# Calculations Report

Job no.: 000192

# Yoker Building, Clyde Riverfront

# Glasgow

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## Report Revision History

| Author | Description | Date | Rev |
|---|---|---|---|
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## Introduction

The following calculation package has been carried out by Smith and Wallwork on behalf of CCG who are the client for the Yoker Building project in the Clyde Riverfront, Glasgow.

The Yoker Building comprises a 7 storey residential development constructed from cross laminated timber (CLT) from ground floor to roof level. The CLT structure is supported at ground floor by reinforced concrete foundations. Smith and Wallwork is responsible for the design of the CLT superstructure only (including connections). This calculation package covers the design criteria, load take down, stability, foundations loads, disproportional collapse and design of main structural elements and their connections. The concrete foundations are designed others. Also the light weight steel stairs and the connections of the steel down-stand beams to the CLT are contractor design elements.

The CLT forms walls, roof and floor structure as well as the lift enclosures. This panelised form of construction and the massive nature of the CLT product delivers a robust structure.

Design criteria including loads have been taken from the client design team where available and where information is not available or specified Eurocode and/or Building Regulations have been consulted.

This calculation report is to be read in conjunction with the additional reports issued subsequent to the Building Warrant 2:

- *20160226_SaW_YOK_Additional calculation report*
- *20160722_SaW_YOK_GF transfer calculation report*

Revision 3 includes the VE modification of the South Façade where the steel plates 190mm deep were changed for the integral CLT lintel 595mm deep over the openings as detailed in the stability section below.

## Building Description

The building is located in the Clyde Riverfront, Glasgow. The overall dimensions of the building are approximately 31m by 28m in plan. The overall height of the building is 22m above ground floor slab. It has a gross floor area of 3745m$^2$ and a foot print area of 550m$^2$.

The 7 storey building has a T shape in plan formed by two rectangular wings, south and north, linked together at all levels by the lobby where the stairwell and lift are located. The northern wing of 31mx13m contains 4 flats divided in two lots to the west and east by the lobby. The southern wing of 15mx13m is formed by two lots of flats per storey facing the Clyde Riverfront.

The building utilises a light weight cladding minimising the loads on the façade.

## Design Philosophy

The building is designed as a solid timber panel construction, load bearing structure from ground floor to the roof. This panelised form of construction utilises cross laminated timber (CLT) to create a rigid box like structure. The simple form of the building generally creates direct load paths through the building which the CLT structure transfers safely via a combination of 3D rigid box and shear wall action.

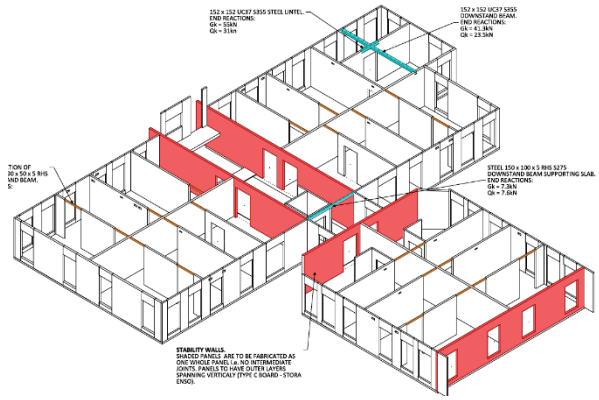
Stability of the CLT structure is provided through CLT walls acting as a vertical cantilevers. This design approach will require as many walls as possible in the building to be load bearing to enhance the 3D rigid box action required. This strategy will also enhance the robustness of the building with respect to disproportionate collapse, creating alternative load paths through the building.

The 3D rigid box strategy will stress the CLT panels both in-plane and perpendicular to plane. In this respect minimum 5 layer boards are preferred with lamella area in both directions to be a similar as possible. Furthermore, some wall panels with openings in the key areas will be specified as Type C Board panels (Stora Enso name for long panel made in one piece with the main layers spanning in the short direction) minimising the number of panel to panel connections and enabling shear walls to act as one homogeneous element. In particular the wall panels separating the flats between each other and each flat to the lobby will play a key role in providing the 3D rigid box behaviour required, as such service penetrations in this area should be kept to a minimum. The use of large format Type C Board panels will also speed the erection of the CLT structure.

