# BubbleDeck Voided Flat Slab Solutions

# Technical Paper

## BubbleDeck® Span Guide

**August 2006**

**Revision 6.3 January 2009**

# BubbleDeck Maximum Indicative Spans

The appropriate BubbleDeck slab version is bespoke engineered to suit building configuration, span length between supports, applied loadings and vertical alignment of supports. Indicative spans are given as a guide to what can be achieved.

Maximum spans indicated are based on 20mm concrete cover to bottom rebar (1 hour fire resistance); live load 3+1 kN/$m^2$, dead load 1.5 kN/$m^2$ and lightweight external envelope maximum 6 kN/m line load. Completed slab mass and Site Concrete Quantity based on 3 metre x 9 metre pre-cast elements with 51 kg/$m^2$ total reinforcement.

| Version | Slab Thickness | Bubbles | Span (Multiple bays) | Cantilever Maximum Length | Span (Single bays) | Completed Slab Mass | Site Concrete Quantity |
|---|---|---|---|---|---|---|---|
| | mm | mm | metres | metres | metres | kN/$m^2$ | $m^3/m^2$ |
| **BD230** | 230 | Ø 180 | 5 – 8.3 | ≤ 2.8 | 5 – 6.5 | 4.34 | 0.109 |
| **BD280** | 280 | Ø 225 | 7 – 10.1 | ≤ 3.3 | 6 – 7.8 | 5.17 | 0.142 |
| **BD340** | 340 | Ø 270 | 9 – 12.5 | ≤ 4.0 | 7 – 9.5 | 6.25 | 0.186 |
| **BD390** | 390 | Ø 315 | 11 – 14.4 | ≤ 4.7 | 9 – 10.9 | 6.93 | 0.213 |
| **BD450** | 450 | Ø 360 | 13 – 16.4 | ≤ 5.4 | 10 – 12.5 | 7.94 | 0.245 |
| **BD510 *** | 510 | Ø 410 | 15 – 18.8 | ≤ 6.1 | 11 – 13.9 | 9.06 | 0.291 |
| **BD600 *** | 600 | Ø 500 | 16 – 21.0 | ≤ 7.2 | 12 – 15.0 | 10.22 | 0.338 |

* New 2006 BubbleDeck slab configurations: Agrément certification pending, outside scope of KOMO technical certificate.

# Schematic Design Basic Principle

As a general guide for project scoping purposes at feasibility stage the maximum achievable spans for each BubbleDeck slab depth is usually determined by deflection limitations. This criteria is controlled by the ratio of span / effective depth (L/d) stipulated in BS8110 or EC2 and modified by applying a factor of approximately 1.5, permitted by these Standards to take account of BubbleDeck's dramatically lower dead weight than traditional solid flat slabs.

**BubbleDeck Span / Depth ratios (R)**

**L/d ≤ 30 for simply supported floors (Single Bay Rows) *[1]**

**L/d ≤ 41 for continuously supported floors (Multiple Spans) *[2]**

**L/d ≤ 13.0 for cantilevers.**

This basic principle has been verified for up to 4.5 kPa live + 1.5 kPa dead uniformly distributed loadings following full calculation and proven by full finite element analysis modelling to provide a generally reliable indication.

**Notes**
*[1] Single Bay Rows refers to primary single span in one direction with multiple spans in other direction. *[2] Multiple Spans refers to multiple bays in both directions.

**Firstly,** to determine the span dimension (L) in the case of spanning onto columns without beams (flat slab construction) take the longest span dimension (in metres) between column centres, where the slab will span onto walls or beams take the shortest span dimension (in metres) between the walls or beams.

**Then,** to determine the effective depth (d) of a BubbleDeck slab use the table below to find either approximate required total concrete cover ($c^t$); or approximate effective depth (d) for different levels of fire resistance. Effective depth is the overall depth less nominal concrete cover to all reinforcement for durability and fire resistance purposes (from bottom mesh reinforcement underside to bottom of slab) and approximately half overall depth of bottom mesh reinforcement. Actual effective depth required for any project is determined from a combination of required fire resistance, durability classification, reinforcement quantity and stress levels – so this estimation method is only an approximate guide.

