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TECHNICAL RECOMMENDATION

NO: 9

DESIGN OF LIGHT TIMBER FRAMED WALLS AND FLOORS FOR FIRE RESISTANCE

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Contents

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RELEVANCE

Walls and floors are required in some buildings to comply with New Zealand building code requirements for fire resistance. Sometimes these can be of light timber framed construction.

Fire resistance of an element of construction is usually established by testing on a full sized prototype of the element. However, due to limitations on size and loading capacity of the testing equipment, and the cost of testing all possible combinations, it is often impractical to test the desired construction.

The methods of extrapolation described here relate to light timber framed wall and floor constructions respectively which are similar to a tested wall or floor prototype.

Some limitations are imposed by the design methods as follows:

- walls or floors must be lined with the same lining materials as the tested prototype
- changes are permitted to the heights of walls and spans of floors
- changes are permitted to the loads imposed on walls
- for floors, the loading may be reduced but not increased

ACCEPTANCE

It is recommended that elements of construction designed in accordance with the extrapolation methods specified in this document be accepted as a means of compliance with New Zealand building code requirements.

SCOPE OF APPLICATION

There are two extrapolation methods described here which apply to the design of light timber framed walls and floors respectively.

Using the results from a floor or wall prototype test, these methods enable designers to produce a wall or floor having at least the same structural fire resistance as the original prototype. These methods cannot be used to increase the fire resistance of tested designs.

These extrapolation methods are not intended to replace any accepted design method or code based on normal service criteria, including wind and earthquake etc. Therefore, designs produced by these methods should still be checked for compliance with other relevant service criteria.

Walls

The extrapolation method for wall design applies to any wall, of timber framed construction, either loadbearing or non-loadbearing, lined on both sides with a protective membrane fixed directly to the framing, which has been tested in prototype in accordance with a standard fire resistance test.

Floors

The extrapolation method for floor design applies to any loadbearing floor system lined on the underside with a protective membrane fixed directly to the timber framing, which has been tested in prototype in accordance with a standard fire resistance test.

General Rules for Testing Prototypes

To obtain maximum use of results from a prototype test, and avoid some of the restrictions discussed later, the following guidelines for selecting prototype parameters should be followed:

- test to the minimum depth of stud or joist that is expected to be required, i.e., the minimum gap between linings.
- test to the minimum width of stud or joist that is expected to be required.
- test to the maximum stud or joist spacing that is expected to be required.
- dwangs to be included at the maximum spacing required in the extrapolated system (see below).
- top plates to be included if required in extrapolated design, and these shall be point-loaded between studs to simulate floor joists.
- framing timber shall be dried to not greater than 16% moisture content.
- floors shall be tested to the maximum stress that is expected to be required in future extrapolations.
- walls shall be loaded so that the prototype fails by structural collapse, otherwise an unnecessarily conservative extrapolation will result.

SPECIFICATION

Definitions

Unless otherwise stated, terms are consistent with those used in NZS 1900 Chapter 5, NZS 3603 and NZS 3604.

EXPOSED SIDE is the face of a test specimen that is exposed to the fire.

FIRE RESISTANCE is the time (minutes) to failure under one of the relevant criteria of the fire resistance test standard as defined in NZS 1900 Chapter 5.

FIRE RESISTANCE RATING (FRR) is a rating (in hours) assigned to a particular element of construction which resists fire. This is usually based on the FIRE RESISTANCE of a prototype construction.

UNEXPOSED SIDE is the face of a fire resistance test specimen not exposed to fire.

General Rules for Extrapolation

These general rules are in addition to the specific rules set out in the Extrapolation Methods section for each particular type of element.

(1) Materials used in Extrapolated Walls and Floors

The materials used for framing, lining and insulating the construction shall be at least equivalent in terms of their response to fire to those used in the tested prototype.

Framing - Timber of the same species to be of the same or greater density.

- Timber to be of the same grade or better.

- Timber of another species to be of higher average density.

Lining - Gypsum plasterboard to be of the same grade, equal or greater thickness, and from the same manufacturing specification.

- Wood-based sheet linings to be of the same formulation, and equal or greater thickness and density.

- Sprayed or mineral fibre protection to be the same product and density, and of equal or greater thickness.

- Other sheet lining materials to be of same composition and density, and equal or greater thickness, and from the same manufacturer.

- Other linings to be the same type, density and equal or greater thickness as used in the test specimen.

Insulation - Insulation included in the wall or floor cavity for acoustic control and/or thermal insulation, is to be from the same manufacturer, of the same type, thickness, density and rating as used in the test specimen. This also means that insulation cannot be added to an extrapolated design, unless it was included in the tested prototype, and vice versa.

(2) Construction of Extrapolated Walls and Floors

Framing - Studs and joists to be at the same or closer spacings than those in the tested prototype.

- Studs and joists not to be smaller in either cross-section dimension than in the tested prototype.

- Dwangs shall be included in both the prototype and extrapolated construction. The spacing between dwangs in the extrapolated wall cannot be greater than that used in the protoype and shall be in accordance with the following table.

Stud, depth/breadth ratio	Maximum dwang spacing (mm)
<2	as for protoype
2	800
3	600

The dwangs are required to provide restraint against lateral deflection of the studs and provide at least an equivalent security of fixing for the exposed lining as in the prototype test.

Lining - Sheet linings shall be fixed in exactly the same manner as in the test specimen, i.e., using nails or screws of the same type, diameter and penetration into framing, and at the same spacing.