The interface between CLT structure and RC foundations at ground floor will be solved with angle brackets tying the CLT down to the foundations to transfer the shear and tension loads caused by the wind actions.

The central stair and lift core is constant through the height of the building and no transfers are required. Although none of the CLT is planned to be left exposed, the corridor wall immediately on the perimeter of the central lobby and the floor slab are designed to withstand 60min of fire on one face.

There are four disable flats located in the first four floors of the north east part of the building. Then the floor slab between the third and fourth floor will contain a transfer structure to distribute the loads from the top three floors down.



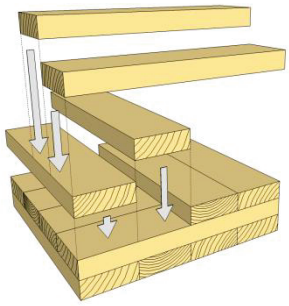
*Typical floor isometric view showing CLT panel structure with Type C board panels in red*

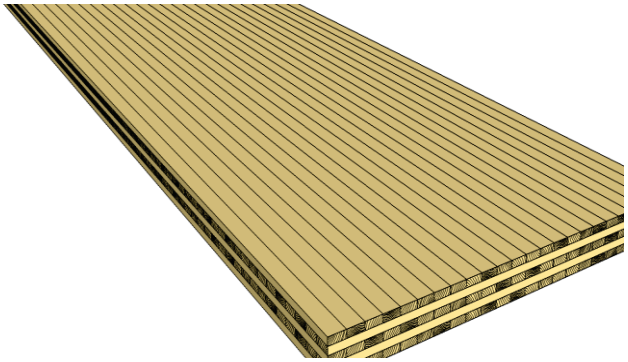
## CLT Description

The primary structural material for the project is cross laminated timber. This panelised form of construction was originally developed in Austria and Germany and over the last decade a significant number of buildings constructed of CLT have been delivered. There are a number of UK examples of school buildings up to 10,000m$^2$ in area that have been completed in CLT.

Cross laminated timber is manufactured using Spruce planks that are glued together in a series of layers with alternating transverse and longitudinal orientation. The resulting solid timber panels can be manufactured in thicknesses ranging from 60mm to 300mm and panel sizes are up to 2.95m by 16.50m.

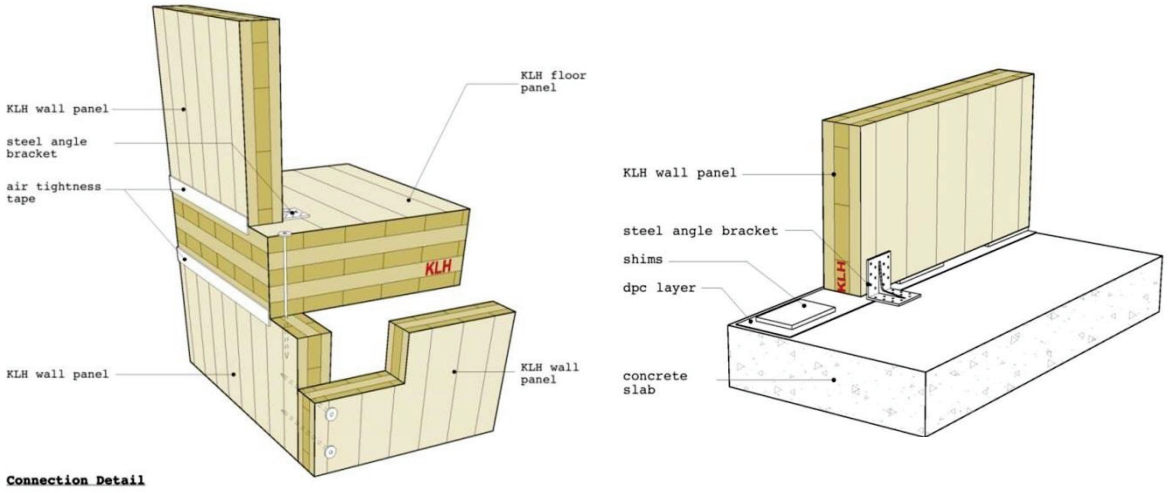
Panels can be used as wall, floor, roof and beam elements that are fixed together using screws using platform construction methods.





