overall force coefficient of 2.2 could be divided between the clad sides. This could be modelled by changing the surface coefficients for the clad near and far end walls under `left' wind to +1.1 and -1.1 respectively. Obviously the right wind coefficients would be -1.1 and +1.1. There is no information relating to internal surface pressures. However referring to Table 18 it seems unlikely that the range Cpi = -0.67 to +0.85 would be exceeded. The following text is based on the foregoing tentative interpretation and should be followed only at readers own discretion.

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	−0.60 +0.52	−0.46 +0.67	−0.57 +0.77	−0.63 +0.40
180°	−0.39	−0.43	−0.60	−0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole left/right face is open the diagonal dimension is given with sufficient accuracy by:

a = Sqrt{$36^2 + 5^2$} = 36.3 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.85

If only one bay is open a = Sqrt{$6^2 + 5^2$} = 7.8 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.96

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1.1 above from 0.739 to 0.90.

Internal surface coefficients

From the above discussion it is suggested that the internal pressure and suction coefficients are unlikely to be worse than + 0.85 and -0.67. These values actually correspond to wind directions oblique to the X (left – right) axis. The positive pressure value occurs when the inclination directs the wind into the building whilst the negative suction value occurs when the inclination directs the wind away from the building. This will happen at different frames. Therefore edit the default internal coefficients from -0.300 and +0.20 to -0.67 and +0.85.

After editing, the internal surface coefficients should appear as shown in fig 11.1 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.850	0.850	0.850	0.850
Factored Pressure Coefficient	0.789	0.789	0.789	0.789
Basic Suction Coefficient	-0.670	-0.670	-0.670	-0.670
Factored Suction Coefficient	-0.622	-0.622	-0.622	-0.622

Fig 11.1 Internal surface coefficients after editing for open left and right sides.

External surface coefficients

The external surface coefficients for main frames are unchanged except for the open left and right sides. The coefficients for the left and right sides depend on the situation at the frame being considered for design. As previously noted (in section 2), the whole of the left or right side may be unclad or the opening may be restricted to one or more bays. In this latter case there are clearly two or more wind loading conditions which need to be considered and if necessary justified.

In the current version of SMART Portal 2D it is necessary to run these cases separately.

For the case where the columns have cladding attached both sides (the opening being one or more bays distant), the treatment is simple because the external pressure or suction can co-exist with either internal pressure or suction. The problem reduces to the normal `all sides clad' case with enhanced internal pressures and suctions and no further editing is required. We will refer to this as case 1. Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This solution is 5% heavier than the design for the equivalent closed sided building as given in section 3.1. In other circumstances there may be differences. At the other extreme a left or right column (or both) may have no cladding attached in which case it will attract only negligible wind force. Although this results in lesser direct wind force on the column(s), the overall effect on the frame and the column stability may be critical. We will refer to this as case 2. In principle this case may be modelled by applying external surface coefficients equal and opposite to the internal surface coefficients on the relevant columns. Unfortunately the current versions of SMART Portal provide only one set of external surface coefficients per wind direction which are combined with the two sets of internal coefficients. Forthcoming versions of the software will provide two sets of external coefficients which will also cater for the cases where the wind code provides alternative + and – coefficients for the windward roof slopes. In the meantime it is necessary to exercise some engineering judgement and approximations in order to use the software safely and economically. Alternatively several versions of the frame can be run:-

- Case 2a: Left column without cladding. Right column with cladding. Internal pressure.

  The left column is subjected to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic +ve coeff = 0.789/(1.031 x 0.963) = 0.795.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.795	0.795	0.795	0.795
Factored Pressure Coefficient	0.790	0.790	0.790	0.790
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

Fig 11.2 Edited external surface coefficients for case 2a.

Autodesign produces the following sections for this case:

Rafters: 457 x 191 UKB 67 Columns: 457 x 191 UKB 74 Steel weight per frame: 2387 kg

This represents a 39% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2b: Left column without cladding. Right column with cladding. Internal suction.

The left column is subjected to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left or right basic coeff = -0.622/(1.031 x 0.963) = -0.626.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.626	-0.626	-0.626	-0.626
Factored Pressure Coefficient	-0.622	-0.622	-0.622	-0.622
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

Fig 11.3 shows the edited external surface coefficients for case 2b.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 60 Columns: 533 x 210 UKB 82 Steel weight per frame: 2319 kg

This represents a 35% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

Case 2b also passes with the sections selected for case 2a

- Case 2c: Left column with cladding. Right column without cladding. Internal pressure.

The right column is subjected to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic +ve coeff = 0.789/(1.031 x 0.963) = 0.795.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.795	0.795	0.795	0.795
Factored Pressure Coefficient	0.790	0.790	0.790	0.790

Fig 11.4 Edited external surface coefficients for case 2c.

Autodesign produces the following sections for this case:

Rafters: 457 x 191 UKB 67 Columns: 457 x 191 UKB 74 Steel weight per frame: 2387 kg

This represents a 39% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

Case 2d: Left column with cladding. Right column without cladding. Internal suction.

The right column is subjected to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left or right basic coeff = -0.622/(1.031 x 0.963) = -0.626.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.626	-0.626	-0.626	-0.626
Factored Pressure Coefficient	-0.622	-0.622	-0.622	-0.622

Fig 11.5 shows the edited external surface coefficients for case 2d.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 60 Columns: 533 x 210 UKB 82 Steel weight per frame: 2319 kg

This represents a 35% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

Case 2d also passes with the sections selected for case 2c

Case 2e: Left column without cladding. Right column without cladding. Internal pressure.

The left and right columns are subjected to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic +ve coeff = 0.789/(1.031 x 0.963) = 0.795.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.795	0.795	0.795	0.795
Factored Pressure Coefficient	0.790	0.790	0.790	0.790
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.795	0.795	0.795	0.795
Factored Pressure Coefficient	0.790	0.790	0.790	0.790

Fig 11.6 Edited external surface coefficients for case 2e.

Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This represents a 5% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater. The column sizes were increased for member stability.

- Case 2f: Left column without cladding. Right column without cladding. Internal suction.

