Canadian Concrete Masonry Producers' Association

# Empirical Masonry Design Guidelines

# EMPIRICAL DESIGN FOR MASONRY BUILDINGS

## INTRODUCTION

The Empirical or Conventional Design for Masonry is based on a simplified analysis of the loads and forces acting on the structure. When this approach is utilized, the limitations of height, load location, seismic zone, wind loading, the size of any openings and lateral support requirements must be considered.
Structures resulting from this type of procedure are often described by such phrases as "deemed to perform based on long-term experience".

Engineered Analysis, results in a more cost effective structure in many instances and must be used whenever the limitations are exceeded.

This chapter is a commentary on selected details of Clause 16, Masonry Design for Buildings (Limit States Design) S304.1-94 does not purport to be a total design analysis.

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# Empirical Masonry Design Guidelines

**The Canadian Concrete Masonry Producers' Association gratefully acknowledges the contributions of the following:**

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This "Guide" is intended to facilitate the use of concrete block construction in accordance with CSA-S304.1, Masonry Design for Buildings, (Limit States Design) Clause 16

While all possible care has been taken to ensure that the information contained herein is accurate neither the Canadian Concrete Masonry Producers' Association nor any of the contributors can accept responsibility for any errors or omissions.

APPLICABILITY

The Empirical Rules can be used for non-reinforced Masonry where:

1. Total height of loadbearing walls above the first storey floor does not exceed 11 metres.

2. Total height of exterior non-loadbearing walls above grade does not exceed 20 metres and the 1 in 30 years wind pressure does not exceed 0.5 kN/m$^2$. (Refer to Table 2.5.1.1, Ontario Building Code, for applicable data).

3. Foundation walls are not subject to lateral pressure. The Ontario Building Code (9.15) allows limited usage on basis of "deems to" i.e. proven, performance. (See Figure 3.0)

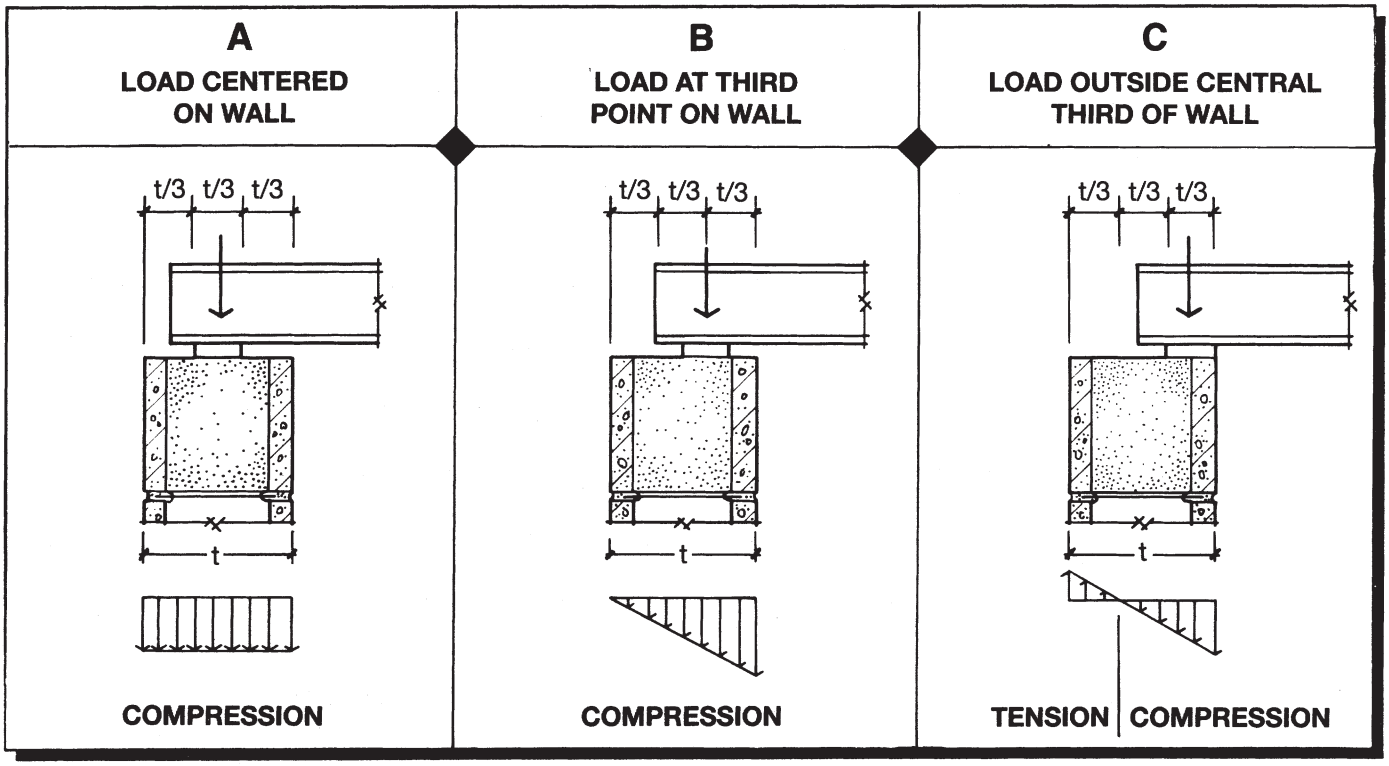
4. The structure is not subjected to lateral pressure other than wind loads.