*Cross Laminated Timber*

Platform construction is used to describe the method of 'stacked' construction used in most modern multi-storey timber structures. Floor panels sit on top of wall panels and subsequent walls are then placed on top of the floor panels.




*Platform construction illustration*

## Design Criteria

Design Life: *50 years, design working life category 4 to BS EN 1990*

Service Class: *CLT: Class 1, internal heated to BS EN 1995*

Deflection Limits: *Total net final deflection:*

*Floors or roofs with plaster ceilings: span/250, to BS EN 1995*
*Floors or roofs without plaster ceilings: span/150, to BS EN 1995*

*Horizontal deflection under lateral load (wind): h/500, to BS EN 1995*

Vibration: *Typically greater than or equal to 8Hz for CLT floors*
*(where less then additional calculation is carried out)*

Fire Resistance: *All CLT is fire boarded (1hr) apart from described below*
*CLT floors of close typically designed for soffit 60min exposure to fire*
*CLT walls of close typically designed for 1 side 60min exposure to fire*

Materials: *Stora Enso cross laminated timber panels to ETA-14/0349 (C24 timber)*
*Structural steel grades S275JR and S355JR*

Disproportionate Collapse: *In accordance with the Scottish Technical Handbooks 2013 Domestic – Structure*
*Risk group 2B*

Self-weight Loads: *In accordance with BS EN 1991-1-1*
*Refer to 'Characteristic Loads' section of these calculations*

Variable Loads: *In accordance with NA to BS EN 1991-1-1*

| | | |
|---|---|---|
| *A2 residential units* | $q_k = 1.5kN/m^2$ | $Q_k = 2.0kN$ |
| *A6 common areas and balconies* | $q_k = 3.0kN/m^2$ | $Q_k = 2.0kN$ |
| *Non-accessible roof areas* | $q_k = 0.6kN/m^2$ | $Q_k = 0.9kN$ |

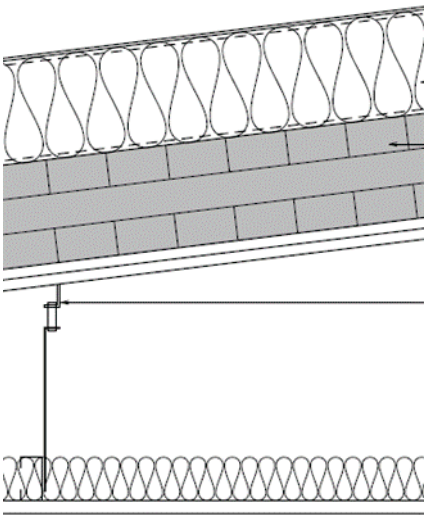
Load Reduction: *In accordance with NA to BS EN 1991-1-1*
$\alpha_n = 0.60$

Snow Loads: *In accordance with NA to BS EN 1991-1-3*
$s_k = 0.26\ kN/m^2$

Wind Loads: *In accordance with NA to BS EN 1991-1-4*
$v_{b,map} = 25.2\ m/s$
$q_b = 0.396\ kN/m^2$ *(reference mean velocity pressure)*