  The left and right columns are subjected to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left or right basic coeff = -0.622/(1.031 x 0.963) = -0.626.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.626	-0.626	-0.626	-0.626
Factored Pressure Coefficient	-0.622	-0.622	-0.622	-0.622
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.626	-0.626	-0.626	-0.626
Factored Pressure Coefficient	-0.622	-0.622	-0.622	-0.622

Fig 11.7 Edited external surface coefficients for case 2f.

Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This represents a 5% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

For this particular frame configuration the design outcomes may be summarised as follows:-

	Rafters	Columns	Weight		
Left and right columns clad	356x171UKB45	406x178UKB60	1717	kg	100%
Left unclad right clad	457x191UKB67	457x191UKB74	2387	kg	139%
Left clad right unclad	457x191UKB67	457x191UKB74	2387	kg	139%
Both sides unclad	356x171UKB45	457x191UKB67	1798	kg	105%

Clearly the unsymmetrically clad case is critical.

3.12 Duopitch portal building with near, far and left sides open

The following text explains the modifications to be made for three adjacent sides open. The procedure is the same but `handed' for an open near, far and right sides but is given in full in section 3.13 to avoid cross referencing and interpretation. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2:

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60 +0.52	–0.46 +0.67	–0.57 +0.77	–0.63 +0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Attention is drawn to note (a) to the table which applies when the left side is completely open. The implication here is that different internal surface coefficients are applicable to the roof and walls. This does not seem entirely logical and cannot be accommodated in the present version of SMART Portal. However the difference between applying the relevant table 5 and table 18 coefficients to the single wall is marginal and of the same order as the uncertainties implicit in the guidance. Therefore it is proposed to ignore note (a) in the interests of simplicity and practical use of the software.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole left face is open the diagonal dimension is given with sufficient accuracy by:

a = Sqrt{$36^2 + 5^2$} = 36.3 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.85

If only one bay is open a = Sqrt{$6^2 + 5^2$} = 7.8 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.96

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

In BS 6399-2 Table 18, left wind equates to wind 0° blowing into the open longer face for which Cpi = 0.60. Therefore edit the default internal pressure coefficient from +0.20 to + 0.60.

There is no corresponding suction value for this wind direction so leave the default value – 0.30 unchanged.

Internal surface coefficients – wind blowing from right

This direction equates to 180^o in table 18 for which Cpi = -0.56. Therefore edit the default internal suction coefficient from -0.300 to -0.56.

There is no corresponding internal pressure value in table 18 for this wind direction so leave the default value + 0.200 unchanged.

Internal surface coefficients – wind blowing on near end

This direction equates to wind 90^o in table 18 for which Cpi = + 0.40 or -0.63. The positive coefficient corresponds to wind blowing into the building at a skew angle so as to attack the inside face of the right wall. The negative coefficient corresponds to wind blowing onto the building at a skew angle so as to attack the outside face of the right wall. Therefore edit the default values +0.20 and -0.30 to +0.40 and -0.63 respectively.

Internal surface coefficients – wind blowing on far end

This direction equates to wind 90^o in table 18 for which Cpi = + 0.40 or -0.63. The positive coefficient corresponds to wind blowing into the building at a skew angle so as to attack the inside face of the right wall. The negative coefficient corresponds to wind blowing onto the building at a skew angle so as to attack the outside face of the right wall. Therefore edit the default values +0.20 and -0.30 to +0.40 and -0.63 respectively.

After editing the internal surface coefficients should appear as shown in fig 11 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.600	0.200	0.400	0.400
Factored Pressure Coefficient	0.557	0.186	0.371	0.371
Basic Suction Coefficient	-0.300	-0.560	-0.630	-0.630
Factored Suction Coefficient	-0.278	-0.520	-0.585	-0.585

Fig 12.1 Internal surface coefficients after editing for open left, near and far sides.

External surface coefficients

The external surface coefficients for main frames are unchanged except for the open left side. The coefficients for the left side depend on the situation at the frame being considered for design. As previously noted (in section 2), the whole of the left side may be unclad or the opening may be restricted to one or more bays. In this latter case there are clearly two or more wind loading conditions which need to be considered and if necessary justified.

In the current version of SMART Portal 2D it is necessary to run these cases separately.

For the case where the left column has cladding attached both sides (the opening being one or more bays distant), the treatment is simple because the external pressure or suction can co-exist with either internal pressure or suction. The problem reduces to the normal `all sides clad' case with enhanced internal pressures and suctions and no further editing is required. We will refer to this as case 1. Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 51 Columns: 406 x 178 UKB 60 Steel weight per frame: 1854 kg

This solution represents an 8% increase over the design for a closed sided building. In other circumstances the difference would be lesser or greater.

At the other extreme a left column may have no cladding attached in which case it will attract only negligible wind force. Although this results in lesser direct wind force on the column, the overall effect on the frame and the column stability may be critical. We will refer to this as case 2. In principle this case may be modelled by applying left external surface coefficients equal and opposite to the internal surface coefficients. Unfortunately the current versions of SMART Portal provide only one set of external surface coefficients per wind direction which are combined with the two sets of internal coefficients. Forthcoming versions of the software will provide two sets of external coefficients which will also cater for the cases where the wind code provides alternative + and – coefficients for the windward roof slopes. In the meantime it is necessary to exercise some engineering judgement and approximations in order to use the software safely and economically. Alternatively two versions of the frame can be run:-

- Case 2a: with the left column subject to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic coeff = -0.557/(1.031 x 0.963) = 0.561.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.561	0.187	0.373	0.373
Factored Pressure Coefficient	0.557	0.186	0.371	0.371
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

Fig 12.2 Edited external surface coefficients for case 2a.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 457 x 191 UKB 67 Steel weight per frame: 2007 kg

This represents a 17% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2b: with the left column subject to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind right basic coeff = -0.521/(1.031 x 0.963) = -0.524.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.280	-0.524	-0.589	-0.589
Factored Pressure Coefficient	-0.278	-0.521	-0.585	-0.585
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

Fig 12.3 shows the edited external surface coefficients for case 2b.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 60 Columns: 457 x 191 UKB 74 Steel weight per frame: 2227 kg

This represents a 30% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater. The internal suction case 2b therefore governs the design.