**Approximate Total Cover & Effective Depth Data**

| | | **BubbleDeck Slabs Total Concrete Cover ($c^t$)** | | | **BubbleDeck Slabs Effective Depth (d)** | | |
|---|---|---|---|---|---|---|---|
| **Version** | **Slab Thickness** | **1 Hour FR** | **1.5 Hour FR** | **2 Hour FR** | **1 Hour FR** | **1.5 Hour FR** | **2 Hour FR** |
| | mm | mm | mm | mm | mm | mm | mm |
| **BD230** | 230 | 34 | 39 | 44 | 196 | 191 | 186 |
| **BD280** | 280 | 34 | 39 | 44 | 246 | 241 | 236 |
| **BD340** | 340 | 36 | 41 | 46 | 304 | 299 | 294 |
| **BD390** | 390 | 44 | 49 | 54 | 346 | 341 | 336 |
| **BD450** | 450 | 49 | 54 | 59 | 401 | 396 | 391 |
| **BD510** | 520 | 49 | 54 | 59 | 461 | 456 | 451 |
| **BD600** | 600 | 49 | 54 | 59 | 551 | 546 | 541 |

Table based on nominal concrete cover of 20mm for 1 hour FR, 25mm for 1.5 hour FR and 30mm for 2 hour FR with mild exposure (internal concrete surfaces) condition.

**Note:** For externally exposed slabs, such as car parking decks, reduce the effective depth given for 1 Hour Fire Resistance by an additional 15mm to allow minimum 35mm nominal concrete cover below bottom reinforcement to meet durability requirements.

**Finally either:**

**a) BubbleDeck slab depth for given Spans:** when the required span dimension is known divide span dimension (L) in metres into the span/effective depth ratio (R) for the appropriate slab configuration given above; then add on the required total concrete cover ($c^t$) from the table to arrive at the minimum BD voided slab thickness. The required BubbleDeck slab type is the next size up from the minimum BD voided slab thickness.

As an example for a 9 metre span between columns with multiple spans and requiring 1.5 hour fire resistance, span / effective depth ratio (R) will be 41, so 9 metres/41 = 219mm,

then adding ($c^t$) of 39 mm (for 1.5 hour FR in relevant range) indicates a minimum BD voided slab thickness of 258mm – requiring BD280 slab type for this span condition.

**b) Approximate span for given BubbleDeck slab depth:** to determine an indicative possible maximum span for a given slab depth multiply the relevant Effective Depth (d) by the span/effective depth ratio (R) for the appropriate slab configuration given above.

As an example for BD280 slab version, with 1.5 hour fire resistance, (d) is 241 mm so 41xd indicates a maximum 9.88 metre continuously supported (multiple bay) span; 30xd indicates a maximum 7.23 metre simply supported (single bay) span, and 12.5xd indicates a maximum 3.01 metre cantilever is potentially feasible.

We can confirm this estimation method by undertaking preliminary calculations and we would be pleased to give you advice on a specific project.

## Post Tensioned BubbleDeck Slabs

When mega spans are required (above 15 metres) we can provide a Post–Tensioned (PT) BubbleDeck solution incorporated into our BD390 to BD600 slab range. The above span / depth ratios can be increased by a further 15% to 30% with post – tensioned BubbleDeck slabs.

## BubbleDeck Slab Calculator

For more refined preliminary design we can provide a CD–Rom containing our BubbleDeck slab calculator – contact us for details.