5. The resultant vertical force of a load falls within the middle third of the wall thickness. (See Figure 1.0)

6. Construction is located within seismic zones 0 and 1. (Refer to Table 2.5.1.1 Ontario Building Code, for applicable data).

7. The Empirical Rules can only be used for plain, non-reinforced masonry. Note that joint reinforcing for bonding or crack control and reinforcing in secondary structural elements such as short span lintels, does not invalidate this design approach.

Figure 1 MIDDLE THIRD RULE




NOTES:
1.0 Conditions `A' and `B' fall within Empirical approach
2.0 Condition `C' requires Engineered Analysis

## ALLOWABLE COMPRESSIVE STRESSES

Maximum allowable compressive stresses on masonry, based on gross cross-sectional area, are given in Table 7 in CAN3-S304.1 Where concentrated loads occur, Clause 16.1.6.2 allows maximum stresses to be increased by 25% (But the total load on the masonry cannot exceed value allowable).

Note that the latest specification for concrete block CAN3-A165.1, designates strengths in terms of net area.

**TABLE A:**
**MAXIMUM ALLOWABLE COMPRESSIVE STRESS FOR NON-REINFORCED CONCRETE MASONRY BASED ON GROSS CROSS-SECTIONAL AREA (MPa)**

| WALL TYPES | MORTAR TYPES | |
|---|---|---|
| | S | N |
| SOLID MASONRY<br>20 MPa & over | 1.6 | 1.4 |
| Solid Unit<br>12.5 - 20 MPa | 1.1 | 1.0 |
| Hollow Unit<br>7.5 MPa | 0.7 | 0.6 |
| CAVITY WALL<br>Solid Unit<br>12.5 MPa | 0.9 | 0.8 |
| Hollow unit<br>7.5 MPa | 0.5 | 0.4 |

NOTES:

1.0 For the purposes of Table `A', the conversion from Net to Gross Area strength of standard units is as follows:

See Tables `B' and `C' for allowable loads on standard strength units. 15 MPa net is the standard strength available from CCMPA Members

See Section 11.

| UNIT TYPE | NET MPa | GROSS MPa |
|---|---|---|
| HOLLOW | 15.0 | 7.5 |
| SOLID | 15.0 | 12.5 |

2.0 Solid Units with a strength of 20 MPa and over are available on a made to order basis.

3.0 Where masonry is constructed of different types or grades of units or mortar, the allowable stress shall be based on the weakest combination.

4.0 Where the wythes of a cavity wall are of different types of material, it is recommended that only one wythe be loaded. Where only one wythe is loaded, the allowable stress shall be based on the loaded wythe.

**TABLE B:**
**ALLOWABLE LOADS FOR SOLID or SINGLE WYTHE MASONRY**
**(Standard Strength Concrete Block) (kN/m)**

| MORTAR TYPE | UNIT TYPE (15 MPa) | ALLOWABLE STRESS MPa | UNIT SIZE 90 | 140 | 190 | 240 | 290 |
|---|---|---|---|---|---|---|---|
| N | Hollow | 0.6 | 54 | 84 | 114 | 144 | 174 |
| | Solid 1 | 1.0 | 90 | 140 | 190 | 240 | 290 |
| S | Hollow | 0.7 | 63 | 98 | 133 | 168 | 203 |
| | Solid 1 | 1.1 | 99 | 154 | 209 | 264 | 319 |

**TABLE C:**
**ALLOWABLE LOADS FOR LOADED CAVITY WYTHE 2**
**(Standard Strength Concrete Block) (kN/m)**

| MORTAR TYPE | UNIT TYPE (15 MPa) | ALLOWABLE STRESS MPa | UNIT SIZE 90 | 140 | 190 | 240 | 290 |
|---|---|---|---|---|---|---|---|
| N | Hollow | 0.4 | 36 | 56 | 76 | 96 | 116 |
| | Solid 1 | 0.8 | 72 | 112 | 152 | 192 | 232 |
| S | Hollow | 0.5 | 45 | 70 | 95 | 120 | 145 |
| | Solid 1 | 0.9 | 81 | 126 | 171 | 216 | 261 |

NOTES:

1.0 Solid Unit means a structural masonry unit with a net cross sectional area of at least 75% of its gross cross sectional area in any plane parallel to its bearing surface.

