

## Structural Design Calculations

|                     |                                                              |
|---------------------|--------------------------------------------------------------|
| <b>Project:</b>     | <b>New portal frame workshops</b>                            |
| <b>Site:</b>        | <b>8-10 Spring Vale St<br/>Tottington<br/>Bury</b>           |
| <b>Client:</b>      | <b>Pavetec Ltd</b>                                           |
| <b>Contractor:</b>  | <b>Pavetec Ltd</b>                                           |
| <b>Architect:</b>   | <b>N B Design and Build Ltd</b>                              |
| <b>Date:</b>        | <b>16/07/20</b>                                              |
| <b>Job Ref:</b>     | <b>20-4106</b>                                               |
| <b>Prepared by:</b> | <b>M Rawat</b>                                               |
| <b>Checked by:</b>  |                                                              |
| <b>Revisions:</b>   | <b>Rev A- Front/ Rear ground Beams adjusted for culvert.</b> |

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## Construction (Design & Management) Regulations 2015.

Under the C(D&M) Regs the designer's responsibility is limited to the reasonably foreseeable risks to persons involved in the construction, maintenance and repair of a structure from hazards that arise from the design. Therefore, this DRA only assesses the possible hazards that may arise from the specific structural design at this stage of the project. Should any alterations to the structure be carried out without the knowledge of the designer then no responsibility can be attributed.

It is the Contractors responsibility to use this document for the construction and future maintenance of the building as designed at this stage. This is not a Method Statement.

Under the C(D&M) Regulations 2015 it is the clients responsibility to ensure that every person designing the structure and every contractor who has been or may be appointed to work on the project is promptly provided with sufficient pre-construction information to ensure so far as is reasonably practicable the health and safety of all persons engaged in the construction work, liable to be affected by the way in which it is carried out, and who will use the structure in future.

## Designers Risk Analysis.

Considerations to be given are:

During initial construction.

Noise and vibrations. Not only consider the effects these may have on workers but also neighbours.

Contamination. Where ground may be contaminated may need to consider substructure works that do not allow leaching through surface etc.

Falls from height, generally over 2m. These include around edges of deep excavations, upper floor and roof edges.

Collapse of the structure under both temporary and permanent imposed loads.

Handling of structural elements. Consideration must be given to the weight of elements specified and whether mechanical handling is feasible. Otherwise consider splicing beams and columns etc or the use of lightweight masonry if acceptable.

Fire. Although on site welding may be necessary, using this near combustible materials is not wise.

Long term.

Falls from height, generally over 2m. Consideration should be given for the future maintenance of the building such as ladder restraint to upper walls.

Collapse of the structure under the permanent imposed loads. The structural elements should be clearly marked on the drawings.

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| Hazard ref | Hazard Source                    | Risk Category | Preventative/Control Measures                                                                                                                                                                                                                                                                                                                                      | Residual Risk |
|------------|----------------------------------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| 1          | Manual handling                  | MEDIUM        | Use lighter sections/material where possible and keep lengths to minimum.<br>Where necessary allow for splicing longer, heavier sections and provide details                                                                                                                                                                                                       | LOW           |
| 2          | Competence                       | HIGH          | Consideration to be given during design of persons undertaking building works.<br>Where complicated structural works are to be carried then suitable design information is to be produced and risks highlighted                                                                                                                                                    | MEDIUM        |
| 3          | Structural stability of building | HIGH          | Design is to consider the temporary (during works) and permanent stability of the building<br>Unless we have been instructed to provide the temporary works design, it is the contractors responsibility to design all temporary works to facilitate the structural alterations.<br>Any element where risk is possible to be highlighted in our design information | MEDIUM        |
| 4          | Noise/vibration                  | MEDIUM        | The design is to consider the effects of any recommended works on the workforce and/or neighbours.<br>Risks to be advised on design information                                                                                                                                                                                                                    | LOW           |
| 5          | Working at height                | MEDIUM        | The design is to consider any unnecessary height issues such as foundation/excavation depths and working overhead.<br>Ultimately, this is the contractors' responsibility to provide all temporary support and platforms                                                                                                                                           | LOW           |
|            |                                  |               |                                                                                                                                                                                                                                                                                                                                                                    |               |
|            |                                  |               |                                                                                                                                                                                                                                                                                                                                                                    |               |

#### Risk Category/Residual Risk

| Low                        | Medium                                        | High                                           |
|----------------------------|-----------------------------------------------|------------------------------------------------|
| No further action required | Risk to be highlighted to contractor/end user | Action required within design to mitigate risk |

## Standard documents.

### Documents used:

|                                        |               |                       |
|----------------------------------------|---------------|-----------------------|
| Building Regulation Approved Documents | Part A        | Structure             |
|                                        | Part B        | Fire                  |
|                                        | Part C        | Site Preparation      |
|                                        | Part H        | Drainage              |
| British Codes of Practice              | BS8110 Part 1 | Concrete              |
|                                        | BS5950 Part 1 | Steel                 |
|                                        | BS5628 Part   | Unreinforced masonry  |
|                                        | BS5977        | Lintel design         |
|                                        | BS5268 Part   | Timber                |
|                                        | BS6399 Parts  | Dead & Imposed loads  |
| Euro Codes                             | EC1           | Actions on structures |
|                                        | EC2           | Concrete design       |
|                                        | EC3           | Steel Design          |
|                                        | EC5           | Timber design         |
|                                        | EC6           | Masonry design        |
| NHBC Standards 2011                    | Chapter 4.3   | Building near Trees   |

## Standard Construction Notes.

These calculations have been produced for the sole purpose of obtaining Building Regulations Approval for the structural elements of the proposed scheme as per our terms of instruction. These calculations are based on the structural alterations required and either as shown on the Architects' drawings or in the design brief. These calculations should be read in conjunction with such information. Due care and attention has been given in the production of these calculations, however, it is the Contractors' responsibility to advise STL of any discrepancies prior to commencing on site.

Any dimensions shown in these calculations are purely for design purposes only and must not be used for ordering lengths of members. All measurements must be taken on site and lengths of required bearings added.

Unless specifically stated, STL have not undertaken any ground investigations or survey of the existing structure and the suitability of such is presumed to be structurally sound for the purpose of these calculations. All supporting walls are presumed to have suitable foundations and it is the Contractors' responsibility to ensure such before creating new load paths. These calculations do not constitute a structural appraisal of the building, and it is the Clients responsibility to employ an experienced Contractor who has full knowledge and understanding of current building practice.

We also recommend that Building Regulation Approval is obtained for any structural works. The design calculations should be provided as part of any such approval, however STL take no responsibility applying for such approval unless specifically instructed. Additional fees may be charged for such work in addition to Building Control Fees.

All attempts have been made to simplify the design of any supports and reduce the risks and hazards associated with the implementation of such. It is the contractor's responsibility to ensure that he is satisfied with the scheme and design and install all the necessary temporary support of the existing structure and ensure the safety of all persons involved in the construction and secure the site.

Where we have not been asked to undertake any ground investigations we cannot advise on the required foundations for the new project. Therefore, all new foundations are to be of adequate width and taken down to a suitable depth to be confirmed on site with the Engineer or Building Inspector. Where posts or piers are specified then we will provide approximate pad foundation sizes based upon presumed safe bearing capacities of the substrata. These will need to be confirmed on site. Should specialist foundations be required then STL are more than happy to design these but at extra cost. Where new foundations pass over existing or new drain runs they should be taken down below the invert level of the drains and pre cast concrete lintels used to span over.

All steel specified in these calculations is to be of minimum grade S275 to Standard British sections to BS5950. All steelwork is to be protected from corrosion by standard 2 coats of zinc rich primer and being touched up on site as necessary. Where steel is in external exposed conditions, then we recommend shot blasting and hot dip galvanising plus the use of cavity trays etc where applicable. All bearings for beams supporting the structure over new openings should be a minimum of 100mm, sat on 440x100x215mm deep C35 concrete padstones built into the new/existing masonry walls. Where increased bearing is required these will be specified in the calculations/drawings. All steel to steel connections are to be made with M16 Grade 8.8 bolts minimum or 6mm full penetration fillet welds all round.

All lintels are to be installed in accordance with the manufacturers' recommendations, with a minimum bearing of 150mm unless specified otherwise.

All new load bearing masonry should be of minimum 7N/mm<sup>2</sup> block or 10N/mm<sup>2</sup> brickwork bed in class iii mortar to BS5628 unless advised otherwise in the calculations.

All new timber sections are to be of structural graded timber as specified in the calculations to BS5268. All timber delivered to site should be marked with the grade and this should be checked with the calculations for compatibility. All timber should be kept covered, off the ground and out of the elements. Any special timber trusses or floor joists should be stored in accordance with the manufacturer's instructions.

It should be noted that any structural works to the existing building fabric may cause some damage to adjacent plastered/decorated areas and this should be taken into consideration with respect to any redecoration costs.

Where any of the structure is built into or adjacent a Party Wall Structure, you have a legal requirement under the Party Wall etc Act 1996, to notify the owner such structure before undertaking any work. We recommend that a condition survey is undertaken of the affected area as any damage that may occur during the work is your responsibility to correct. Sometime disputes can arise and you will need the services of a Party Wall Surveyor.

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## Loadings:

Please note, these loadings are for general design purposes and may not refer to this specific project.

### Roof **Profile insulated panel roof**

|               |                             |                                      |
|---------------|-----------------------------|--------------------------------------|
| Dead loads;   | Insulated sheeting          | 0.20                                 |
|               | Purlins                     | 0.05                                 |
|               | Services                    | 0.25                                 |
|               | Total                       | <b>0.50kN/m<sup>2</sup> on plan.</b> |
| Imposed Load; | access only for maintenance | <b>0.60kN/m<sup>2</sup></b>          |

### Walls **Solid brick internal walls:**

|             |                       |                             |
|-------------|-----------------------|-----------------------------|
| Dead loads; | Plaster & skim finish | 0.23                        |
|             | 4" brick              | 2.00                        |
|             | Plaster & skim finish | <u>0.23</u>                 |
|             | Total                 | <b>2.46kN/m<sup>2</sup></b> |

### Walls **Brick/block (medium dense) cavity walls:**

|             |                       |                             |
|-------------|-----------------------|-----------------------------|
| Dead loads; | brick                 | 2.00                        |
|             | Insulation            | 0.05                        |
|             | block                 | 1.80                        |
|             | Plaster & skim finish | <u>0.23</u>                 |
|             | Total                 | <b>4.08kN/m<sup>2</sup></b> |

### Walls **Solid block (medium dense) internal load bearing walls:**

|             |                       |                             |                            |                             |
|-------------|-----------------------|-----------------------------|----------------------------|-----------------------------|
| Dead loads; | Plaster & skim finish | 0.23                        | Plasterboard & skim finish | 0.15                        |
|             | 100mm block           | 1.80                        |                            |                             |
|             | Plaster & skim finish | <u>0.23</u>                 | Plasterboard & skim finish | <u>0.15</u>                 |
|             | Total                 | <b>2.26kN/m<sup>2</sup></b> |                            | <b>2.10kN/m<sup>2</sup></b> |

### Walls **Timber stud internal non load bearing partition walls:**

|             |                            |                             |
|-------------|----------------------------|-----------------------------|
| Dead loads; | Plasterboard & skim finish | 0.15                        |
|             | Timber studs at 400mm c/c  | 0.06                        |
|             | Plasterboard & skim finish | <u>0.15</u>                 |
|             | Total                      | <b>0.36kN/m<sup>2</sup></b> |

### Floors: **Suspended timber floor:**

|             |                               |                             |
|-------------|-------------------------------|-----------------------------|
| Dead loads; | boards                        | 0.09                        |
|             | Joists (say 50x175 @ 400 c/c) | 0.15                        |
|             | Ceiling board & skim finish   | <u>0.15</u>                 |
|             | Total                         | <b>0.39kN/m<sup>2</sup></b> |

### Floor: **Suspended precast concrete beam and block floor:**

|             |                             |             |
|-------------|-----------------------------|-------------|
| Dead loads; | 65mm sand cement screed     | 1.56        |
|             | 150mm B&B floor say         | 2.60        |
|             | Ceiling board & skim finish | <u>0.15</u> |

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Total **4.27kN/m<sup>2</sup>**

Floor: **Suspended precast concrete floor:**

|             |                               |                             |
|-------------|-------------------------------|-----------------------------|
| Dead loads; | 65mm screed                   | 1.30                        |
|             | Insulation                    | 0.02                        |
|             | 150mm precast concrete planks | 3.20                        |
|             | Ceiling board & skim finish   | <u>0.15</u>                 |
|             | Total                         | <b>4.67kN/m<sup>2</sup></b> |

Floor: **Suspended reinforced concrete floor:**

|             |                             |                             |
|-------------|-----------------------------|-----------------------------|
| Dead loads; | 65mm screed                 | 1.30                        |
|             | Insulation                  | 0.02                        |
|             | 150mm slab on profiled deck | 2.80                        |
|             | Ceiling board & skim finish | <u>0.15</u>                 |
|             | Total                       | <b>4.27kN/m<sup>2</sup></b> |

Imposed Loads; BS6399 Part 1 Table 1

|                      |                             |
|----------------------|-----------------------------|
| Office use           | <b>2.50kN/m<sup>2</sup></b> |
| Factories/ workshops | <b>5.00kN/m<sup>2</sup></b> |

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## Design.

### Metsec- Wind Loading

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Date: 16/07/2020

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#### Wind Assessment to BS6399-2

##### Data Entry:-

|                        |         |     |                       |       |                        |        |   |
|------------------------|---------|-----|-----------------------|-------|------------------------|--------|---|
| Site Altitude          | 145.000 | m   | Reference Height (Hr) |       | Diagonal Dimension (a) |        |   |
| Basic Wind Speed       | 22.500  | m/s | Roof                  | 6.000 | Roof                   | 26.000 | m |
| Seasonal Factor (Ss)   | 1.000   |     | Side Walls            | 5.000 | Sides                  | 16.000 | m |
| Probability Factor(Sp) | 1.000   |     | Gables                | 6.000 | Gables                 | 20.000 | m |
| Site ID                |         |     |                       |       |                        |        |   |

#### Dynamic Pressure Results

| Wind Direction (deg)          | 0     | 30    | 60    | 90    | 120   | 150   | 180   | 210   | 240   | 270   | 300   | 330   |
|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Direction Factor Sd           | 0.78  | 0.73  | 0.73  | 0.74  | 0.73  | 0.80  | 0.85  | 0.93  | 1.00  | 0.99  | 0.91  | 0.82  |
| Topographic Location Factor s | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Altitude Factor Sa            | 1.145 | 1.145 | 1.145 | 1.145 | 1.145 | 1.145 | 1.145 | 1.145 | 1.145 | 1.145 | 1.145 | 1.145 |
| Effective Height He(m)        | Roof  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  |
|                               | Sides | 5.00  | 5.00  | 5.00  | 5.00  | 5.00  | 5.00  | 5.00  | 5.00  | 5.00  | 5.00  | 5.00  |
|                               | Gable | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  | 6.00  |
| Terrain & Building Factor Sb  | Roof  | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 |
|                               | Sides | 1.519 | 1.519 | 1.519 | 1.519 | 1.519 | 1.519 | 1.519 | 1.519 | 1.519 | 1.519 | 1.519 |
|                               | Gable | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 | 1.553 |
| Site Wind Speed Vs(m/s)       | Roof  | 20.09 | 18.81 | 18.81 | 19.06 | 18.81 | 20.61 | 21.90 | 23.96 | 25.76 | 25.50 | 23.44 |
|                               | Sides | 20.09 | 18.81 | 18.81 | 19.06 | 18.81 | 20.61 | 21.90 | 23.96 | 25.76 | 25.50 | 23.44 |
|                               | Gable | 20.09 | 18.81 | 18.81 | 19.06 | 18.81 | 20.61 | 21.90 | 23.96 | 25.76 | 25.50 | 23.44 |
| Effective Wind Speed Ve(m/s)  | Roof  | 31.20 | 29.20 | 29.20 | 29.60 | 29.20 | 32.00 | 34.00 | 37.20 | 40.00 | 39.60 | 36.40 |
|                               | Sides | 30.53 | 28.57 | 28.57 | 28.96 | 28.57 | 31.31 | 33.27 | 36.40 | 39.14 | 38.74 | 35.61 |
|                               | Gable | 31.20 | 29.20 | 29.20 | 29.60 | 29.20 | 32.00 | 34.00 | 37.20 | 40.00 | 39.60 | 36.40 |
| Dynamic Pressure q (kN/m²)    | Roof  | 0.597 | 0.523 | 0.523 | 0.537 | 0.523 | 0.628 | 0.709 | 0.848 | 0.981 | 0.961 | 0.812 |
|                               | Sides | 0.571 | 0.500 | 0.500 | 0.514 | 0.500 | 0.601 | 0.678 | 0.812 | 0.939 | 0.920 | 0.777 |
|                               | Gable | 0.597 | 0.523 | 0.523 | 0.537 | 0.523 | 0.628 | 0.709 | 0.848 | 0.981 | 0.961 | 0.812 |
| Size Effect Factor Cae        | Roof  | 0.879 | 0.879 | 0.879 | 0.879 | 0.879 | 0.879 | 0.879 | 0.879 | 0.879 | 0.879 | 0.879 |
|                               | Sides | 0.920 | 0.920 | 0.920 | 0.920 | 0.920 | 0.920 | 0.920 | 0.920 | 0.920 | 0.920 | 0.920 |
|                               | Gable | 0.900 | 0.900 | 0.900 | 0.900 | 0.900 | 0.900 | 0.900 | 0.900 | 0.900 | 0.900 | 0.900 |

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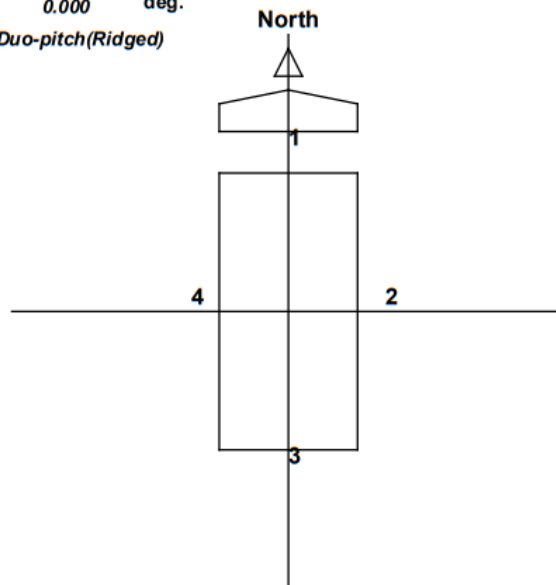
Tel: 0161 969 3218 Fax:

Email: mohammed@stlprojectsLtd.co.uk

### Wind Assessment to BS6399-2

Roof Orientation 0.000 deg.

Roof Type Duo-pitch(Ridged)



### Dynamic Pressure kN/m<sup>2</sup>

| Orthogonal Direction 1 | Orthogonal Direction 2 | Orthogonal Direction 3 | Orthogonal Direction 4 |
|------------------------|------------------------|------------------------|------------------------|
| 0.659                  | 0.537                  | 0.848                  | 0.981                  |

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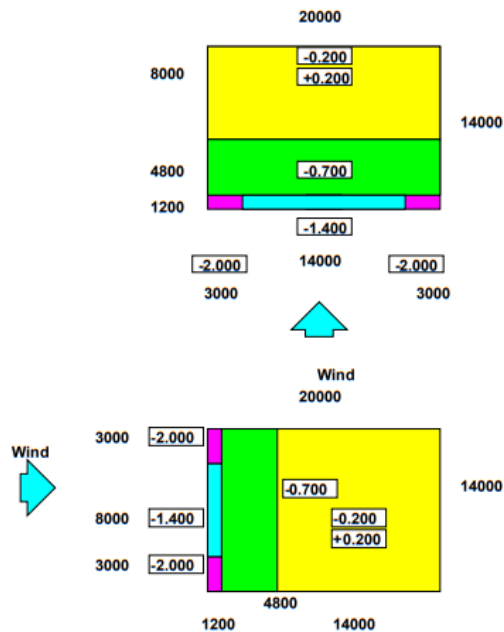
Tel:  
Email:

Fax:

### Wind Analysis to BS6399-2 - Cpe Results for Roofs

#### DATA ENTRY:-

Short Face Length of Building 14.000 m Reference Height 6.000m  
Long Face of Building 20.000 m  
Roof Type Flat roof- sharp eaves



NB: All dimensions are in millimetres, except Cpe values

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Date 16/07/2020

**Registered Details:-**

**Tel:**

**Email:**

**Fax:**

### Wind Analysis to BS6399-2 - Cpe Results for Walls

**DATA ENTRY:-**

### Short Face 1 or 3

14.000 m

### Long Face 2 or 4

20.000 m

### Reference Face

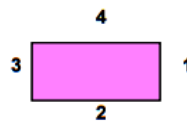
Face 1 (Side)

### Reference Height

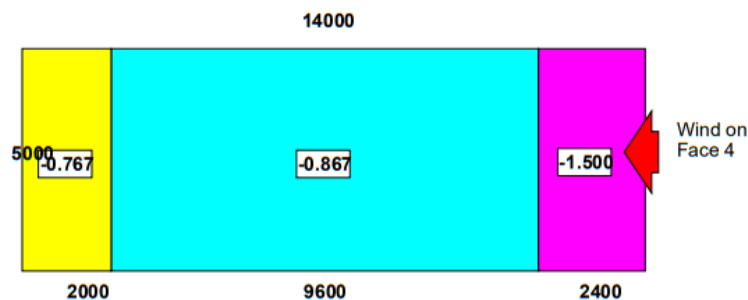
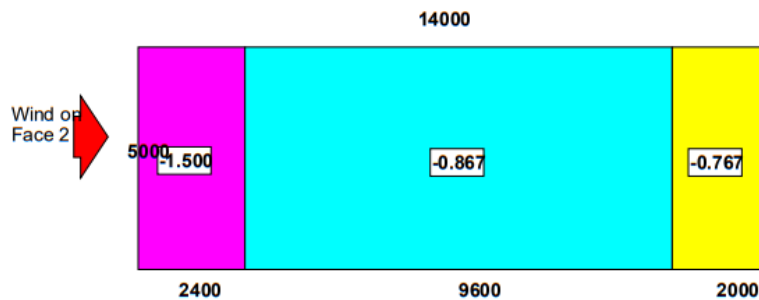
5.000 m

### Gap Between Buildings

5.000 m



Reference Face



-Cpe On Reference Face1

**+Cpe On Reference Face =+0.600**

**-Cpe On Opposite(Leeward) Face =-0.500**

**NB: All dimensions are in millimetres, except Cpe values**

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Registered Details:-

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### Wind Analysis to BS6399-2 - Cpe Results for Walls

#### DATA ENTRY:-

Short Face 1 or 3

14.000 m

Long Face 2 or 4

20.000 m

Reference Face

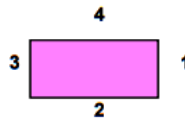
Face 2 (Gable)

Reference Height

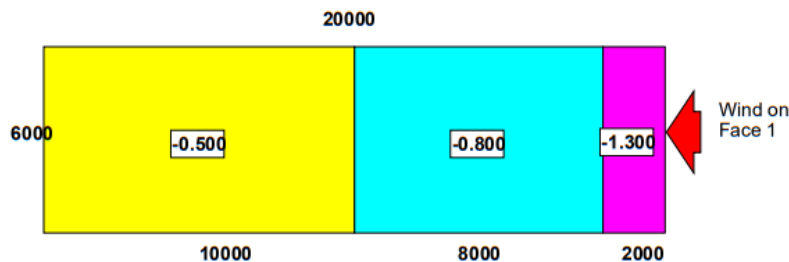
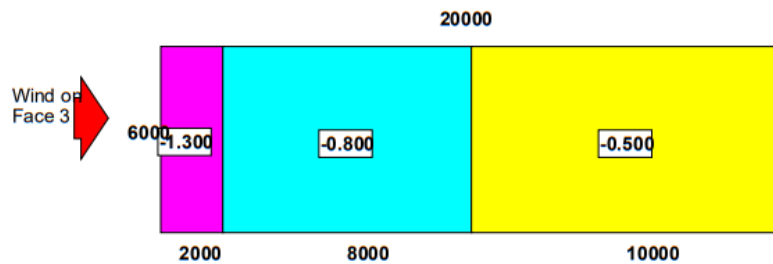
6.000 m