- Each individual sheet shall be of the same or greater size than in the test specimen.

- All sheet joints shall be formed over timber framing members, unless other jointing techniques were used in the tested prototype.

- Linings other than sheet linings shall be applied in the same manner as in the tested prototype.

Insulation - Shall be fixed in a similar manner to that used in the tested prototype and located so the air gap between the insulation and lining on either side is not less than for the tested prototype. If the insulation is expected to provide some fire protection to the timber framing, then allowance for the same degree of protection should be made in the extrapolated construction.

Extrapolation Methods

(1) Walls, Loadbearing and Non-loadbearing

The fire resistance determined by test for a loadbearing timber framed wall may be applied to a wall of similar construction, at a different width, height and/or load, subject to the general rules listed above, and using the extrapolation method set out below.

1. Using Table 1.1 or 1.2, depending on whether the tested prototype was 3 m or 4 m in height, determine the "charfactor" for the tested stud size and load (in kN per stud) at structural failure. It is permitted to interpolate between loads to determine the charfactor. In non-loadbearing walls the stud load is considered to be zero; in this case the method only applies to walls less than or **equal to 1 hour fire resistance.**

For a non-loadbearing prototype wall which does not fail structurally, a conservative extrapolation can be avoided if some judgement on the likely charfactor is exercised. The testing laboratory can make an assessment of the charfactor from the recorded test data and an inspection of the specimen at the conclusion of the test, provided it was extinguished in time. If it is not possible to determine a charfactor, e.g., when studs of the prototype test wall have been completely consumed by charring and only the lining remains, this method is then not applicable.

The results of non-loadbearing wall tests can only be extrapolated to other non-loadbearing walls. Sometimes it may be preferable to use a loaded prototype test result for extrapolation to a non-loadbearing wall.

2. From Figures 1.1 to 1.5 select the new wall height.

3. Use the charfactor to determine a new stud size or stud load for the extrapolated wall. Check that neither of the cross-section dimensions of the stud have been reduced in the extrapolation process from the tested prototype stud dimension. If a reduced dimension is indicated a larger stud size shall be chosen to satisfy the general rules under "construction of extrapolated walls and floors" (see above).

4. If the stud size determined is unavailable, it may be substituted for one capable of bearing a greater load. Composite studs can be used, two 100 x 50 mm studs nailed together can be substituted for a single 100 x 100 mm stud, provided the greater cross-section dimension is across the wall cavity.

5. If a loaded wall is supporting a floor above, and the top plate becomes a point loaded beam due to unequal spacing between floor joists and wall studs, a new top plate must be selected by using Figure 2.1 or 2.2. These Figures apply to a stud spacing of 600 mm between centres. For stud spacings of 480 mm and 400 mm, the permitted load per stud may be increased by factors of 1.25 and 1.5 respectively.

6. Check the extrapolated design so that it complies with the relevant design code for the service required, and the maximum permissible stresses are not exceeded.

(2) Floors

The result of a fire resistance test on a loadbearing floor system may be applied to a floor of a similar construction subject to the general rules set out above. Also, the calculated stress induced in critical areas of the extrapolated construction must not be greater than that in the test specimen.

Example 1: Loadbearing wall

A wall has been tested at a 3.0 m height using 100 x 50 mm studs at 600 mm centres with a load per stud of 8 kN. A new wall is required 4.0 m in height with a stud load of 15 kN and 600 mm stud spacing.

1. The charfactor for the tested wall (determined from Table 1.1) at structural failure is 14.

2. The new height required is 4.0 m, so Figure 1.3 is used.

3. For a charfactor of 14 and load per stud of 15 kN, the new stud size is 150 x 50 mm.

4. From Figures 2.1 and 2.2, a new top plate is selected. Either a single 150 x 75 mm top plate or two 150 x 50 mm top plates are required to carry a stud load of 15 kN. The orientation of top plates is with the greater dimension in the same direction as that of the studs.

Example 2: Non-Loadbearing Wall

A non-loadbearing wall has been tested at a 3.0 m height using 100 x 50 mm studs at 600 mm centres. A new non-loadbearing wall is required 5.0 m in height.

1. The charfactor for the tested wall (determined from Table 1.1) at structural failure is 38.

2. The new height required is 5.0 m, so Figure 1.5 is used.

3. For a charfactor of 38 and zero load per stud, the new stud size is 150 x 75 mm.

4. The top plate can be the same cross-section dimensions as the stud.

The above extrapolation could be considered very conservative. Assessment of the charfactor indicates a more likely value of 14, if example 1 was the prototype test. In this instance the extrapolated design derived from Figure 1.5 indicates a new stud size of 150 x 50 mm.

Example 3: Floor

A floor has been tested at a 4 m span using nominal 250 x 50 mm joists at 600 mm centres, with a load of 3 kPa. A new floor is required with a 5 m span and a 3 kPa load. Note that loads may be reduced for fire design in accordance with combinations given in the loadings code.