2.0 Where the exterior wythe is designed as a veneer, the values in Table `B' may be used for the loadbearing wythe.

**TABLE D:**
**ALLOWABLE COMBINED LOADS FOR BOTH WYTHES (kN/m)**
**(Standard Strength Concrete Block)**

| MORTAR TYPE | UNIT TYPE (15 MPa) | ALLOWABLE STRESS MPa | WYTHES WIDTH 90 + 90 | 140 + 140 | 190 + 190 | 240 + 240 | 290 + 290 |
|---|---|---|---|---|---|---|---|
| N | Hollow | 0.4 | 72 | 92 | 112 | 132 | 152 |
| | Solid | 0.8 | 144 | 184 | 224 | 264 | 304 |
| S | Hollow | 0.5 | 90 | 115 | 140 | 165 | 190 |
| | Solid | 0.9 | 162 | 207 | 252 | 297 | 342 |

**TABLE E:**
**ALLOWABLE LOADS FOR HIGH STRENGTH SOLID UNITS**
**(> 20 MPa)1 (kN/m)**

| MORTAR TYPE | ALLOWABLE STRESS MPa | UNIT SIZE 90 | 140 | 190 | 240 | 290 |
|---|---|---|---|---|---|---|
| N | 1.4 | 126 | 196 | 266 | 366 | 406 |
| S | 1.6 | 144 | 224 | 304 | 384 | 464 |

NOTE: 1.0 High strength units are available on a made to order basis only.

**TABLE F:**
**WALL WEIGHT & MASS FOR STANDARD WEIGHT UNITS (2100 kg/m3)**

| MORTAR TYPE | ALLOWABLE STRESS MPa | UNIT SIZE 90 | 140 | 190 | 240 | 290 |
|---|---|---|---|---|---|---|
| WALL MASS ($kg/m^2$) | Hollow | 138 | 170 | 223 | 267 | 310 |
| | 75% Solid | 155 | 235 | 310 | 393 | 475 |
| | Solid | 189 | 294 | 400 | 503 | 609 |
| WALL WEIGHT ($kg/m^2$) | Hollow | 1.35 | 1.67 | 2.19 | 2.62 | 3.04 |
| | 75% Solid | 1.52 | 2.31 | 3.04 | 3.85 | 4.66 |
| | Solid | 1.85 | 2.88 | 3.92 | 4.93 | 5.97 |

NOTE: 1.0 Wall weight = mass x 9.81 ÷ 1000

## Lateral Support

Lateral support must be provided at either horizontal or vertical intervals not exceeding 20 times the actual wall thickness (t) except as follows:

1. For partition walls, lateral support is required at 36t.
2. For cavity walls, the wall thickness shall be based on two thirds (2/3) the sum of both wythes but not less than the thickness of either wythe. This derived effective thickness ($t^e$) applies irrespective of the loading of the wythes.

Note that raked joints reduce the usable thickness and cannot be used where unit width is less than 90mm.

**TABLE G:**
**HEIGHT & THICKNESS OF SOLID MASONRY1**

| TYPE OF WALL | HEIGHT/THICKNESS RATIO $h/t^2$ | | | |
|---|---|---|---|---|
| | MAXIMUM $h/t^2$ | MINIMUM WALL $t^3$ (mm) | MINIMUM WYTHE t (mm) | MAXIMUM TOTAL HEIGHT |
| LOADBEARING (Solid or Hollow Units) | 20 | 190 | 90 | 11 metres |
| EXTERIOR NON-LOADBEARING (Solid or Hollow Units) | 20 | 190 | 75 | 20 metres |
| PARTITIONS4 | 36 | 75 | 75 | 72 x actual thickness |

NOTES:
1.0 Solid masonry means masonry of solid or hollow units that does not have cavities between the wythes, e.g. single wythe masonry is included in this definition.
2.0 Unsupported height or length of wall between horizontal or vertical lateral supports.

3.0 Minimum thickness may be reduced; the 140mm solid masonry unit can be used
a) in loadbearing applications, the maximum height at eave is 2.8m and 4.6m at the gable (See Figure 2.0)
b) in exterior, non-loadbearing applications, with a maximum height of 3m but Type `S' mortar is required
4.0 Denotes partitions in buildings with small exterior openings or with unbalanced air pressures not exceeding 24 kPa.