Gap Between Buildings

40.000 m



Reference Face



-Cpe On Reference Face2

+Cpe On Reference Face = +0.739

-Cpe On Opposite (Leeward) Face = -0.500

NB: All dimensions are in millimetres, except Cpe values

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

Date: 16/07/20

Ref: 20-4106

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Date 16/07/2020

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Email:

Fax:

### Wind Analysis to BS6399-2 - Cpe Results for Walls

#### DATA ENTRY:-

Short Face 1 or 3

14.000 m

Long Face 2 or 4

20.000 m

Reference Face

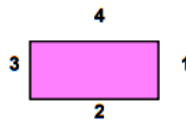
Face 3 (Side)

Reference Height

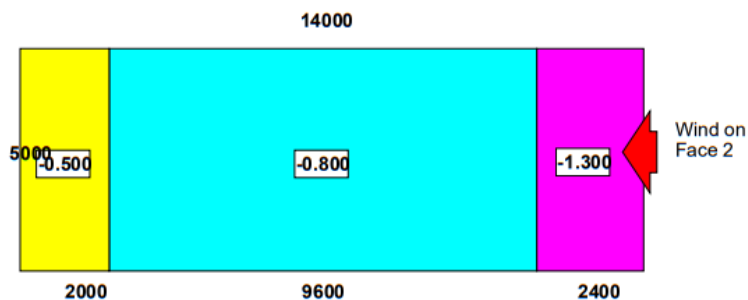
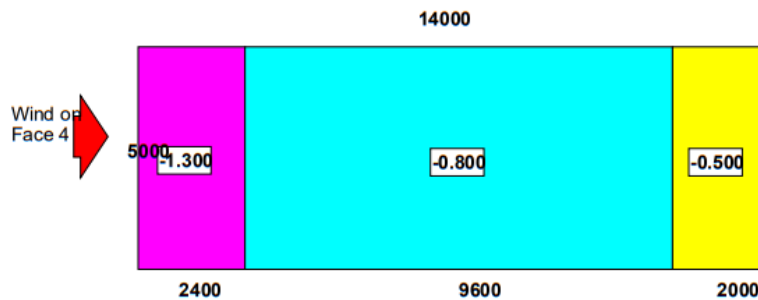
5.000 m

Gap Between Buildings

0.000 m



Reference Face



#### -Cpe On Reference Face3

+Cpe On Reference Face = +0.600

-Cpe On Opposite (Leeward) Face = -0.500

NB: All dimensions are in millimetres, except Cpe values

Client: Pavetec Ltd

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## Designer

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**Registered Details:-**

**Tel:**  
**Email:**

**Fax:**

### Wind Analysis to BS6399-2 - Cpe Results for Walls

**DATA ENTRY:-**

### Short Face 1 or 3

14.000 m

### Long Face 2 or 4

20.000 m

### Reference Face

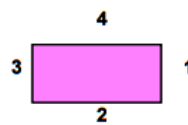
### Face 4 (Gable)

### Reference Height

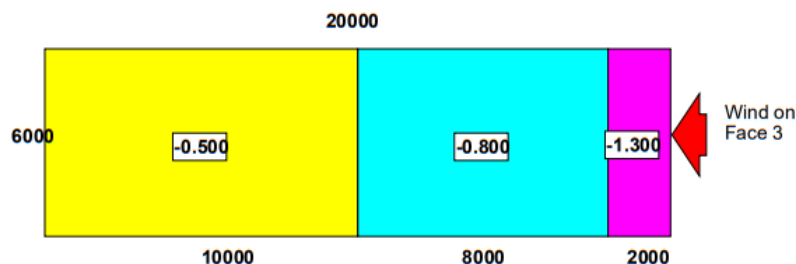
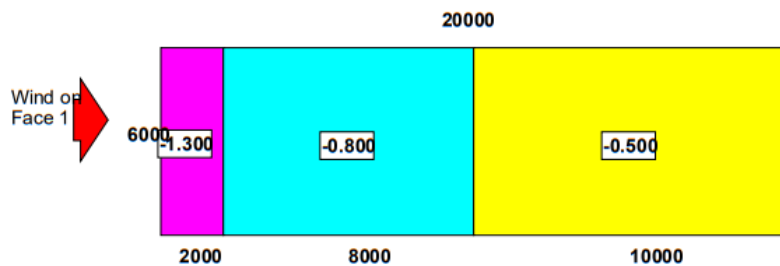
6.000 m

### Gap Between Buildings

0.000 m



Reference Face



-Cpe On Reference Face4

**+Cpe On Reference Face =+0.739**

-Cpe On Opposite(Leeward) Face =-0.500

**NB: All dimensions are in millimetres, except Cpe values**

Client: Pavetec Ltd

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STL Projects Ltd  
1 Barkers Lane, Sale,  
Tel: 0161 969 3218 Fax:  
Email: mohammed@stlprojectsLtd.co.uk

### Wind Assessment to BS6399-2

#### Data Entry:-

| Condition       | Without Dominant Opening | Reference Height (Hr) |
|-----------------|--------------------------|-----------------------|
| Internal Volume | 770.000 m³               | Roof 6.000 m          |
|                 |                          | Side Walls 5.000 m    |
|                 |                          | Gables 6.000 m        |
| Cpi             | -ve 0.300                |                       |
|                 | +ve 0.200                |                       |

#### Size Effect Factors For Cpi

| Wind Direction (deg)          | 0     | 30    | 60    | 90    | 120   | 150   | 180   | 210   | 240   | 270   | 300   | 330   |
|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Size Effect Factor Cai (Roof) | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 |

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1 Barkers Lane, Sale,  
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Email: mohammed@stlprojectsLtd.co.uk

### Wind Assessment to BS6399-2

#### Data Entry:-

| Condition       | Without Dominant Opening | Reference Height (Hr) |
|-----------------|--------------------------|-----------------------|
| Internal Volume | 770.000 m³               | Roof 6.000 m          |
|                 |                          | Side Walls 5.000 m    |
|                 |                          | Gables 6.000 m        |
| Cpi             | -ve 0.300                |                       |
|                 | +ve 0.200                |                       |

#### Size Effect Factors For Cpi

| Wind Direction (deg)           | 0     | 30    | 60    | 90    | 120   | 150   | 180   | 210   | 240   | 270   | 300   | 330   |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Size Effect Factor Cai (Walls) |       |       |       |       |       |       |       |       |       |       |       |       |
| Side                           | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 |
| Gable                          | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 | 0.779 |

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

Date: 16/07/20

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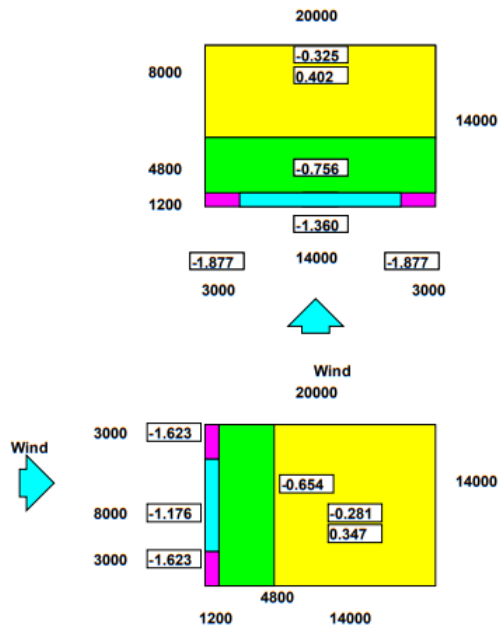
### Wind Analysis to BS6399-2 - Wind Loads for Roofs

#### DATA ENTRY:-

Short Face Length of Building 14.000 m Reference Height 6.000m

Long Face of Building 20.000 m

Roof Type Flat roof- sharp eaves



NB: All dimensions are in millimetres and wind loads in kN/m<sup>2</sup>

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

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### Wind Analysis to BS6399-2 - Wind Loads for Walls

**DATA ENTRY:-**

### Short Face 1 or 3

14.000 m

### Long Face 2 or 4

20.000 m

### Reference Face

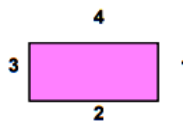
Face 1 (Side)

### Reference Height

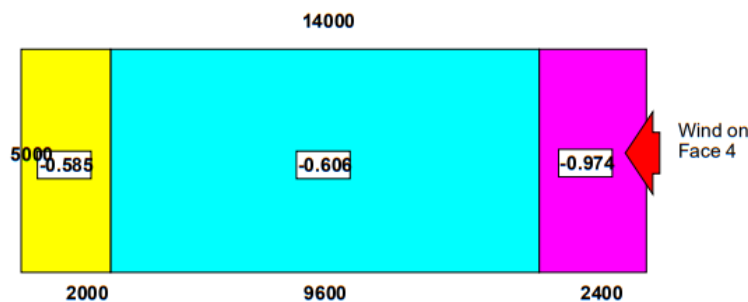
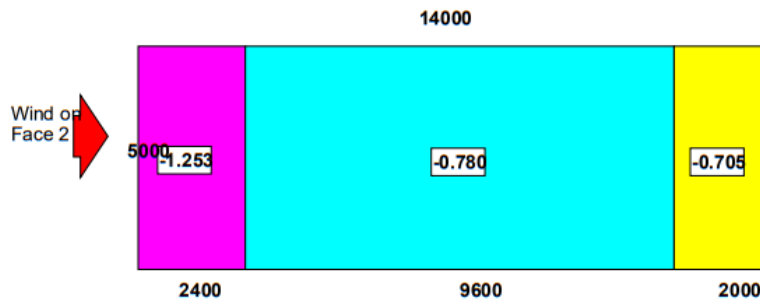
5.000 m

### Gap Between Buildings

5.000 m



Reference Face



**Suction(kN/m<sup>2</sup>) On Reference Face1**

**Pressure (kN/m<sup>2</sup>) On Reference Face = +0.409**

Pressure/Suction (kN/m<sup>2</sup>) On Opposite(Leeward) Face = -0.320

**Note: The above loads are not applicable to parapets which must be designed separately.**

**NB: All dimensions are in millimetres and wind loads in kN/m<sup>2</sup>**

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Project: 8- 10 Spring Vale Street Bury

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## Wind Analysis to BS6399-2 - Wind Loads for Walls

### DATA ENTRY:-

Short Face 1 or 3

14.000 m

Long Face 2 or 4

20.000 m

Reference Face

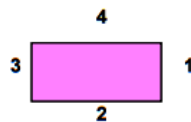
Face 2 (Gable)

Reference Height

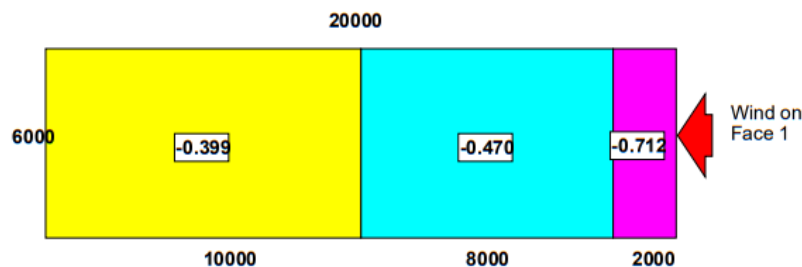
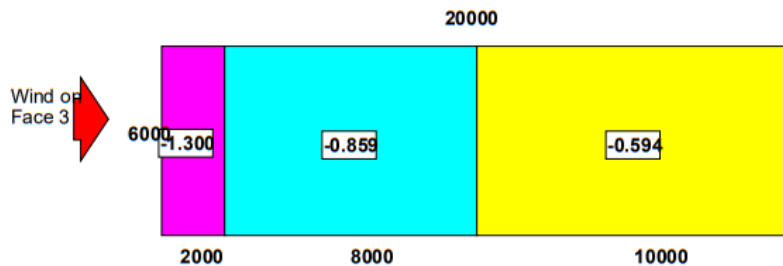
6.000 m

Gap Between Buildings

40.000 m



Reference Face



### Suction(kN/m<sup>2</sup>) On Reference Face2

Pressure (kN/m<sup>2</sup>) On Reference Face = +0.762

Pressure/Suction (kN/m<sup>2</sup>) On Opposite(Leeward) Face = -0.514

**Note: The above loads are not applicable to parapets which must be designed separately.**

NB: All dimensions are in millimetres and wind loads in kN/m<sup>2</sup>

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### Wind Analysis to BS6399-2 - Wind Loads for Walls

#### DATA ENTRY:-

Short Face 1 or 3

14.000 m

Long Face 2 or 4

20.000 m

Reference Face

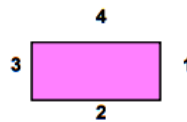
Face 3 (Side)

Reference Height

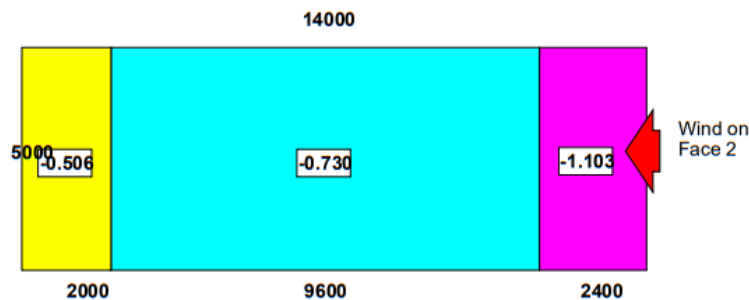
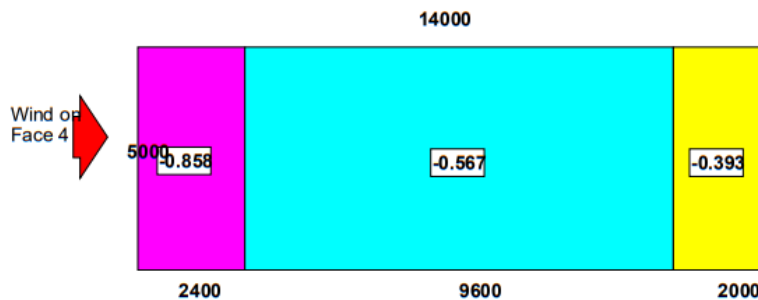
5.000 m

Gap Between Buildings

0.000 m



Reference Face



#### Suction(kN/m²) On Reference Face3

Pressure (kN/m²) On Reference Face = +0.747

Pressure/Suction (kN/m²) On Opposite(Leeward) Face = -0.585

**Note: The above loads are not applicable to parapets which must be designed separately.**

NB: All dimensions are in millimetres and wind loads in kN/m²

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## Wind Analysis to BS6399-2 - Wind Loads for Walls

### DATA ENTRY:-

Short Face 1 or 3

14.000 m

Long Face 2 or 4

20.000 m

Reference Face

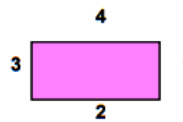
Face 4 (Gable)

Reference Height

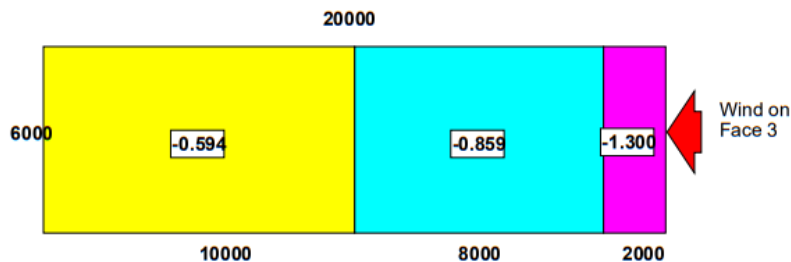
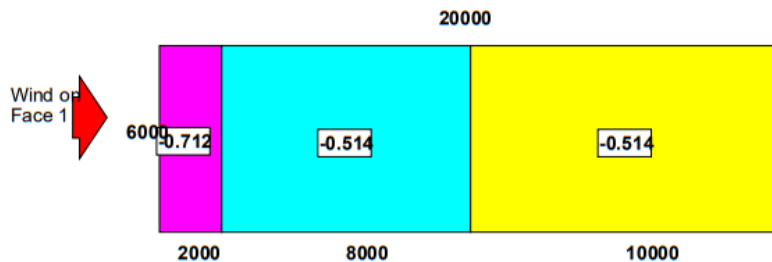
6.000 m

Gap Between Buildings

0.000 m



Reference Face



### Suction(kN/m²) On Reference Face4

Pressure (kN/m²) On Reference Face = +0.593

Pressure/Suction (kN/m²) On Opposite(Leeward) Face = -0.399

**Note: The above loads are not applicable to parapets which must be designed separately.**

NB: All dimensions are in millimetres and wind loads in kN/m²

Client: Pavetec Ltd

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## Metsec Purlins and Sheeting Rails

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Email: [mohammed@stlprojectsLtd.co.uk](mailto:mohammed@stlprojectsLtd.co.uk)

Site:

Comment:

#### PURLIN SELECTION

Z PURLIN SYSTEM TYPE:

SLEEVED

METAL CLADDING

#### Dimensions & Limits

Span: 5.400 m

Centres: 1.800 m

Def. Limit: Span/ 180

Roof Slope: 3.0 deg.

#### Design Loads in kN/m<sup>2</sup>

Dead Load : 0.500

Service Load : 0.250

Super Load : 0.600

Roof type: Flat-sharp eaves. (Purlins Parallel to short face)

| STEPPED WIND UPLIFT LOADS- PURLIN ZONE- (2)-Eaves Condition |        |                            |            |        |                            |
|-------------------------------------------------------------|--------|----------------------------|------------|--------|----------------------------|
| Wind @ 0°                                                   |        |                            | Wind @ 90° |        |                            |
| From (m)                                                    | To (m) | Loads (kN/m <sup>2</sup> ) | From (m)   | To (m) | Loads (kN/m <sup>2</sup> ) |
| 0.000                                                       | 1.200  | 1.877                      | 0.000      | 3.000  | 1.623                      |
| 1.200                                                       | 6.000  | 0.756                      | 3.000      | 11.000 | 1.176                      |
| 6.000                                                       | 14.000 | 0.325                      | 11.000     | 14.000 | 1.623                      |

#### SELECTED PURLINS

| Spans 1+2 Section Pass    |                |           |  | Load Capacity Ratios           |                       |                      |
|---------------------------|----------------|-----------|--|--------------------------------|-----------------------|----------------------|
| Elsewhere Section Pass    |                |           |  | Unfactored load for deflection | Ultimate gravity load | Ultimate wind uplift |
| Section Reference         | Weight in kg/m | Restraint |  |                                |                       |                      |
| Spans 1+2 <b>172.Z.15</b> | 3.73           | 1 Sags    |  | 0.981                          | 0.963                 | 0.936                |
| Elsewhere <b>172.Z.15</b> | 3.73           | 1 Sags    |  | 0.981                          | 0.963                 | 0.831                |

The above values assume that the cladding panel or liner tray is screw fixed to the section(s) at a maximum spacing of 600mm.

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

Date: 16/07/20

Ref: 20-4106

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Site:

Comment:

#### PURLIN SELECTION

Z PURLIN SYSTEM TYPE: SLEEVED METAL CLADDING

#### Dimensions & Limits

Span: 5.400 m  
Centres: 1.800 m  
Def. Limit: Span/ 180  
Roof Slope: 3.0 deg.

#### Design Loads in kN/m<sup>2</sup>

Dead Load : 0.500  
Service Load : 0.250  
Super Load : 0.600

Roof type: Flat-sharp eaves. (Purlins Parallel to short face)

| STEPPED WIND UPLIFT LOADS- PURLIN ZONE- (2)-Eaves Condition |        |                            |            |        |                            |
|-------------------------------------------------------------|--------|----------------------------|------------|--------|----------------------------|
| Wind @ 0°                                                   |        |                            | Wind @ 90° |        |                            |
| From (m)                                                    | To (m) | Loads (kN/m <sup>2</sup> ) | From (m)   | To (m) | Loads (kN/m <sup>2</sup> ) |
| 0.000                                                       | 1.200  | 1.877                      | 0.000      | 3.000  | 1.623                      |
| 1.200                                                       | 6.000  | 0.756                      | 3.000      | 11.000 | 1.176                      |
| 6.000                                                       | 14.000 | 0.325                      | 11.000     | 14.000 | 1.623                      |

#### SELECTED PURLINS

| Spans 1+2 Section Pass |                |           |  | Load Capacity Ratios           |                       |                      |
|------------------------|----------------|-----------|--|--------------------------------|-----------------------|----------------------|
| Elsewhere Section Pass |                |           |  | Unfactored load for deflection | Ultimate gravity load | Ultimate wind uplift |
| Section Reference      | Weight in kg/m | Restraint |  |                                |                       |                      |
| Spans 1+2 172.Z.15     | 3.73           | 1 Sags    |  | 0.981                          | 0.963                 | 0.936                |
| Elsewhere 172.Z.15     | 3.73           | 1 Sags    |  | 0.981                          | 0.963                 | 0.831                |

The above values assume that the cladding panel or liner tray is screw fixed to the section(s) at a maximum spacing of 600mm.

Client: Pavetec Ltd

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Tel: 0161 969 3218 Fax:

Email: [mohammed@stlprojectsltd.co.uk](mailto:mohammed@stlprojectsltd.co.uk)

Site:

Comment:

### PURLIN SELECTION

Z PURLIN SYSTEM TYPE: SLEEVED

METAL CLADDING

#### Dimensions & Limits

Span: 5.400 m

Centres: 1.800 m

Deflection Limit: Span/ 180

Roof Slope: 3.0 deg.

#### Design Loads in kN/m<sup>2</sup>

Dead Load : 0.500

Service Load : 0.250

Super Load : 0.600

Wind Uplift Load : 1.060

### SELECTED PURLINS

| Section                               | Pass           | Unfactored load for deflection | Ultimate download | Ultimate wind uplift |
|---------------------------------------|----------------|--------------------------------|-------------------|----------------------|
| Required Loads in kN/m <sup>2</sup> : |                | 1.350                          | 2.010             | 0.984                |
| Capacity Loads in kN/m <sup>2</sup> : |                |                                |                   |                      |
| Section Reference                     | Weight in kg/m | Restraint                      |                   |                      |
| 172.Z.15                              | 3.73           | 1 Sags                         | 1.376             | 2.085                |
|                                       |                |                                |                   | 2.134                |

The above values assume that the cladding panel or liner tray is screw fixed to the section(s) at a maximum spacing of 600mm.

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

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Email: [mohammed@stlprojectsltd.co.uk](mailto:mohammed@stlprojectsltd.co.uk)

Site:

Comment:

### SIDE RAIL ENTERED DATA

#### SYSTEM TYPE :

#### Z Sleeved System

#### Dimensions & Limits

Span : 5.400 m  
Centres : 2.000 m  
Deflection Limit : Span / 150(36mm)  
No. of Supports: 1  
Cladding : Restraining

#### Design Loads in kN/m<sup>2</sup>

Cladding Weight: 0.250  
Wind Pressure: 0.760  
Wind Suction 0.540

### SELECTED SIDE RAILS

| Span No. | Reference | Weight<br>(kg/m) | Factored Loads<br>(kN/m <sup>2</sup> ) |         | Capacities<br>(kN/m <sup>2</sup> ) |         | Unfactored<br>Load (defln) | Deflection<br>Capacity<br>(kN/m <sup>2</sup> ) | Pass /<br>Fail |
|----------|-----------|------------------|----------------------------------------|---------|------------------------------------|---------|----------------------------|------------------------------------------------|----------------|
|          |           |                  | Pressure                               | Suction | Pressure                           | Suction |                            |                                                |                |
| 1        | 142.Z.15  | 3.26             | 1.064                                  | 0.756   | 1.308                              | 1.308   | 0.760                      | 0.949                                          | Pass           |

The above values assume that the cladding panel or liner tray is screw fixed to the section(s) at a maximum spacing of 600mm.