1. Determine the maximum stress in the joists

Distributed load on the joist, $w = Ps$
where: P = floor load in kPa
s = joist spacing in metres

$$w = 3 \text{ kPa} \times 0.6 \text{ m} = 1.8 \text{ kN/m}$$

Maximum bending moment, $$M = \frac{wl^2}{8}$$

where, l = span of joist in metres

$$M = \frac{1.8 \text{ kN/m} \times (4\text{m})^2}{8} = 3.6 \times 10^3 \text{ Nm}$$

Maximum stress in bending, $f = M/Z$

where section modulus, $Z = \dfrac{bd^2}{6}$

where b = breadth of joist
d = depth of joist

Actual dimensions of joist, "dry green gauged" are 239 x 46 mm

$$Z = \frac{(46 \times 10^{-3})(239 \times 10^{-3})^2}{6}$$
$$= 4.38 \times 10^{-4} m^3$$

Therefore maximum stress $f = \dfrac{3.6 \times 10^3 \, Nm}{4.38 \times 10^{-4} \, m^3}$
$= 8.2 \, MPa$

2. For the extrapolated floor, try reducing joist spacing to 400 mm and determine the joist size required.

Distributed load on joist,
$$w = Ps$$
$$= 3 \, kPa \times 0.4 \, m$$
$$= 1.2 \, kN/m$$

Maximum bending moment
$$M = \frac{wl^2}{8}$$
$$= \frac{1.2 \, kN/m \times (5m)^2}{8}$$
$$= 3.75 \, kN/m$$

Maximum strength $f = M/Z < 8.2 \, MPa$
Therefore: $Z > 3.75 \times 10^3 Nm / 8.2 \times 10^6 \, Pa$
$> 4.6 \times 10^{-4} \, m^3$

The size of joist which satisfies this condition is determined as follows.

$$Z = \frac{bd^2}{6}$$

$$\frac{bd^2}{6} > 4.6 \times 10^{-4} \, m^3$$
$$bd^2 > 2.76 \times 10^{-3} \, m^3$$

If $b = 0.046$ m (nominal 50 mm breadth)

Then $d^2 > 0.06 \, m^2$
$d > 0.2449$ m (245 mm)

The next actual depth of joist available is 288 mm or 300 mm nominal.

So the size of joist required is 300 x 50 mm with actual dimensions of 288 x 46 mm and section modulus Z of 6.35×10^{-4} m^3.

The new floor will have 300 x 50 joists at 400 mm spacings and a span of 5 m with a maximum load of 3 kPa.

BASIS OF RECOMMENDATIONS

This technical recommendation results from a research project which included six fire resistance tests on loaded light timber framed walls (Collier, 1991). Walls were designed specifically to study the structural failure mechanisms over a range of loads, stud size and wall height.

In addition, numerous fire resistance tests have been carried out by BRANZ on light timber framed walls, both loadbearing and non-loadbearing, and on loadbearing timber framed floors.

The extrapolation methods in this Technical Recommendation are based on an engineering evaluation of the results of these tests. Conservative assessment of fire resistance will result in all cases.

RELEVANT DOCUMENTS

NZS 3603:1990. Code of practice for timber design.

NZS 3604:1990. Code of practice for light timber framed buildings not requiring specific design.

NZS 1900 Chapter 5:1988. Fire resisting construction and means of egress.

King, J.J. 1987. Fire resistance testing of loaded timber floors. The New Zealand Journal of Timber Construction, 3(1): pp 9-11.

Collier P.C.R. 1991. Design of light timber framed walls for fire resistance. BRANZ Study Report No. 36. Judgeford.

Table 1.1

Charfactors - Tested Wall Height 3 m

Load (kN)	Stud Size (mm)		
	75 x 50	100 x 50	150 x 50
0	30	38	43
1	21	32	41
2	16	28	39
3	12	25	37
4	10	22	35
5	7	20	34
6	5	18	33
7	3	16	32
8	2	14	30
9	0	13	29
10		12	28
11		10	27
12		9	26
13		8	25
14		7	25
15		6	24
16		5	23
17		4	22
18		3	21
19		3	21
20		2	20
21		1	19
22		1	19
23			18
24			17
25			17
26			16
27			16
28			15
29			15
30			14

Table 1.2

Charfactors - Tested Wall Height 4 m.

Load (kN)	Stud Size (mm)		
	75 x 50	100 x 50	150 x 50
0	24	33	41
1	15	27	38
2	10	22	36
3	6	18	34
4	2	16	32
5		13	30
6		11	29
7		9	27
8		7	26
9		5	25
10		4	23
11		2	22
12		1	21
13			20
14			19
15			18
16			17
17			16