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Revision B 5th January 2007

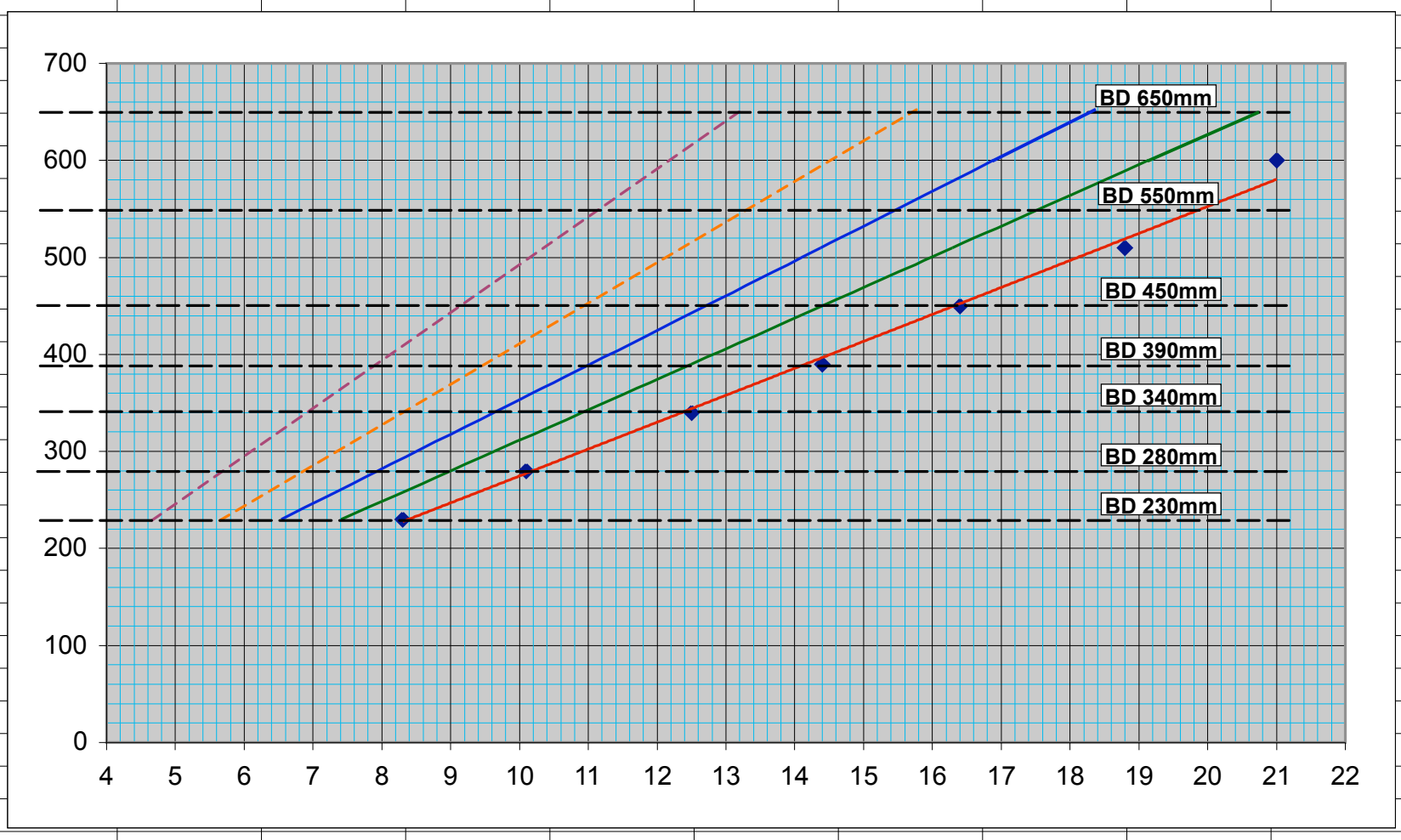
# BubbleDeck Maximum Span Guide
# Span - Depth Summary Table
# For Multiple (Continuous) Span Condition

## Span/depth for various thicknesses, taken from previous results:

## Continuous spans:

(two or more spans in relevant direction)

| Total Imposed Dead + Live Load: | | 2.5 kPa | 5.0 kPa | 7.5 kPa | 10.0 kPa | 12.5 kPa | (excl slab weight) |
|---|---|---|---|---|---|---|---|
| h | d | $L_{2.5}$ | $L_5$ | $L_{7.5}$ | $L_{10.0}$ | $L_{12.5}$ | |
| (mm) | (mm) | (m) | (m) | (m) | (m) | (m) | |
| 230 | 196 | 8.3 | 7.4 | 6.5 | 5.6 | 4.7 | |
| 280 | 246 | 10.1 | 9.0 | 7.9 | 6.8 | 5.7 | |
| 340 | 304 | 12.5 | 10.9 | 9.6 | 8.3 | 6.9 | |
| 390 | 346 | 14.4 | 12.5 | 11.0 | 9.5 | 7.9 | |
| 450 | 401 | 16.4 | 14.4 | 12.7 | 10.9 | 9.2 | |
| 550 | 501 | 19.8 | 17.5 | 15.4 | 13.3 | 11.1 | |
| 650 | 601 | 22.9 | 20.7 | 18.3 | 15.7 | 13.2 | |




**KEY**

Solid Lines - Data from FE maximum span calculation results up to BD450, interpolated above