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## Portal Frame Analysis

### Materials Table - units: N/mm<sup>2</sup>

Type E  
Steel 205000

### Sections Table - units: cm<sup>2</sup>, cm<sup>4</sup>

| Code | Description   | A     | I       |
|------|---------------|-------|---------|
| A    | 254x146x31 UB | 39.70 | 4410.00 |

### Joints Table - units: mm

| Joint | X     | Y    |
|-------|-------|------|
| 1     | 0     | 0    |
| 2     | 0     | 4700 |
| 3     | 0     | 5000 |
| 4     | 0     | 2500 |
| 5     | 850   | 5090 |
| 6     | 4850  | 5500 |
| 7     | 9200  | 5955 |
| 8     | 9700  | 0    |
| 9     | 9700  | 5700 |
| 10    | 9700  | 6000 |
| 11    | 9700  | 2500 |
| 12    | 10200 | 5955 |
| 13    | 14550 | 5500 |
| 14    | 18550 | 5090 |
| 15    | 19400 | 0    |
| 16    | 19400 | 2500 |
| 17    | 19400 | 4700 |
| 18    | 19400 | 5000 |

### Members Table

| Member | Code | Description   |
|--------|------|---------------|
| 1-4    | A    | 254x146x31 UB |
| 2-4    | A    | 254x146x31 UB |
| 2-3    | A    | 254x146x31 UB |
| 2-5    | B    | 305x127x37 UB |
| 3-5    | B    | 305x127x37 UB |
| 5-6    | B    | 305x127x37 UB |
| 6-7    | B    | 305x127x37 UB |
| 7-10   | B    | 305x127x37 UB |
| 7-9    | B    | 305x127x37 UB |
| 8-11   | A    | 254x146x31 UB |
| 9-11   | A    | 254x146x31 UB |
| 9-10   | A    | 254x146x31 UB |
| 9-12   | B    | 305x127x37 UB |
| 10-12  | B    | 305x127x37 UB |
| 12-13  | B    | 305x127x37 UB |
| 13-14  | B    | 305x127x37 UB |
| 14-18  | B    | 305x127x37 UB |
| 14-17  | B    | 305x127x37 UB |
| 15-16  | A    | 254x146x31 UB |
| 16-17  | A    | 254x146x31 UB |
| 17-18  | A    | 254x146x31 UB |

### Load Cases Table

| Case | Description |
|------|-------------|
| 1    | Load Case 1 |

### Load Combination Table

|               | Load Case 1 |     |     | Load Case 2 |   |   | Load Case 3 |   |   | Load Case 4 |   |   |
|---------------|-------------|-----|-----|-------------|---|---|-------------|---|---|-------------|---|---|
|               | G           | Q   | W   | G           | Q | W | G           | Q | W | G           | Q | W |
| Combination 1 | 1.4         | 1.6 |     |             |   |   |             |   |   |             |   |   |
| Combination 2 | 1.2         | 1.2 | 1.2 |             |   |   |             |   |   |             |   |   |
| Combination 3 | 1           |     |     |             |   |   |             |   |   |             |   |   |
| Combination 4 |             | 1   |     |             |   |   |             |   |   |             |   |   |
| Combination 5 |             |     | 1   |             |   |   |             |   |   |             |   |   |

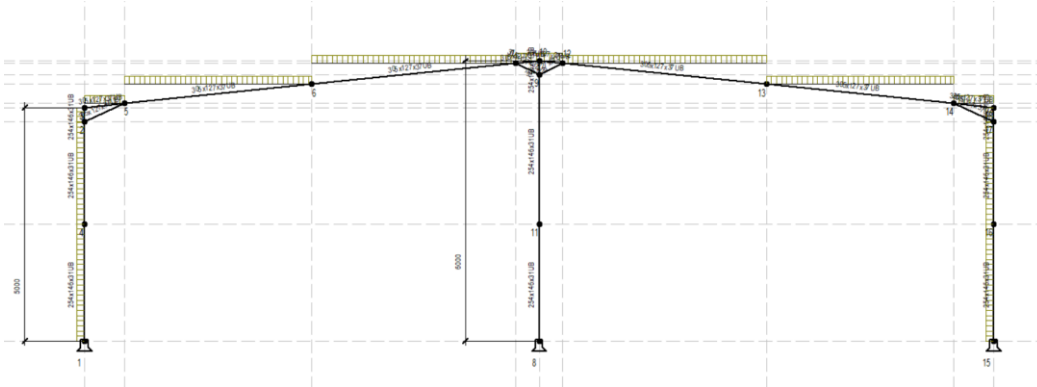
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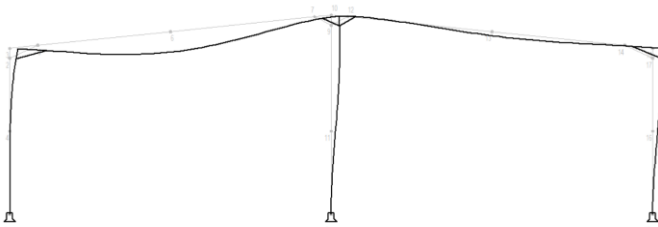
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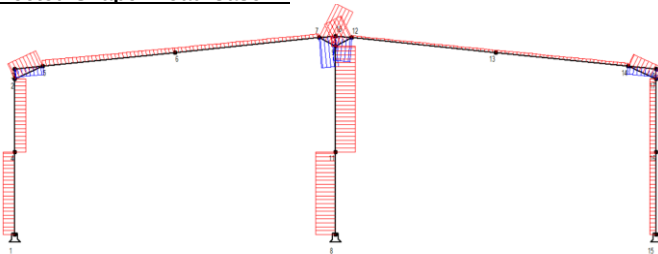
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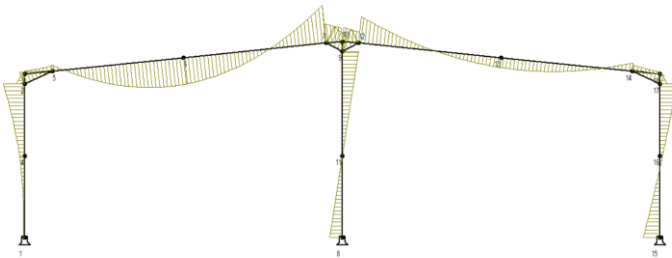
**Load Case 1 - "Load Case 1"**



**Deflected Shape "Load Case 1"**



**Axial Forces "Load Case 1"**



**Moment Forces "Load Case 1"**



**Shear Forces "Load Case 1"**

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| <b>Member Loads</b> - units: UD Load kN/m, Point Load kN, Distance mm, Angle Degrees |      |     |     |     |                 |
|--------------------------------------------------------------------------------------|------|-----|-----|-----|-----------------|
| Member                                                                               | Type | G   | Q   | W   | Direction       |
| 1-4                                                                                  | UDL  | 0.0 | 0.0 | 6.1 | left to right   |
| 2-4                                                                                  | UDL  | 0.0 | 0.0 | 6.1 | left to right   |
| 2-3                                                                                  | UDL  | 0.0 | 0.0 | 6.1 | left to right   |
| 3-5                                                                                  | UDL  | 4.1 | 3.6 | 6.1 | vertically down |
| 5-6                                                                                  | UDL  | 4.1 | 3.6 | 6.1 | vertically down |
| 6-7                                                                                  | UDL  | 4.1 | 3.6 | 6.1 | vertically down |
| 7-10                                                                                 | UDL  | 4.1 | 3.6 | 6.1 | vertically down |
| 10-12                                                                                | UDL  | 4.1 | 3.6 | 0.0 | vertically down |
| 12-13                                                                                | UDL  | 4.1 | 3.6 | 0.0 | vertically down |
| 13-14                                                                                | UDL  | 4.1 | 3.6 | 0.0 | vertically down |
| 14-18                                                                                | UDL  | 4.1 | 3.6 | 0.0 | vertically down |
| 17-18                                                                                | UDL  | 0.0 | 0.0 | 1.4 | left to right   |
| 16-17                                                                                | UDL  | 0.0 | 0.0 | 1.4 | left to right   |
| 15-16                                                                                | UDL  | 0.0 | 0.0 | 1.4 | left to right   |

| <b>Joint Deflections</b> - units: Deflections mm, Rotations degrees |       |        |         |
|---------------------------------------------------------------------|-------|--------|---------|
| Joint                                                               | X     | Y      | Theta   |
| 1                                                                   | 0.00  | 0.00   | 0.0000  |
| 2                                                                   | 10.92 | -0.36  | -0.5175 |
| 3                                                                   | 13.71 | -0.36  | -0.5455 |
| 4                                                                   | 1.21  | -0.19  | -0.0822 |
| 5                                                                   | 14.63 | -8.68  | -0.5796 |
| 6                                                                   | 16.98 | -32.75 | 0.1054  |
| 7                                                                   | 13.70 | -2.47  | 0.2341  |
| 8                                                                   | 0.00  | 0.00   | 0.0000  |
| 9                                                                   | 14.43 | -0.78  | 0.1436  |
| 10                                                                  | 13.64 | -0.79  | 0.1534  |
| 11                                                                  | 7.43  | -0.34  | -0.2573 |
| 12                                                                  | 13.81 | 0.27   | 0.0927  |
| 13                                                                  | 12.86 | -8.28  | -0.0601 |
| 14                                                                  | 13.45 | -1.80  | 0.1275  |
| 15                                                                  | 0.00  | 0.00   | 0.0000  |
| 16                                                                  | 8.71  | -0.11  | -0.2716 |
| 17                                                                  | 14.11 | -0.20  | 0.0731  |
| 18                                                                  | 13.66 | -0.20  | 0.0949  |

| <b>Member Forces</b> - units: Axial kN (-ve tension), Shear kN, Bending kNm |        |       |                |       |         |       |                |       |         |
|-----------------------------------------------------------------------------|--------|-------|----------------|-------|---------|-------|----------------|-------|---------|
| Member                                                                      |        |       | -----End1----- |       |         |       | -----End2----- |       |         |
| Ref.                                                                        | Length | Joint | Axial          | Shear | Bending | Joint | Axial          | Shear | Bending |
| 1-4                                                                         | 2500   | 1     | 62.7           | 3.6   | -3.3    | 4     | 62.7           | -11.7 | -13.4   |
| 2-4                                                                         | 2200   | 2     | 62.7           | -25.1 | 53.9    | 4     | 62.7           | -11.7 | 13.4    |
| 2-3                                                                         | 300    | 2     | -6.1           | 46.2  | -21.6   | 3     | -6.1           | 44.4  | -8.0    |
| 2-5                                                                         | 935    | 2     | 93.5           | 32.8  | -32.3   | 5     | 93.5           | 32.8  | -1.7    |
| 3-5                                                                         | 855    | 3     | -44.8          | -1.4  | -8.0    | 5     | -46.0          | -13.1 | -14.1   |
| 5-6                                                                         | 4021   | 5     | 32.0           | 47.9  | -15.9   | 6     | 26.4           | -7.0  | 66.5    |
| 6-7                                                                         | 4374   | 6     | 26.3           | -7.0  | 66.5    | 7     | 20.1           | -66.7 | -94.9   |
| 7-10                                                                        | 502    | 7     | -167.5         | 30.4  | -48.3   | 10    | -168.1         | 23.5  | -34.8   |
| 7-9                                                                         | 561    | 7     | 211.2          | 18.4  | -46.5   | 9     | 211.2          | 18.4  | -36.2   |
| 8-11                                                                        | 2500   | 8     | 111.2          | 12.6  | -32.0   | 11    | 111.2          | 12.6  | -0.4    |
| 9-11                                                                        | 3200   | 9     | 111.2          | 12.6  | -40.0   | 11    | 111.2          | 12.6  | 0.4     |
| 9-10                                                                        | 300    | 9     | 22.1           | -37.5 | 10.8    | 10    | 22.1           | -37.5 | -0.5    |
| 9-12                                                                        | 561    | 9     | 134.7          | -58.0 | -7.0    | 12    | 134.7          | -58.0 | -39.5   |
| 10-12                                                                       | 502    | 10    | -134.2         | 18.5  | -35.3   | 12    | -133.9         | 14.7  | -27.0   |
| 12-13                                                                       | 4374   | 12    | 10.5           | 37.4  | -66.5   | 13    | 13.9           | 4.1   | 24.3    |
| 13-14                                                                       | 4021   | 13    | 14.0           | 4.1   | 24.3    | 14    | 17.1           | -26.6 | -20.9   |
| 14-18                                                                       | 855    | 14    | -43.7          | 15.0  | -15.2   | 18    | -43.1          | 8.4   | -5.2    |
| 14-17                                                                       | 935    | 14    | 71.0           | -19.9 | -5.7    | 17    | 71.0           | -19.9 | -24.2   |
| 15-16                                                                       | 2500   | 15    | 34.7           | 21.1  | -42.0   | 16    | 34.7           | 17.7  | 6.4     |
| 16-17                                                                       | 2200   | 16    | 34.7           | 17.7  | 6.4     | 17    | 34.7           | 14.7  | 42.0    |
| 17-18                                                                       | 300    | 17    | -12.9          | -41.5 | 17.8    | 18    | -12.9          | -41.9 | 5.2     |

| <b>Support Reactions</b> - units: kN |       |       |        |
|--------------------------------------|-------|-------|--------|
| Joint                                | X     | Y     | Moment |
| 1                                    | -3.6  | 62.7  | 3.3    |
| 8                                    | -12.6 | 111.2 | 32.0   |
| 15                                   | -21.1 | 34.7  | 42.0   |

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## Load Combination 1

### Member Loads

- units: UD Load kN/m, Point Load kN, Distance mm, Angle Degrees

| Member | Type | G   | Q   | W   | Direction       | Position |
|--------|------|-----|-----|-----|-----------------|----------|
| 3-5    | UDL  | 5.7 | 5.8 | 0.0 | vertically down |          |
| 5-6    | UDL  | 5.7 | 5.8 | 0.0 | vertically down |          |
| 6-7    | UDL  | 5.7 | 5.8 | 0.0 | vertically down |          |
| 7-10   | UDL  | 5.7 | 5.8 | 0.0 | vertically down |          |
| 10-12  | UDL  | 5.7 | 5.8 | 0.0 | vertically down |          |
| 12-13  | UDL  | 5.7 | 5.8 | 0.0 | vertically down |          |
| 13-14  | UDL  | 5.7 | 5.8 | 0.0 | vertically down |          |
| 14-18  | UDL  | 5.7 | 5.8 | 0.0 | vertically down |          |

### Joint Deflections

- units: Deflections mm, Rotations degrees

| Joint | X     | Y      | Theta   |
|-------|-------|--------|---------|
| 1     | 0.00  | 0.00   | 0.0000  |
| 2     | -1.88 | -0.29  | -0.3378 |
| 3     | -0.03 | -0.29  | -0.3637 |
| 4     | -4.70 | -0.16  | 0.1068  |
| 5     | 0.61  | -5.90  | -0.3966 |
| 6     | 2.23  | -22.48 | 0.0951  |
| 7     | -0.06 | -1.20  | 0.0770  |
| 8     | 0.00  | 0.00   | 0.0000  |
| 9     | 0.00  | -0.85  | 0.0000  |
| 10    | 0.00  | -0.86  | 0.0000  |
| 11    | 0.00  | -0.37  | 0.0000  |
| 12    | 0.06  | -1.20  | -0.0770 |
| 13    | -2.23 | -22.48 | -0.0951 |
| 14    | -0.61 | -5.90  | 0.3966  |
| 15    | 0.00  | 0.00   | 0.0000  |
| 16    | 4.70  | -0.16  | -0.1068 |
| 17    | 1.88  | -0.29  | 0.3378  |
| 18    | 0.03  | -0.29  | 0.3637  |

### Member Forces

- units: Axial kN (-ve tension), Shear kN, Bending kNm

| Ref.  | Length | Joint | Axial  | Shear | Bending | Joint | Axial  | Shear | Bending |
|-------|--------|-------|--------|-------|---------|-------|--------|-------|---------|
| 1-4   | 2500   | 1     | 51.1   | -16.4 | 27.3    | 4     | 51.1   | -16.4 | -13.8   |
| 2-4   | 2200   | 2     | 51.1   | -16.4 | 50.0    | 4     | 51.1   | -16.4 | 13.8    |
| 2-3   | 300    | 2     | -8.9   | 45.8  | -20.5   | 3     | -8.9   | 45.8  | -6.8    |
| 2-5   | 935    | 2     | 81.5   | 28.6  | -29.5   | 5     | 81.5   | 28.6  | -2.8    |
| 3-5   | 855    | 3     | -46.5  | -4.0  | -6.8    | 5     | -47.5  | -13.8 | -14.4   |
| 5-6   | 4021   | 5     | 20.6   | 39.4  | -17.1   | 6     | 15.9   | -6.4  | 49.2    |
| 6-7   | 4374   | 6     | 15.9   | -6.4  | 49.2    | 7     | 10.7   | -56.2 | -87.6   |
| 7-10  | 502    | 7     | -167.5 | 8.6   | -41.0   | 10    | -168.0 | 2.9   | -38.2   |
| 7-9   | 561    | 7     | 185.9  | 40.6  | -46.6   | 9     | 185.9  | 40.6  | -23.8   |
| 8-11  | 2500   | 8     | 121.0  | 0.0   | 0.0     | 11    | 121.0  | 0.0   | 0.0     |
| 9-11  | 3200   | 9     | 121.0  | 0.0   | 0.0     | 11    | 121.0  | 0.0   | 0.0     |
| 9-10  | 300    | 9     | 24.4   | 0.0   | 0.0     | 10    | 24.4   | 0.0   | 0.0     |
| 9-12  | 561    | 9     | 185.9  | -40.6 | -23.8   | 12    | 185.9  | -40.6 | -46.6   |
| 10-12 | 502    | 10    | -168.0 | -2.9  | -38.2   | 12    | -167.5 | -8.6  | -41.0   |
| 12-13 | 4374   | 12    | 10.7   | 56.2  | -87.6   | 13    | 15.9   | 6.4   | 49.2    |
| 13-14 | 4021   | 13    | 15.9   | 6.4   | 49.2    | 14    | 20.6   | -39.4 | -17.1   |
| 14-18 | 855    | 14    | -47.5  | 13.8  | -14.4   | 18    | -46.5  | 4.0   | -6.8    |
| 14-17 | 935    | 14    | 81.5   | -28.6 | -2.8    | 17    | 81.5   | -28.6 | -29.5   |
| 15-16 | 2500   | 15    | 51.1   | 16.4  | -27.3   | 16    | 51.1   | 16.4  | 13.8    |
| 16-17 | 2200   | 16    | 51.1   | 16.4  | 13.8    | 17    | 51.1   | 16.4  | 50.0    |
| 17-18 | 300    | 17    | -8.9   | -45.8 | 20.5    | 18    | -8.9   | -45.8 | 6.8     |

### Support Reactions

- units: kN

| Joint | X     | Y     | Moment |
|-------|-------|-------|--------|
| 1     | 16.4  | 51.1  | -27.3  |
| 8     | 0.0   | 121.0 | 0.0    |
| 15    | -16.4 | 51.1  | 27.3   |

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## Load Combination 2

### Member Loads

- units: UD Load kN/m, Point Load kN, Distance mm, Angle Degrees

| Member | Type | G   | Q   | W   | Direction       | Position |
|--------|------|-----|-----|-----|-----------------|----------|
| 1-4    | UDL  | 0.0 | 0.0 | 7.3 | left to right   |          |
| 2-4    | UDL  | 0.0 | 0.0 | 7.3 | left to right   |          |
| 2-3    | UDL  | 0.0 | 0.0 | 7.3 | left to right   |          |
| 3-5    | UDL  | 4.9 | 4.3 | 7.3 | vertically down |          |
| 5-6    | UDL  | 4.9 | 4.3 | 7.3 | vertically down |          |
| 6-7    | UDL  | 4.9 | 4.3 | 7.3 | vertically down |          |
| 7-10   | UDL  | 4.9 | 4.3 | 7.3 | vertically down |          |
| 10-12  | UDL  | 4.9 | 4.3 | 0.0 | vertically down |          |
| 12-13  | UDL  | 4.9 | 4.3 | 0.0 | vertically down |          |
| 13-14  | UDL  | 4.9 | 4.3 | 0.0 | vertically down |          |
| 14-18  | UDL  | 4.9 | 4.3 | 0.0 | vertically down |          |
| 17-18  | UDL  | 0.0 | 0.0 | 1.6 | left to right   |          |
| 16-17  | UDL  | 0.0 | 0.0 | 1.6 | left to right   |          |
| 15-16  | UDL  | 0.0 | 0.0 | 1.6 | left to right   |          |

### Joint Deflections

- units: Deflections mm, Rotations degrees

| Joint | X     | Y      | Theta   |
|-------|-------|--------|---------|
| 1     | 0.00  | 0.00   | 0.0000  |
| 2     | 13.10 | -0.43  | -0.6210 |
| 3     | 16.45 | -0.43  | -0.6546 |
| 4     | 1.45  | -0.23  | -0.0987 |
| 5     | 17.56 | -10.41 | -0.6955 |
| 6     | 20.37 | -39.30 | 0.1265  |
| 7     | 16.44 | -2.96  | 0.2810  |
| 8     | 0.00  | 0.00   | 0.0000  |
| 9     | 17.31 | -0.93  | 0.1723  |
| 10    | 16.37 | -0.94  | 0.1840  |
| 11    | 8.92  | -0.41  | -0.3088 |
| 12    | 16.57 | 0.32   | 0.1113  |
| 13    | 15.43 | -9.94  | -0.0721 |
| 14    | 16.15 | -2.16  | 0.1530  |
| 15    | 0.00  | 0.00   | 0.0000  |
| 16    | 10.46 | -0.13  | -0.3259 |
| 17    | 16.94 | -0.24  | 0.0877  |
| 18    | 16.40 | -0.23  | 0.1139  |

### Member Forces

- units: Axial kN (-ve tension), Shear kN, Bending kNm

| Member |        |       | -----End1----- |       |         |       |        | -----End2----- |         |  |  |
|--------|--------|-------|----------------|-------|---------|-------|--------|----------------|---------|--|--|
| Ref.   | Length | Joint | Axial          | Shear | Bending | Joint | Axial  | Shear          | Bending |  |  |
| 1-4    | 2500   | 1     | 75.2           | 4.3   | -3.9    | 4     | 75.2   | -14.0          | -16.1   |  |  |
| 2-4    | 2200   | 2     | 75.2           | -30.1 | 64.7    | 4     | 75.2   | -14.0          | 16.1    |  |  |
| 2-3    | 300    | 2     | -7.3           | 55.5  | -25.9   | 3     | -7.3   | 53.3           | -9.6    |  |  |
| 2-5    | 935    | 2     | 112.2          | 39.3  | -38.8   | 5     | 112.2  | 39.3           | -2.1    |  |  |
| 3-5    | 855    | 3     | -53.7          | -1.7  | -9.6    | 5     | -55.2  | -15.7          | -17.0   |  |  |
| 5-6    | 4021   | 5     | 38.4           | 57.5  | -19.0   | 6     | 31.6   | -8.4           | 79.8    |  |  |
| 6-7    | 4374   | 6     | 31.6           | -8.4  | 79.8    | 7     | 24.1   | -80.1          | -113.9  |  |  |
| 7-10   | 502    | 7     | -201.0         | 36.5  | -58.0   | 10    | -201.8 | 28.2           | -41.8   |  |  |
| 7-9    | 561    | 7     | 253.4          | 22.1  | -55.9   | 9     | 253.4  | 22.1           | -43.5   |  |  |
| 8-11   | 2500   | 8     | 133.4          | 15.2  | -38.4   | 11    | 133.4  | 15.2           | -0.5    |  |  |
| 9-11   | 3200   | 9     | 133.4          | 15.2  | -48.0   | 11    | 133.4  | 15.2           | 0.5     |  |  |
| 9-10   | 300    | 9     | 26.5           | -45.0 | 12.9    | 10    | 26.5   | -45.0          | -0.6    |  |  |
| 9-12   | 561    | 9     | 161.6          | -69.6 | -8.4    | 12    | 161.6  | -69.6          | -47.4   |  |  |
| 10-12  | 502    | 10    | -161.1         | 22.2  | -42.4   | 12    | -160.7 | 17.6           | -32.4   |  |  |
| 12-13  | 4374   | 12    | 12.6           | 44.9  | -79.8   | 13    | 16.7   | 4.9            | 29.2    |  |  |
| 13-14  | 4021   | 13    | 16.7           | 4.9   | 29.2    | 14    | 20.5   | -31.9          | -25.1   |  |  |
| 14-18  | 855    | 14    | -52.5          | 17.9  | -18.3   | 18    | -51.7  | 10.1           | -6.3    |  |  |
| 14-17  | 935    | 14    | 85.2           | -23.8 | -6.8    | 17    | 85.2   | -23.8          | -29.1   |  |  |
| 15-16  | 2500   | 15    | 41.7           | 25.3  | -50.5   | 16    | 41.7   | 21.2           | 7.6     |  |  |
| 16-17  | 2200   | 16    | 41.7           | 21.2  | 7.6     | 17    | 41.7   | 17.6           | 50.4    |  |  |
| 17-18  | 300    | 17    | -15.5          | -49.8 | 21.3    | 18    | -15.5  | -50.3          | 6.3     |  |  |