## Characteristic Loads

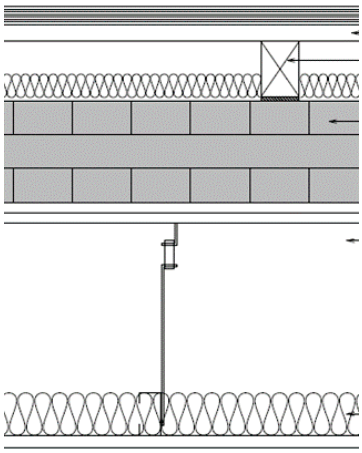
Roof



| | | |
|---|---|---|
| Variable Load | 0.60 | kN/m2 |
| Self-weight: | | |
| alumasc derbigum roofing membrane | 0.05 | kN/m2 |
| alumasc derbigum underlay | 0.05 | kN/m2 |
| Vapour barrier | 0.05 | kN/m2 |
| 170mm Rigid insulation board | 0.05 | kN/m2 |
| CLT slab (100mm) | 0.50 | kN/m2 |
| 25mm Fireline board | 0.21 | kN/m2 |
| service zone | 0.10 | kN/m2 |
| 50mm Mineral wool | 0.05 | kN/m2 |
| 12.5mm wallboard | 0.11 | kN/m2 |
| Self-weight total: | 1.17 | kN/m2 |

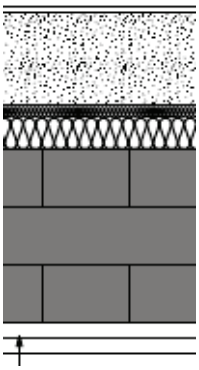
## Floors

### 1st – 6th floors (rooms)



| | | |
|---|---|---|
| Variable Load | 1.5 | kN/m2 |
| Self-weight: | | |
| Floor finishes | 0.1 | kN/m2 |
| 22mm Chipboard flooring | 0.15 | kN/m2 |
| 19mm Gyproc plank | 0.15 | kN/m2 |
| 70x50mm Dynamic battens (500cc) | 0.05 | kN/m2 |
| 25mm Mineral wool | 0.03 | kN/m2 |
| CLT floor panel (120mm) | 0.60 | kN/m2 |
| 2x12.5mm Fireline board | 0.21 | kN/m2 |
| 200mm Service zone | 0.10 | kN/m2 |
| 50mm Mineral wool | 0.05 | kN/m2 |
| 15mm Soundbloc | 0.12 | kN/m2 |
| Self-weight total: | 1.56 | kN/m2 |

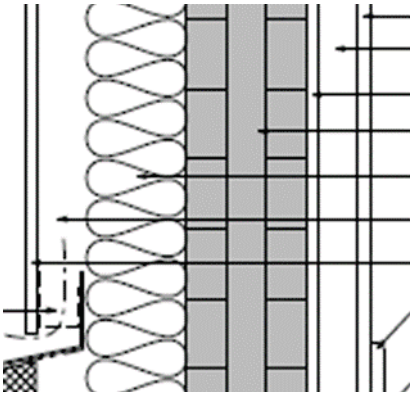
### 1st – 6th floors (core areas)



| | | |
|---|---|---|
| Variable Load | 3.00 | kN/m2 |
| Self-weight: | | |
| 75mm screed | 1.47 | kN/m2 |
| 35mm rigid insulation | 0.10 | kN/m2 |
| CLT (140mm) | 0.70 | kN/m2 |
| 25mm Fireline board | 0.21 | kN/m2 |
| 200mm Service zone | 0.10 | kN/m2 |
| 50mm Mineral wool | 0.05 | kN/m2 |
| 15mm Soundbloc | 0.12 | kN/m2 |
| Self-weight total: | 2.75 | kN/m2 |