Dashed Lines - Interpolated from lower loadings



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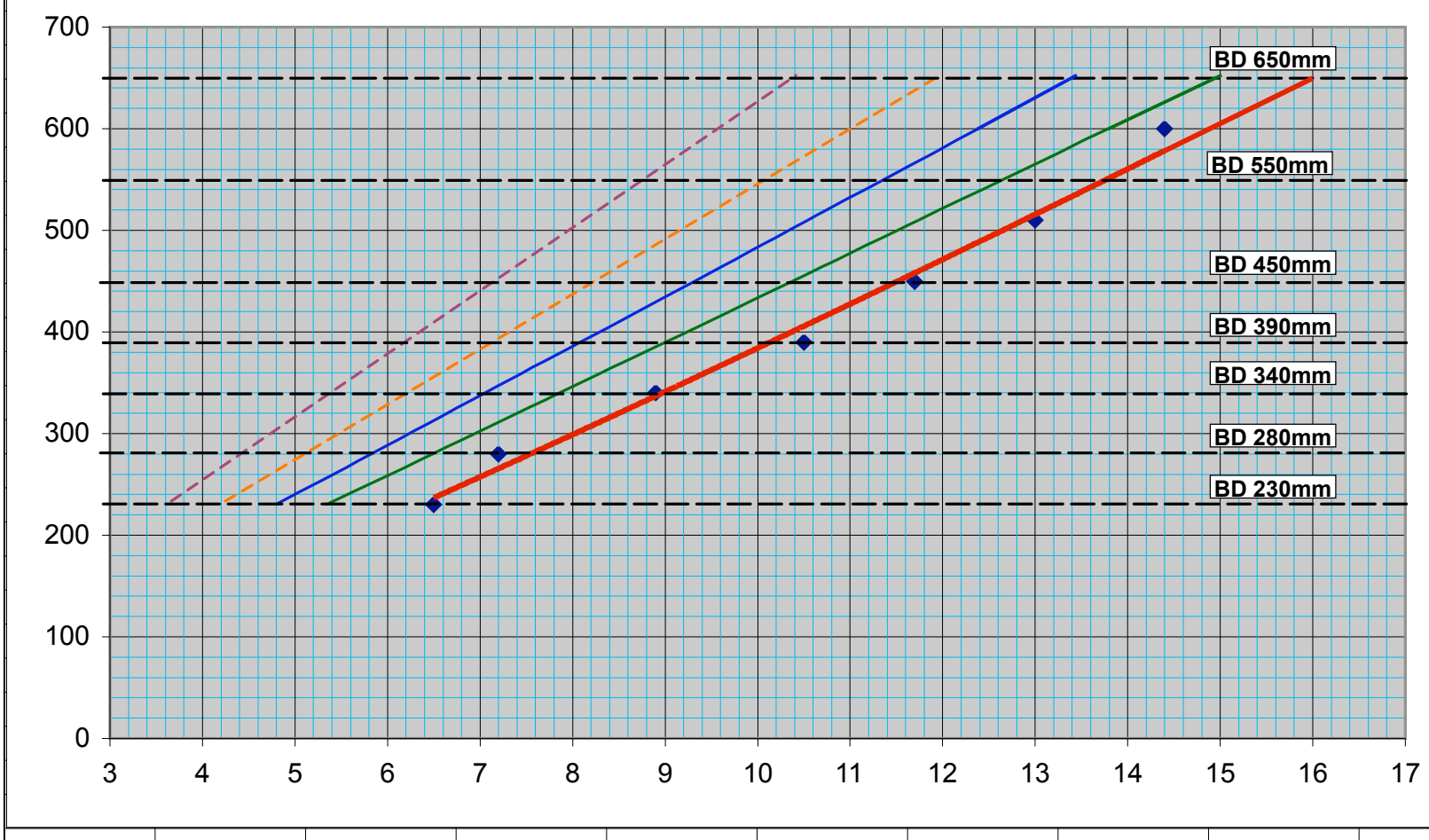
Revision 6.3 15/1/09

# BubbleDeck Maximum Span Guide
# Span - Depth Summary Table
# For Single (One Bay) Span Condition

## Single spans:

(one span between columns in relevant direction)

| Total Imposed Dead + Live Load: | | 2.5 kPa | 5.0 kPa | 7.5 kPa | 10.0 kPa | 12.5 kPa | (excl slab weight) |
|---|---|---|---|---|---|---|---|
| h | d | $L_{2.5}$ | $L_5$ | $L_{7.5}$ | $L_{10.0}$ | $L_{12.5}$ | |
| (mm) | (mm) | (m) | (m) | (m) | (m) | (m) | |
| 230 | 196 | 6.5 | 5.3 | 4.8 | 4.2 | 3.7 | |
| 280 | 246 | 7.2 | 6.5 | 5.8 | 5.2 | 4.5 | |
| 340 | 304 | 8.9 | 7.9 | 7.1 | 6.2 | 5.4 | |
| 390 | 346 | 10.5 | 9.0 | 8.1 | 7.2 | 6.3 | |
| 450 | 401 | 11.7 | 10.4 | 9.3 | 8.2 | 7.2 | |
| 550 | 501 | 13.8 | 12.6 | 11.4 | 10.1 | 8.8 | |
| 650 | 601 | 16.0 | 15.0 | 13.4 | 11.9 | 10.4 | |