3.13 Duopitch portal building with near, far and right sides open

The following text explains the modifications to be made for three adjacent sides open. The procedure is the same but `handed' for an open near, far and left sides but is given in full in section 3.12 to avoid cross referencing and interpretation. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2:

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	−0.60	−0.46	−0.57	−0.63
	+0.52	+0.67	+0.77	+0.40
180°	−0.39	−0.43	−0.60	−0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Attention is drawn to note (a) to the table which applies when the right side is completely open. The implication here is that different internal surface coefficients are applicable to the roof and walls. This does not seem entirely logical and cannot be accommodated in the present version of SMART Portal. However the difference between applying the relevant table 5 and table 18 coefficients to the single wall is marginal and of the same order as the uncertainties implicit in the guidance. Therefore it is proposed to ignore note (a) in the interests of simplicity and practical use of the software.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole left face is open the diagonal dimension is given with sufficient accuracy by:

a = Sqrt{$36^2 + 5^2$} = 36.3 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.85

If only one bay is open a = Sqrt{$6^2 + 5^2$} = 7.8 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.96

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

This direction equates to 180° in table 18 for which Cpi = -0.56. Therefore edit the default internal suction coefficient from -0.300 to -0.56.

There is no corresponding internal pressure value in table 18 for this wind direction so leave the default value + 0.200 unchanged.

Internal surface coefficients – wind blowing from right

In BS 6399-2 Table 18, right wind equates to wind 0^o blowing into the open longer face for which Cpi = 0.60. Therefore edit the default internal pressure coefficient from +0.20 to + 0.60.

There is no corresponding suction value for this wind direction so leave the default value – 0.30 unchanged.

Internal surface coefficients – wind blowing on near end

This direction equates to wind 90^o in table 18 for which Cpi = + 0.40 or -0.63. The positive coefficient corresponds to wind blowing into the building at a skew angle so as to attack the inside face of the left wall. The negative coefficient corresponds to wind blowing onto the building at a skew angle so as to attack the outside face of the left wall. Therefore edit the default values +0.20 and -0.30 to +0.40 and -0.63 respectively.

Internal surface coefficients – wind blowing on far end

This direction equates to wind 90^o in table 18 for which Cpi = + 0.40 or -0.63. The positive coefficient corresponds to wind blowing into the building at a skew angle so as to attack the inside face of the left wall. The negative coefficient corresponds to wind blowing onto the building at a skew angle so as to attack the outside face of the left wall. Therefore edit the default values +0.20 and -0.30 to +0.40 and -0.63 respectively.

After editing the internal surface coefficients should appear as shown in fig 11 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.200	0.600	0.400	0.400
Factored Pressure Coefficient	0.186	0.557	0.371	0.371
Basic Suction Coefficient	-0.560	-0.300	-0.630	-0.630
Factored Suction Coefficient	-0.520	-0.278	-0.585	-0.585

Fig 13.1 Internal surface coefficients after editing for open right, near and far sides.

External surface coefficients

The external surface coefficients for main frames are unchanged except for the open right side. The coefficients for the right side depend on the situation at the frame being considered for design. As previously noted (in section 2), the whole of the right side may be unclad or the opening may be restricted to one or more bays. In this latter case there are clearly two or more wind loading conditions which need to be considered and if necessary justified.

In the current version of SMART Portal 2D it is necessary to run these cases separately.

For the case where the right column has cladding attached both sides (the opening being one or more bays distant), the treatment is simple because the external pressure or suction can co-exist with either internal pressure or suction. The problem reduces to the normal `all sides clad' case with enhanced internal pressures and suctions and no further editing is required. We will refer to this as case 1. Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 51 Columns: 406 x 178 UKB 60 Steel weight per frame: 1854 kg

This solution represents an 8% increase over the design for a closed sided building. In other circumstances the difference would be lesser or greater.

At the other extreme a right column may have no cladding attached in which case it will attract only negligible wind force. Although this results in lesser direct wind force on the column, the overall effect on the frame and the column stability may be critical. We will refer to this as case 2. In principle this case may be modelled by applying right external surface coefficients equal and opposite to the internal surface coefficients. Unfortunately the current versions of SMART Portal provide only one set of external surface coefficients per wind direction which are combined with the two sets of internal coefficients. Forthcoming versions of the software will provide two sets of external coefficients which will also cater for the cases where the wind code provides alternative + and – coefficients for the windward roof slopes. In the meantime it is necessary to exercise some engineering judgement and approximations in order to use the software safely and economically. Alternatively two versions of the frame can be run:-

- Case 2a: with the right column subject to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind right basic coeff = 0.557/(1.031 x 0.963) = 0.561.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.187	0.561	0.374	0.374
Factored Pressure Coefficient	0.186	0.557	0.372	0.372

  Fig 13.2 Edited external surface coefficients for case 2a.

  Autodesign produces the following sections for this case:

  Rafters: 406 x 178 UKB 54 Columns: 457 x 191 UKB 67 Steel weight per frame: 2007 kg

  This represents a 17% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2b: with the right column subject to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic coeff = 0.520/(1.031 x 0.963) = 0.523.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.523	-0.280	-0.589	-0.589
Factored Pressure Coefficient	-0.520	-0.278	-0.585	-0.585

Fig 12.3 shows the edited external surface coefficients for case 2b.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 533 x 210 UKB 82   Steel weight per frame: 2182 kg

This represents a 27% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater. The internal suction case 2b therefore governs the design

3.14 Duopitch portal building with near, left and right sides open

The following text explains the modifications to be made for three adjacent sides open. The procedure is the same but `handed' for an open far, left and right sides but that case is given in full in section 3.15 to avoid cross referencing and interpretation. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2:

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face: Shorter	One open face: Longer	Two adjacent open faces	Three open faces[a]
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60	–0.46	–0.57	–0.63
	+0.52	+0.67	+0.77	+0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Attention is drawn to note (a) to the table. The implication here is that different internal surface coefficients are applicable to the roof and the single wall. This does not seem entirely logical and cannot be accommodated in the present version of SMART Portal. However the difference between applying the relevant table 5 and table 18 coefficients to the single wall is marginal and of the same order as the uncertainties implicit in the guidance. Therefore it is proposed to ignore note (a) in the interests of simplicity and practical use of the software.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension a for internal pressure is the diagonal dimension of the open face. In the present example if the whole left or right face is open the diagonal dimension is given with sufficient accuracy by:

$$a = \mathrm{Sqrt}\{36^2 + 5^2\} = 36.3 \text{ m}$$

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.85

If only one bay is open a = Sqrt{$6^2 + 5^2$} = 7.8 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.96

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

This direction equates to wind 90^o in table 18 for which Cpi = + 0.40 or -0.63. The positive coefficient corresponds to wind blowing into the building at a skew angle so as to attack the inside face of the far wall. The negative coefficient corresponds to wind blowing onto the building at a skew angle so as to attack the outside face of the far wall. Therefore edit the default values +0.20 and -0.30 to +0.40 and -0.63 respectively.