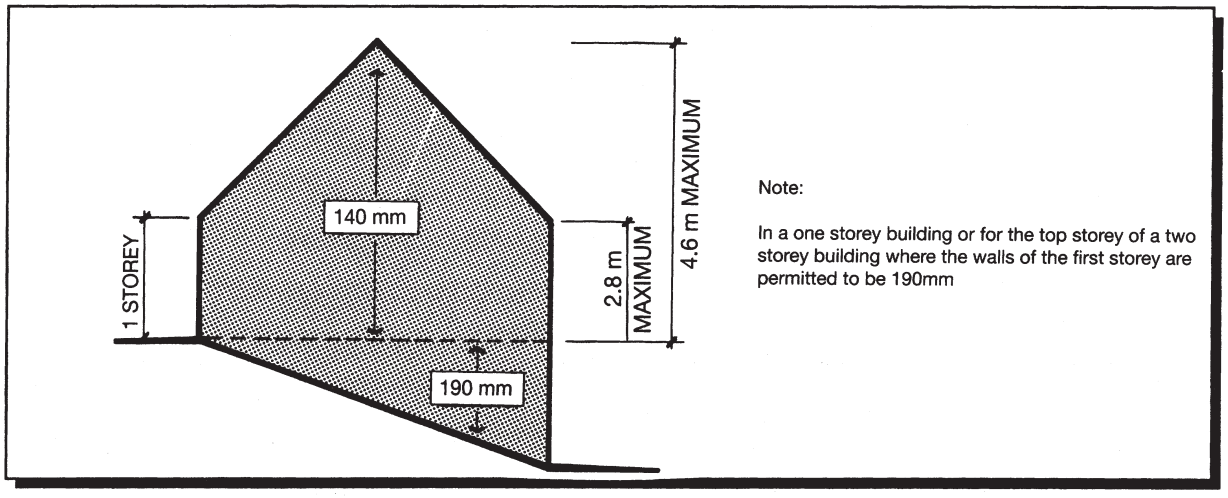


**TABLE H:**
**EFFECTIVE THICKNESS & LATERAL SUPPORT FOR CAVITY WALLS**

| WYTHES WIDTHS [1] | EFFECTIVE THICKNESS [4] ($t^e$) (mm) | LATERAL SUPPORT (m) | MAXIMUM BUILDING HEIGHT [3] (m) |
|---|---|---|---|
| 90 + 90[3] | 120 | 2.40 | 11 |
| 90 + 140 | 153 | 3.06 | 11 |
| 90 + 190 | 190[2] | 3.80 | 11 |
| 90 + 240 | 240[2] | 4.80 | 11 |
| 90 + 290 | 290[2] | 5.80 | 11 |

NOTES:
1.0 Other wythe combinations are possible, e.g. 140 and 140mm will produce at te of 186.6mm and allows lateral support at 3.732m.
2.0 Note use of width of thicker wythe to determine te.
3.0 Where both wythes are solid units, one wythe may be 75mm (CAN3-S304, 6.4.4): lateral support is required at 2.4m but maximum building height is limited to 6m above first storey floor.
4.0 For cavity walls, the effective thickness shall be based on two thirds (2/3) the sum of both wythes but not less than the actual thickness of the greater wythe.

**WALLS NOT SUPPORTED AT THE TOP**
**(CAN3-S304, Clause 6.2.3)**

**PARAPETS**

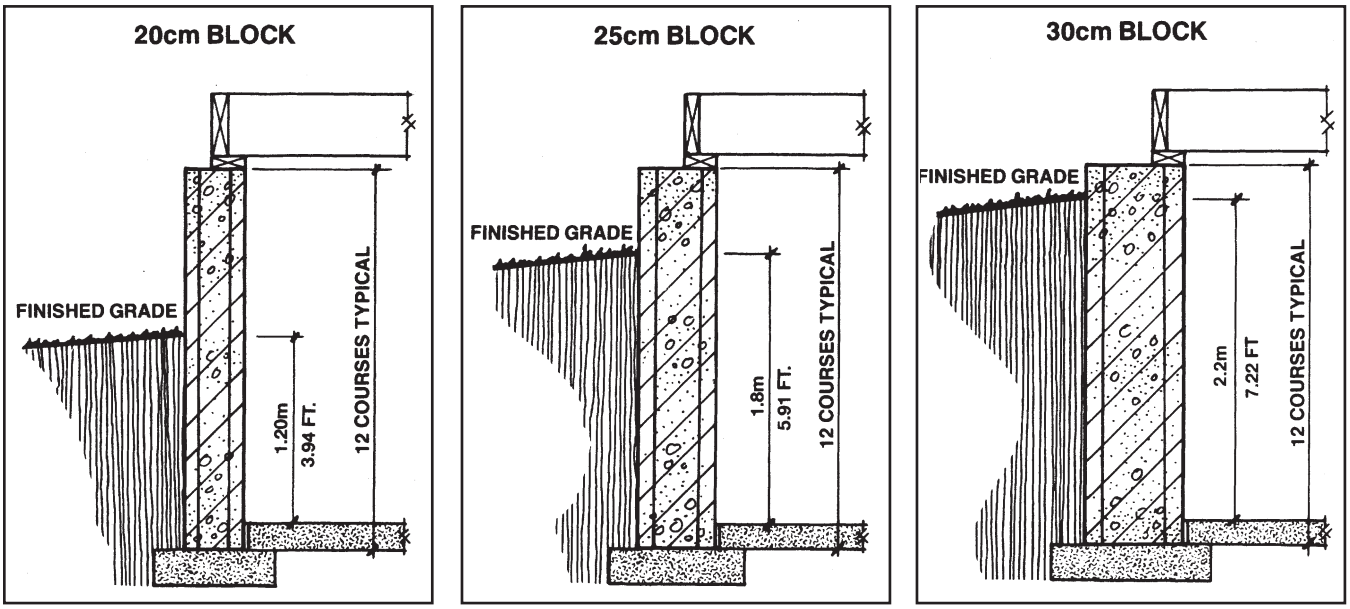
A cantilevered wall cannot exceed a slenderness ratio (h/t) of four, unless horizontal lateral supports are provided in accordance with the requirement of Table 8 in Code. (generally 20t or 20 te for cavity walls)