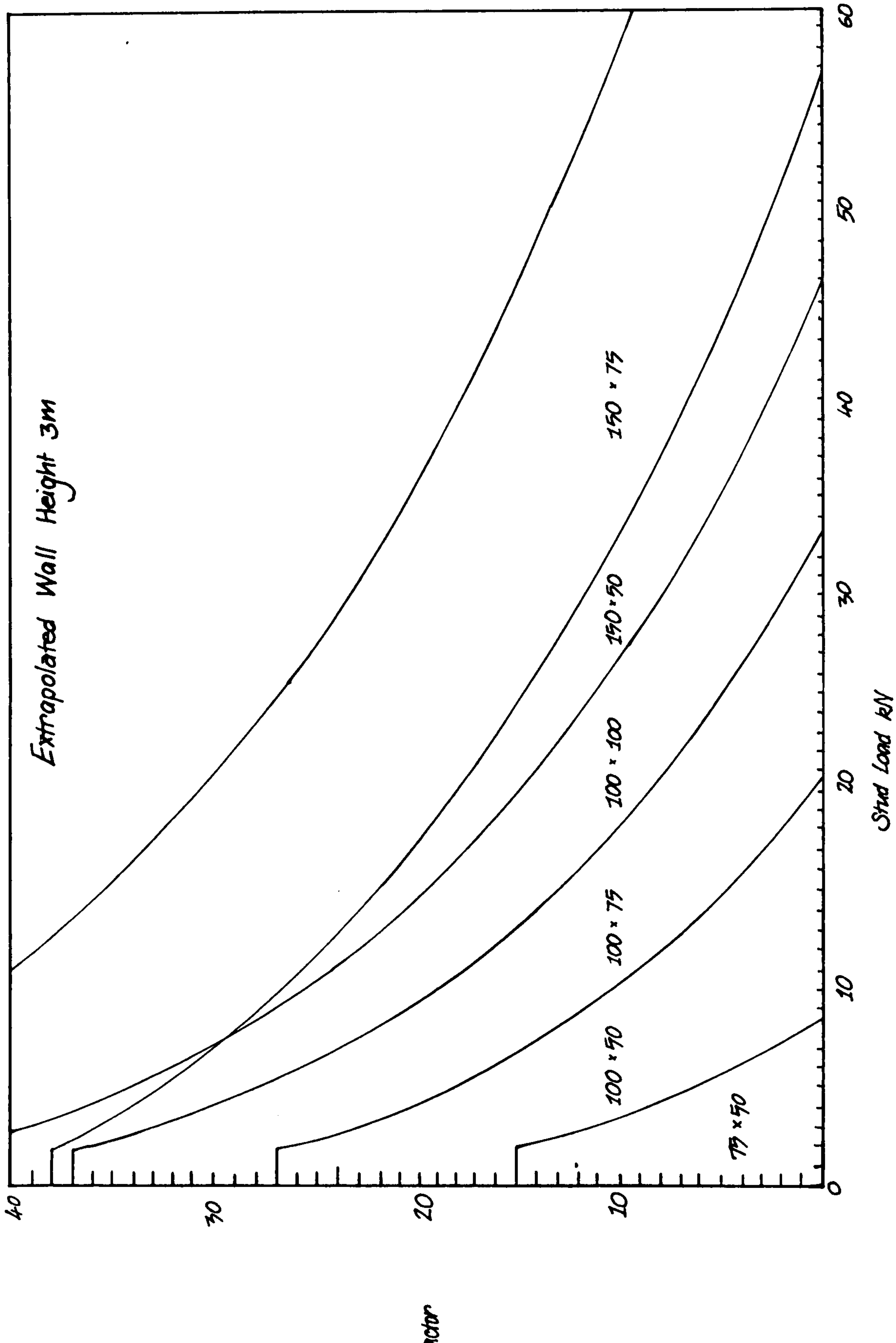

Extrapolated Wall Height 3m
150 × 75
150 × 50
100 × 100
100 × 75
100 × 50
75 × 50
Charfactor
Stud Load kN
0
10
20
30
40
50
60
10
20
30
40