**KEY**

Solid Lines - Data from FE maximum span calculation results up to BD450, interpolated above

Dashed Lines - Interpolated from lower loadings



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Revision 6.3 15/1/09

# BubbleDeck Maximum Span Guide
# Simple & FE Calculation Results
# (Continuous Spans)

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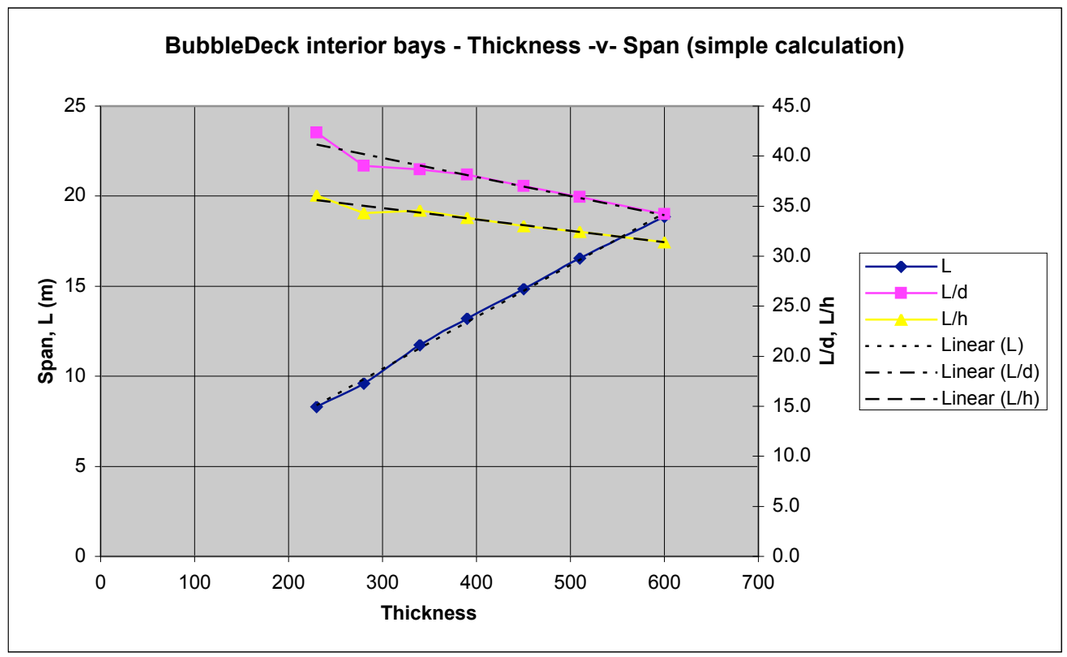
**Inner bays - simple calculation:**

| h | L | Ly | d | L/d | L/h |
|---|---|---|---|---|---|
| 230 | 8.3 | 5.4 | 196 | 42.3 | 36.1 |
| 280 | 9.6 | 6.3 | 246 | 39.0 | 34.3 |
| 340 | 11.75 | 8.3 | 304 | 38.7 | 34.6 |
| 390 | 13.2 | 9.6 | 346 | 38.2 | 33.8 |
| 450 | 14.85 | 10.5 | 401 | 37.0 | 33.0 |
| 510 | 16.55 | 12 | 461 | 35.9 | 32.5 |
| 600 | 18.85 | 12 | 551 | 34.2 | 31.4 |