**WINDOW SILLS**

The unsupported distance from sill to the floor below cannot exceed a slenderness ratio (h/t) of 3 but only where the length exceeds the requirements of Table 8 in Code. (20t or 20$t^e$)

Where lateral support is provided along the top or where the length of wall below the sill is equal or less than permitted, vertical supports are not required.

**FIGURE 3.0 DESIGN FOR LATERAL SOIL PRESSURES**




NOTES:
1.0 Requirements from 9.15, Ontario Building Code
2.0 Below grade depth measured from top of floor slab

3.0 Footing must be below frost line
4.0 Ontario Building Code 9.15.4 gives lateral support requirement**s**

## ALLOWABLE OPENINGS IN EXTERIOR W ALLS

Clause 16.7 (S304.1) provides requirements to avoid over stressing walls between openings for doors, windows and ends of wall due to reduced wall area. These requirements apply to walls laterally supported at top and bottom.

Resistance to wind loads is deemed sufficient where a specified percentage of the wall remains. The minimum length depends on the slenderness ratio (h/t): as the ratio increases (i.e. the wall becomes more slender) the required length of wall remaining increases. Calculation of the required percentage remainingis based on the length between centre points of adjacent openings and between centre point of an opening and the end or return of a wall. (See Figure 4.) Where the length of wall remaining is less than 3t, the wall shall be designed as a column with lateral support at 10t.