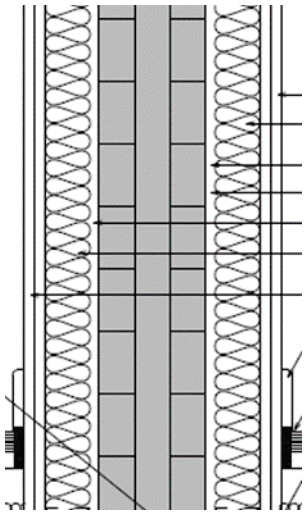
## Walls

**External wall**



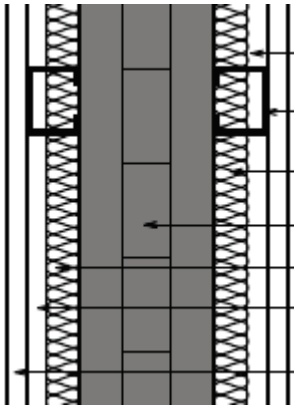
| | | |
|---|---|---|
| Variable Load | n/a | |
| Self-weight: | | |
| Rainscreen cladding | 0.20 | kN/m2 |
| 50mm Vertical SW Battens (500cc) | 0.05 | kN/m2 |
| 80mm Rigid Insulation | 0.03 | kN/m2 |
| CLT (100/120/140 mm) | 0.50/0.6/0.7 | kN/m2 |
| GL1 lining channel | 0.01 | kN/m2 |
| 25mm mineral fibre quilt | 0.10 | kN/m2 |
| 2x12.5mm Fiberboard | 0.20 | kN/m2 |
| Self-weight total: | 1.09/1.19/1.29 | kN/m2 |

**Separating wall**



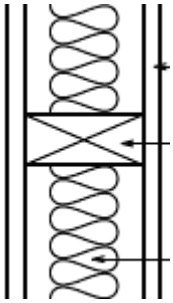
| | | |
|---|---|---|
| Variable Load | n/a | |
| Self-weight: | | |
| 2x12.5mm Soundbloc | 0.21 | kN/m2 |
| 50mm Independent frame with mineral wool insulation | 0.075 | kN/m2 |
| CLT wall panel (120/140 mm) | 0.6/0.7 | kN/m2 |
| 50mm Independent frame with mineral wool insulation | 0.075 | kN/m2 |
| 2x12.5mm Soundbloc | 0.21 | kN/m2 |
| Self-weight total: | 1.17/1.27 | kN/m2 |

Internal loadbearing partition



| | | |
|---|---|---|
| Variable Load | n/a | |
| Self-weight: | | |
| 15mm Fiberboard | 0.10 | kN/m2 |
| 25mm mineral fibre quilt | 0.10 | kN/m2 |
| GL1 lining channel | 0.01 | kN/m2 |
| CLT (100/120 mm) | 0.50/0.60 | kN/m2 |
| GL1 lining channel | 0.01 | kN/m2 |
| 25mm mineral fibre quilt | 0.10 | kN/m2 |
| 15mm Fiberboard | 0.10 | kN/m2 |
| Self-weight total: | 0.93/1.03 | kN/m2 |

**Internal non-loadbearing partition**



| | | |
|---|---|---|
| Variable Load | n/a | |
| Self-weight: | | |
| 12.5mm Gyproc ten | 0.1 | kN/m2 |
| 50mm Mineral Wool insulation | 0.05 | kN/m2 |
| 89x38mm Timber studs | 0.03 | kN/m2 |
| 12.5mm Gyproc ten | 0.1 | kN/m2 |
| Self-weight total: | 0.28 | kN/m2 |