Figure 1.1

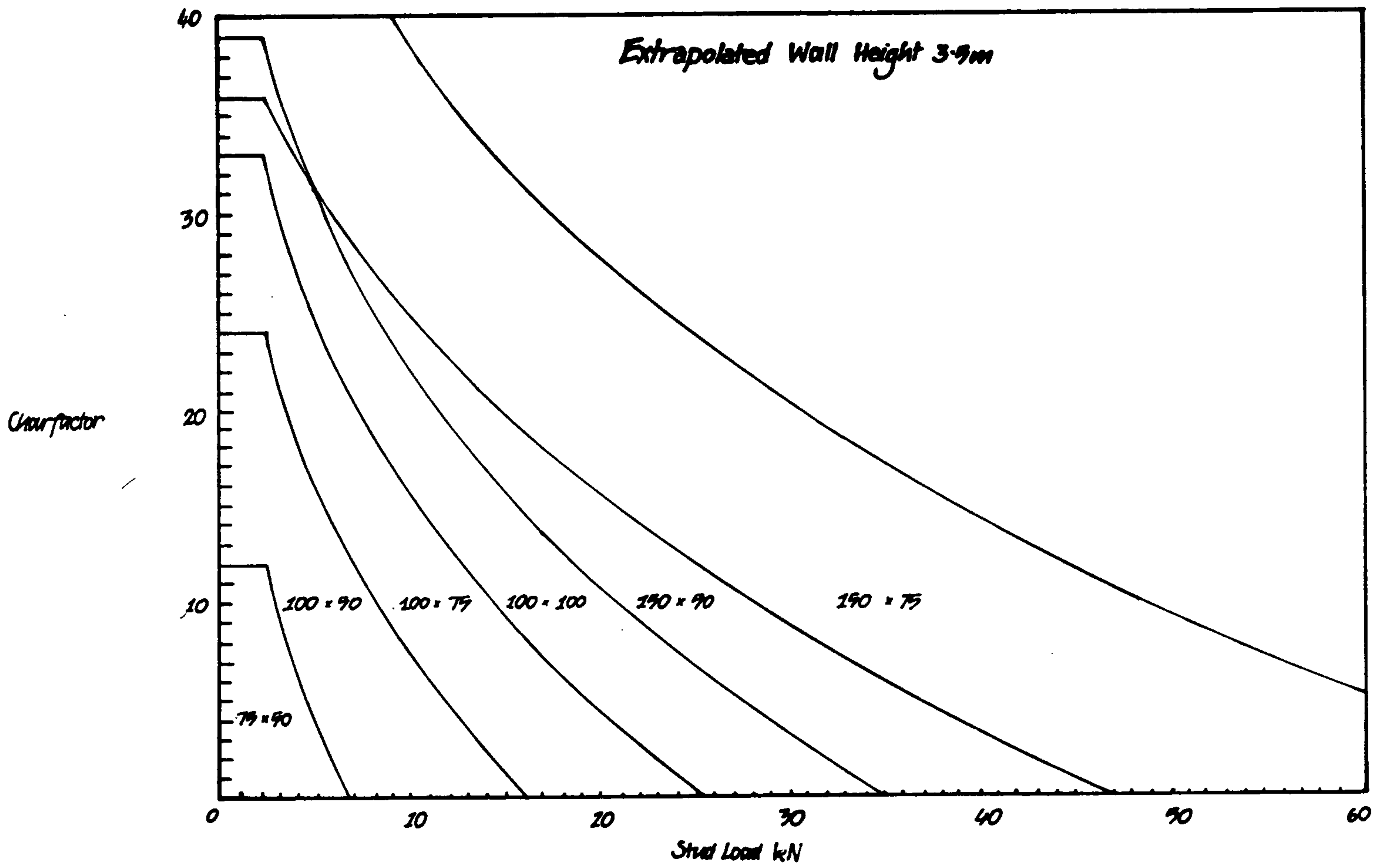
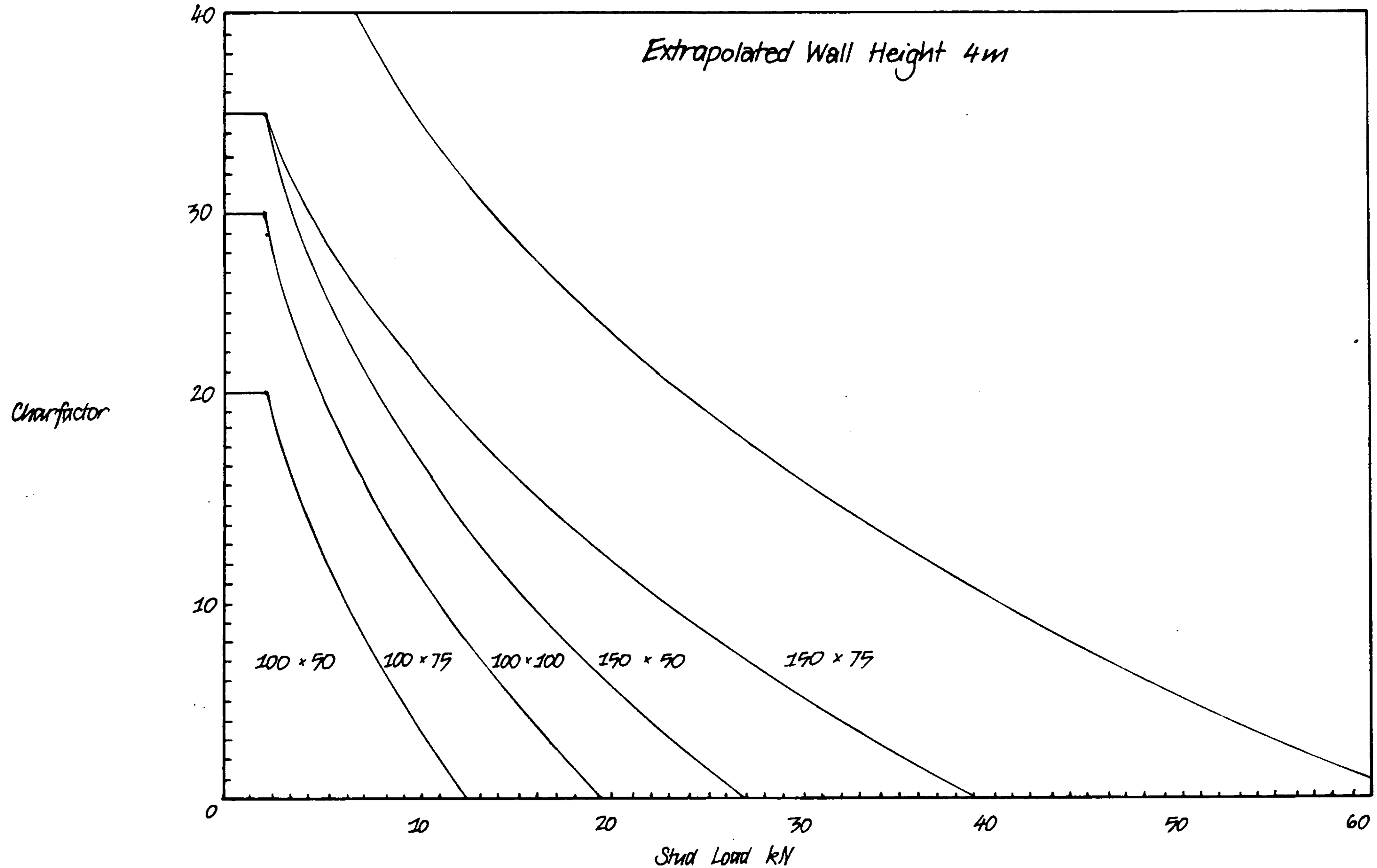

Extrapolated Wall Height 3.5m
Charfactor
Stud Load kN
40
30
20
10
0
10
20
30
40
50
60
75 x 50
100 x 90
100 x 75
100 x 100
150 x 90
150 x 75