FIGURE 4.0 ALLOWABLE OPENINGS

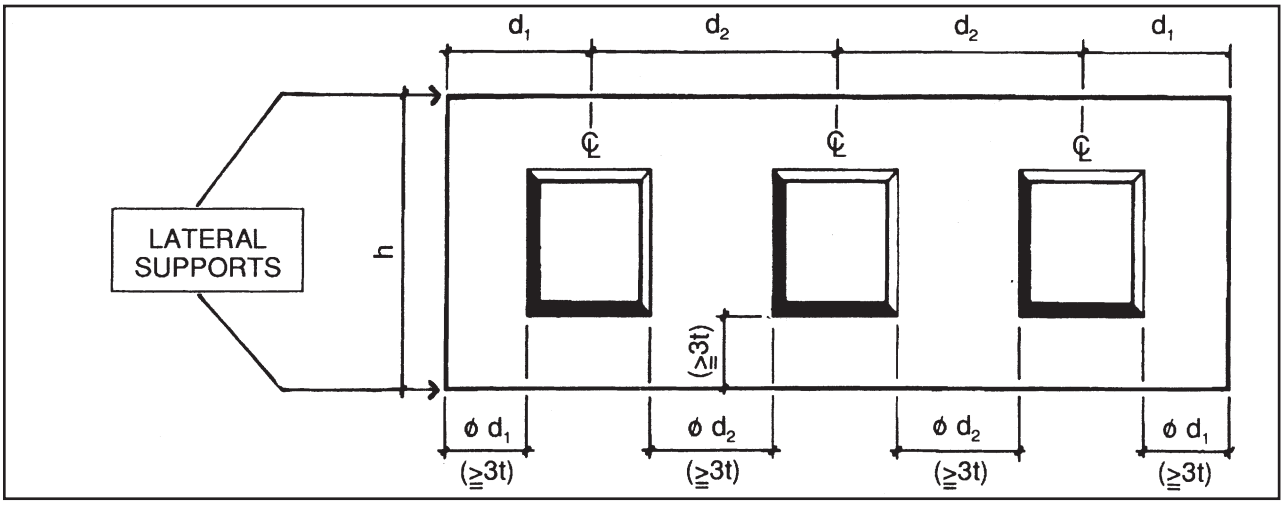
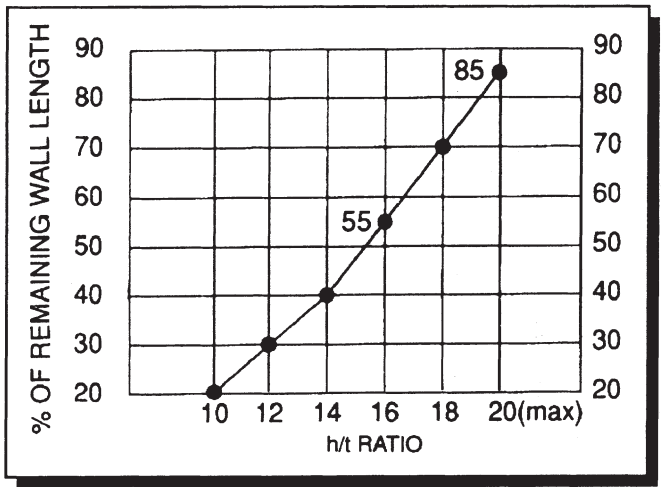
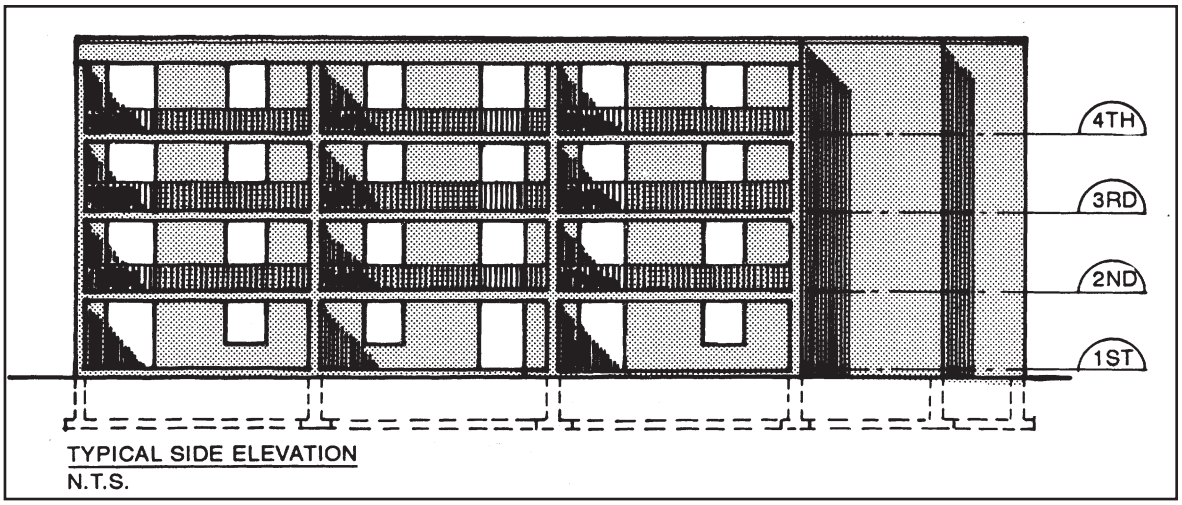