### Support Reactions

- units: kN

| Joint | X     | Y     | Moment |
|-------|-------|-------|--------|
| 1     | -4.3  | 75.2  | 3.9    |
| 8     | -15.2 | 133.4 | 38.4   |
| 15    | -25.3 | 41.7  | 50.5   |

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## Load Combination 3

### Member Loads

- units: UD Load kN/m, Point Load kN, Distance mm, Angle Degrees

| Member | Type | G   | Q   | W   | Direction       | Position |
|--------|------|-----|-----|-----|-----------------|----------|
| 3-5    | UDL  | 4.1 | 0.0 | 0.0 | vertically down |          |
| 5-6    | UDL  | 4.1 | 0.0 | 0.0 | vertically down |          |
| 6-7    | UDL  | 4.1 | 0.0 | 0.0 | vertically down |          |
| 7-10   | UDL  | 4.1 | 0.0 | 0.0 | vertically down |          |
| 10-12  | UDL  | 4.1 | 0.0 | 0.0 | vertically down |          |
| 12-13  | UDL  | 4.1 | 0.0 | 0.0 | vertically down |          |
| 13-14  | UDL  | 4.1 | 0.0 | 0.0 | vertically down |          |
| 14-18  | UDL  | 4.1 | 0.0 | 0.0 | vertically down |          |

### Joint Deflections

- units: Deflections mm, Rotations degrees

| Joint | X     | Y     | Theta   |
|-------|-------|-------|---------|
| 1     | 0.00  | 0.00  | 0.0000  |
| 2     | -0.67 | -0.11 | -0.1204 |
| 3     | -0.01 | -0.10 | -0.1297 |
| 4     | -1.68 | -0.06 | 0.0381  |
| 5     | 0.22  | -2.10 | -0.1414 |
| 6     | 0.79  | -8.02 | 0.0339  |
| 7     | -0.02 | -0.43 | 0.0275  |
| 8     | 0.00  | 0.00  | 0.0000  |
| 9     | 0.00  | -0.30 | 0.0000  |
| 10    | 0.00  | -0.31 | 0.0000  |
| 11    | 0.00  | -0.13 | 0.0000  |
| 12    | 0.02  | -0.43 | -0.0275 |
| 13    | -0.79 | -8.02 | -0.0339 |
| 14    | -0.22 | -2.10 | 0.1414  |
| 15    | 0.00  | 0.00  | 0.0000  |
| 16    | 1.68  | -0.06 | -0.0381 |
| 17    | 0.67  | -0.11 | 0.1204  |
| 18    | 0.01  | -0.10 | 0.1297  |

### Member Forces

- units: Axial kN (-ve tension), Shear kN, Bending kNm

| Member |        |       | -----End1----- |       |         |       | -----End2----- |       |         |
|--------|--------|-------|----------------|-------|---------|-------|----------------|-------|---------|
| Ref.   | Length | Joint | Axial          | Shear | Bending | Joint | Axial          | Shear | Bending |
| 1-4    | 2500   | 1     | 18.2           | -5.9  | 9.7     | 4     | 18.2           | -5.9  | -4.9    |
| 2-4    | 2200   | 2     | 18.2           | -5.9  | 17.8    | 4     | 18.2           | -5.9  | 4.9     |
| 2-3    | 300    | 2     | -3.2           | 16.3  | -7.3    | 3     | -3.2           | 16.3  | -2.4    |
| 2-5    | 935    | 2     | 29.1           | 10.2  | -10.5   | 5     | 29.1           | 10.2  | -1.0    |
| 3-5    | 855    | 3     | -16.6          | -1.4  | -2.4    | 5     | -16.9          | -4.9  | -5.1    |
| 5-6    | 4021   | 5     | 7.3            | 14.0  | -6.1    | 6     | 5.7            | -2.3  | 17.5    |
| 6-7    | 4374   | 6     | 5.7            | -2.3  | 17.5    | 7     | 3.8            | -20.0 | -31.2   |
| 7-10   | 502    | 7     | -59.7          | 3.1   | -14.6   | 10    | -59.9          | 1.0   | -13.6   |
| 7-9    | 561    | 7     | 66.3           | 14.5  | -16.6   | 9     | 66.3           | 14.5  | -8.5    |
| 8-11   | 2500   | 8     | 43.1           | 0.0   | 0.0     | 11    | 43.1           | 0.0   | 0.0     |
| 9-11   | 3200   | 9     | 43.1           | 0.0   | 0.0     | 11    | 43.1           | 0.0   | 0.0     |
| 9-10   | 300    | 9     | 8.7            | 0.0   | 0.0     | 10    | 8.7            | 0.0   | 0.0     |
| 9-12   | 561    | 9     | 66.3           | -14.5 | -8.5    | 12    | 66.3           | -14.5 | -16.6   |
| 10-12  | 502    | 10    | -59.9          | -1.0  | -13.6   | 12    | -59.7          | -3.1  | -14.6   |
| 12-13  | 4374   | 12    | 3.8            | 20.0  | -31.2   | 13    | 5.7            | 2.3   | 17.5    |
| 13-14  | 4021   | 13    | 5.7            | 2.3   | 17.5    | 14    | 7.3            | -14.0 | -6.1    |
| 14-18  | 855    | 14    | -16.9          | 4.9   | -5.1    | 18    | -16.6          | 1.4   | -2.4    |
| 14-17  | 935    | 14    | 29.1           | -10.2 | -1.0    | 17    | 29.1           | -10.2 | -10.5   |
| 15-16  | 2500   | 15    | 18.2           | 5.9   | -9.7    | 16    | 18.2           | 5.9   | 4.9     |
| 16-17  | 2200   | 16    | 18.2           | 5.9   | 4.9     | 17    | 18.2           | 5.9   | 17.8    |
| 17-18  | 300    | 17    | -3.2           | -16.3 | 7.3     | 18    | -3.2           | -16.3 | 2.4     |

### Support Reactions

- units: kN

| Joint | X    | Y    | Moment |
|-------|------|------|--------|
| 1     | 5.9  | 18.2 | -9.7   |
| 8     | 0.0  | 43.1 | 0.0    |
| 15    | -5.9 | 18.2 | 9.7    |

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## Load Combination 4

### Member Loads

- units: UD Load kN/m, Point Load kN, Distance mm, Angle Degrees

| Member | Type | G   | Q   | W   | Direction       | Position |
|--------|------|-----|-----|-----|-----------------|----------|
| 3-5    | UDL  | 0.0 | 3.6 | 0.0 | vertically down |          |
| 5-6    | UDL  | 0.0 | 3.6 | 0.0 | vertically down |          |
| 6-7    | UDL  | 0.0 | 3.6 | 0.0 | vertically down |          |
| 7-10   | UDL  | 0.0 | 3.6 | 0.0 | vertically down |          |
| 10-12  | UDL  | 0.0 | 3.6 | 0.0 | vertically down |          |
| 12-13  | UDL  | 0.0 | 3.6 | 0.0 | vertically down |          |
| 13-14  | UDL  | 0.0 | 3.6 | 0.0 | vertically down |          |
| 14-18  | UDL  | 0.0 | 3.6 | 0.0 | vertically down |          |

### Joint Deflections

- units: Deflections mm, Rotations degrees

| Joint | X     | Y     | Theta   |
|-------|-------|-------|---------|
| 1     | 0.00  | 0.00  | 0.0000  |
| 2     | -0.59 | -0.09 | -0.1058 |
| 3     | -0.01 | -0.09 | -0.1139 |
| 4     | -1.47 | -0.05 | 0.0334  |
| 5     | 0.19  | -1.85 | -0.1242 |
| 6     | 0.70  | -7.04 | 0.0298  |
| 7     | -0.02 | -0.37 | 0.0241  |
| 8     | 0.00  | 0.00  | 0.0000  |
| 9     | 0.00  | -0.27 | 0.0000  |
| 10    | 0.00  | -0.27 | 0.0000  |
| 11    | 0.00  | -0.12 | 0.0000  |
| 12    | 0.02  | -0.37 | -0.0241 |
| 13    | -0.70 | -7.04 | -0.0298 |
| 14    | -0.19 | -1.85 | 0.1242  |
| 15    | 0.00  | 0.00  | 0.0000  |
| 16    | 1.47  | -0.05 | -0.0334 |
| 17    | 0.59  | -0.09 | 0.1058  |
| 18    | 0.01  | -0.09 | 0.1139  |

### Member Forces

- units: Axial kN (-ve tension), Shear kN, Bending kNm

| Member |        |       | -----End1----- |       |         |       | -----End2----- |       |         |
|--------|--------|-------|----------------|-------|---------|-------|----------------|-------|---------|
| Ref.   | Length | Joint | Axial          | Shear | Bending | Joint | Axial          | Shear | Bending |
| 1-4    | 2500   | 1     | 16.0           | -5.1  | 8.5     | 4     | 16.0           | -5.1  | -4.3    |
| 2-4    | 2200   | 2     | 16.0           | -5.1  | 15.6    | 4     | 16.0           | -5.1  | 4.3     |
| 2-3    | 300    | 2     | -2.8           | 14.3  | -6.4    | 3     | -2.8           | 14.3  | -2.1    |
| 2-5    | 935    | 2     | 25.5           | 8.9   | -9.2    | 5     | 25.5           | 8.9   | -0.9    |
| 3-5    | 855    | 3     | -14.5          | -1.3  | -2.1    | 5     | -14.9          | -4.3  | -4.5    |
| 5-6    | 4021   | 5     | 6.4            | 12.3  | -5.4    | 6     | 5.0            | -2.0  | 15.4    |
| 6-7    | 4374   | 6     | 5.0            | -2.0  | 15.4    | 7     | 3.3            | -17.6 | -27.4   |
| 7-10   | 502    | 7     | -52.4          | 2.7   | -12.8   | 10    | -52.6          | 0.9   | -11.9   |
| 7-9    | 561    | 7     | 58.2           | 12.7  | -14.6   | 9     | 58.2           | 12.7  | -7.5    |
| 8-11   | 2500   | 8     | 37.9           | 0.0   | 0.0     | 11    | 37.9           | 0.0   | 0.0     |
| 9-11   | 3200   | 9     | 37.9           | 0.0   | 0.0     | 11    | 37.9           | 0.0   | 0.0     |
| 9-10   | 300    | 9     | 7.7            | 0.0   | 0.0     | 10    | 7.7            | 0.0   | 0.0     |
| 9-12   | 561    | 9     | 58.2           | -12.7 | -7.5    | 12    | 58.2           | -12.7 | -14.6   |
| 10-12  | 502    | 10    | -52.6          | -0.9  | -11.9   | 12    | -52.4          | -2.7  | -12.8   |
| 12-13  | 4374   | 12    | 3.3            | 17.6  | -27.4   | 13    | 5.0            | 2.0   | 15.4    |
| 13-14  | 4021   | 13    | 5.0            | 2.0   | 15.4    | 14    | 6.4            | -12.3 | -5.4    |
| 14-18  | 855    | 14    | -14.9          | 4.3   | -4.5    | 18    | -14.5          | 1.3   | -2.1    |
| 14-17  | 935    | 14    | 25.5           | -8.9  | -0.9    | 17    | 25.5           | -8.9  | -9.2    |
| 15-16  | 2500   | 15    | 16.0           | 5.1   | -8.5    | 16    | 16.0           | 5.1   | 4.3     |
| 16-17  | 2200   | 16    | 16.0           | 5.1   | 4.3     | 17    | 16.0           | 5.1   | 15.6    |
| 17-18  | 300    | 17    | -2.8           | -14.3 | 6.4     | 18    | -2.8           | -14.3 | 2.1     |

### Support Reactions

- units: kN

| Joint | X    | Y    | Moment |
|-------|------|------|--------|
| 1     | 5.1  | 16.0 | -8.5   |
| 8     | 0.0  | 37.9 | 0.0    |
| 15    | -5.1 | 16.0 | 8.5    |

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## Load Combination 5

### Member Loads

- units: UD Load kN/m, Point Load kN, Distance mm, Angle Degrees

| Member | Type | G   | Q   | W   | Direction       | Position |
|--------|------|-----|-----|-----|-----------------|----------|
| 1-4    | UDL  | 0.0 | 0.0 | 6.1 | left to right   |          |
| 2-4    | UDL  | 0.0 | 0.0 | 6.1 | left to right   |          |
| 2-3    | UDL  | 0.0 | 0.0 | 6.1 | left to right   |          |
| 3-5    | UDL  | 0.0 | 0.0 | 6.1 | vertically down |          |
| 5-6    | UDL  | 0.0 | 0.0 | 6.1 | vertically down |          |
| 6-7    | UDL  | 0.0 | 0.0 | 6.1 | vertically down |          |
| 7-10   | UDL  | 0.0 | 0.0 | 6.1 | vertically down |          |
| 17-18  | UDL  | 0.0 | 0.0 | 1.4 | left to right   |          |
| 16-17  | UDL  | 0.0 | 0.0 | 1.4 | left to right   |          |
| 15-16  | UDL  | 0.0 | 0.0 | 1.4 | left to right   |          |

### Joint Deflections

- units: Deflections mm, Rotations degrees

| Joint | X     | Y      | Theta   |
|-------|-------|--------|---------|
| 1     | 0.00  | 0.00   | 0.0000  |
| 2     | 12.17 | -0.16  | -0.2913 |
| 3     | 13.73 | -0.16  | -0.3020 |
| 4     | 4.35  | -0.09  | -0.1537 |
| 5     | 14.23 | -4.73  | -0.3140 |
| 6     | 15.48 | -17.69 | 0.0417  |
| 7     | 13.74 | -1.67  | 0.1826  |
| 8     | 0.00  | 0.00   | 0.0000  |
| 9     | 14.43 | -0.21  | 0.1436  |
| 10    | 13.64 | -0.21  | 0.1534  |
| 11    | 7.43  | -0.09  | -0.2573 |
| 12    | 13.77 | 1.07   | 0.1443  |
| 13    | 14.35 | 6.77   | 0.0036  |
| 14    | 13.86 | 2.15   | -0.1380 |
| 15    | 0.00  | 0.00   | 0.0000  |
| 16    | 5.57  | 0.00   | -0.2000 |
| 17    | 12.86 | 0.00   | -0.1531 |
| 18    | 13.64 | 0.00   | -0.1486 |

### Member Forces

- units: Axial kN (-ve tension), Shear kN, Bending kNm

| Member |        |       | -----End1----- |       |         |       | -----End2----- |       |         |
|--------|--------|-------|----------------|-------|---------|-------|----------------|-------|---------|
| Ref.   | Length | Joint | Axial          | Shear | Bending | Joint | Axial          | Shear | Bending |
| 1-4    | 2500   | 1     | 28.5           | 14.6  | -21.6   | 4     | 28.5           | -0.7  | -4.2    |
| 2-4    | 2200   | 2     | 28.5           | -14.1 | 20.5    | 4     | 28.5           | -0.7  | 4.2     |
| 2-3    | 300    | 2     | -0.1           | 15.6  | -7.8    | 3     | -0.1           | 13.7  | -3.4    |
| 2-5    | 935    | 2     | 38.9           | 13.6  | -12.6   | 5     | 38.9           | 13.6  | 0.1     |
| 3-5    | 855    | 3     | -13.7          | 1.3   | -3.4    | 5     | -14.2          | -3.8  | -4.5    |
| 5-6    | 4021   | 5     | 18.2           | 21.6  | -4.4    | 6     | 15.7           | -2.7  | 33.5    |
| 6-7    | 4374   | 6     | 15.7           | -2.7  | 33.5    | 7     | 13.0           | -29.1 | -36.2   |
| 7-10   | 502    | 7     | -55.4          | 24.7  | -20.9   | 10    | -55.6          | 21.6  | -9.3    |
| 7-9    | 561    | 7     | 86.7           | -8.8  | -15.4   | 9     | 86.7           | -8.8  | -20.3   |
| 8-11   | 2500   | 8     | 30.2           | 12.6  | -32.0   | 11    | 30.2           | 12.6  | -0.4    |
| 9-11   | 3200   | 9     | 30.2           | 12.6  | -40.0   | 11    | 30.2           | 12.6  | 0.4     |
| 9-10   | 300    | 9     | 5.7            | -37.5 | 10.8    | 10    | 5.7            | -37.5 | -0.5    |
| 9-12   | 561    | 9     | 10.2           | -30.8 | 9.0     | 12    | 10.2           | -30.8 | -8.3    |
| 10-12  | 502    | 10    | -21.8          | 20.4  | -9.8    | 12    | -21.8          | 20.4  | 0.5     |
| 12-13  | 4374   | 12    | 3.3            | -0.2  | -7.9    | 13    | 3.3            | -0.2  | -8.7    |
| 13-14  | 4021   | 13    | 3.3            | -0.2  | -8.7    | 14    | 3.3            | -0.2  | -9.4    |
| 14-18  | 855    | 14    | -12.0          | 5.7   | -5.6    | 18    | -12.0          | 5.7   | -0.7    |
| 14-17  | 935    | 14    | 16.4           | -0.7  | -3.8    | 17    | 16.4           | -0.7  | -4.5    |
| 15-16  | 2500   | 15    | 0.5            | 10.0  | -23.8   | 16    | 0.5            | 6.7   | -2.9    |
| 16-17  | 2200   | 16    | 0.5            | 6.7   | -2.9    | 17    | 0.5            | 3.7   | 8.5     |
| 17-18  | 300    | 17    | -7.0           | -10.9 | 4.0     | 18    | -7.0           | -11.3 | 0.7     |

### Support Reactions

- units: kN

| Joint | X     | Y    | Moment |
|-------|-------|------|--------|
| 1     | -14.6 | 28.5 | 21.6   |
| 8     | -12.6 | 30.2 | 32.0   |
| 15    | -10.0 | 0.5  | 23.8   |

## UB / UC bending check- Portal rafter

Calculations in accordance with BS5950:Part1:2000 and the SCI 'Steelwork Design Guide to BS5950'

|                          |                         |
|--------------------------|-------------------------|
| Span                     | = 9.3 m                 |
| Section size             | - 305x127x37 UB         |
| Section class            | - 1 (Plastic)           |
| Steel grade              | - S 355                 |
| Design strength of steel | = 355 N/mm <sup>2</sup> |

|               |                          |             |
|---------------|--------------------------|-------------|
| Design forces | - maximum span moment    | = 124.3 kNm |
|               | - left support reaction  | = 53.5 kN   |
|               | - right support reaction | = 53.5 kN   |

| Load Description | Type | A | B   | C | Gk  | Qk  |
|------------------|------|---|-----|---|-----|-----|
| Roof             | UDL  | 0 | 9.3 |   | 4.1 | 3.6 |

End restraint type: (As defined in Table 13)

Left hand end - Compression flange laterally restrained. Nominal torsional restraint against rotation about longitudinal axis, as detailed in 4.2.2. Both flanges fully restrained against rotation on plan.

Right hand end - Compression flange laterally restrained. Nominal torsional restraint against rotation about longitudinal axis, as detailed in 4.2.2. Both flanges partially restrained against rotation on plan.

Compression flange provided with full lateral restraint in accordance with clause 4.2.2.

### Results summary

|                              |            |
|------------------------------|------------|
| Maximum applied shear force  | = 53.5 kN  |
| Shear capacity               | = 459.7 kN |
| Section subject to LOW SHEAR |            |

|                                 |             |
|---------------------------------|-------------|
| Maximum applied ultimate moment | = 124.3 kNm |
| Section moment capacity         | = 191.3 kNm |

|                              |                             |
|------------------------------|-----------------------------|
| Total load deflection        | = 50.8 mm<br>( span / 183 ) |
| Imposed load only deflection | = 23.8 mm<br>( span / 391 ) |

**Portal rafter- Use min 305x127x37 UB**

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## UB column design - in simple construction- Portal Columns - External

Calculations in accordance with BS5950:Part1:2000 and the SCI 'Steelwork Design Guide to BS5950'

|                                  |                         |
|----------------------------------|-------------------------|
| Section size                     | - 254x146x31 UB         |
| Section class                    | - 2 (Compact)           |
| Steel grade                      | - S 355                 |
| Design strength of steel         | = 355 N/mm <sup>2</sup> |
| Length                           | = 5300 mm               |
| Applied loads -                  |                         |
| Direct ultimate compressive load | = 10 kN                 |
| Member at A                      | - load = 60 kN          |
|                                  | - eccentricity = 100 mm |
| Member at B                      | - load = 5 kN           |
|                                  | - eccentricity = 100 mm |
| Member at D                      | - load = 5 kN           |
|                                  | - eccentricity = 100 mm |

End restraint type: (As defined in Table 22)

|                  |                                                                       |
|------------------|-----------------------------------------------------------------------|
| Bottom, x-x axis | - Effectively held in position and partially restrained in direction. |
| Top, x-x axis    | - Effectively held in position and restrained in direction.           |
| Bottom, y-y axis | - Effectively held in position and partially restrained in direction. |
| Top, y-y axis    | - Effectively held in position and partially restrained in direction. |

### Applied forces

|                           |                                                                                        |
|---------------------------|----------------------------------------------------------------------------------------|
| Total compressive load    | $F_c = F + R_a + R_b + R_c + R_d = 80 \text{ kN}$                                      |
| Moment about the x-x axis | $M_{xx} = \text{ABS}((R_a * (e_a + D/2) - R_c * (e_c + D/2))/1000) = 13.5 \text{ kNm}$ |
| Moment about the y-y axis | $M_{yy} = \text{ABS}((R_b * (e_b + t/2) - R_d * (e_d + t/2))/1000) = 0.0 \text{ kNm}$  |

### Determine the member capacity

#### (a) Compression

The effective length factor for the x-x axis combination of restraints is

|                                     |                                             |
|-------------------------------------|---------------------------------------------|
|                                     | $L_{fx} = 0.85$                             |
| and for the y-y axis is             | $L_{fy} = 0.85$                             |
| For the x-x axis the slenderness is | $\lambda_x = L_0 * L_{fx} / r_{xx} = 42.9$  |
| and for the y-y axis                | $\lambda_y = L_0 * L_{fy} / r_{yy} = 134.1$ |

The y-y axis is the weakest and the allowable compressive strength from Table 24(b), with the maximum section thickness not exceeding 40mm, is

|                                                        |                                             |
|--------------------------------------------------------|---------------------------------------------|
|                                                        | $p_c = 95.3 \text{ N/mm}^2$                 |
| hence the capacity of section in accordance with 4.7.4 | $P_c = p_c * A_g / 1000 = 378.3 \text{ kN}$ |

#### (b) x-x axis bending

The equivalent slenderness from clause 4.7.7 is

|                                     |                                                                           |
|-------------------------------------|---------------------------------------------------------------------------|
|                                     | $\lambda_{LT} = 0.5 * L_0 / r_{yy} = 78.9$                                |
| The limiting equivalent slenderness | $\lambda_{L0} = 0.4 * \text{SQR}(\text{PI}^2 * 205000 / p_y) = 30.2$      |
|                                     | $pE = (\text{PI}^2 * 205000) / (\lambda_{LT}^2) = 325.012 \text{ N/mm}^2$ |

The Robertson constant

The perry factor

|  |                                                                           |
|--|---------------------------------------------------------------------------|
|  | $a_{LT} = 7$                                                              |
|  | $\text{eta}_{LT} = a_{LT} * (\lambda_{LT} - \lambda_{L0}) / 1000 = 0.341$ |
|  | $\text{phi}_{LT} = (p_y + ((\text{eta}_{LT} + 1) * pE)) / 2 = 395.404$    |

The design strength of steel

|                                            |                                                                                                            |
|--------------------------------------------|------------------------------------------------------------------------------------------------------------|
|                                            | $p_b = (pE * p_y) / (\text{phi}_{LT} + \text{SQR}(\text{phi}_{LT}^2 - pE * p_y)) = 193.006 \text{ N/mm}^2$ |
| The buckling resistance moment (App B.2.1) | $M_{bs} = p_b * S_{xx} / 10^6 = 75.851 \text{ kNm}$                                                        |

#### (c) y-y axis bending

The moment of resistance from clause 4.7.7 is

|  |                                                   |
|--|---------------------------------------------------|
|  | $M_{Ry} = p_y * Z_{yy} / 10^6 = 21.8 \text{ kNm}$ |
|--|---------------------------------------------------|

### Overall check

Combining the applied loads and capacities using the following relationship given in clause 4.7.7

|       |                                                                        |
|-------|------------------------------------------------------------------------|
| Ratio | $= F_c / P_c + M_{xx} / M_{bs} + M_{yy} / p_y * Z_{yy} \leq 1$         |
| gives | $\text{Ratio} = F_c / P_c + M_{xx} / M_{bs} + M_{yy} / M_{Ry} = 0.389$ |

As the ratio is not more than 1.0, section OK.