Figure 1.2



Extrapolated Wall Height 4m
Charfactor
Stud Load kN
100 × 50
100 × 75
100 × 100
150 × 50
150 × 75
0
10
20
30
40
50
60

Figure 1.3

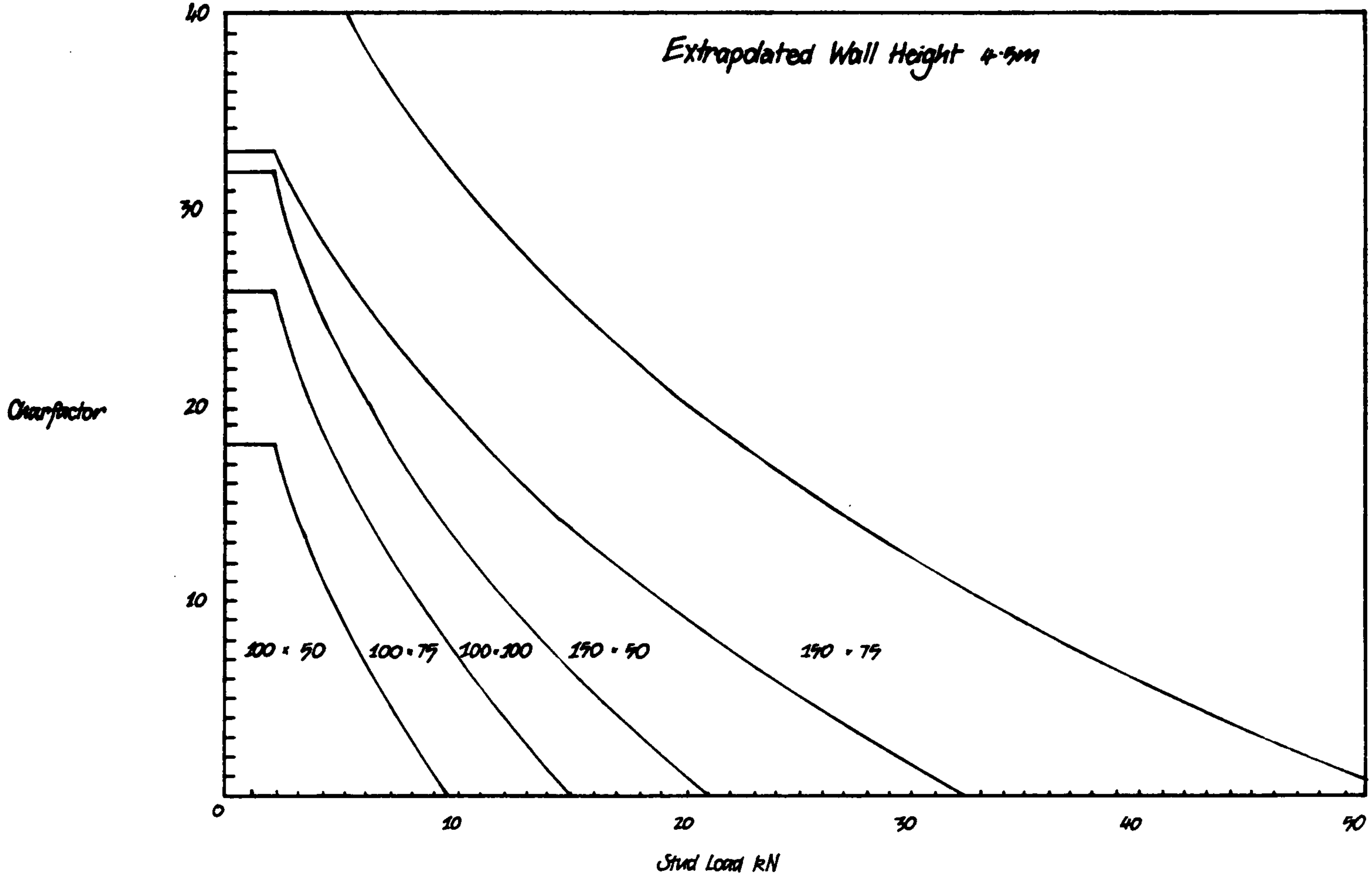

Extrapolated Wall Height 4·5m
Charfactor
40
30
20
10
0
10
20
30
40
50
100 × 50
100 × 75
100 × 100
150 × 50
150 × 75
Stud Load kN