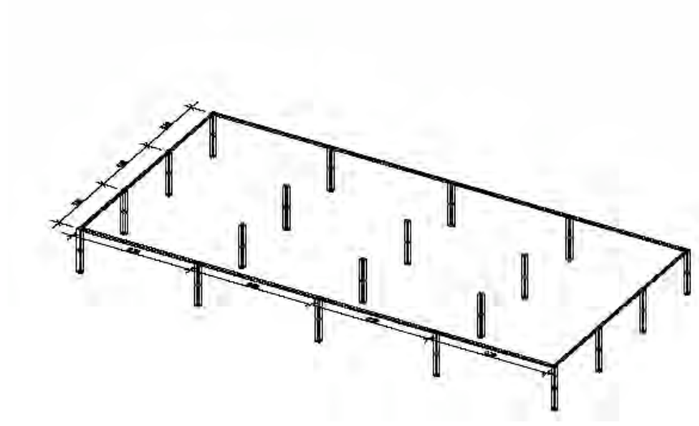
**Inner bays - FE calculation:**

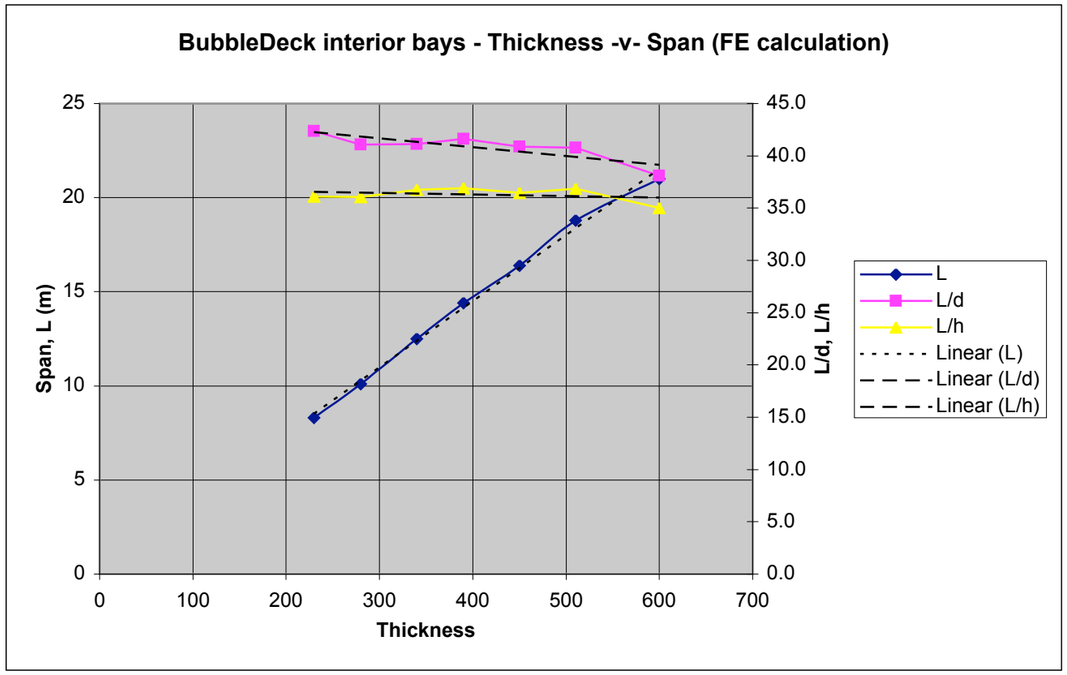
| h | L | Ly | d | L/d | L/h |
|---|---|---|---|---|---|
| 230 | 8.3 | 5.4 | 196 | 42.3 | 36.1 |
| 280 | 10.1 | 6.3 | 246 | 41.1 | 36.1 |
| 340 | 12.5 | 8.3 | 304 | 41.1 | 36.8 |
| 390 | 14.4 | 9.6 | 346 | 41.6 | 36.9 |
| 450 | 16.4 | 10.5 | 401 | 40.9 | 36.4 |
| 510 | 18.8 | 12 | 461 | 40.8 | 36.9 |
| 600 | 21 | 12 | 551 | 38.1 | 35.0 |

Creep included. Shrinkage excluded.
Cracked section, non linear analysis.




**Basic Geometry**





# BubbleDeck Maximum Span Guide
# Simple & FE Calculation Results
# (Single Row with Continuous Bays)

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**Single row continuous bays - simple calculation:**

| h | L | Ly | d | L/d | L/h |
|---|---|---|---|---|---|
| 230 | | 0 | 192 | 0.0 | 0.0 |
| 280 | | 0 | 242 | 0.0 | 0.0 |
| 340 | | 0 | 296 | 0.0 | 0.0 |
| 390 | | 0 | 337 | 0.0 | 0.0 |
| 450 | | 0 | 391 | 0.0 | 0.0 |
| 510 | | 0 | 456 | 0.0 | 0.0 |
| 600 | | 0 | 546 | 0.0 | 0.0 |

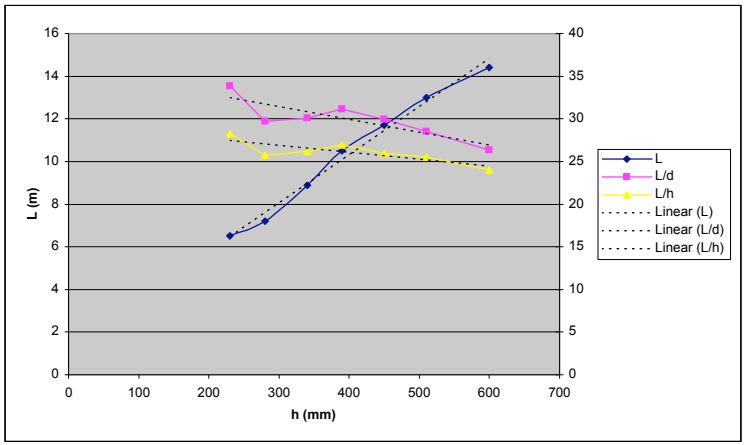
**Single row continuous bays - FE calculation**