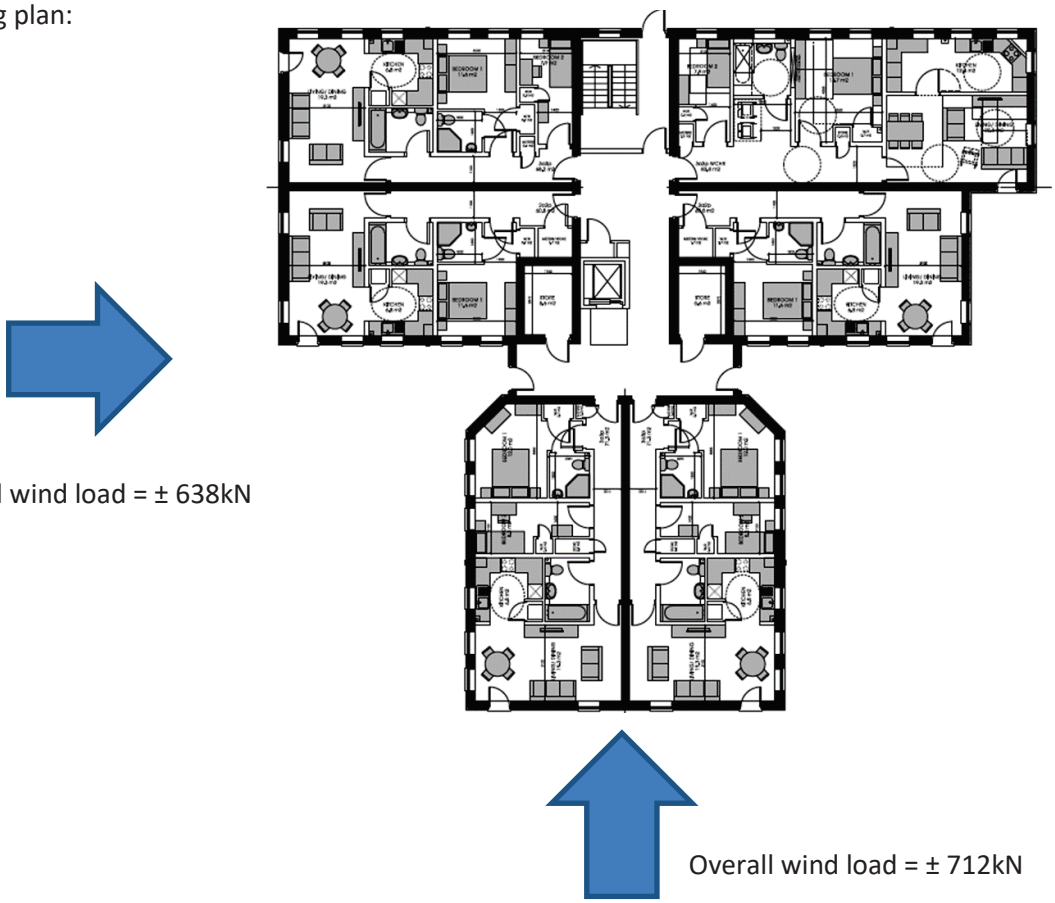
Wind

In order to calculate the wind load on the structure, the building form was converted into a simple box of plan dimensions 31m by 28m and 22m tall. This represents the 7 storey building.

In accordance with NA to BS EN 1991-1-4 the following factors were taken:

- $v_{b,map}$ = 25.2 m/s
- $q_b$ = 0.396 kN/m$^2$

Building plan:



Overall wind load = ± 638kN

Overall wind load = ± 712kN

(Note: loads shown are total applied to building from ground floor to roof)

Below are listed typical values of wind load for both walls and roof elements calculated with Tedds (see Annex A for detailed calculation).

| Walls | Value (kN/m$^2$) |
|---|---|
| Peak wind suction | -1.47 |
| Mean wind suction | -1.05 |
| Peak wind pressure | 1.11 |

| Roof | Value (kN/m$^2$) |
|---|---|
| Peak wind suction | -2.18 |
| Mean wind suction | -0.95 |
| Peak wind pressure | 0.55 |

## Load Take Down

The following load take down serves to estimate the total weight of the building which will be used to calculate the foundation loads transfer to the ground floor rc slab.

| Ground floor | Load | Area | Length | Height | Weight |
|---|---|---|---|---|---|
| External walls | 1.09 kN/m2 | | 123.0 m | 2.84 m | 381.4 kN |
| Separating walls | 1.27 kN/m2 | | 62.5 m | 2.84 m | 225.7 kN |
| Partitions (loadbearing) | 1.03 kN/m2 | | 88.0 m | 2.84 m | 257.3 kN |
| Partitions (non-loadbearing) | 0.28 kN/m2 | | 80.0 m | 2.84 m | 63.3 kN |
| Imposed load (rooms) | 1.50 kN/m2 | 431 m2 | | | 646.5 kN |
| Imposed load (hall) | 3.00 kN/m2 | 74 m2 | | | 222.0 kN |
| | | | | Total DL: | 927.8 kN |
| | | | | Total IL: | 868.5 kN |
| | | | | Total: | 1796.3 kN |