Internal surface coefficients – wind blowing from right

This direction equates to wind 90^o in table 18 for which Cpi = + 0.40 or -0.63. The positive coefficient corresponds to wind blowing into the building at a skew angle so as to attack the inside face of the far wall. The negative coefficient corresponds to wind blowing onto the building at a skew angle so as to attack the outside face of the far wall. Therefore edit the default values +0.20 and -0.30 to +0.40 and -0.63 respectively.

Internal surface coefficients – wind blowing from near side

In BS 6399-2 Table 18, near wind equates to wind 0^o blowing into the open shorter face for which Cpi = 0.60. Therefore edit the default internal pressure coefficient from +0.20 to + 0.60.

There is no corresponding suction value for this wind direction so leave the default value – 0.30 unchanged.

Internal surface coefficients – wind blowing from far side

This direction equates to 180^o in table 18 for which Cpi = -0.56. Therefore edit the default internal suction coefficient from -0.300 to -0.56.

There is no corresponding internal pressure value in table 18 for this wind direction so leave the default value + 0.200 unchanged.

After editing the internal surface coefficients should appear as shown in fig 14.1 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.400	0.400	0.600	0.200
Factored Pressure Coefficient	0.371	0.371	0.557	0.186
Basic Suction Coefficient	-0.630	-0.630	-0.300	-0.560
Factored Suction Coefficient	-0.585	-0.585	-0.278	-0.520

Fig 14.1 Internal surface coefficients after editing for open left, right and near sides.

External surface coefficients

The external surface coefficients for main frames are unchanged except for the open left and right sides. The coefficients for the left and right sides depend on the situation at the frame being considered for design. As previously noted (in section 2), the whole of the left or right side may be unclad or the opening may be restricted to one or more bays. In this latter case there are clearly two or more wind loading conditions which need to be considered and if necessary justified.

In the current version of SMART Portal 2D it is necessary to run these cases separately.

For the case where the columns have cladding attached both sides (the opening being one or more bays distant), the treatment is simple because the external pressure or suction can co-exist with either internal pressure or suction. The problem reduces to the normal `all sides clad' case with enhanced internal pressures and suctions and no further editing is required. We will refer to this as case 1. Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 406 x 178 UKB 60 Steel weight per frame: 1717 kg

This solution is the same as the design for the equivalent closed sided building as given in section 3.1. In other circumstances there may be differences. At the other extreme a left or right column (or both) may have no cladding attached in which case it will attract only negligible wind force. Although this results in lesser direct wind force on the column(s), the overall effect on the frame and the column stability may be critical. We will refer to this as case 2. In principle this case may be modelled by applying external surface coefficients equal and opposite to the internal surface coefficients on the relevant columns. Unfortunately the current versions of SMART Portal provide only one set of external surface coefficients per wind direction which are combined with the two sets of internal coefficients. Forthcoming versions of the software will provide two sets of external coefficients which will also cater for the cases where the wind code provides alternative + and – coefficients for the windward roof slopes. In the meantime it is necessary to exercise some engineering judgement and approximations in order to use the software safely and economically. Alternatively several versions of the frame can be run:-

- Case 2a: Left column without cladding. Right column with cladding. Internal pressure.

  The left column is subjected to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic +ve coeff = 0.371/(1.031 x 0.963) = 0.373.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.373	0.373	0.561	0.187
Factored Pressure Coefficient	0.371	0.371	0.557	0.186
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

  Fig 14.2 Edited external surface coefficients for case 2a.

  Autodesign produces the following sections for this case:

  Rafters: 406 x 178 UKB 54 Columns: 533 x 210 UKB 82 Steel weight per frame: 2182 kg

  This represents a 27% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2b: Left column without cladding. Right column with cladding. Internal suction.

The left column is subjected to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left or right basic coeff = -0.585/(1.031 x 0.963) = -0.589.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.589	0.589	-0.523	-0.280
Factored Pressure Coefficient	-0.585	0.585	-0.520	-0.278
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

Fig 14.3 shows the edited external surface coefficients for case 2b.

Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This represents a 5% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2c: Left column with cladding. Right column without cladding. Internal pressure.

  The right column is subjected to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic +ve coeff = 0.371/(1.031 x 0.963) = 0.373.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.373	0.373	0.557	0.187
Factored Pressure Coefficient	0.371	0.371	0.553	0.186

Fig 14.4 Edited external surface coefficients for case 2c.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 533 x 210 UKB 82 Steel weight per frame: 2182 kg

This represents a 27% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2d: Left column with cladding. Right column without cladding. Internal suction.

  The right column is subjected to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left or right basic coeff = -0.585/(1.031 x 0.963) = -0.589.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.589	-0.589	-0.280	-0.524
Factored Pressure Coefficient	-0.585	-0.585	-0.278	-0.521

Fig 14.5 shows the edited external surface coefficients for case 2d.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 533 x 210 UKB 82 Steel weight per frame: 2182 kg

This represents a 27% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2e: Left column without cladding. Right column without cladding. Internal pressure.

  The left and right columns are subjected to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic +ve coeff = 0.371/(1.031 x 0.963) = 0.373.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.373	0.373	0.561	0.187
Factored Pressure Coefficient	0.371	0.371	0.557	0.186
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.373	0.373	0.561	0.187
Factored Pressure Coefficient	0.371	0.371	0.557	0.186

Fig 14.6 Edited external surface coefficients for case 2e.

Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This represents a 5% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater. The column sizes were increased for member stability.

- Case 2f: Left column without cladding. Right column without cladding. Internal suction.