| h | L | Ly | | L/d | L/h | $\Delta_{QP}$ | $\Delta_{P+I}$ | $\Delta_{P}$ | $\Delta_{I=(P+I)-P}$ | $L/\Delta_{QP}$ | $L/\Delta_{I}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 230 | 6.5 | 4.5 | 192 | 33.9 | 28.3 | 24 | 26 | 13 | 15 | 275 | 446 |
| 280 | 7.2 | 4.8 | 242 | 29.8 | 25.7 | 28 | 27 | 15 | 12 | 261 | 591 |
| 340 | 8.9 | 5.9 | 296 | 30.1 | 26.2 | 31 | 32 | 19 | 14 | 284 | 637 |
| 390 | 10.5 | 7 | 337 | 31.2 | 26.9 | 45 | 42 | 27 | 16 | 232 | 672 |
| 450 | 11.7 | 7.8 | 391 | 29.9 | 26.0 | 48 | 43 | 29 | 15 | 245 | 804 |
| 510 | 13 | 8.7 | 456 | 28.5 | 25.5 | 53 | 47 | 32 | 15 | 246 | 869 |
| 600 | 14.4 | 9.6 | 546 | 26.4 | 24.0 | 63 | 57 | 40 | 17 | 227 | 829 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 23 | 18 | 12 | 13 | 12 | 15 | 10 | 5 |
| 27 | 25 | 19 | 15 | 15 | 13 | 12 | 10 | 5 |
| 32 | 29 | 24 | 18 | 19 | 19 | 14 | 11 | 5 |
| 42 | 40 | 32 | 26 | 27 | 25 | 16 | 13 | 6 |
| 43 | 41 | 33 | 28 | 29 | 27 | 15 | 12 | 6 |
| 47 | 45 | 37 | 32 | 32 | 31 | 15 | 13 | 6 |
| 57 | 54 | 46 | 40 | 40 | 40 | 17 | 15 | 7 |

| h | L | L/d | L/h |
|---|---|---|---|
| 230 | 6.5 | 33.9 | 28.3 |
| 280 | 7.2 | 29.8 | 25.7 |
| 340 | 8.9 | 30.1 | 26.2 |
| 390 | 10.5 | 31.2 | 26.9 |
| 450 | 11.7 | 29.9 | 26.0 |
| 510 | 13 | 28.5 | 25.5 |
| 600 | 14.4 | 26.4 | 24.0 |

Creep included. Shrinkage excluded.
Cracked section, non linear analysis.
Most deflections within or acceptably close to limits (L/250 and L/500).




**Basic Geometry**

Shaded cases as above.
Shaded cases governed by long term load (by inspection of previous above).

**Single row continuous bays - FE calculation**

| h | L | Ly | | L/d | L/h | $\Delta_{QP}$ | $\Delta_{P+I}$ | $\Delta_{P}$ | $\Delta_{I=(P+I)-P}$ | $L/\Delta_{QP}$ | $L/\Delta_{I}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 230 | 6.5 | 4.5 | 192 | 33.9 | 28.3 | 24 | | | | 275 | |
| 280 | 7.2 | 4.8 | 242 | 29.8 | 25.7 | 28 | | | | 261 | |
| 340 | 8.9 | 5.9 | 296 | 30.1 | 26.2 | 31 | | | | 284 | |
| 390 | 11 | 6 | 337 | 32.6 | 28.2 | 52 | | | | 210 | |
| 450 | 12 | 6 | 391 | 30.7 | 26.7 | 49 | | | | 243 | |
| 510 | 13.6 | 7.2 | 456 | 29.8 | 26.7 | 59 | | | | 231 | |
| 600 | 15 | 7.2 | 546 | 27.5 | 25.0 | 69 | | | | 216 | |

# BubbleDeck Maximum Span Guide
# Simple & FE Calculation Results
# (Single bay both directions)

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**Single bay - simple calculation:**