**Portal Columns - External-Use min 254x146x31 UB**

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

Date: 16/07/20

Ref: 20-4106

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## UB column design - in simple construction- Portal Columns- Internal

Calculations in accordance with BS5950:Part1:2000 and the SCI 'Steelwork Design Guide to BS5950'

|                                  |                         |
|----------------------------------|-------------------------|
| Section size                     | - 254x146x31 UB         |
| Section class                    | - 2 (Compact)           |
| Steel grade                      | - S 355                 |
| Design strength of steel         | = 355 N/mm <sup>2</sup> |
| Length                           | = 6500 mm               |
| Applied loads -                  |                         |
| Direct ultimate compressive load | = 10 kN                 |
| Member at A                      | - load = 60 kN          |
|                                  | - eccentricity = 100 mm |
| Member at B                      | - load = 5 kN           |
|                                  | - eccentricity = 100 mm |
| Member at C                      | - load = 60 kN          |
|                                  | - eccentricity = 100 mm |
| Member at D                      | - load = 5 kN           |
|                                  | - eccentricity = 100 mm |

End restraint type: (As defined in Table 22)

|                  |                                                                       |
|------------------|-----------------------------------------------------------------------|
| Bottom, x-x axis | - Effectively held in position and partially restrained in direction. |
| Top, x-x axis    | - Effectively held in position and restrained in direction.           |
| Bottom, y-y axis | - Effectively held in position and partially restrained in direction. |
| Top, y-y axis    | - Effectively held in position and partially restrained in direction. |

### Applied forces

|                           |          |                                                                 |
|---------------------------|----------|-----------------------------------------------------------------|
| Total compressive load    | $F_c$    | = $F + R_a + R_b + R_c + R_d = 140$ kN                          |
| Moment about the x-x axis | $M_{xx}$ | = $ABS((R_a * (e_a + D/2) - R_c * (e_c + D/2))/1000) = 0.0$ kNm |
| Moment about the y-y axis | $M_{yy}$ | = $ABS((R_b * (e_b + t/2) - R_d * (e_d + t/2))/1000) = 0.0$ kNm |

### Determine the member capacity

#### (a) Compression

The effective length factor for the x-x axis combination of restraints is

$$L_{fx} = 0.85$$

and for the y-y axis is

$$L_{fy} = 0.85$$

For the x-x axis the slenderness is

$$\lambda_x = L_0 * L_{fx} / r_{xx} = 52.6$$

and for the y-y axis

$$\lambda_y = L_0 * L_{fy} / r_{yy} = 164.4$$

The y-y axis is the weakest and the allowable compressive strength from Table 24(b), with the maximum section thickness not exceeding 40mm, is

$$p_c = 65.9 \text{ N/mm}^2$$

hence the capacity of section in accordance with 4.7.4

$$P_c = p_c * A_g / 1000 = 261.6 \text{ kN}$$

#### (b) x-x axis bending

The equivalent slenderness from clause 4.7.7 is

$$\lambda_{LT} = 0.5 * L_0 / r_{yy} = 96.7$$

The limiting equivalent slenderness

$$\lambda_{L0} = 0.4 * \text{SQR}(\text{PI}^2 * 205000 / p_y) = 30.2$$

$$pE = (\text{PI}^2 * 205000) / (\lambda_{LT}^2) = 216.372 \text{ N/mm}^2$$

The Robertson constant

$$a_{LT} = 7$$

The perry factor

$$\eta_{LT} = a_{LT} * (\lambda_{LT} - \lambda_{L0}) / 1000 = 0.466$$

$$\phi_{LT} = (p_y + ((\eta_{LT} + 1) * pE)) / 2 = 336.046$$

The design strength of steel

$$p_b = (pE * p_y) / (\phi_{LT} + \text{SQR}(\phi_{LT}^2 - pE * p_y)) = 146.006 \text{ N/mm}^2$$

The buckling resistance moment (App B.2.1)

$$M_{bs} = p_b * S_{xx} / 10^6 = 57.381 \text{ kNm}$$

#### (c) y-y axis bending

The moment of resistance from clause 4.7.7 is

$$M_{Ry} = p_y * Z_{yy} / 10^6 = 21.8 \text{ kNm}$$

### Overall check

Combining the applied loads and capacities using the following relationship given in clause 4.7.7

$$\text{Ratio} = F_c / P_c + M_{xx} / M_{bs} + M_{yy} / p_y * Z_{yy} \leq 1$$

$$\text{gives Ratio} = F_c / P_c + M_{xx} / M_{bs} + M_{yy} / M_{Ry} = 0.535$$

As the ratio is not more than 1.0, section OK.

**Portal Columns- Internal- Use min 254x146x31 UB**

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

Date: 16/07/20

Ref: 20-4106

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## UB / UC bending check- Gable Rafters

Calculations in accordance with BS5950:Part1:2000 and the SCI 'Steelwork Design Guide to BS5950'

|                          |                         |
|--------------------------|-------------------------|
| Span                     | = 4.8 m                 |
| Section size             | - 178x102x19 UB         |
| Section class            | - 1 (Plastic)           |
| Steel grade              | - S 355                 |
| Design strength of steel | = 355 N/mm <sup>2</sup> |

|               |                          |            |
|---------------|--------------------------|------------|
| Design forces | - maximum span moment    | = 15.3 kNm |
|               | - left support reaction  | = 12.7 kN  |
|               | - right support reaction | = 12.7 kN  |

| Load Description | Type | A | B   | C | Gk  | Qk   |
|------------------|------|---|-----|---|-----|------|
| Roof             | UDL  | 0 | 4.8 |   | 1.9 | 1.65 |

End restraint type: (As defined in Table 13)

Left hand end - Compression flange laterally restrained. Nominal torsional restraint against rotation about longitudinal axis, as detailed in 4.2.2. Both flanges partially restrained against rotation on plan.

Right hand end - Compression flange laterally restrained. Nominal torsional restraint against rotation about longitudinal axis, as detailed in 4.2.2. Both flanges partially restrained against rotation on plan.

Section unrestrained over its length.

### Results summary

|                              |            |
|------------------------------|------------|
| Maximum applied shear force  | = 12.7 kN  |
| Shear capacity               | = 181.9 kN |
| Section subject to LOW SHEAR |            |

|                                                |            |
|------------------------------------------------|------------|
| Maximum applied ultimate moment                | = 15.3 kNm |
| Section moment capacity                        | = 60.7 kNm |
| Effective length                               | = 3840 mm  |
| $M_b / m_{LT}$                                 | = 23.9 kNm |
| Maximum sub-beam moment                        | = 15.3 kNm |
| Note: $M_b$ can never be greater than $M_{cx}$ |            |

|                              |                             |
|------------------------------|-----------------------------|
| Total load deflection        | = 8.8 mm<br>( span / 545 )  |
| Imposed load only deflection | = 4.1 mm<br>( span / 1171 ) |

**Gable Rafters- Use min 178x102x19 UB**

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

Date: 16/07/20

Ref: 20-4106

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## UB column design - in simple construction- Gable columns – Roof load

Calculations in accordance with BS5950:Part1:2000 and the SCI 'Steelwork Design Guide to BS5950'

|                                  |                         |
|----------------------------------|-------------------------|
| Section size                     | - 203x102x23 UB         |
| Section class                    | - 1 (Plastic)           |
| Steel grade                      | - S 355                 |
| Design strength of steel         | = 355 N/mm <sup>2</sup> |
| Length                           | = 6000 mm               |
| Applied loads -                  |                         |
| Direct ultimate compressive load | = 10 kN                 |
| Member at B                      | - load = 13 kN          |
|                                  | - eccentricity = 100 mm |
| Member at D                      | - load = 13 kN          |
|                                  | - eccentricity = 100 mm |

End restraint type: (As defined in Table 22)

|                  |                                                                       |
|------------------|-----------------------------------------------------------------------|
| Bottom, x-x axis | - Effectively held in position and partially restrained in direction. |
| Top, x-x axis    | - Effectively held in position and partially restrained in direction. |
| Bottom, y-y axis | - Effectively held in position and partially restrained in direction. |
| Top, y-y axis    | - Effectively held in position and partially restrained in direction. |

### Applied forces

|                           |                                                                                       |
|---------------------------|---------------------------------------------------------------------------------------|
| Total compressive load    | $F_c = F + R_a + R_b + R_c + R_d = 36 \text{ kN}$                                     |
| Moment about the x-x axis | $M_{xx} = \text{ABS}((R_a * (e_a + D/2) - R_c * (e_c + D/2))/1000) = 0.0 \text{ kNm}$ |
| Moment about the y-y axis | $M_{yy} = \text{ABS}((R_b * (e_b + t/2) - R_d * (e_d + t/2))/1000) = 0.0 \text{ kNm}$ |

### Determine the member capacity

#### (a) Compression

The effective length factor for the x-x axis combination of restraints is

$$L_{fx} = 0.85$$

and for the y-y axis is

$$L_{fy} = 0.85$$

For the x-x axis the slenderness is

$$\lambda_x = L_0 * L_{fx} / r_{xx} = 60.2$$

and for the y-y axis

$$\lambda_y = L_0 * L_{fy} / r_{yy} = 216.1$$

The y-y axis is the weakest and the allowable compressive strength from Table 24(b), with the maximum section thickness not exceeding 40mm, is

$$p_c = 39.5 \text{ N/mm}^2$$

and hence the capacity of the section in accordance with clause 4.7.4 is

$$P_c = p_c * A_g / 1000 = 116.1 \text{ kN}$$

#### (b) x-x axis bending

The equivalent slenderness from clause 4.7.7 is

$$\lambda_{LT} = 0.5 * L_0 / r_{yy} = 127.1$$

The limiting equivalent slenderness

$$\lambda_{L0} = 0.4 * \text{SQR}(PI^2 * 205000 / p_y) = 30.2$$

$$pE = (PI^2 * 205000) / (\lambda_{LT}^2) = 125.246 \text{ N/mm}^2$$

The Robertson constant

$$a_{LT} = 7$$

The perry factor

$$\eta_{LT} = a_{LT} * (\lambda_{LT} - \lambda_{L0}) / 1000 = 0.678$$

$$\phi_{LT} = (p_y + ((\eta_{LT} + 1) * pE)) / 2 = 282.6$$

The design strength of steel

$$p_b = (pE * p_y) / (\phi_{LT} + \text{SQR}(\phi_{LT}^2 - pE * p_y)) = 94.45 \text{ N/mm}^2$$

The buckling resistance moment (using Appendix B.2.1)  $M_{bs}$

$$= p_b * S_{xx} / 10^6 = 22.101 \text{ kNm}$$

#### (c) y-y axis bending

The moment of resistance from clause 4.7.7 is

$$M_{ry} = p_y * Z_{yy} / 10^6 = 11.4 \text{ kNm}$$

### Overall check

Combining the applied loads and capacities using the following relationship given in clause 4.7.7

$$\text{Ratio} = F_c / P_c + M_{xx} / M_{bs} + M_{yy} / p_y * Z_{yy} \leq 1$$

$$\text{gives Ratio} = F_c / P_c + M_{xx} / M_{bs} + M_{yy} / M_{ry} = 0.31$$

As the ratio is not more than 1.0, section OK.

**Gable columns– Use min 203x102x23 UB**

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

Date: 16/07/20

Ref: 20-4106

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## UB / UC bending check- Gable columns – wind loading

Calculations in accordance with BS5950:Part1:2000 and the SCI 'Steelwork Design Guide to BS5950'

|                          |                         |
|--------------------------|-------------------------|
| Span                     | = 6 m                   |
| Section size             | - 203x102x23 UB         |
| Section class            | - 1 (Plastic)           |
| Steel grade              | - S 355                 |
| Design strength of steel | = 355 N/mm <sup>2</sup> |

|               |                          |            |
|---------------|--------------------------|------------|
| Design forces | - maximum span moment    | = 18.2 kNm |
|               | - left support reaction  | = 12.1 kN  |
|               | - right support reaction | = 12.1 kN  |

| Load Description | Type | A | B   | C | Gk  | Qk   |
|------------------|------|---|-----|---|-----|------|
| wind             | UDL  | 0 | 6.0 |   | 1.0 | 1.65 |

End restraint type: (As defined in Table 13)

Left hand end - Compression flange laterally restrained. Nominal torsional restraint against rotation about longitudinal axis, as detailed in 4.2.2. Both flanges partially restrained against rotation on plan.

Right hand end - Compression flange laterally restrained. Nominal torsional restraint against rotation about longitudinal axis, as detailed in 4.2.2. Both flanges partially restrained against rotation on plan.

Section unrestrained over its length.

### Results summary

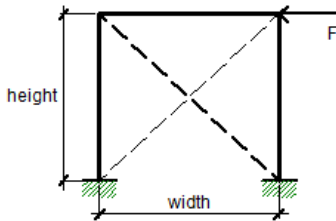
|                              |            |
|------------------------------|------------|
| Maximum applied shear force  | = 12.1 kN  |
| Shear capacity               | = 233.4 kN |
| Section subject to LOW SHEAR |            |

|                                                |            |
|------------------------------------------------|------------|
| Maximum applied ultimate moment                | = 18.2 kNm |
| Section moment capacity                        | = 83.1 kNm |
| Effective length                               | = 4800 mm  |
| $M_b / m_{LT}$                                 | = 26 kNm   |
| Maximum sub-beam moment                        | = 18.2 kNm |
| Note: $M_b$ can never be greater than $M_{cx}$ |            |

|                              |                             |
|------------------------------|-----------------------------|
| Total load deflection        | = 10.3 mm<br>( span / 583 ) |
| Imposed load only deflection | = 6.4 mm<br>( span / 938 )  |

**Gable columns – wind loading- Use min 203x102x23 UB**

## Single storey cross brace design- Vertical X Bracing



Calculations in accordance with BS5950:Part1:2000 and the SCI 'Steelwork Design Guide to BS5950'

Horizontal distance between bracing attachments  
Vertical distance between bracing attachments

$L = 5400 \text{ mm}$   
 $h = 5000 \text{ mm}$

Steel grade  
Design strength of steel

- S 355  
 $p_y = 355 \text{ N/mm}^2$

Applied ultimate load

$F = 75 \text{ kN}$

### Determine maximum force in the bracing

The bracings are assumed to act as a crossed pair, with the total applied force being resisted by one brace in tension.

Length of upper brace

$$\begin{aligned} L_b &= \text{SQR}(L^2 + h^2) \\ &= \text{SQR}((5400)^2 + (5000)^2) \\ &= 7359 \text{ mm} \end{aligned}$$

Maximum tensile force

$$\begin{aligned} F_t &= F \cdot L_b / L \\ &= 75 \cdot 7359 / 5400 \\ &= 102.2 \text{ kN} \end{aligned}$$

### Determine section size required

Note: The design is based on the full cross section of steel plate. A manual check is required to take account of bolt holes on net cross sectional area at the connections.

Section area of flat required

$$\begin{aligned} A_r &= F_t \cdot 1000 / p_y \\ &= 102.2 \cdot 1000 / 355 \\ &= 288 \text{ mm}^2 \end{aligned}$$

For a thickness of 8 mm, the minimum width of plate (to 25mm) required is

$$\begin{aligned} W_p &= A_r / t \\ &= 288 / 8 \\ &= 50 \text{ mm} \end{aligned}$$

Hence use a minimum of **50 wide x 8 thick plate** ( 400 mm<sup>2</sup> ).

**Vertical X Bracing- use min 65w x 8 th MS Plate Vertical cross bracing**

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

Date: 16/07/20

Ref: 20-4106

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## Roof Bracing - Analysis

### Materials Table - units: N/mm<sup>2</sup>

|       |        |
|-------|--------|
| Type  | E      |
| Steel | 205000 |

### Sections Table - units: cm<sup>2</sup>,cm<sup>4</sup>

| Code | Description   | A     | I       |
|------|---------------|-------|---------|
| A    | 305x127x37 UB | 47.20 | 7170.00 |
| B    | 178x102x19 UB | 24.30 | 1360.00 |
| C    | 88.9x5.0 CHS  | 13.20 | 116.00  |

### Joints Table - units: mm

| Joint | X     | Y    |
|-------|-------|------|
| 1     | 0     | 0    |
| 2     | 0     | 5200 |
| 3     | 4800  | 0    |
| 4     | 4800  | 5200 |
| 5     | 9600  | 5200 |
| 6     | 9600  | 0    |
| 7     | 14400 | 5200 |
| 8     | 14400 | 0    |
| 9     | 19200 | 5200 |
| 10    | 19200 | 0    |

### Members Table

| Member | Code | Description   |
|--------|------|---------------|
| 1-3    | A    | 305x127x37 UB |
| 1-2    | B    | 178x102x19 UB |
| 1-4    | C    | 88.9x5.0 CHS  |
| 2-4    | B    | 178x102x19 UB |
| 3-6    | A    | 305x127x37 UB |
| 4-5    | B    | 178x102x19 UB |
| 4-6    | C    | 88.9x5.0 CHS  |
| 5-7    | B    | 178x102x19 UB |
| 5-6    | B    | 178x102x19 UB |
| 6-8    | A    | 305x127x37 UB |
| 6-7    | C    | 88.9x5.0 CHS  |
| 7-9    | B    | 178x102x19 UB |
| 7-10   | C    | 88.9x5.0 CHS  |
| 8-10   | A    | 305x127x37 UB |
| 9-10   | B    | 178x102x19 UB |

### Load Cases Table

| Case | Description |
|------|-------------|
| 1    | Load Case 1 |

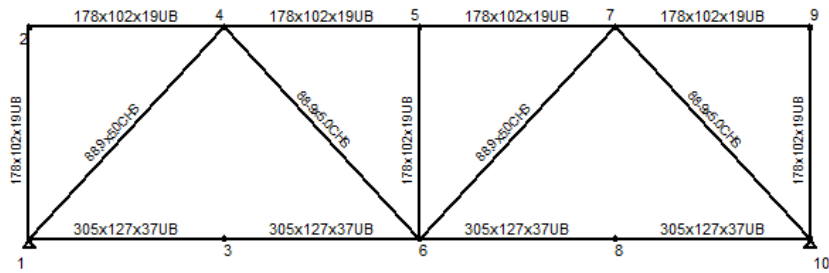
Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

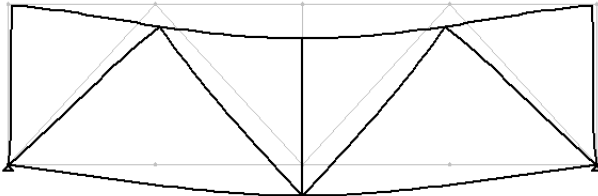
Date: 16/07/20

Ref: 20-4106

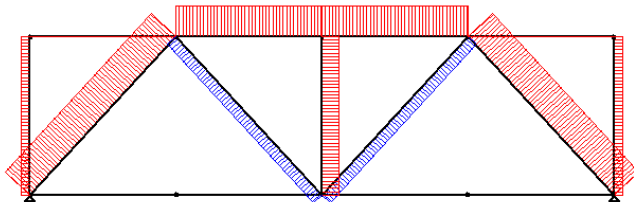
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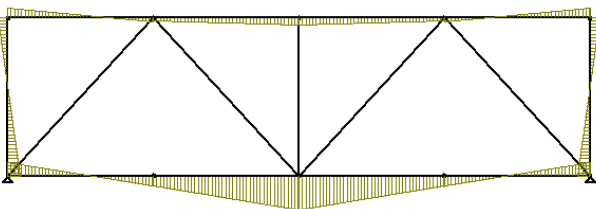
## "Load Case 1"



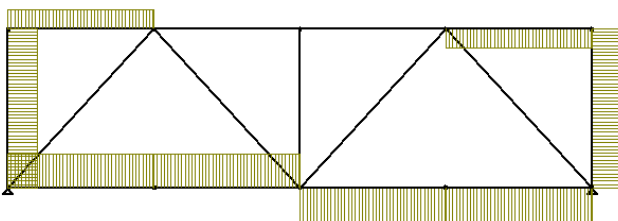
## Deflected Shape "Load Case 1"



## Axial Forces "Load Case 1"



## Moment Forces "Load Case 1"



## Shear Forces "Load Case 1"

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

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**Joint Deflections** - units: Deflections mm, Rotations degrees

| Joint | X     | Y     | Theta   |
|-------|-------|-------|---------|
| 1     | 0.00  | 0.00  | -0.0138 |
| 2     | 0.28  | -0.08 | -0.0069 |
| 3     | 0.00  | -1.31 | -0.0149 |
| 4     | 0.28  | -1.41 | -0.0168 |
| 5     | 0.00  | -2.21 | 0.0000  |
| 6     | 0.00  | -2.05 | 0.0000  |
| 7     | -0.28 | -1.41 | 0.0168  |
| 8     | 0.00  | -1.31 | 0.0149  |
| 9     | -0.28 | -0.08 | 0.0069  |
| 10    | 0.00  | 0.00  | 0.0138  |