Figure 1.4

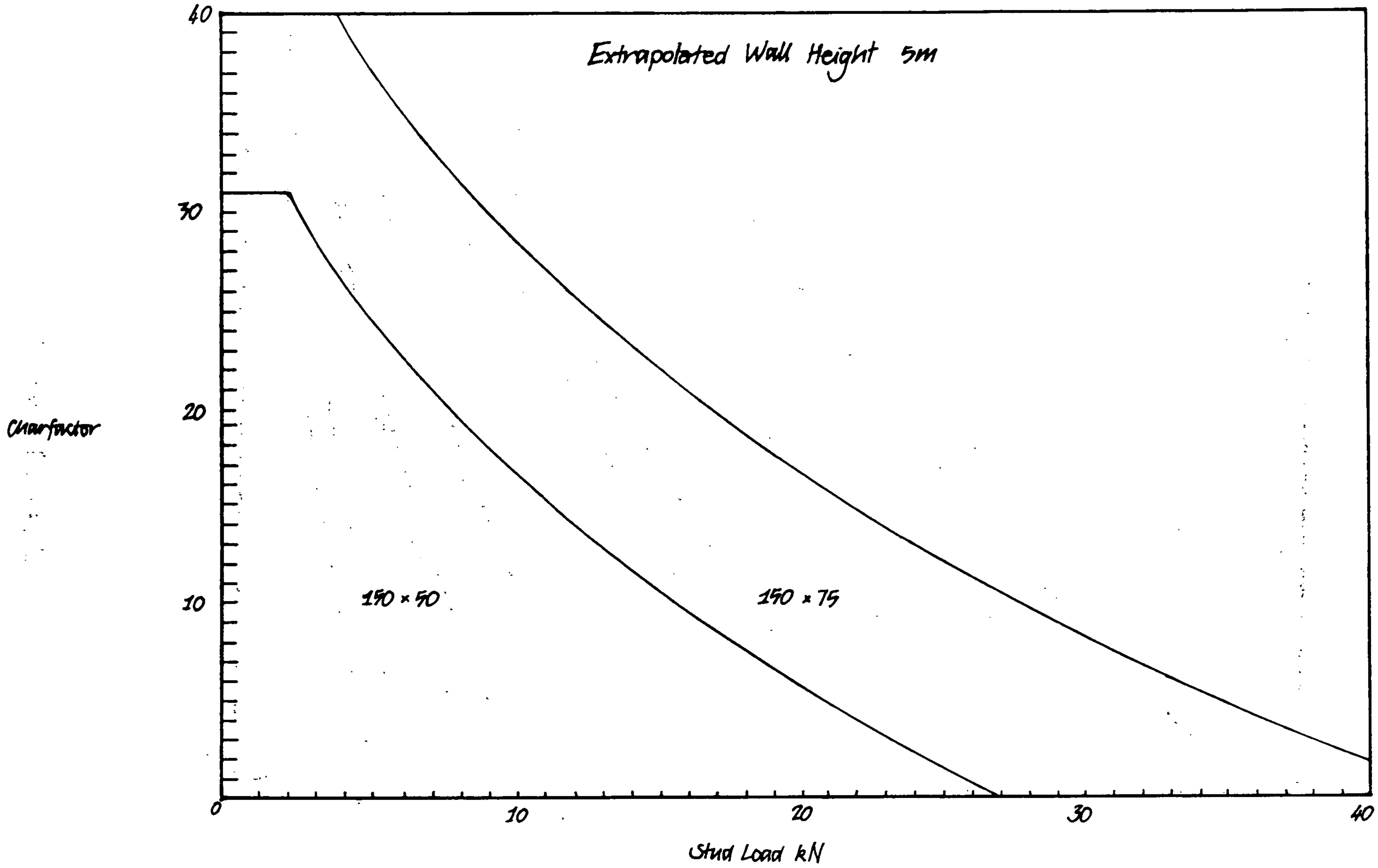

Extrapolated Wall Height 5m
Charfactor
40
30
20
10
0
10
20
30
40
Stud Load kN
150 × 50
150 × 75