  The left and right columns are subjected to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left or right basic coeff = -0.585/(1.031 x 0.963) = -0.589.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.589	-0.589	-0.280	-0.524
Factored Pressure Coefficient	-0.585	-0.585	-0.278	-0.521
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.589	-0.589	-0.280	-0.524
Factored Pressure Coefficient	-0.585	-0.585	-0.278	-0.521

Fig 14.7 Edited external surface coefficients for case 2f.

Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This represents a 5% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

For this particular frame configuration the design outcomes may be summarised as follows:-

Case	Rafters	Columns	Weight		
1 Left and right columns clad	356x171UKB45	406x178UKB60	1717	kg	100%
2a/b Left unclad right clad	406x178UKB54	533x210UKB82	2182	kg	127%
2c/d Left clad right unclad	406x178UKB54	533x210UKB82	2182	kg	127%
2e/f Both sides unclad	356x171UKB45	457x191UKB67	1798	kg	105%

Clearly the unsymmetrically clad case is critical.

3.15 Duopitch portal building with far, left and right sides open

The following text explains the modifications to be made for three adjacent sides open. The procedure is the same but `handed' for an open near, left and right sides but that case is given in full in section 3.14 to avoid cross referencing and interpretation. Reference should be made to section 2.6.3 and Table 18 of BS 6399-2:

Table 18 — Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face		Two adjacent open faces	Three open faces[a]
	Shorter	Longer		
0°	+0.85	+0.80	+0.77	+0.60
90°[b]	–0.60 +0.52	–0.46 +0.67	–0.57 +0.77	–0.63 +0.40
180°	–0.39	–0.43	–0.60	–0.56

[a] Values given should be applied to underside of roof only. For the single wall, use pressure coefficients for walls given in Table 5.
[b] Where two sets of values are given they should be treated as separate load cases.

Attention is drawn to note (a) to the table. The implication here is that different internal surface coefficients are applicable to the roof and the single wall. This does not seem entirely logical and cannot be accommodated in the present version of SMART Portal. However the difference between applying the relevant table 5 and table 18 coefficients to the single wall is marginal and of the same order as the uncertainties implicit in the guidance. Therefore it is proposed to ignore note (a) in the interests of simplicity and practical use of the software.

Internal size effect factor Ca

According to 2.6.3, the relevant dimension (a) for internal pressure is the diagonal dimension of `the open face'. In the present example if the whole left or right face is open the diagonal dimension is given with sufficient accuracy by:

a = Sqrt{$36^2 + 5^2$} = 36.3 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.85

If only one bay is open a = Sqrt{$6^2 + 5^2$} = 7.8 m

The corresponding size effect factor can be read from BS 6399-2 fig 4 for a site in country >2 km from the sea: Ca = 0.96

For the purposes of the example let us assume Ca = 0.90

Therefore edit the value of Ca in fig 1 above from 0.739 to 0.90.

Internal surface coefficients – wind blowing from left

This direction equates to wind 90^o in table 18 for which Cpi = + 0.40 or -0.63. The positive coefficient corresponds to wind blowing into the building at a skew angle so as to attack the inside face of the near wall. The negative coefficient corresponds to wind blowing onto the building at a skew angle so as to attack the outside face of the near wall. Therefore edit the default values +0.20 and -0.30 to +0.40 and -0.63 respectively.

Internal surface coefficients – wind blowing from right

This direction equates to wind 90^o in table 18 for which Cpi = + 0.40 or -0.63. The positive coefficient corresponds to wind blowing into the building at a skew angle so as to attack the inside face of the near wall. The negative coefficient corresponds to wind blowing onto the building at a skew angle so as to attack the outside face of the near wall. Therefore edit the default values +0.20 and -0.30 to +0.40 and -0.63 respectively.

Internal surface coefficients – wind blowing from near side

This direction equates to 180^o in table 18 for which Cpi = -0.56. Therefore edit the default internal suction coefficient from -0.300 to -0.56.

There is no corresponding internal pressure value in table 18 for this wind direction so leave the default value + 0.200 unchanged.

Internal surface coefficients – wind blowing from far side

In BS 6399-2 Table 18, far wind equates to wind 0^o blowing into the open shorter face for which Cpi = 0.60. Therefore edit the default internal pressure coefficient from +0.20 to + 0.60.

There is no corresponding suction value for this wind direction so leave the default value – 0.30 unchanged.

After editing the internal surface coefficients should appear as shown in fig 15.1 below.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.400	0.400	0.200	0.600
Factored Pressure Coefficient	0.371	0.371	0.186	0.557
Basic Suction Coefficient	-0.630	-0.630	-0.560	-0.300
Factored Suction Coefficient	-0.585	-0.585	-0.520	-0.278

Fig 15.1 Internal surface coefficients after editing for open left, right and far sides.

External surface coefficients

The external surface coefficients for main frames are unchanged except for the open left and right sides. The coefficients for the left and right sides depend on the situation at the frame being considered for design. As previously noted (in section 2), the whole of the left or right side may be unclad or the opening may be restricted to one or more bays. In this latter case there are clearly two or more wind loading conditions which need to be considered and if necessary justified.

In the current version of SMART Portal 2D it is necessary to run these cases separately.

For the case where the columns have cladding attached both sides (the opening being one or more bays distant), the treatment is simple because the external pressure or suction can co-exist with either internal pressure or suction. The problem reduces to the normal `all sides clad' case with enhanced internal pressures and suctions and no further editing is required. We will refer to this as case 1. Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 406 x 178 UKB 60 Steel weight per frame: 1717 kg

This solution is the same as the design for the equivalent closed sided building given in section 3.1. In other circumstances there may be differences. At the other extreme a left or right column (or both) may have no cladding attached in which case it will attract only negligible wind force. Although this results in lesser direct wind force on the column(s), the overall effect on the frame and the column stability may be critical. We will refer to this as case 2. In principle this case may be modelled by applying external surface coefficients equal and opposite to the internal surface coefficients on the relevant columns. Unfortunately the current versions of SMART Portal provide only one set of external surface coefficients per wind direction which are combined with the two sets of internal coefficients. Forthcoming versions of the software will provide two sets of external coefficients which will also cater for the cases where the wind code provides alternative + and – coefficients for the windward roof slopes. In the meantime it is necessary to exercise some engineering judgement and approximations in order to use the software safely and economically. Alternatively several versions of the frame can be run:-

- Case 2a: Left column without cladding. Right column with cladding. Internal pressure.