**Member Forces** - units: Axial kN (-ve tension), Shear kN, Bending kNm

| Member |        | -----End1----- |       |       |         | -----End2----- |       |       |         |
|--------|--------|----------------|-------|-------|---------|----------------|-------|-------|---------|
| Ref.   | Length | Joint          | Axial | Shear | Bending | Joint          | Axial | Shear | Bending |
| 1-3    | 4800   | 1              | 0.0   | 0.2   | -0.5    | 3              | 0.0   | 0.2   | 0.4     |
| 1-2    | 5200   | 1              | 8.1   | -0.2  | 0.5     | 2              | 8.1   | -0.2  | -0.3    |
| 1-4    | 7077   | 1              | 32.3  | 0.0   | 0.0     | 4              | 32.3  | 0.0   | 0.0     |
| 2-4    | 4800   | 2              | 0.2   | 0.1   | -0.3    | 4              | 0.2   | 0.1   | 0.1     |
| 3-6    | 4800   | 3              | 0.0   | 0.2   | 0.4     | 6              | 0.0   | 0.2   | 1.2     |
| 4-5    | 4800   | 4              | 29.3  | 0.0   | 0.1     | 5              | 29.3  | 0.0   | 0.2     |
| 4-6    | 7077   | 4              | -10.6 | 0.0   | 0.0     | 6              | -10.6 | 0.0   | 0.0     |
| 5-7    | 4800   | 5              | 29.3  | 0.0   | 0.2     | 7              | 29.3  | 0.0   | 0.1     |
| 5-6    | 5200   | 5              | 15.9  | 0.0   | 0.0     | 6              | 15.9  | 0.0   | 0.0     |
| 6-8    | 4800   | 6              | 0.0   | -0.2  | 1.2     | 8              | 0.0   | -0.2  | 0.4     |
| 6-7    | 7077   | 6              | -10.6 | 0.0   | 0.0     | 7              | -10.6 | 0.0   | 0.0     |
| 7-9    | 4800   | 7              | 0.2   | -0.1  | 0.1     | 9              | 0.2   | -0.1  | -0.3    |
| 7-10   | 7077   | 7              | 32.3  | 0.0   | 0.0     | 10             | 32.3  | 0.0   | 0.0     |
| 8-10   | 4800   | 8              | 0.0   | -0.2  | 0.4     | 10             | 0.0   | -0.2  | -0.5    |
| 9-10   | 5200   | 9              | 8.1   | 0.2   | -0.3    | 10             | 8.1   | 0.2   | 0.5     |

**Support Reactions** - units: kN

| Joint | X     | Y    | Moment |
|-------|-------|------|--------|
| 1     | 22.1  | 32.0 | 0.0    |
| 10    | -22.1 | 32.0 | 0.0    |

Client: Pavetec Ltd

Project: 8- 10 Spring Vale Street Bury

Date: 16/07/20

Ref: 20-4106

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## CHS section subject to direct compression (Hot rolled sections only)- Roof Bracing- outer brace

Calculations in accordance with BS5950:Part1:2000 and the SCI 'Steelwork Design Guide to BS5950'

|                                   |                         |
|-----------------------------------|-------------------------|
| Section size                      | - 88.9x5.0 CHS          |
| Section class                     | - 1 (Plastic)           |
| Steel grade                       | - S 355                 |
| Design strength of steel          | = 355 N/mm <sup>2</sup> |
| Length                            | = 7200 mm               |
| Applied ultimate compressive load | = 52 kN                 |

End restraint type: (As defined in Table 22)

|                  |                                                                       |
|------------------|-----------------------------------------------------------------------|
| Bottom, x-x axis | - Effectively held in position and partially restrained in direction. |
| Top, x-x axis    | - Effectively held in position and partially restrained in direction. |
| Bottom, y-y axis | - Effectively held in position and partially restrained in direction. |
| Top, y-y axis    | - Effectively held in position and partially restrained in direction. |

### Determine the member slenderness

The effective length factor for the x-x axis combination of restraints is

$$L_{fx} = 0.85$$

and for the y-y axis is

$$L_{fy} = 0.85$$

For the x-x axis the slenderness is

$$\begin{aligned}\lambda_x &= L_o * L_{fx} / r_{xx} \\ &= 7200 * 0.85 / 29.6 \\ &= 206.8\end{aligned}$$

and for the y-y axis

$$\begin{aligned}\lambda_y &= L_o * L_{fy} / r_{yy} \\ &= 7200 * 0.85 / 29.6 \\ &= 206.8\end{aligned}$$

### Determine the capacity of the section

The allowable compressive strength, based on a maximum slenderness 206.8 , from Table 24(a) is

$$p_c = 45 \text{ N/mm}^2$$

and hence the capacity of the section in accordance with clause 4.7.4 is

$$\begin{aligned}P_c &= p_c * A_g / 1000 \\ &= 45 * 1320 / 1000 \\ &= 59.4 \text{ kN}\end{aligned}$$

**Section OK**

**Roof Bracing- outer brace- Use min 88.9x5.0 CHS**

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## CHS section subject to direct compression (Hot rolled sections only)- Roof Bracing – Inner brace

Calculations in accordance with BS5950:Part1:2000 and the SCI 'Steelwork Design Guide to BS5950'

|                                   |                         |
|-----------------------------------|-------------------------|
| Section size                      | - 76.1x5.0 CHS          |
| Section class                     | - 1 (Plastic)           |
| Steel grade                       | - S 355                 |
| Design strength of steel          | = 355 N/mm <sup>2</sup> |
| Length                            | = 7200 mm               |
| Applied ultimate compressive load | = 20 kN                 |

End restraint type: (As defined in Table 22)

|                  |                                                                       |
|------------------|-----------------------------------------------------------------------|
| Bottom, x-x axis | - Effectively held in position and partially restrained in direction. |
| Top, x-x axis    | - Effectively held in position and partially restrained in direction. |
| Bottom, y-y axis | - Effectively held in position and partially restrained in direction. |
| Top, y-y axis    | - Effectively held in position and partially restrained in direction. |

### Determine the member slenderness

The effective length factor for the x-x axis combination of restraints is

$$L_{fx} = 0.85$$

and for the y-y axis is

$$L_{fy} = 0.85$$

For the x-x axis the slenderness is

$$\begin{aligned}\lambda_x &= L_o * L_{fx} / r_{xx} \\ &= 7200 * 0.85 / 25.2 \\ &= 242.9\end{aligned}$$

and for the y-y axis

$$\begin{aligned}\lambda_y &= L_o * L_{fy} / r_{yy} \\ &= 7200 * 0.85 / 25.2 \\ &= 242.9\end{aligned}$$

### Determine the capacity of the section

The allowable compressive strength, based on a maximum slenderness 242.9 , from Table 24(a) is

$$p_c = 33 \text{ N/mm}^2$$

and hence the capacity of the section in accordance with clause 4.7.4 is

$$\begin{aligned}P_c &= p_c * A_g / 1000 \\ &= 33 * 1120 / 1000 \\ &= 37.0 \text{ kN}\end{aligned}$$

**Section OK**

**Roof Bracing – Inner brace- Use min 76.1x5.0 CHS**

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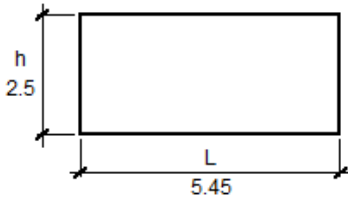
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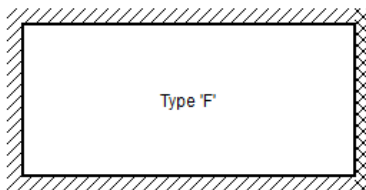
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## Cavity wall panel under lateral load to BS5628 : Part 1 : 2005- Cavity Wall- GL 1



|                                             |                               |
|---------------------------------------------|-------------------------------|
| Length of wall panel                        | $L = 5.45 \text{ m}$          |
| Height of wall panel                        | $h = 2.5 \text{ m}$           |
| Outer leaf weight                           | $wt_o = 20 \text{ kN/m}^3$    |
| Inner leaf weight                           | $wt_i = 18 \text{ kN/m}^3$    |
| Thickness of outer leaf                     | $t_o = 100 \text{ mm}$        |
| Thickness of inner leaf                     | $t_i = 100 \text{ mm}$        |
| Mortar designation (Table 1)                | $M_{des} = 3$                 |
| Materials partial safety factor             | $\gamma_m = 3$                |
| Characteristic wind load                    | $W_k = 1.03 \text{ kN/m}^2$   |
| Outer leaf is clay brick                    |                               |
| Water absorption of outer leaf              | $wa_o = 10 \%$                |
| Inner leaf is blockwork                     |                               |
|                                             | $f_{ki} = 2.9 \text{ N/mm}^2$ |
| Removal of panel would not effect stability |                               |
| Partial safety factor, loads                | $\gamma_f = 1.2$              |

### Bending in outer leaf



**Wall Panel**  
**BS5628-1:2005 Table 8, Type F**

Enhance orthogonal strength ratio by allowing for the effects of self weight at mid height

|                              |                                                                        |
|------------------------------|------------------------------------------------------------------------|
| Design vert load / unit area | $n_{sw} = wt_o \cdot (h/2) / 1000 = 0.025 \text{ N/mm}^2$              |
| Orthogonal strength ratio    | $\mu = (fkx_{ob} + \gamma_m \cdot n_{sw}) / fkx_{op} = 0.43$           |
| Section modulus              | $Z = 1000 \cdot t_o^2 / 6 = 1666666.67 \text{ mm}^3/\text{m}$          |
| Design moment of resistance  | $M_d = fkx_{op} \cdot Z / (\gamma_m \cdot 10^6) = 0.61 \text{ kNm/m}$  |
| Bending moment coefficient   | $\alpha = \text{Table}(tabo, m, h'L) = 0.024$                          |
| Allowable load on outer leaf | $Lo = M_d / (\alpha \cdot \gamma_f \cdot L^2) = 0.7254 \text{ kN/m}^2$ |

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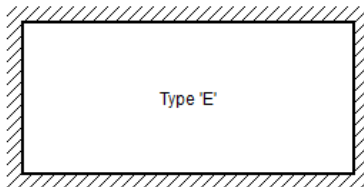
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## Bending in inner leaf



**Wall Panel**  
**BS5628-1:2005 Table 8, Type E**

Enhance orthogonal strength ratio by allowing for the effects of self weight at mid height

$$\text{Design vert load / unit area} \quad n_{sw} = w t_i (h/2) / 1000 = 0.023 \text{ N/mm}^2$$

$$\text{Orthogonal strength ratio} \quad \mu = (f k x_{ib} + \gamma_m n_{sw}) / f k x_{ip} = 0.79$$

$$\text{Section modulus} \quad Z = 1000 t_i^2 / 6 = 1666666.67 \text{ mm}^3/\text{m}$$

$$\text{Design moment of resistance} \quad M_d = f k x_{ip} * Z / (\gamma_m * 10^6) = 0.22 \text{ kNm/m}$$

$$\text{Bending moment coefficient} \quad \alpha = \text{Table}(t_{bi}, m, h'L) = 0.019$$

$$\text{Allowable load on inner leaf} \quad L_i = M_d / (\alpha * \gamma_f * L^2) = 0.33 \text{ kN/m}^2$$

## Bending for both leaves combined

$$\text{Allowable lateral load} \quad L_{max} = L_o + L_i = 1.06 \text{ kN/m}^2$$

Wind load, 1.03 within bending capacity, 1.06 - OK

## Shear for both leaves combined

$$\text{Max area panel support at side} \quad a_s = h * L / 2 = 6.81 \text{ m}^2$$

$$\text{Design shear load at side} \quad V_s = a_s * \gamma_f * W_k = 8.42 \text{ kN}$$

$$\text{Allowable shear load at side} \quad L_s = L_{os} + L_{is} = 70 \text{ kN}$$

$$\text{Max area panel supported at base} \quad a_b = h * L / 2 = 6.81 \text{ m}^2$$

$$\text{Design shear load at base} \quad V_f = a_b * \gamma_f * W_k = 8.42 \text{ kN}$$

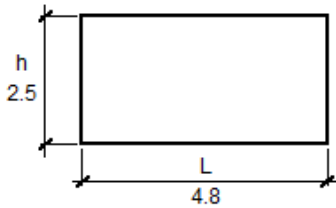
$$\text{Allowable shear load at base} \quad L_b = L_{ob} + L_{ib} = 165.03 \text{ kN}$$

Design shear at side, 8.42 is within capacity, 70 - OK

Design shear at base, 8.42 is within capacity, 165.03 - OK

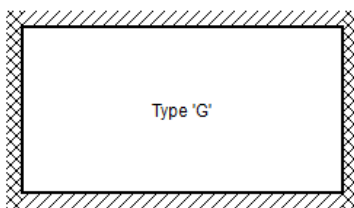
**Use min 100mm facing brick outer leaf with min 20N/mm2 compressive strength and 100mm DCM blockwork inner leaf with min 7N/mm2 compressive strength with 100mm insulated cavity all set in mortar grade (iii)/ M4 Cavity wall panel to be restrained at head with designed sheeting rails.**

## Cavity wall panel under lateral load to BS5628 : Part 1 : 2005- Cavity Wall – GL A



|                                             |                               |
|---------------------------------------------|-------------------------------|
| Length of wall panel                        | $L = 4.8 \text{ m}$           |
| Height of wall panel                        | $h = 2.5 \text{ m}$           |
| Outer leaf weight                           | $wt_o = 20 \text{ kN/m}^3$    |
| Inner leaf weight                           | $wt_i = 18 \text{ kN/m}^3$    |
| Thickness of outer leaf                     | $t_o = 100 \text{ mm}$        |
| Thickness of inner leaf                     | $t_i = 100 \text{ mm}$        |
| Mortar designation (Table 1)                | $M_{des} = 3$                 |
| Materials partial safety factor             | $\gamma_m = 3$                |
| Characteristic wind load                    | $W_k = 1.33 \text{ kN/m}^2$   |
| Outer leaf is clay brick                    |                               |
| Water absorption of outer leaf              | $wa_o = 10 \%$                |
| Inner leaf is blockwork                     |                               |
|                                             | $f_{ki} = 7.3 \text{ N/mm}^2$ |
| Removal of panel would not effect stability |                               |
| Partial safety factor, loads                | $\gamma_f = 1.2$              |

### Bending in outer leaf



**Wall Panel**  
**BS5628-1:2005 Table 8, Type G**

|                                                                                            |                                                                |
|--------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| Enhance orthogonal strength ratio by allowing for the effects of self weight at mid height |                                                                |
| Design vert load / unit area                                                               | $n_{sw} = wt_o * (h/2) / 1000 = 0.025 \text{ N/mm}^2$          |
| Orthogonal strength ratio                                                                  | $\mu = (fkx_{ob} + \gamma_m * n_{sw}) / fkx_{op} = 0.43$       |
| Section modulus                                                                            | $Z = 1000 * t_o^2 / 6 = 1666666.67 \text{ mm}^3/\text{m}$      |
| Design moment of resistance                                                                | $M_d = fkx_{op} * Z / (\gamma_m * 10^6) = 0.61 \text{ kNm/m}$  |
| Bending moment coefficient                                                                 | $\alpha = \text{Table}(tabo, m, h'L) = 0.023$                  |
| Allowable load on outer leaf                                                               | $Lo = M_d / (\alpha * \gamma_f * L^2) = 0.9563 \text{ kN/m}^2$ |

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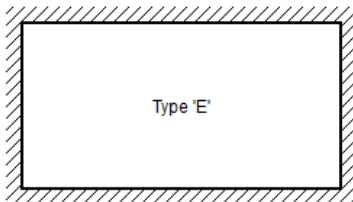
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## Bending in inner leaf



**Wall Panel**  
**BS5628-1:2005 Table 8, Type E**

Enhance orthogonal strength ratio by allowing for the effects of self weight at mid height

Design vert load / unit area  $n_{sw} = w t_i (h/2)/1000 = 0.023 \text{ N/mm}^2$

Orthogonal strength ratio  $\mu = (f k x_{ib} + \gamma_m n_{sw}) / f k x_{ip} = 0.53$

Section modulus  $Z = 1000 t_i^2 / 6 = 1666666.67 \text{ mm}^3/\text{m}$

Design moment of resistance  $M_d = f k x_{ip} Z / (\gamma_m \cdot 10^6) = 0.33 \text{ kNm/m}$

Bending moment coefficient  $\alpha = \text{Table}(t_{bi}, m, h'L) = 0.028$

Allowable load on inner leaf  $L_i = M_d / (\alpha \gamma_f L^2) = 0.42 \text{ kN/m}^2$

## Bending for both leaves combined

Allowable lateral load  $L_{max} = L_o + L_i = 1.38 \text{ kN/m}^2$

**Wind load, 1.33 within bending capacity, 1.38 - OK**

## Shear for both leaves combined

Max area panel support at side  $a_s = h \cdot L / 2 = 6 \text{ m}^2$

Design shear load at side  $V_s = a_s \gamma_f W_k = 9.58 \text{ kN}$

Allowable shear load at side  $L_s = L_{os} + L_{is} = 70 \text{ kN}$

Max area panel supported at base  $a_b = h \cdot L / 2 = 6 \text{ m}^2$

Design shear load at base  $V_f = a_b \gamma_f W_k = 9.58 \text{ kN}$

Allowable shear load at base  $L_b = L_{ob} + L_{ib} = 145.34 \text{ kN}$

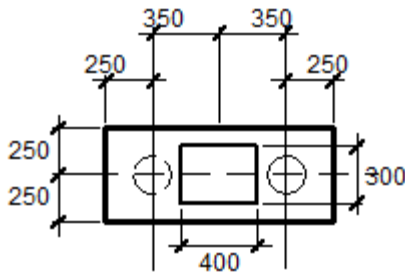
**Design shear at side, 9.58 is within capacity, 70 - OK**

**Design shear at base, 9.58 is within capacity, 145.34 - OK**

**Use min 100mm facing brick outer leaf with min 20N/mm2 compressive strength and 100mm DCM blockwork inner leaf with min 7N/mm2 compressive strength with 100mm insulated cavity all set in mortar grade (iii)/ M4 Cavity wall panel to be restrained at head with designed sheeting rails.**

## Double Pile Cap Design/ Reinforcement

### Two pile cap



Calculations for reinforcement are in accordance with BS8110:1997, the 'Struct E' Manual for the design of reinforced concrete building structures' and the 'Reinforced Concrete Designers Handbook' by Reynolds and Steedman

|                                                      |                                  |
|------------------------------------------------------|----------------------------------|
| Pile diameter                                        | = 200 mm                         |
| Pile spacing                                         | = 700 mm                         |
| Clearance from edge of pile to face of pile cap      | = 150 mm                         |
| Overall pile cap length                              | = 1200 mm                        |
| Effective overall pile cap width                     | = 500 mm                         |
| Overall pile cap depth                               | = 600 mm                         |
| Column length parallel to line between pile centres  | = 400 mm                         |
| Column width perpendicular to line between pile ctrs | = 300 mm                         |
| Nominal concrete cover to bottom reinforcement       | = 75 mm                          |
| Nominal concrete cover to side reinforcement         | = 50 mm                          |
| Tolerance between minimum and nominal cover          | $\Delta_c$ = 10 mm               |
| Preferred tension bar diameter                       | = 16 mm                          |
| Preferred transverse bar diameter                    | = 16 mm                          |
| Compressive strength class of concrete               | - C25/30                         |
| Characteristic concrete strength                     | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure               | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                 | $\gamma_{mcv}$ = 1.25            |
| Characteristic strength of longitudinal bars         | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement        | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                    | - type 2 deformed bars           |
| Characteristic strength of links                     | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                             | $\gamma_{msv}$ = 1.15            |

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|                                      |            |           |
|--------------------------------------|------------|-----------|
| Service load per pile                | $N_{serv}$ | = 400 kN  |
| Ultimate load factor                 | $\gamma_f$ | = 1.5     |
| Ultimate load per pile               | $N_{ult}$  | = 600 kN  |
| Service load capacity of pile group  | $P_{serv}$ | = 800 kN  |
| Ultimate load capacity of pile group | $P_{ult}$  | = 1200 kN |

## Reinforcement

| Zone                                | F<br>(kN) | V<br>(kN) | $A_{sreqd}$<br>(mm <sup>2</sup> ) | $A_{sprov}$<br>(mm <sup>2</sup> ) | Bar details |
|-------------------------------------|-----------|-----------|-----------------------------------|-----------------------------------|-------------|
| Main long. bars                     | 362       | 600       | 833                               | 1005                              | 5 H 16      |
| Minimum internal radius of main bar |           |           | 121 mm                            |                                   |             |
| Allowable shear                     |           | 1132.7    |                                   |                                   |             |
| Transverse bars                     |           |           | 936                               | 1005                              | 5 H 16      |

NOTE: If column and/or pile loads are high, a check for punching shear should be made.

**Provide min 600w x 200lg x 600dp RC Pile cap with 5 H16 longitudinal bars top and bottom with double H10 links at 200ctr (78.5 x 12= 942mm<sup>2</sup>)**

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## Concrete industrial ground floor design to TR34 - Fourth edition- Ground Bearing floor slab

### Slab details

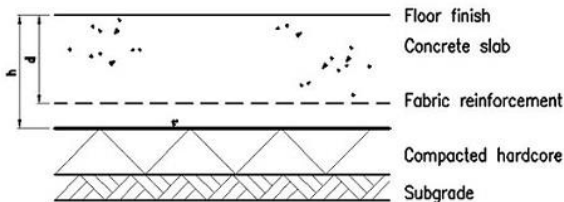
Reinforcement type Fabric  
Thickness of slab  $h = 225 \text{ mm}$

### Reinforcement details

Characteristic strength of mesh  $f_{yk} = 500 \text{ N/mm}^2$   
Fabric reinforcement (bottom) A252  
Area of reinforcement in each direction  $A_s = \frac{\pi \phi^2}{4} \cdot \frac{1000}{s_p}$   
 $= \frac{3.14 \cdot (8)^2}{4} \cdot \frac{1000}{200}$   
 $= 251.33 \text{ mm}^2/\text{m}$   
Percentage of reinforcement provided  $A_{s\_per} = \frac{A_s}{(h \cdot 10)}$   
 $= \frac{251.33}{(225 \cdot 10)}$   
 $= 0.11 \%$

*Percentage reinforcement is within recommended limits*

Diameter of reinforcement  $\phi = 8 \text{ mm}$   
Depth of nominal cover to reinforcement  $c_{nom} = 50 \text{ mm}$   
Ave. effective depth of reinforcement  $d = h - c_{nom} - (\phi/2)$   
 $= 225 - 50 - (8/2)$   
 $= 171 \text{ mm}$



### Strength properties of concrete (Table 6.1)

Char. compressive strength (cylinder)  $f_{ck} = 28 \text{ N/mm}^2$   
Char. compressive strength (cube)  $f_{cu} = 35 \text{ N/mm}^2$   
Mean compressive strength (cylinder)  $f_{cm} = 36 \text{ N/mm}^2$   
Mean axial tensile strength  $f_{ctm} = 2.8 \text{ N/mm}^2$   
Secant modulus of elasticity  $E_{cm} = 32 \text{ kN/mm}^2$   
Shear factor  $k_s = 1 + (200/d)^{0.5}$   
 $= 1 + (200/171)^{0.5}$   
 $= 2.08$   
Minimum shear strength of concrete  $V_{Rd\_ct} = 0.035 \cdot (k_s)^{1.5} \cdot (f_{ck}/1)^{0.5}$   
 $= 0.035 \cdot (2.08)^{1.5} \cdot (28/1)^{0.5}$   
 $= 0.56 \text{ N/mm}^2$   
(cl 6.1.1)  
Design flexural tensile strength  $f_{ctd\_fl} = f_{ctm} \cdot ((1.6 - (h/1000))/\gamma_c)$   
 $= 2.8 \cdot ((1.6 - (225/1000))/1.5)$   
 $= 2.57 \text{ N/mm}^2$   
Moment capacity of plain concrete  $M_{un} = f_{ctd\_fl} \cdot h^2/6 \cdot 10^{(-3)}$   
 $= 2.57 \cdot (225)^2/6 \cdot 10^{(-3)}$   
 $= 21.66 \text{ kNm/m}$

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## Subgrade construction

Modulus of sub-grade reaction  $k = 0.05 \text{ N/mm}^3$

## Properties of reinforced slabs - (cl 6.3.2)

Moment capacity  $M_{p\_fab} = 0.95 \cdot A_{s\_yk} \cdot f_{yk} \cdot (d \cdot 10^{-6})$   
 $= 0.95 \cdot 251.33 \cdot 500 / 1.15 \cdot (171 \cdot 10^{-6})$   
 $= 17.75 \text{ kNm/m}$