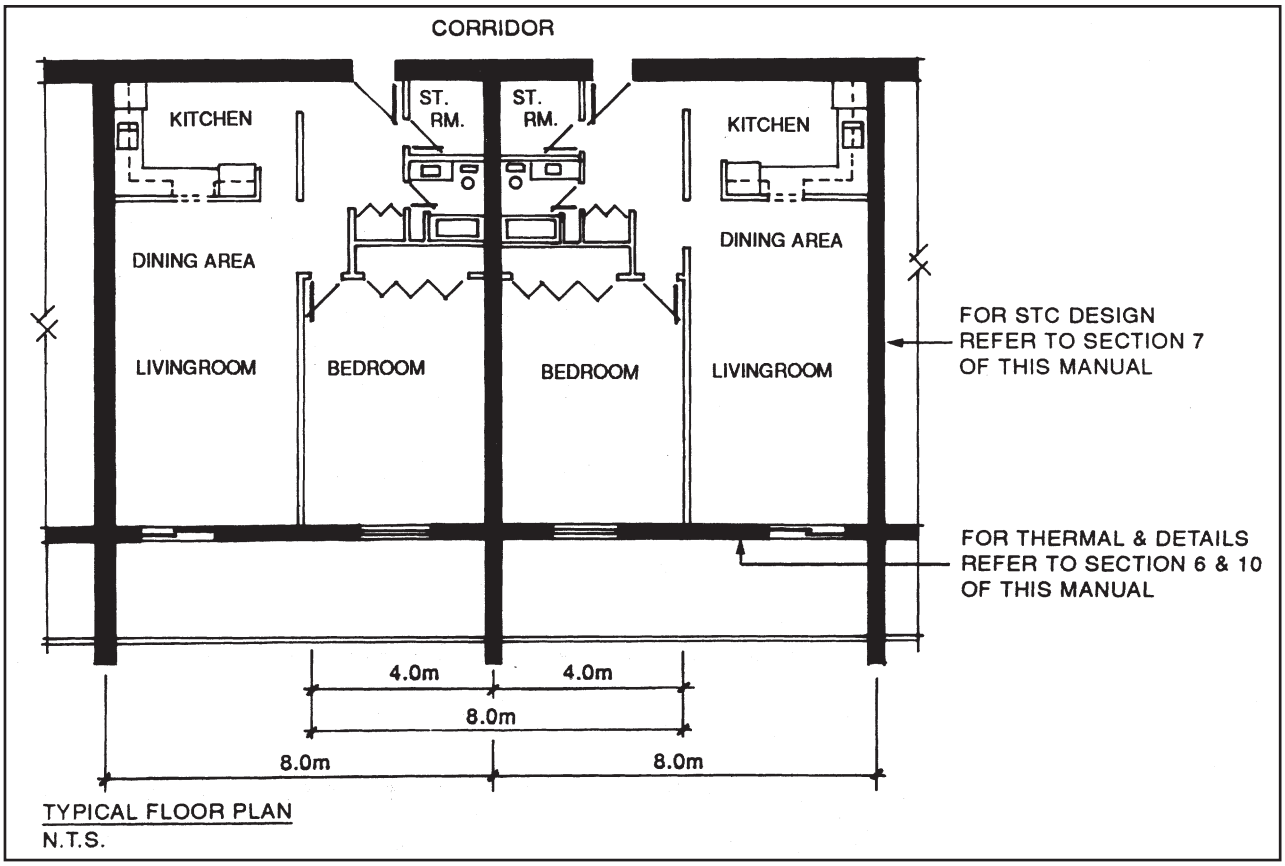

Chart 1 PERCENTAGE OF WALL REQUIRED



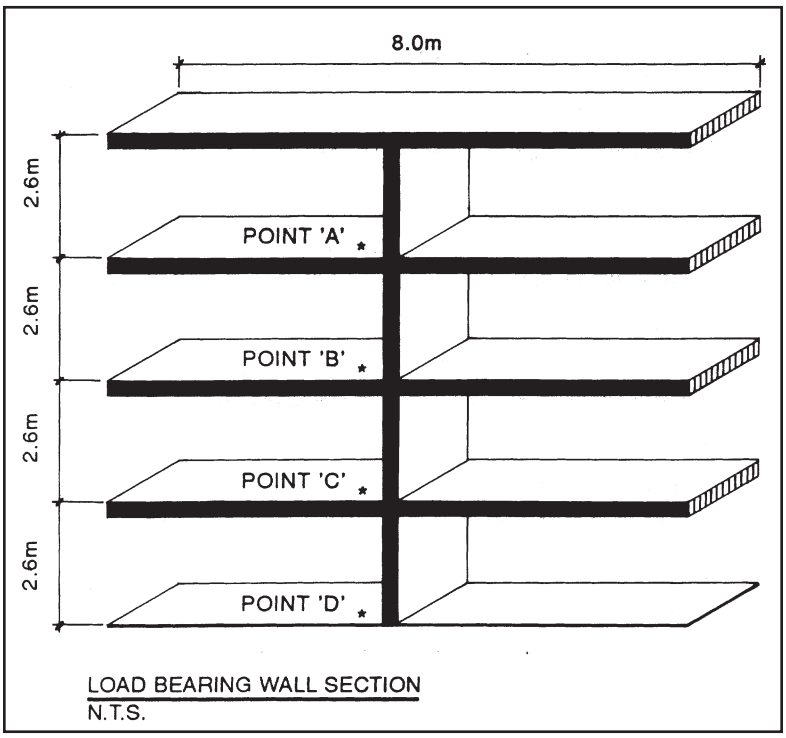

NOTES:
1.0 Chart 1 illustrates values from Table 9 (S304.1).
2.0 Lineal interpolation is permitted e.g. h/t = 13: required wall = 35% of total.
3.0 Allowable openings vary from 80% of total wall (where h/t = 10) to a minimum of 15% (where h/t = 20)

Empirical Design Example
Four Storey Residence



Four Storey Residence




LOAD BEARING WALL SECTION
N.T.S.