  The left column is subjected to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic +ve coeff = 0.371/(1.031 x 0.963) = 0.373.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.371	0.371	0.187	0.561
Factored Pressure Coefficient	0.369	0.369	0.186	0.557
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

Fig 15.2 Edited external surface coefficients for case 2a.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 406 x 178 UKB 60 Steel weight per frame: 1925 kg

This represents a 12% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2b: Left column without cladding. Right column with cladding. Internal suction.

  The left column is subjected to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left or right basic coeff = -0.585/(1.031 x 0.963) = -0.589.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.589	0.589	-0.523	-0.280
Factored Pressure Coefficient	-0.585	0.585	-0.520	-0.278
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.500	0.614	-0.800	-0.500
Factored Pressure Coefficient	-0.497	0.610	-0.795	-0.497

#

  Fig 15.3 shows the edited external surface coefficients for case 2b.

  Autodesign produces the following sections for this case:

  Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

  This represents a 5% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2c: Left column with cladding. Right column without cladding. Internal surface.

  The right column is subjected to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic +ve coeff = 0.371/(1.031 x 0.963) = 0.373.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.373	0.373	0.187	0.561
Factored Pressure Coefficient	0.371	0.371	0.186	0.557

Fig 15.4 Edited external surface coefficients for case 2c.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 406 x 178 UKB 60 Steel weight per frame: 1925 kg

This represents a 12% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2d: Left column with cladding. Right column without cladding. Internal suction.

The right column is subjected to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to \`ignore'. Note that it is the \`factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left or right basic coeff = -0.585/(1.031 x 0.963) = -0.589.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.614	-0.500	-0.800	-0.500
Factored Pressure Coefficient	0.610	-0.497	-0.795	-0.497
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.589	-0.589	-0.524	-0.280
Factored Pressure Coefficient	-0.585	-0.585	-0.521	-0.278

Fig 15.5 shows the edited external surface coefficients for case 2d.

Autodesign produces the following sections for this case:

Rafters: 406 x 178 UKB 54 Columns: 533 x 210 UKB 82 Steel weight per frame: 2182 kg

This represents a 27% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

- Case 2e: Left column without cladding. Right column without cladding. Internal pressure.

The left and right columns are subjected to external surface coefficients balancing the internal pressure coefficients and deleting all the load combinations with internal suction or setting them to \`ignore'. Note that it is the \`factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left basic +ve coeff = 0.371/(1.031 x 0.963) = 0.373.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.373	0.373	0.187	0.561
Factored Pressure Coefficient	0.371	0.371	0.186	0.557
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.373	0.373	0.187	0.561
Factored Pressure Coefficient	0.371	0.371	0.186	0.557

Fig 15.6 Edited external surface coefficients for case 2e.

Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This represents a 5% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater. The column sizes were increased for member stability.

- Case 2f: Left column without cladding. Right column without cladding. Internal suction.

  The left and right columns are subjected to external surface coefficients balancing the internal suction coefficients and deleting all the load combinations with internal pressure or setting them to `ignore'. Note that it is the `factored' internal coefficients which are to be balanced. Enter the value of basic external coefficient = factored internal coefficient /(dynamic augmentation factor x external size factor) In the example for wind left or right basic coeff = -0.585/(1.031 x 0.963) = -0.589.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.589	-0.589	-0.524	-0.280
Factored Pressure Coefficient	-0.585	-0.585	-0.521	-0.278
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	-0.589	-0.589	-0.524	-0.280
Factored Pressure Coefficient	-0.585	-0.585	-0.521	-0.278

Fig 15.7 Edited external surface coefficients for case 2f.

Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This represents a 5% increase over the design for a closed sided building. In other circumstances the difference could be lesser or greater.

For this particular frame configuration the design outcomes may be summarised as follows:-

Case	Rafters	Columns	Frame weight		
1: Left and right columns clad	356x171UKB45	406x178UKB60	1717	kg	100%
2a/b Left unclad right clad	406x178UKB54	533x210UKB82	2182	kg	127%
2c/d Left clad right unclad	406x178UKB54	533x210UKB82	2182	kg	127%
2e/f Both sides unclad	356x171UKB45	457x191UKB67	1798	kg	105%

Clearly the unsymmetrically clad case is critical.

3.16 Duopitch portal building with all sides partly open

BS 6399-2 does not deal specifically with the case of four sides partly open as defined in section 2 of this guide. However comparison of results for other configurations indicates that for the purpose of designing main portal frames case 11 in this guide may be adopted.

3.17 Duopitch portal building with all sides fully open (canopy)

BS 6399-2 provides guidance for wind effects on free-standing canopies in section 2.5.9.1 and tables 13, 14 and 15. It is important to note that although free-standing canopies are usually designed for full or partial blockage, the blocking object or materials are not connected to the structure and the columns do not sustain any significant wind load from cladding attached thereto. The tables therefore provide coefficients for wind actions on the roof only. The tabulated coefficients are net values of the resultant of pressure/suctions on the upper and lower surfaces of the roof and do not reveal the individual surface contributions which would be helpful for structures with separate soffit cladding and framing such as petrol station canopies. However it is possible to deduce/infer the upper and lower surface values by comparison with the external surface coefficients for closed buildings. For the purpose of this guide we will assume single layer cladding.

It will be observed that many canopies have significant edge or fascia cladding. Clause 2.5.9.1.5 provides force coefficients. It is not possible to model this in the current version of SMART Portal so it is assumed that once a satisfactory design has been obtained the data will be exported to CADS A3D MAX so that fascia loading can be added and the design re-analysed and code-checked. It is planned to add fascia wind loading in a future upgrade of SMART Portal.

The following example is derived from the basic fully clad duopitch building discussed in section 2 of this guide and has the same frame dimensions, dead and imposed loads and dynamic wind pressure.