Negative moment capacity  $M_n = (f_{ctd\_fl} \cdot h^2 / (6 \cdot \gamma_c)) / 1000$   
 $= (2.57 \cdot (225)^2 / (6 \cdot 1.5)) / 1000$   
 $= 14.44 \text{ kNm/m}$

Poisson's ratio  $\nu = 0.2$

## Characteristic of system

$\lambda = (3 \cdot k / (E_{cm} \cdot (h/1000)^3))^{0.25}$   
 $= (3 \cdot 0.05 / (32 \cdot (225/1000)^3))^{0.25}$   
 $= 0.8 \text{ m}^{-1}$

## Characteristic of system

$\lambda = (3 \cdot k / (E_{cm} \cdot (h/1000)^3))^{0.25}$   
 $= (3 \cdot 0.05 / (32 \cdot (225/1000)^3))^{0.25}$   
 $= 0.8 \text{ m}^{-1}$

## Line load - (cl 7.10)

Line load  $l_k = 30 \text{ kN/m}$

## Safe load capacity under line load

Safe line load cap. (+ive moments)  $P_{lin\_p} = 4 \cdot \lambda \cdot M_p$   
 $= 4 \cdot 0.8 \cdot 17.75$   
 $= 56.87 \text{ kN/m}$

Safe line load cap. (-ive moments)  $P_{lin\_n} = 4 \cdot \lambda \cdot M_n / 0.21$   
 $= 4 \cdot 0.8 \cdot 14.44 / 0.21$   
 $= 220.26 \text{ kN/m}$

Safe load cap. of slab  $P_{lin} = P_{lin\_p}$   
 $= 56.87 \text{ kN/m}$

**Pass - The applied line load is within the safe load capacity**

## Uniform distributed load

(cl 7.12)

Uniform distributed load  $U_k = 12 \text{ kN/m}^2$

## Safe load capacity under a uniform distributed load

Safe UDL capacity (+ive moments)  $w_p = \lambda^2 \cdot M_p / 0.16$   
 $= (0.8)^2 \cdot 17.75 / 0.16$   
 $= 70.73 \text{ kN/m}^2$

Safe UDL capacity (-ive moments)  $w_n = \lambda^2 \cdot M_n / 0.17$   
 $= (0.8)^2 \cdot 14.44 / 0.17$   
 $= 55.13 \text{ kN/m}^2$

Safe load cap. of slab per unit area  $w = w_n$   
 $= 55.13 \text{ kN/m}^2$

**Pass - The applied UDL is within the safe load capacity**

**Provide min 225mm RC ground bearing floor slab with min 1 layer A252 reinforcement top and bottom.**  
**Ground/ sub-base to be proof rolled and tested to achieve min 5% CBR**

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## Reinforced Ground Beam A1- A5

### Rectangular beam section- G Beam A1-A2

Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'

|                                                                                                 |                                  |
|-------------------------------------------------------------------------------------------------|----------------------------------|
| Beam span                                                                                       | = 4.8 m                          |
| Depth of beam                                                                                   | = 450 mm                         |
| Breadth of beam                                                                                 | = 450 mm                         |
| Span type                                                                                       | - Continuous                     |
| Maximum no. of layers of tension reinforcement                                                  | = 1                              |
| Number of bars per layer                                                                        | = 4                              |
| Nominal concrete cover to bottom reinforcement                                                  | = 35 mm                          |
| Nominal concrete cover to top reinforcement                                                     | = 35 mm                          |
| Nominal concrete side cover to reinforcement                                                    | = 35 mm                          |
| Tolerance between minimum and nominal cover                                                     | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete                                                          | - C25/30                         |
| Characteristic concrete strength                                                                | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                          | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                            | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                    | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                                   | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                               | - type 2 deformed bars           |
| Characteristic strength of links                                                                | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                        | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                             | = 4                              |
| Preferred link diameter                                                                         | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                                   | = 88.6 kNm                       |
| Maximum redistributed ultimate hogging moment<br>(this moment occurs at the right hand support) | = -84.5 kNm                      |
| Redistributed ultimate positive shear at LH support                                             | = 88.4 kN                        |
| Redistributed ultimate negative shear at RH support                                             | = -123.2 kN                      |

### Envelopes from Multi Span : 20-4106-GB-A1-A5

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description | Type | A | B   | C | Gk   | Qk   |
|------------------|------|---|-----|---|------|------|
| Wall/ floor      | UDL  | 0 | 4.8 |   | 20.0 | 10.0 |

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|     | UpLt | Elastic Support Moments |      |      | Support Reactions |       |
|-----|------|-------------------------|------|------|-------------------|-------|
|     |      | DnLt                    | UpRt | DnRt | Lt                | Rt    |
| Max |      |                         |      |      | 88.4              | 197.4 |
| Min |      |                         |      |      | 34.5              | 90.4  |

### Main Reinforcement

| Zone            |           | M     | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details |
|-----------------|-----------|-------|-----|--------------------|--------------------|-------------|
| Span bottom     | - layer 1 | 88.6  | 378 | 539                | 804                | 4 H 16      |
| Right supp. top | - layer 1 | -84.5 | 379 | 513                | 804                | 4 H 16      |

NOTE: 100% of reinforcement assumed to be fully anchored past support.

### Shear Reinforcement

| Zone                                                                                                                                                                               | V      | v     | v <sub>c</sub> | Shear reinforcement details    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-------|----------------|--------------------------------|
| Left support                                                                                                                                                                       | 88.4   | 0.495 | 0.409          | 4 legs of H 8 links at 295 c/c |
| The support moment is zero, the shear design is based on the provision of 50% of the area of span bottom reinforcement, fully anchored at the support ( 402 mm <sup>2</sup> )      |        |       |                |                                |
| Right support                                                                                                                                                                      | -123.2 | 0.69  | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |        |       |                |                                |

### Span to Effective depth ratio

|                 |      |              |         |
|-----------------|------|--------------|---------|
| Allowable ratio | = 39 | Actual ratio | = 12.09 |
|                 |      | Section OK   |         |

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## **Rectangular beam section- G Beam A2-A3**

*Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'*

|                                                                                                |                                  |
|------------------------------------------------------------------------------------------------|----------------------------------|
| Beam span                                                                                      | = 4.8 m                          |
| Depth of beam                                                                                  | = 450 mm                         |
| Breadth of beam                                                                                | = 450 mm                         |
| Span type                                                                                      | - Continuous                     |
| Maximum no. of layers of tension reinforcement                                                 | = 1                              |
| Number of bars per layer                                                                       | = 4                              |
| Nominal concrete cover to bottom reinforcement                                                 | = 35 mm                          |
| Nominal concrete cover to top reinforcement                                                    | = 35 mm                          |
| Nominal concrete side cover to reinforcement                                                   | = 35 mm                          |
| Tolerance between minimum and nominal cover                                                    | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete                                                         | - C25/30                         |
| Characteristic concrete strength                                                               | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                         | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                           | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                   | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                                  | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                              | - type 2 deformed bars           |
| Characteristic strength of links                                                               | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                       | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                            | = 4                              |
| Preferred link diameter                                                                        | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                                  | = 28.5 kNm                       |
| Ultimate design moment at right hand support                                                   | = -45.5 kNm                      |
| Maximum redistributed ultimate hogging moment<br>(this moment occurs at the left hand support) | = -84.5 kNm                      |
| Redistributed ultimate positive shear at LH support                                            | = 74.2 kN                        |
| Redistributed ultimate negative shear at RH support                                            | = -58.6 kN                       |

## **Envelopes from Multi Span : 20-4106-GB-A1-A5**

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description | Type | A | B   | C | Gk   | Qk  |
|------------------|------|---|-----|---|------|-----|
| Wall/ Nominal fl | UDL  | 0 | 4.8 |   | 12.5 | 5.0 |

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| Max<br>Min | UpLt | Elastic Support Moments |      | DnRt | Support Reactions |       |
|------------|------|-------------------------|------|------|-------------------|-------|
|            |      | DnLt                    | UpRt |      | Lt                | Rt    |
|            |      |                         |      |      | 197.4             | 122.0 |
|            |      |                         |      |      | 90.4              | 53.1  |

## Main Reinforcement

| Zone                                                                   |           | M     | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details |
|------------------------------------------------------------------------|-----------|-------|-----|--------------------|--------------------|-------------|
| Span bottom                                                            | - layer 1 | 28.5  | 391 | 168                | 804                | 4 H 16      |
| Left supp. top -                                                       | layer 1   | -84.5 | 379 | 513                | 804                | 4 H 16      |
| NOTE: 100% of reinforcement assumed to be fully anchored past support. |           |       |     |                    |                    |             |
| Right supp. top                                                        | - layer 1 | -45.5 | 387 | 270                | 804                | 4 H 16      |
| NOTE: 100% of reinforcement assumed to be fully anchored past support. |           |       |     |                    |                    |             |

## Shear Reinforcement

| Zone                                                                                                                                                                               | V     | v     | v <sub>c</sub> | Shear reinforcement details    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|----------------|--------------------------------|
| Left support                                                                                                                                                                       | 74.2  | 0.415 | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |       |       |                |                                |
| Right support                                                                                                                                                                      | -58.6 | 0.328 | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |       |       |                |                                |

## Span to Effective depth ratio

|                 |      |              |         |
|-----------------|------|--------------|---------|
| Allowable ratio | = 52 | Actual ratio | = 12.09 |
| Section OK      |      |              |         |

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## **Rectangular beam section- G Beam A3-A4**

*Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'*

|                                                                                              |                                  |
|----------------------------------------------------------------------------------------------|----------------------------------|
| Beam span                                                                                    | = 4.8 m                          |
| Depth of beam                                                                                | = 450 mm                         |
| Breadth of beam                                                                              | = 450 mm                         |
| Span type                                                                                    | - Continuous                     |
| Maximum no. of layers of tension reinforcement                                               | = 1                              |
| Number of bars per layer                                                                     | = 4                              |
| Nominal concrete cover to bottom reinforcement                                               | = 35 mm                          |
| Nominal concrete cover to top reinforcement                                                  | = 35 mm                          |
| Nominal concrete side cover to reinforcement                                                 | = 35 mm                          |
| Tolerance between minimum and nominal cover                                                  | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete                                                       | - C25/30                         |
| Characteristic concrete strength                                                             | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                       | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                         | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                 | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                                | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                            | - type 2 deformed bars           |
| Characteristic strength of links                                                             | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                     | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                          | = 4                              |
| Preferred link diameter                                                                      | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                                | = 35.5 kNm                       |
| Redistributed ultimate hogging moment at LH support                                          | = -45.5 kNm                      |
| Maximum redistributed ultimate hogging moment (this moment occurs at the right hand support) | = -66 kNm                        |
| Redistributed ultimate positive shear at LH support                                          | = 63.5 kN                        |
| Redistributed ultimate negative shear at RH support                                          | = -68.9 kN                       |

## **Envelopes from Multi Span : 20-4106-GB-A1-A5**

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description | Type | A | B   | C | Gk   | Qk  |
|------------------|------|---|-----|---|------|-----|
| Wall/ Nominal fl | UDL  | 0 | 4.8 |   | 12.5 | 5.0 |

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| Max<br>Min | UpLt | Elastic Support Moments |      | DnRt | Support Reactions |       |
|------------|------|-------------------------|------|------|-------------------|-------|
|            |      | DnLt                    | UpRt |      | Lt                | Rt    |
|            |      |                         |      |      | 122.0             | 154.7 |
|            |      |                         |      |      | 53.1              | 59.2  |

## Main Reinforcement

| Zone                                                                   |           | M     | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details |
|------------------------------------------------------------------------|-----------|-------|-----|--------------------|--------------------|-------------|
| Span bottom                                                            | - layer 1 | 35.5  | 389 | 210                | 804                | 4 H 16      |
| Left supp. top -                                                       | layer 1   | -45.5 | 387 | 270                | 804                | 4 H 16      |
| NOTE: 100% of reinforcement assumed to be fully anchored past support. |           |       |     |                    |                    |             |
| Right supp. top                                                        | - layer 1 | -66   | 383 | 396                | 804                | 4 H 16      |
| NOTE: 100% of reinforcement assumed to be fully anchored past support. |           |       |     |                    |                    |             |

## Shear Reinforcement

| Zone                                                                                                                                                                               | V     | v     | v <sub>c</sub> | Shear reinforcement details    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|----------------|--------------------------------|
| Left support                                                                                                                                                                       | 63.5  | 0.355 | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |       |       |                |                                |
| Right support                                                                                                                                                                      | -68.9 | 0.386 | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |       |       |                |                                |

## Span to Effective depth ratio

|                 |      |              |         |
|-----------------|------|--------------|---------|
| Allowable ratio | = 52 | Actual ratio | = 12.09 |
| Section OK      |      |              |         |

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## **Rectangular beam section- G Beam A4-A5**

*Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'*

|                                                                                                |                                  |
|------------------------------------------------------------------------------------------------|----------------------------------|
| Beam span                                                                                      | = 4.8 m                          |
| Depth of beam                                                                                  | = 450 mm                         |
| Breadth of beam                                                                                | = 450 mm                         |
| Span type                                                                                      | - Continuous                     |
| Maximum no. of layers of tension reinforcement                                                 | = 1                              |
| Number of bars per layer                                                                       | = 4                              |
| Nominal concrete cover to bottom reinforcement                                                 | = 35 mm                          |
| Nominal concrete cover to top reinforcement                                                    | = 35 mm                          |
| Nominal concrete side cover to reinforcement                                                   | = 35 mm                          |
| Tolerance between minimum and nominal cover                                                    | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete                                                         | - C25/30                         |
| Characteristic concrete strength                                                               | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                         | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                           | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                   | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                                  | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                              | - type 2 deformed bars           |
| Characteristic strength of links                                                               | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                       | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                            | = 4                              |
| Preferred link diameter                                                                        | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                                  | = 58.9 kNm                       |
| Maximum redistributed ultimate hogging moment<br>(this moment occurs at the left hand support) | = -66 kNm                        |
| Redistributed ultimate positive shear at LH support                                            | = 85.8 kN                        |
| Redistributed ultimate negative shear at RH support                                            | = -59.5 kN                       |

## **Envelopes from Multi Span : 20-4106-GB-A1-A5**

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description | Type | A | B   | C | Gk   | Qk   |
|------------------|------|---|-----|---|------|------|
| Wall/ Nominal fl | UDL  | 0 | 4.8 |   | 10.0 | 10.0 |

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|     | UpLt | Elastic Support Moments |      |      | Support Reactions |      |
|-----|------|-------------------------|------|------|-------------------|------|
|     |      | DnLt                    | UpRt | DnRt | Lt                | Rt   |
| Max |      |                         |      |      | 154.7             | 59.5 |
| Min |      |                         |      |      | 59.2              | 13.7 |

### Main Reinforcement

| Zone             |           | M    | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details |
|------------------|-----------|------|-----|--------------------|--------------------|-------------|
| Span bottom      | - layer 1 | 58.9 | 384 | 353                | 804                | 4 H 16      |
| Left supp. top - | layer 1   | -66  | 383 | 396                | 804                | 4 H 16      |

NOTE: 100% of reinforcement assumed to be fully anchored past support.

### Shear Reinforcement

| Zone                                                                                                                                                                               | V     | v     | v <sub>c</sub> | Shear reinforcement details    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|----------------|--------------------------------|
| Left support                                                                                                                                                                       | 85.8  | 0.48  | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |       |       |                |                                |
| Right support                                                                                                                                                                      | -59.5 | 0.333 | 0.409          | 4 legs of H 8 links at 295 c/c |
| The support moment is zero, the shear design is based on the provision of 50% of the area of span bottom reinforcement, fully anchored at the support ( 402 mm <sup>2</sup> )      |       |       |                |                                |

### Span to Effective depth ratio

|                 |      |              |         |
|-----------------|------|--------------|---------|
| Allowable ratio | = 52 | Actual ratio | = 12.09 |
|                 |      | Section OK   |         |

**Provide min 450 x450 RC Ground Beam with 4 H16 bars top and bottom and double H8 links at max 250 ctrs for ground Beam A1- A5**

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## Reinforced Ground Beam A1- D1

### Rectangular beam section- G Beam A1-B1

Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'

|                                                                                                 |                                  |
|-------------------------------------------------------------------------------------------------|----------------------------------|
| Beam span                                                                                       | = 5.5 m                          |
| Depth of beam                                                                                   | = 450 mm                         |
| Breadth of beam                                                                                 | = 450 mm                         |
| Span type                                                                                       | - Continuous                     |
| Maximum no. of layers of tension reinforcement                                                  | = 1                              |
| Number of bars per layer                                                                        | = 4                              |
| Nominal concrete cover to bottom reinforcement                                                  | = 35 mm                          |
| Nominal concrete cover to top reinforcement                                                     | = 35 mm                          |
| Nominal concrete side cover to reinforcement                                                    | = 35 mm                          |
| Tolerance between minimum and nominal cover                                                     | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete                                                          | - C25/30                         |
| Characteristic concrete strength                                                                | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                          | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                            | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                    | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                                   | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                               | - type 2 deformed bars           |
| Characteristic strength of links                                                                | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                        | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                             | = 4                              |
| Preferred link diameter                                                                         | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                                   | = 81.4 kNm                       |
| Maximum redistributed ultimate hogging moment<br>(this moment occurs at the right hand support) | = -101.2 kNm                     |
| Redistributed ultimate positive shear at LH support                                             | = 73.5 kN                        |
| Redistributed ultimate negative shear at RH support                                             | = -109.7 kN                      |

### Envelopes from Multi Span :

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description | Type | A | B   | C | Gk   | Qk  |
|------------------|------|---|-----|---|------|-----|
| Wall/ Floor      | UDL  | 0 | 5.5 |   | 18.0 | 5.0 |

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|     | UpLt | Elastic Support Moments |      |      | Support Reactions |       |
|-----|------|-------------------------|------|------|-------------------|-------|
|     |      | DnLt                    | UpRt | DnRt | Lt                | Rt    |
| Max |      |                         |      |      | 73.5              | 210.8 |
| Min |      |                         |      |      | 33.3              | 114.7 |

## Main Reinforcement

| Zone            |           | M      | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details |
|-----------------|-----------|--------|-----|--------------------|--------------------|-------------|
| Span bottom     | - layer 1 | 81.4   | 379 | 494                | 804                | 4 H 16      |
| Right supp. top | - layer 1 | -101.2 | 375 | 621                | 804                | 4 H 16      |

NOTE: 100% of reinforcement assumed to be fully anchored past support.

## Shear Reinforcement

| Zone                                                                                                                                                                               | V      | v     | v <sub>c</sub> | Shear reinforcement details    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-------|----------------|--------------------------------|
| Left support                                                                                                                                                                       | 73.5   | 0.411 | 0.409          | 4 legs of H 8 links at 295 c/c |
| The support moment is zero, the shear design is based on the provision of 50% of the area of span bottom reinforcement, fully anchored at the support ( 402 mm <sup>2</sup> )      |        |       |                |                                |
| Right support                                                                                                                                                                      | -109.7 | 0.614 | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |        |       |                |                                |

## Span to Effective depth ratio

|                 |         |              |         |
|-----------------|---------|--------------|---------|
| Allowable ratio | = 42.12 | Actual ratio | = 13.85 |
|                 |         | Section OK   |         |

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## **Rectangular beam section- G Beam B1-C1**

*Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'*

|                                                                                             |                                  |
|---------------------------------------------------------------------------------------------|----------------------------------|
| Beam span                                                                                   | = 5.5 m                          |
| Depth of beam                                                                               | = 450 mm                         |
| Breadth of beam                                                                             | = 450 mm                         |
| Span type                                                                                   | - Continuous                     |
| Maximum no. of layers of tension reinforcement                                              | = 1                              |
| Number of bars per layer                                                                    | = 4                              |
| Nominal concrete cover to bottom reinforcement                                              | = 35 mm                          |
| Nominal concrete cover to top reinforcement                                                 | = 35 mm                          |
| Nominal concrete side cover to reinforcement                                                | = 35 mm                          |
| Tolerance between minimum and nominal cover                                                 | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete                                                      | - C25/30                         |
| Characteristic concrete strength                                                            | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                      | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                        | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                               | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                           | - type 2 deformed bars           |
| Characteristic strength of links                                                            | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                    | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                         | = 4                              |
| Preferred link diameter                                                                     | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                               | = 52.8 kNm                       |
| Ultimate design moment at right hand support                                                | = -63.6 kNm                      |
| Maximum redistributed ultimate hogging moment (this moment occurs at the left hand support) | = -101.2 kNm                     |
| Redistributed ultimate positive shear at LH support                                         | = 101.1 kN                       |
| Redistributed ultimate negative shear at RH support                                         | = -87 kN                         |

## **Envelopes from Multi Span :**

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description | Type | A | B   | C | Gk   | Qk  |
|------------------|------|---|-----|---|------|-----|
| Wall/ Floor      | UDL  | 0 | 5.5 |   | 18.0 | 5.0 |

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|     | UpLt | Elastic Support Moments |      |      | Support Reactions |       |
|-----|------|-------------------------|------|------|-------------------|-------|
|     |      | DnLt                    | UpRt | DnRt | Lt                | Rt    |
| Max |      |                         |      |      | 210.8             | 161.1 |
| Min |      |                         |      |      | 114.7             | 84.3  |

## Main Reinforcement

| Zone                                                                   |           | M      | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details |
|------------------------------------------------------------------------|-----------|--------|-----|--------------------|--------------------|-------------|
| Span bottom                                                            | - layer 1 | 52.8   | 386 | 315                | 804                | 4 H 16      |
| Left supp. top -                                                       | layer 1   | -101.2 | 375 | 621                | 804                | 4 H 16      |
| NOTE: 100% of reinforcement assumed to be fully anchored past support. |           |        |     |                    |                    |             |
| Right supp. top                                                        | - layer 1 | -63.6  | 383 | 382                | 804                | 4 H 16      |
| NOTE: 100% of reinforcement assumed to be fully anchored past support. |           |        |     |                    |                    |             |

## Shear Reinforcement

| Zone                                                                                                                                                                               | V     | v     | v <sub>c</sub> | Shear reinforcement details    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|----------------|--------------------------------|
| Left support                                                                                                                                                                       | 101.1 | 0.566 | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |       |       |                |                                |
| Right support                                                                                                                                                                      | -87   | 0.487 | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |       |       |                |                                |

## Span to Effective depth ratio

|                 |      |              |         |
|-----------------|------|--------------|---------|
| Allowable ratio | = 52 | Actual ratio | = 13.85 |
| Section OK      |      |              |         |

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## **Rectangular beam section- G Beam C1-D1**

*Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'*

|                                                                                                |                                  |
|------------------------------------------------------------------------------------------------|----------------------------------|
| Beam span                                                                                      | = 3.3 m                          |
| Depth of beam                                                                                  | = 450 mm                         |
| Breadth of beam                                                                                | = 450 mm                         |
| Span type                                                                                      | - Continuous                     |
| Maximum no. of layers of tension reinforcement                                                 | = 1                              |
| Number of bars per layer                                                                       | = 4                              |
| Nominal concrete cover to bottom reinforcement                                                 | = 35 mm                          |
| Nominal concrete cover to top reinforcement                                                    | = 35 mm                          |
| Nominal concrete side cover to reinforcement                                                   | = 35 mm                          |
| Tolerance between minimum and nominal cover                                                    | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete                                                         | - C25/30                         |
| Characteristic concrete strength                                                               | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                         | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                           | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                   | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                                  | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                              | - type 2 deformed bars           |
| Characteristic strength of links                                                               | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                       | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                            | = 4                              |
| Preferred link diameter                                                                        | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                                  | = 29.4 kNm                       |
| Maximum redistributed ultimate hogging moment<br>(this moment occurs at the left hand support) | = -63.6 kNm                      |
| Redistributed ultimate positive shear at LH support                                            | = 74.1 kN                        |
| Redistributed ultimate negative shear at RH support                                            | = -44.2 kN                       |

## **Envelopes from Multi Span :**

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description | Type | A | B   | C | Gk   | Qk  |
|------------------|------|---|-----|---|------|-----|
| Wall/ Floor      | UDL  | 0 | 3.3 |   | 18.0 | 5.0 |

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|     | UpLt | Elastic Support Moments<br>DnLt | UpRt | DnRt | Support Reactions<br>Lt | Rt   |
|-----|------|---------------------------------|------|------|-------------------------|------|
| Max |      |                                 |      |      | 161.1                   | 44.2 |
| Min |      |                                 |      |      | 84.3                    | 10.4 |

## Main Reinforcement

| Zone             |           | M     | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details |
|------------------|-----------|-------|-----|--------------------|--------------------|-------------|
| Span bottom      | - layer 1 | 29.4  | 391 | 173                | 804                | 4 H 16      |
| Left supp. top - | layer 1   | -63.6 | 383 | 382                | 804                | 4 H 16      |

NOTE: 100% of reinforcement assumed to be fully anchored past support.