Figure 1.5

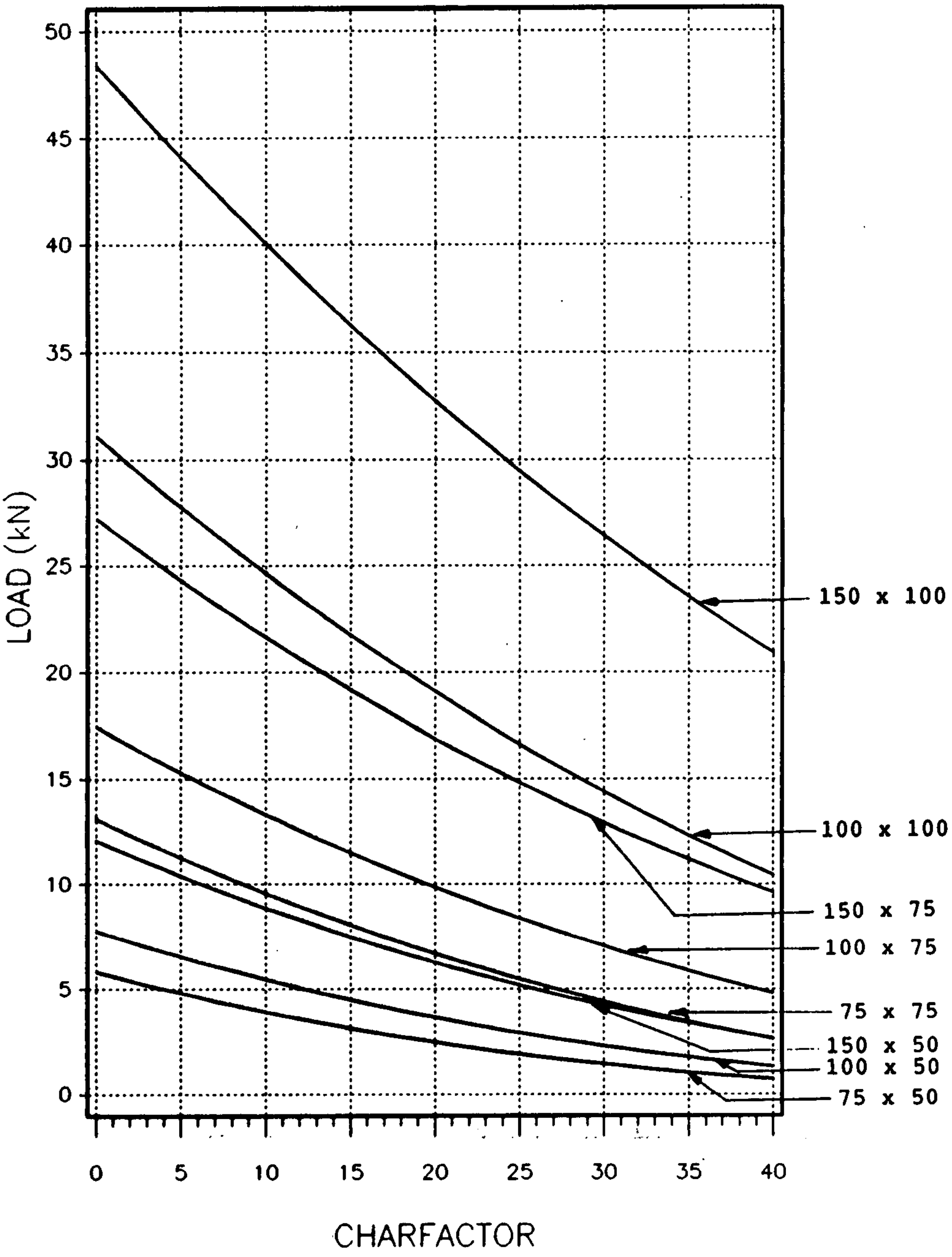


Figure 2.1 Single Top Plates

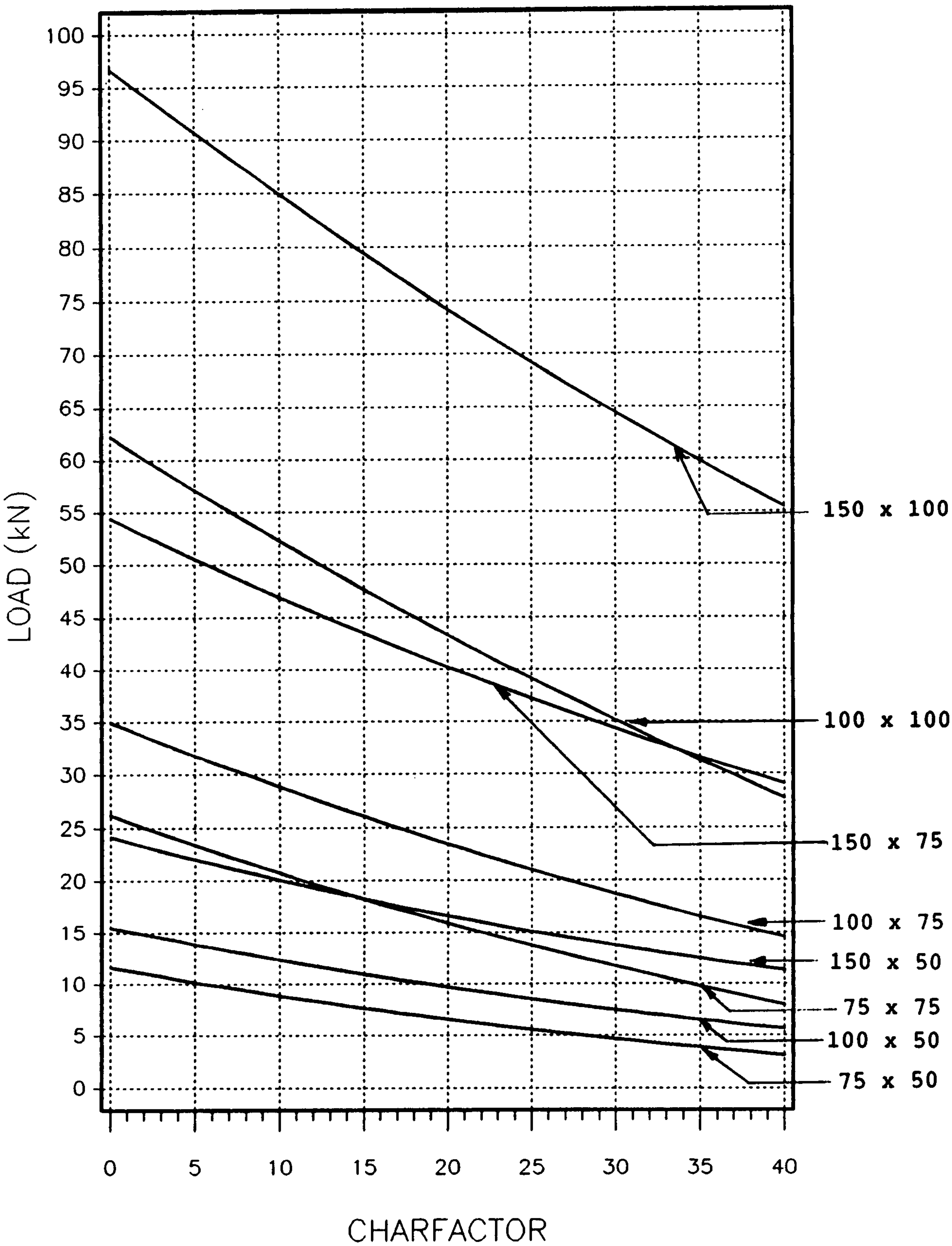


Figure 2.2 Double Top Plates

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