The roof net pressure/suction coefficients are obtained from Table 14 of BS 6399-2 as shown below:

Table 14 — Net pressure coefficients C_p for free-standing duopitch canopy roofs

Pitch angle α	Load case	Overall coefficients	Local coefficients			
			A	B	C	D
–20°	Maximum, all ζ	+0.7	+0.8	+1.6	+0.6	+1.7
	Minimum $\zeta = 0$	–0.7	–0.9	–1.3	–1.6	–0.6
	Minimum $\zeta = 1$	–1.5	–1.5	–2.4	–2.4	–1.2
–15°	Maximum, all ζ	+0.5	+0.6	+1.5	+0.7	+1.4
	Minimum $\zeta = 0$	–0.6	–0.8	–1.3	–1.6	–0.6
	Minimum $\zeta = 1$	–1.5	–1.5	–2.7	–2.6	–1.2
–10°	Maximum, all ζ	+0.4	+0.6	+1.4	+0.8	+1.1
	Minimum $\zeta = 0$	–0.6	–0.8	–1.3	–1.5	–0.6
	Minimum $\zeta = 1$	–1.4	–1.4	–2.5	–2.5	–1.2
–5°	Maximum, all ζ	+0.3	+0.5	+1.5	+0.8	+0.8
	Minimum $\zeta = 0$	–0.5	–0.7	–1.3	–1.6	–0.6
	Minimum $\zeta = 1$	–1.4	–1.4	–2.3	–2.4	–1.2
+5°	Maximum, all ζ	+0.3	+0.6	+1.8	+1.3	+0.4
	Minimum $\zeta = 0$	–0.6	–0.6	–1.4	–1.4	–1.1
	Minimum $\zeta = 1$	–1.2	–1.2	–2.0	–1.8	–1.5
+10°	Maximum, all ζ	+0.4	+0.7	+1.8	+1.4	+0.4
	Minimum $\zeta = 0$	–0.7	–0.7	–1.5	–1.4	–1.4
	Minimum $\zeta = 1$	–1.2	–1.2	–1.8	–1.6	–1.6
+15°	Maximum, all ζ	+0.4	+0.9	+1.9	+1.4	+0.4
	Minimum $\zeta = 0$	–0.8	–0.9	–1.7	–1.4	–1.8
	Minimum $\zeta = 1$	–1.2	–1.2	–1.6	–1.3	–1.7
+20°	Maximum, all ζ	+0.6	+1.1	+1.9	+1.5	+0.4
	Minimum $\zeta = 0$	–0.9	–1.2	–1.8	–1.4	–2.0
	Minimum $\zeta = 1$	–1.2	–1.2	–1.5	–1.2	–1.7
+25°	Maximum, all ζ	+0.7	+1.2	+1.9	+1.6	+0.5
	Minimum $\zeta = 0$	–1.0	–1.4	–1.9	–1.4	–2.0
	Minimum $\zeta = 1$	–1.2	–1.2	–1.4	–1.1	–1.6
+30°	Maximum, all ζ	+0.9	+1.3	+1.9	+1.6	+0.7
	Minimum $\zeta = 0$	–1.0	–1.4	–1.9	–1.4	–2.0
	Minimum $\zeta = 1$	–1.2	–1.2	–1.3	–1.1	–1.6

NOTE 1 Interpolation for solidity ratio may be used in the range $0 < \zeta < 1$.

NOTE 2 Interpolation for intermediate pitch angles may be used between values of the same sign.

NOTE 3 Load cases cover all possible wind directions. When using directional effective wind speeds, use:

a) these values of C_p with the largest value of V_e found; or

b) directional values of C_p from reference [6].

Table 14 is illustrated by fig 24 shown below:

For simplicity and conservatively it will be assumed that the canopy may be full blocked at any position.

Clause 2.5.9.1.4 states that "the values in the columns headed `overall coefficients' should be used for the design of members supporting the canopy". This clearly indicates that it is not necessary to apply the local coefficients to the main portal frames. However when read in conjunction with clause 2.5.9.1.3 the status of purlins is ambiguous. Here we are concerned with the main frames only so we will apply the overall coefficients only.

Clause 2.5.9.1.4 also advises that "duopitch canopies should be able to support forces with one slope at the maximum or minimum and the other unloaded."

We will now consider how these loads may be applied in the context of the current functionality of SMART Portal.