## Shear Reinforcement

| Zone                                                                                                                                                                               | V     | v     | v <sub>c</sub> | Shear reinforcement details    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|----------------|--------------------------------|
| Left support                                                                                                                                                                       | 74.1  | 0.415 | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |       |       |                |                                |
| Right support                                                                                                                                                                      | -44.2 | 0.247 | 0.409          | 4 legs of H 8 links at 295 c/c |
| The support moment is zero, the shear design is based on the provision of 50% of the area of span bottom reinforcement, fully anchored at the support ( 402 mm <sup>2</sup> )      |       |       |                |                                |

## Span to Effective depth ratio

|                 |      |              |        |
|-----------------|------|--------------|--------|
| Allowable ratio | = 52 | Actual ratio | = 8.31 |
|                 |      | Section OK   |        |

**Provide min 450 x450 RC Ground Beam with 4 H16 bars top and bottom and double H8 links at max 250 ctrs for ground Beam A1- D1**

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## Reinforced Ground Beam A3- D3

### Rectangular beam section- G Beam A3-B3

Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'

|                                                                                                 |                                  |
|-------------------------------------------------------------------------------------------------|----------------------------------|
| Beam span                                                                                       | = 5.5 m                          |
| Depth of beam                                                                                   | = 450 mm                         |
| Breadth of beam                                                                                 | = 450 mm                         |
| Span type                                                                                       | - Continuous                     |
| Maximum no. of layers of tension reinforcement                                                  | = 1                              |
| Number of bars per layer                                                                        | = 4                              |
| Nominal concrete cover to bottom reinforcement                                                  | = 35 mm                          |
| Nominal concrete cover to top reinforcement                                                     | = 35 mm                          |
| Nominal concrete side cover to reinforcement                                                    | = 35 mm                          |
| Tolerance between minimum and nominal cover                                                     | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete                                                          | - C25/30                         |
| Characteristic concrete strength                                                                | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                          | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                            | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                    | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                                   | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                               | - type 2 deformed bars           |
| Characteristic strength of links                                                                | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                        | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                             | = 4                              |
| Preferred link diameter                                                                         | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                                   | = 126.7 kNm                      |
| Maximum redistributed ultimate hogging moment<br>(this moment occurs at the right hand support) | = -155.7 kNm                     |
| Redistributed ultimate positive shear at LH support                                             | = 113.7 kN                       |
| Redistributed ultimate negative shear at RH support                                             | = -168.6 kN                      |

### Envelopes from Multi Span :

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description | Type | A | B   | C | Gk   | Qk   |
|------------------|------|---|-----|---|------|------|
| Wall/Floor       | UDL  | 0 | 5.5 |   | 25.0 | 10.0 |

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|     | UpLt | Elastic Support Moments<br>DnLt | UpRt | DnRt | Support Reactions<br>Lt | Rt    |
|-----|------|---------------------------------|------|------|-------------------------|-------|
| Max |      |                                 |      |      | 113.7                   | 324.2 |
| Min |      |                                 |      |      | 44.8                    | 159.4 |

## Main Reinforcement

| Zone            |           | M      | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details |
|-----------------|-----------|--------|-----|--------------------|--------------------|-------------|
| Span bottom     | - layer 1 | 126.7  | 367 | 794                | 1257               | 4 H 20      |
| Right supp. top | - layer 1 | -155.7 | 359 | 998                | 1257               | 4 H 20      |

NOTE: 100% of reinforcement assumed to be fully anchored past support.

## Shear Reinforcement

| Zone          | V      | v     | v <sub>c</sub> | Shear reinforcement details                                                                                                                                                                                           |
|---------------|--------|-------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Left support  | 113.7  | 0.64  | 0.476          | 4 legs of H 8 links at 295 c/c<br>The support moment is zero, the shear design is based on the provision of 50% of the area of span bottom reinforcement, fully anchored at the support ( 629 mm <sup>2</sup> )       |
| Right support | -168.6 | 0.949 | 0.6            | 4 legs of H 8 links at 295 c/c<br>The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 1257 mm <sup>2</sup> ) |

## Span to Effective depth ratio

|                 |         |              |         |
|-----------------|---------|--------------|---------|
| Allowable ratio | = 34.84 | Actual ratio | = 13.92 |
|                 |         | Section OK   |         |

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## **Rectangular beam section- G Beam B3-C3**

*Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'*

|                                                                                             |                                  |
|---------------------------------------------------------------------------------------------|----------------------------------|
| Beam span                                                                                   | = 5.5 m                          |
| Depth of beam                                                                               | = 450 mm                         |
| Breadth of beam                                                                             | = 450 mm                         |
| Span type                                                                                   | - Continuous                     |
| Maximum no. of layers of tension reinforcement                                              | = 1                              |
| Number of bars per layer                                                                    | = 4                              |
| Nominal concrete cover to bottom reinforcement                                              | = 35 mm                          |
| Nominal concrete cover to top reinforcement                                                 | = 35 mm                          |
| Nominal concrete side cover to reinforcement                                                | = 35 mm                          |
| Tolerance between minimum and nominal cover                                                 | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete                                                      | - C25/30                         |
| Characteristic concrete strength                                                            | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                      | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                        | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                               | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                           | - type 2 deformed bars           |
| Characteristic strength of links                                                            | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                    | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                         | = 4                              |
| Preferred link diameter                                                                     | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                               | = 81.6 kNm                       |
| Ultimate design moment at right hand support                                                | = -99.2 kNm                      |
| Maximum redistributed ultimate hogging moment (this moment occurs at the left hand support) | = -155.7 kNm                     |
| Redistributed ultimate positive shear at LH support                                         | = 155.6 kN                       |
| Redistributed ultimate negative shear at RH support                                         | = -135.1 kN                      |

## **Envelopes from Multi Span :**

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description | Type | A | B   | C | Gk   | Qk   |
|------------------|------|---|-----|---|------|------|
| Wall/Floor       | UDL  | 0 | 5.5 |   | 25.0 | 10.0 |

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|                                                                                                                                                                                     | UpLt      | Elastic Support Moments |       |                    | Support Reactions            |             |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|-------------------------|-------|--------------------|------------------------------|-------------|
|                                                                                                                                                                                     |           | DnLt                    | UpRt  | DnRt               | Lt                           | Rt          |
| Max                                                                                                                                                                                 |           |                         |       |                    | 324.2                        | 249.3       |
| Min                                                                                                                                                                                 |           |                         |       |                    | 159.4                        | 117.1       |
| <b><u>Main Reinforcement</u></b>                                                                                                                                                    |           |                         |       |                    |                              |             |
| Zone                                                                                                                                                                                |           | M                       | z     | A <sub>sreqd</sub> | A <sub>sprov</sub>           | Bar details |
| Span bottom                                                                                                                                                                         | - layer 1 | 81.6                    | 377   | 498                | 1257                         | 4 H 20      |
| Left supp. top -                                                                                                                                                                    | layer 1   | -155.7                  | 359   | 998                | 1257                         | 4 H 20      |
| NOTE: 100% of reinforcement assumed to be fully anchored past support.                                                                                                              |           |                         |       |                    |                              |             |
| Right supp. top                                                                                                                                                                     | - layer 1 | -99.2                   | 373   | 612                | 1257                         | 4 H 20      |
| NOTE: 100% of reinforcement assumed to be fully anchored past support.                                                                                                              |           |                         |       |                    |                              |             |
| <b><u>Shear Reinforcement</u></b>                                                                                                                                                   |           |                         |       |                    |                              |             |
| Zone                                                                                                                                                                                |           | V                       | v     | v <sub>c</sub>     | Shear reinforcement details  |             |
| Left support                                                                                                                                                                        |           | 155.6                   | 0.875 | 0.6                | 4 legs of H 8 links at 295 c |             |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 1257 mm <sup>2</sup> ) |           |                         |       |                    |                              |             |
| Right support                                                                                                                                                                       |           | -135.1                  | 0.76  | 0.6                | 4 legs of H 8 links at 295 c |             |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 1257 mm <sup>2</sup> ) |           |                         |       |                    |                              |             |
| <b><u>Span to Effective depth ratio</u></b>                                                                                                                                         |           |                         |       |                    |                              |             |
| Allowable ratio                                                                                                                                                                     |           | = 50.18                 |       |                    | Actual ratio                 | = 13.92     |
|                                                                                                                                                                                     |           |                         |       | Section OK         |                              |             |

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## **Rectangular beam section- G Beam C3-D3**

*Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'*

|                                                                                                |                                  |
|------------------------------------------------------------------------------------------------|----------------------------------|
| Beam span                                                                                      | = 3.3 m                          |
| Depth of beam                                                                                  | = 450 mm                         |
| Breadth of beam                                                                                | = 450 mm                         |
| Span type                                                                                      | - Continuous                     |
| Maximum no. of layers of tension reinforcement                                                 | = 1                              |
| Number of bars per layer                                                                       | = 4                              |
| Nominal concrete cover to bottom reinforcement                                                 | = 35 mm                          |
| Nominal concrete cover to top reinforcement                                                    | = 35 mm                          |
| Nominal concrete side cover to reinforcement                                                   | = 35 mm                          |
| Tolerance between minimum and nominal cover                                                    | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete                                                         | - C25/30                         |
| Characteristic concrete strength                                                               | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                         | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                           | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                   | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                                  | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                              | - type 2 deformed bars           |
| Characteristic strength of links                                                               | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                       | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                            | = 4                              |
| Preferred link diameter                                                                        | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                                  | = 47.5 kNm                       |
| Maximum redistributed ultimate hogging moment<br>(this moment occurs at the left hand support) | = -99.2 kNm                      |
| Redistributed ultimate positive shear at LH support                                            | = 114.2 kN                       |
| Redistributed ultimate negative shear at RH support                                            | = -69.6 kN                       |

## **Envelopes from Multi Span :**

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description | Type | A | B   | C | Gk   | Qk   |
|------------------|------|---|-----|---|------|------|
| Wall/Floor       | UDL  | 0 | 3.3 |   | 25.0 | 10.0 |

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|     | UpLt | Elastic Support Moments |      |      | Support Reactions |      |
|-----|------|-------------------------|------|------|-------------------|------|
|     |      | DnLt                    | UpRt | DnRt | Lt                | Rt   |
| Max |      |                         |      |      | 249.3             | 69.6 |
| Min |      |                         |      |      | 117.1             | 11.2 |

## Main Reinforcement

| Zone             |           | M     | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details |
|------------------|-----------|-------|-----|--------------------|--------------------|-------------|
| Span bottom      | - layer 1 | 47.5  | 385 | 284                | 1257               | 4 H 20      |
| Left supp. top - | layer 1   | -99.2 | 373 | 612                | 1257               | 4 H 20      |

NOTE: 100% of reinforcement assumed to be fully anchored past support.

## Shear Reinforcement

| Zone                                                                                                                                                                                | V     | v     | v <sub>c</sub> | Shear reinforcement details    |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|----------------|--------------------------------|
| Left support                                                                                                                                                                        | 114.2 | 0.642 | 0.6            | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 1257 mm <sup>2</sup> ) |       |       |                |                                |
| Right support                                                                                                                                                                       | -69.6 | 0.392 | 0.476          | 4 legs of H 8 links at 295 c/c |
| The support moment is zero, the shear design is based on the provision of 50% of the area of span bottom reinforcement, fully anchored at the support ( 629 mm <sup>2</sup> )       |       |       |                |                                |

## Span to Effective depth ratio

|                 |      |              |        |
|-----------------|------|--------------|--------|
| Allowable ratio | = 52 | Actual ratio | = 8.35 |
|                 |      | Section OK   |        |

**Provide min 450 x450 RC Ground Beam with 4 H20 bars top and bottom and double H8 links at max 250 ctrs for ground Beam A3- D3**

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## Reinforced Ground Beam D1- D3

### Rectangular beam section- G Beam D1- D2

Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'

|                                                |                    |
|------------------------------------------------|--------------------|
| Beam span                                      | = 4.8 m            |
| Depth of beam                                  | = 450 mm           |
| Breadth of beam                                | = 450 mm           |
| Span type                                      | - Continuous       |
| Maximum no. of layers of tension reinforcement | = 1                |
| Number of bars per layer                       | = 4                |
| Nominal concrete cover to bottom reinforcement | = 35 mm            |
| Nominal concrete cover to top reinforcement    | = 35 mm            |
| Nominal concrete side cover to reinforcement   | = 35 mm            |
| Tolerance between minimum and nominal cover    | $\Delta_c$ = 10 mm |

|                                                                                                 |                                  |
|-------------------------------------------------------------------------------------------------|----------------------------------|
| Compressive strength class of concrete                                                          | - C25/30                         |
| Characteristic concrete strength                                                                | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                          | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                            | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                    | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                                   | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                               | - type 2 deformed bars           |
| Characteristic strength of links                                                                | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                        | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                             | = 4                              |
| Preferred link diameter                                                                         | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                                   | = 71.7 kNm                       |
| Maximum redistributed ultimate hogging moment<br>(this moment occurs at the right hand support) | = -99.5 kNm                      |
| Redistributed ultimate positive shear at LH support                                             | = 74.2 kN                        |
| Redistributed ultimate negative shear at RH support                                             | = -112.9 kN                      |

### Envelopes from Multi Span :

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description    | Type | A | B   | C | Gk   | Qk   |
|---------------------|------|---|-----|---|------|------|
| Wall/ Floor nominal | UDL  | 0 | 4.8 |   | 16.0 | 10.0 |

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|     | UpLt | Elastic Support Moments |      |      | Support Reactions |       |
|-----|------|-------------------------|------|------|-------------------|-------|
|     |      | DnLt                    | UpRt | DnRt | Lt                | Rt    |
| Max |      |                         |      |      | 74.2              | 225.8 |
| Min |      |                         |      |      | 20.4              | 96.0  |

## Main Reinforcement

| Zone            |           | M     | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details |
|-----------------|-----------|-------|-----|--------------------|--------------------|-------------|
| Span bottom     | - layer 1 | 71.7  | 382 | 432                | 804                | 4 H 16      |
| Right supp. top | - layer 1 | -99.5 | 375 | 610                | 804                | 4 H 16      |

NOTE: 100% of reinforcement assumed to be fully anchored past support.

## Shear Reinforcement

| Zone                                                                                                                                                                               | V      | v     | v <sub>c</sub> | Shear reinforcement details    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-------|----------------|--------------------------------|
| Left support                                                                                                                                                                       | 74.2   | 0.415 | 0.409          | 4 legs of H 8 links at 295 c/c |
| The support moment is zero, the shear design is based on the provision of 50% of the area of span bottom reinforcement, fully anchored at the support ( 402 mm <sup>2</sup> )      |        |       |                |                                |
| Right support                                                                                                                                                                      | -112.9 | 0.632 | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |        |       |                |                                |

## Span to Effective depth ratio

|                 |         |              |         |
|-----------------|---------|--------------|---------|
| Allowable ratio | = 47.06 | Actual ratio | = 12.09 |
|                 |         | Section OK   |         |

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## **Rectangular beam section- G Beam D2- D3**

*Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'*

|                                                                                                |                                  |
|------------------------------------------------------------------------------------------------|----------------------------------|
| Beam span                                                                                      | = 4.8 m                          |
| Depth of beam                                                                                  | = 450 mm                         |
| Breadth of beam                                                                                | = 450 mm                         |
| Span type                                                                                      | - Continuous                     |
| Maximum no. of layers of tension reinforcement                                                 | = 1                              |
| Number of bars per layer                                                                       | = 4                              |
| Nominal concrete cover to bottom reinforcement                                                 | = 35 mm                          |
| Nominal concrete cover to top reinforcement                                                    | = 35 mm                          |
| Nominal concrete side cover to reinforcement                                                   | = 35 mm                          |
| Tolerance between minimum and nominal cover                                                    | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete                                                         | - C25/30                         |
| Characteristic concrete strength                                                               | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure                                                         | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear                                                           | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars                                                   | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement                                                  | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                                                              | - type 2 deformed bars           |
| Characteristic strength of links                                                               | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                                                                       | $\gamma_{msv}$ = 1.15            |
| Number of link legs                                                                            | = 4                              |
| Preferred link diameter                                                                        | = 8 mm                           |
| Maximum redistributed ultimate sagging moment                                                  | = 71.7 kNm                       |
| Maximum redistributed ultimate hogging moment<br>(this moment occurs at the left hand support) | = -99.5 kNm                      |
| Redistributed ultimate positive shear at LH support                                            | = 112.9 kN                       |
| Redistributed ultimate negative shear at RH support                                            | = -74.2 kN                       |

## **Envelopes from Multi Span :**

Maximum Load : 1.4Gk+1.6Qk

Minimum Load : 1.0Gk+0.0Qk

% Redistribution = 10

Load Patterns :

All spans loaded with maximum load

Alternate spans loaded with maximum / minimum load

Adjacent pairs of spans loaded with maximum load

| Load Description    | Type | A | B   | C | Gk   | Qk   |
|---------------------|------|---|-----|---|------|------|
| Wall/ Floor nominal | UDL  | 0 | 4.8 |   | 16.0 | 10.0 |

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|     | UpLt | Elastic Support Moments |      |      | Support Reactions |      |
|-----|------|-------------------------|------|------|-------------------|------|
|     |      | DnLt                    | UpRt | DnRt | Lt                | Rt   |
| Max |      |                         |      |      | 225.8             | 74.2 |
| Min |      |                         |      |      | 96.0              | 20.4 |

## Main Reinforcement

| Zone             |           | M     | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details |
|------------------|-----------|-------|-----|--------------------|--------------------|-------------|
| Span bottom      | - layer 1 | 71.7  | 382 | 432                | 804                | 4 H 16      |
| Left supp. top - | layer 1   | -99.5 | 375 | 610                | 804                | 4 H 16      |

NOTE: 100% of reinforcement assumed to be fully anchored past support.

## Shear Reinforcement

| Zone                                                                                                                                                                               | V     | v     | v <sub>c</sub> | Shear reinforcement details    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|----------------|--------------------------------|
| Left support                                                                                                                                                                       | 112.9 | 0.632 | 0.516          | 4 legs of H 8 links at 295 c/c |
| The support moment is negative, the shear design is based on the provision of 100% of the area of support top reinforcement, fully anchored at the support ( 804 mm <sup>2</sup> ) |       |       |                |                                |
| Right support                                                                                                                                                                      | -74.2 | 0.415 | 0.409          | 4 legs of H 8 links at 295 c/c |
| The support moment is zero, the shear design is based on the provision of 50% of the area of span bottom reinforcement, fully anchored at the support ( 402 mm <sup>2</sup> )      |       |       |                |                                |

## Span to Effective depth ratio

|                 |         |              |         |
|-----------------|---------|--------------|---------|
| Allowable ratio | = 47.06 | Actual ratio | = 12.09 |
|                 |         | Section OK   |         |

**Provide min 450 x450 RC Ground Beam with 4 H16 bars top and bottom and double H8 links at max 250 ctrs for ground Beam D1-D3**

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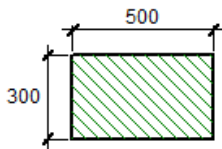
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## Rectangular beam section- Alternative Shallow Ground Beam GB D1/D2- Rev A



Consider shallow Ground Beam to bridge over culvert

Calculations for reinforcement are in accordance with BS8110:1997 and the I Struct E 'Manual for the design of reinforced concrete building structures'

|                                                   |                                  |
|---------------------------------------------------|----------------------------------|
| Beam span                                         | = 4.8 m                          |
| Depth of beam                                     | = 300 mm                         |
| Breadth of beam                                   | = 500 mm                         |
| Span type                                         | - Simple                         |
| Maximum no. of layers of tension reinforcement    | = 1                              |
| Number of bars per layer                          | = 6                              |
| Nominal concrete cover to bottom reinforcement    | = 40 mm                          |
| Nominal concrete cover to top reinforcement       | = 40 mm                          |
| Nominal concrete side cover to reinforcement      | = 40 mm                          |
| Tolerance between minimum and nominal cover       | $\Delta_c$ = 10 mm               |
| Compressive strength class of concrete            | - C25/30                         |
| Characteristic concrete strength                  | $f_{cu}$ = 30 N/mm <sup>2</sup>  |
| Partial factor for concrete in flexure            | $\gamma_{mcf}$ = 1.5             |
| Partial factor for concrete in shear              | $\gamma_{mcs}$ = 1.25            |
| Characteristic strength of longitudinal bars      | $f_y$ = 500 N/mm <sup>2</sup>    |
| Partial factor for longitudinal reinforcement     | $\gamma_{msl}$ = 1.15            |
| Longitudinal bars                                 | - type 2 deformed bars           |
| Characteristic strength of links                  | $f_{yv}$ = 500 N/mm <sup>2</sup> |
| Partial factor for links                          | $\gamma_{msv}$ = 1.15            |
| Number of link legs                               | = 4                              |
| Preferred link diameter                           | = 8 mm                           |
| Maximum ultimate design sagging moment            | = 110.6 kNm                      |
| Ultimate design shear force at left hand support  | = 92.2 kN                        |
| Ultimate design shear force at right hand support | = 92.2 kN                        |

| Load Description | Type | A | B   | C | Gk   | Qk   |
|------------------|------|---|-----|---|------|------|
| Wall             | UDL  | 0 | 4.8 |   | 16.0 | 10.0 |

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## Main Reinforcement

| Zone                  | M     | z   | A <sub>sreqd</sub> | A <sub>sprov</sub> | Bar details        |
|-----------------------|-------|-----|--------------------|--------------------|--------------------|
| Span bottom - layer 1 | 110.6 | 200 | 1272               | 1432               | 2 H 20 plus 4 H 16 |

## Shear Reinforcement

| Zone          | V    | v     | v <sub>c</sub> | Shear reinforcement details                                                                                                                                                                                     |
|---------------|------|-------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Left support  | 92.2 | 0.762 | 0.665          | 4 legs of H 8 links at 180 c/c<br>The support moment is zero, the shear design is based on the provision of 50% of the area of span bottom reinforcement, fully anchored at the support ( 716 mm <sup>2</sup> ) |
| Right support | 92.2 | 0.762 | 0.665          | 4 legs of H 8 links at 180 c/c<br>The support moment is zero, the shear design is based on the provision of 50% of the area of span bottom reinforcement, fully anchored at the support ( 716 mm <sup>2</sup> ) |

## Span to Effective depth ratio

|                                                         |        |              |         |
|---------------------------------------------------------|--------|--------------|---------|
| Allowable ratio                                         | = 17.4 | Actual ratio | = 19.92 |
| Modify reinforcement manually or modify section details |        |              |         |

**Provide min 500w x 300dp RC Ground Beam with 2H20 and 2H16 top and bottom and double H8 links at max 180 ctrs for ground Beam D1- D2 and A2-A3 to bridge over and provide adequate clearance over existing culvert**