**DESIGN LOADS**

- Roof Dead Load -2.60 kN/m$^2$
- Roof Live Loads
  due to snow, ice
  and rain (Sudbury) -1.78 kN/m$^2$
- Floor Dead Load
  Precast Concrete Slab -2.60 kN/m$^2$
- Wall Dead Load
  20cm NW Hollow Block -2.19 kN/m$^2$
  20cm NW 75% Solid Block -3.04 kN/m$^2$
- Occupancy Load -1.90 kN/m$^2$

LOAD @ POINT `A'

$L_A$ = Roof Dead Load + Roof Live Load + Wall Dead Load

= [[8m • (2.60 kN/m$^2$) + (1.78 kN/m$^2$)] + [2.4m x 2.19 kN/m$^2$]]

= [20.8 kN/m + 14.24 kN/m + 5.26 kN/m]

= [35.04 kN/m + 5.26 kN/m]

$L_a$ = 40.3 kN/m

LOAD @ POINT `B'

$L_B$ = Floor Dead Load + Occupancy Load + Wall Dead Load + LA

= [[8.0m • (2.60 kN/m$^2$) + (1.9 kN/m$^2$)] + (2.4m x 2.19kN/m)] + 40.3 kN/m]

= [[20.8 kN/m + 15.2 kN/m + 5.26 kN/m] + 40.3 kN/m]

= [41.26 kN/m + 40.3 kN/m]

$L_b$ = 81.56 kN/m

LOADS @ POINT `C

$L_C$ = Floor Dead Load + Occupancy Load + Wall Dead Load + LB

= [[8.0m • (2.60 kN/m$^2$) + (1.9 kN/m$^2$)] + (2.4m • 2.19 kN/m$^2$)] + 81.56 kN/m]

= [[20.8 kN/m + 15.2 kN/m + 5.26 kN/m] + 81.56 kN/m]

= [41.26 kN/m + 81.56 kN/m]

= 122.82 kN/m

LOADS @ POINT `D'

$L_D$ = Floor Dead Load + Occupancy Load + Wall Dead Load + LC

= [[8.0m • (2.60 kN/m²) + (1.9 kN/m²)] + (2.4m • 3.03 kN/m²)] + 122.82 kN/m]

= [[20.8 kN/m + 15.2 kN/m + 7.272 kN/m] + 122.82 kN/m]

= [50.54 kN/m + 122.82 kN/m]

$L_D$ = 173.36 kN/m

**CONSTRUCTION MATERIAL SELECTIONS**

**1st Floor**

- 20cm 75% solid NW concrete block @ 15 MPa strength with Type `S' mortar

**2nd Floor**

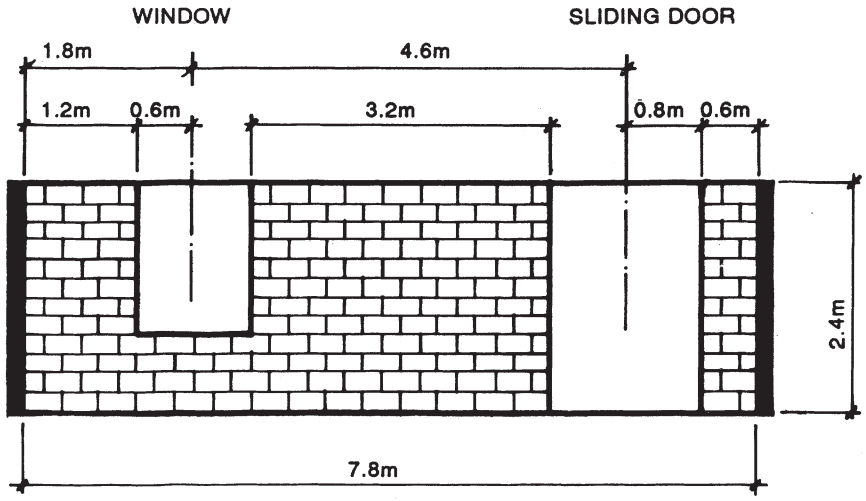
- 20cm Hollow NW concrete block @ 15 MPa strength with Type `S' mortar

**3rd Floor**

- 20cm hollow NW concrete block @ 15 MPa strength with Type `S' mortar

**4th Floor**

- 20cm hollow NW concrete block @ 15 MPa strength with Type `S' mortar




TYPICAL WALL ELEVATION
N.T.S.

**ALLOWABLE OPENINGS**

HEIGHT/THICKNESS RATIO
h/t = 2400/190 = 12.6 say 13%
∴ Area of wall required is 35%
(refer to chart on page 8-10)

DISTANCE TO CHECK

1. Distance from centre of window to end of wall
   ∴ 35% of 1.8m = 0.63m
   Actual Distance = 1.2m
   ∵ Actual Distance 1.2m > 0.62m Minimum Allowable
   ∵ Distance 1.2m OK!

2. Distance between opening centres
   ∴ 35% of 4.6m = 1.61
   Actual Distance = 3.2m
   ∵ Actual Distance 3.2m > 1.61m Minimum Allowable
   ∵ Distance 3.2m OK!

3. Distance from centre of door to end wall
   ∴ 35% of 1.4m = 0.49m
   Actual Distance = 0.60m
   ∵ Actual Distance 0.60m > 0.49m Minimum Allowable
   ∵ Distance 0.60m OK!