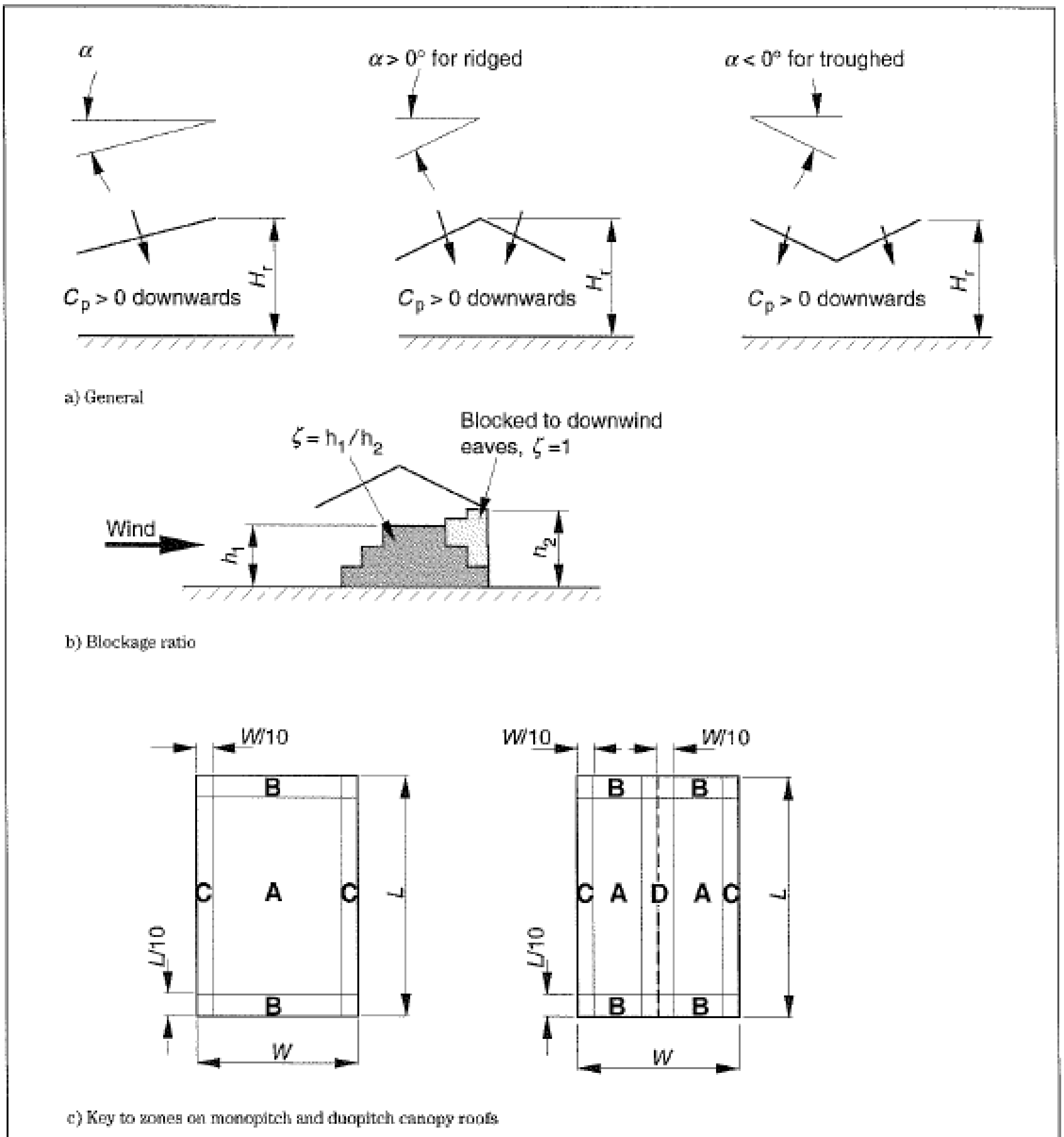


Figure 24 — Key for free-standing canopy roofs

As no separate coefficients are given for pressure or suction on the underside of the roof and also the sides are unclad, the internal pressure inputs to the software are redundant so zero values are input in place of the default values as shown below in fig 17.1.

Wind Blowing From	Left	Right	Near	Far
Dynamic Pressure (qs)	0.751	0.751	0.751	0.751
Dynamic Augmentation Factor (1+Cr)	1.031	1.031	1.031	1.031
Internal Surface Coefficients				
Internal Size Effect Factor Ca	0.900	0.900	0.900	0.900
Basic Pressure Coefficient	0.000	0.000	0.000	0.000
Factored Pressure Coefficient	0.000	0.000	0.000	0.000
Basic Suction Coefficient	0.000	0.000	0.000	0.000
Factored Suction Coefficient	0.000	0.000	0.000	0.000

Fig 17.1 Internal surface surface coefficients edited for canopy open all sides.

Similarly the external surface coefficients for the left and right columns are set to zero as shown below in fig 17.2.

Wind Blowing From	Left	Right	Near	Far
Left Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.000	0.000	0.000	0.000
Factored Pressure Coefficient	0.000	0.000	0.000	0.000
Right Wall/Column				
Size Effect Factor Ca	0.963	0.963	0.963	0.963
Basic Pressure Coefficient	0.000	0.000	0.000	0.000
Factored Pressure Coefficient	0.000	0.000	0.000	0.000

Fig 17.2 External surface coefficients for left and right columns edited for canopy open all sides.

The overall coefficients are applied to the roof as shown below in fig 17.3 and 17.4.

Wind Blowing From	Left	Right	Near	Far
Left Roof/Rafter				
Size Effect Factor Ca	0.936	0.936	0.936	0.936
Basic Main Zone Coefficient	0.300	-1.200	-1.200	0.300
Basic Edge Zone Coefficient	0.300	-1.200	-1.200	0.300
Edge Zone Width (m)	1.265	1.265	0.000	0.000
Reduction Factor	1.000	1.000	1.000	1.000
Factored Main Zone Coefficient	0.289	-1.158	-1.158	0.289
Factored Edge Zone Coefficient	0.289	-1.158	-1.158	0.289

Fig 17.3 External surface coefficients for left rafter edited for canopy open all sides.

Wind Blowing From	Left	Right	Near	Far
Right Roof/Rafter				
Size Effect Factor Ca	0.936	0.936	0.936	0.936
Basic Main Zone Coefficient	0.000	0.000	-1.200	0.300
Basic Edge Zone Coefficient	0.000	0.000	-1.200	0.300
Edge Zone Width (m)	1.265	1.265	0.000	0.000
Reduction Factor	1.000	1.000	1.000	1.000
Factored Main Zone Coefficient	0.000	0.000	-1.158	0.289
Factored Edge Zone Coefficient	0.000	0.000	-1.158	0.289

Fig 17.4 External surface coefficients for right rafter edited for canopy open all sides.

In the above the following assumptions have been made:

- From table 14 for roof slope 5^0, the maximum and minimum overall net coefficients are +0.30 and -1.20.
- The wind near and far conditions are assumed to produce symmetrical loading on the left and right rafters.
- For wind blowing from the near side the canopy is assumed blocked at the far end leading to maximum uplift with C_p = -1.2 on both rafters.
- For wind blowing from the far side the canopy is assumed blocked at the far end leading to suction on the underside and maximum download C_p = +0.30 on both rafters.
- For wind blowing from the left side the canopy is assumed blocked on the left side leading to suction on the underside and maximum down load C_p = +0.30 on the left rafter. To comply

with clause 2.5.9.1.4 to give maximum unsymmetry the right rafter is somehow not loaded so C_p = 0.0.

- For wind blowing from the right side the canopy is assumed blocked on the left side leading to pressure on the underside and external suction so maximum uplift C_p = -1.20 on the left rafter. To comply with clause 2.5.9.1.4 to give maximum unsymmetry the right rafter is somehow not loaded so C_p = 0.0.
- The optional reduction factors (0.60) applied to clad building surfaces where the effect of the load is beneficial (eg suction on windward slope reduces sway effect) are not applied (set to 1.0)because not relevant.

Autodesign produces the following sections for this case:

Rafters: 356 x 171 UKB 45 Columns: 457 x 191 UKB 67 Steel weight per frame: 1798 kg

This solution 5 % heavier than the design for a closed sided building. However the design outcome may be heavier when fascia wind loads are added.

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4 References

1: Cook, NJ *The designer's guide to wind loading of building structures Part 2: static structures.* London, Butterworths, 1989.