| 1-3 floors | Load | Area | Length | Height | Weight |
|---|---|---|---|---|---|
| Floor flat | 1.56 kN/m2 | 478 m2 | | | 745.7 kN |
| Floor hall | 2.75 kN/m2 | 57 m2 | | | 156.8 kN |
| External walls | 1.09 kN/m2 | | 123.0 m | 2.84 m | 381.4 kN |
| Separating walls | 1.27 kN/m2 | | 62.5 m | 2.84 m | 225.7 kN |
| Partitions (loadbearing) | 1.03 kN/m2 | | 88.0 m | 2.84 m | 257.3 kN |
| Partitions (non-loadbearing) | 0.28 kN/m2 | | 73.0 m | 2.84 m | 57.8 kN |
| Imposed load (rooms) | 1.50 kN/m2 | 478 m2 | | | 717.0 kN |
| Imposed load (hall) | 3.00 kN/m2 | 57 m2 | | | 171.0 kN |
| | | | | Total DL: | 1824.7 kN |
| | | | | Total IL: | 888.0 kN |
| | | | | 1 floor: | 2712.7 kN |
| | | | | Total: | 8138.2 kN |

*Transfer Structure between 3rd and 4th floors*

| 4-6 floors | Load | Area | Length | Height | Weight |
|---|---|---|---|---|---|
| Floor flat | 1.56 kN/m2 | 478 m2 | | | 745.7 kN |
| Floor hall | 2.75 kN/m2 | 57 m2 | | | 156.8 kN |
| External walls | 1.09 kN/m2 | | 123.0 m | 2.84 m | 381.4 kN |
| Separating walls | 1.17 kN/m2 | | 62.5 m | 2.84 m | 208.0 kN |
| Partitions (loadbearing) | 0.93 kN/m2 | | 88.0 m | 2.84 m | 232.2 kN |
| Partitions (non-loadbearing) | 0.28 kN/m2 | | 75.0 m | 2.84 m | 59.3 kN |
| Imposed load (rooms) | 1.50 kN/m2 | 478 m2 | | | 717.0 kN |
| Imposed load (hall) | 3.00 kN/m2 | 57 m2 | | | 171.0 kN |
| | | | | Total DL: | 1783.5 kN |
| | | | | Total IL: | 888.0 kN |
| | | | | 1 floor: | 2671.5 kN |
| | | | | Total: | 8014.5 kN |

| Roof | Load | Area | Length | Height | Weight |
|---|---|---|---|---|---|
| Roof dl | 1.17 kN/m2 | 535 m2 | | | 627.8 kN |
| Roof il | 0.60 kN/m2 | 535 m2 | | | 321.0 kN |
| | | | | Total DL: | 627.8 kN |
| | | | | Total IL: | 321.0 kN |
| | | | | Total: | 948.8 kN |

| Stairs (estimated) | Load | Area | Length | Height | Weight |
|---|---|---|---|---|---|
| Stairs self-weight | 2.50 kN/m2 | 4.20 m2 | | | 10.5 kN |
| Stairs imposed load | 3.00 kN/m2 | 4.20 m2 | | | 12.6 KN |
| | | | | Total DL: | 10.5 kN |
| | | | | Total IL: | 12.6 kN |
| | | | | 1 floor: | 23.1 kN |
| | | | | Total: | 161.7 kN |

| Lift (estimated) | Load | Area | Length | Height | Weight |
|---|---|---|---|---|---|
| Shaft walls (loadbearing) | 0.93 kN/m2 | | 7.0 m | 23.00 m | 149.4 kN |
| Lift (estimated) | | | | | 30.0 kN |
| | | | | Total: | 179.4 kN |

*Live load reduction factor,* $\alpha_n$ = 0.6

| | |
|---|---|
| **Total DL** | **12633 kN** |
| **Total IL** | **3963 kN** |
| **Building weight** | **16597 kN** |