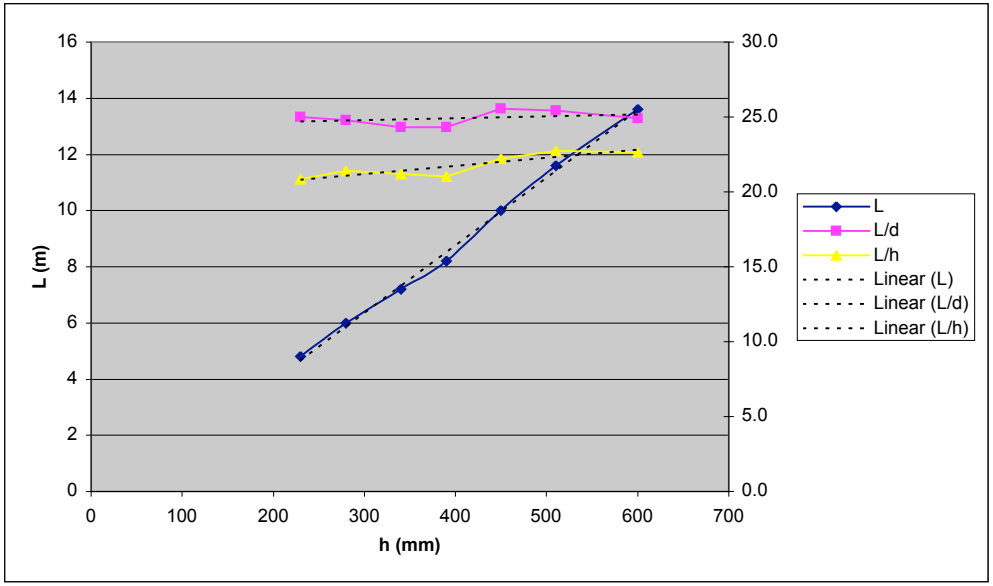
| h | L | Ly | d | L/d | L/h |
|---|---|---|---|---|---|
| 230 | 4.8 | 4.8 | 192 | 25.0 | 20.9 |
| 280 | 6 | 6 | 242 | 24.8 | 21.4 |
| 340 | 7.2 | 7.2 | 296 | 24.3 | 21.2 |
| 390 | 8.2 | 7.2 | 337 | 24.3 | 21.0 |
| 450 | 9.3 | 7.2 | 391 | 23.8 | 20.7 |
| 510 | 10.6 | 7.2 | 456 | 23.2 | 20.8 |
| 600 | 12.8 | 7.2 | 546 | 23.4 | 21.3 |

**Single bay - FE calculation:**

| h | L | Ly | d | L/d | L/h | $\Delta_{QP}$ | $\Delta_{P+I}$ | $\Delta_{P}$ | $\Delta_{I=(P+I)-P}$ | $L/\Delta_{QP}$ | $L/\Delta_{I}$ | $\Delta_{Age}$ | Precamb. | $\Delta'_{QP}$ | $\Delta'_{P+I}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 230 | 4.8 | 4.8 | 192 | 25.0 | 20.9 | 15 | 17 | 7 | 10 | 311 | 467 | 8 | 20 | -5 | -3 |
| 280 | 6 | 6 | 242 | 24.8 | 21.4 | 22 | 23 | 11 | 12 | 270 | 487 | 11 | 25 | -3 | -2 |
| 340 | 7.2 | 7.2 | 296 | 24.3 | 21.2 | 30 | 31 | 16 | 15 | 243 | 490 | 14 | 30 | 0 | 1 |
| 390 | 8.2 | 8.2 | 337 | 24.3 | 21.0 | 33 | 33 | 19 | 15 | 245 | 554 | 15 | 35 | -2 | -2 |
| 450 | 10 | 8.2 | 391 | 25.6 | 22.2 | 38 | 36 | 22 | 14 | 261 | 722 | 16 | 40 | -2 | -4 |
| 510 | 11.6 | 8.2 | 456 | 25.4 | 22.7 | 48 | 42 | 26 | 16 | 244 | 742 | 21 | 50 | -2 | -8 |
| 600 | 13.6 | 8.2 | 546 | 24.9 | 22.7 | 63 | 55 | 38 | 17 | 217 | 797 | 25 | 60 | 3 | -5 |

| h | L | L/d | L/h |
|---|---|---|---|
| 230 | 4.8 | 25.0 | 20.9 |
| 280 | 6 | 24.8 | 21.4 |
| 340 | 7.2 | 24.3 | 21.2 |
| 390 | 8.2 | 24.3 | 21.0 |
| 450 | 10 | 25.6 | 22.2 |
| 510 | 11.6 | 25.4 | 22.7 |
| 600 | 13.6 | 24.9 | 22.7 |

Creep included. Shrinkage excluded.
Cracked section, non linear analysis.
Most deflections within or acceptably close to limits (L/250 and L/500).
Worst possible case one bay with corner columns.



# BubbleDeck Maximum Span Guide
# Simple & FE Calculation Results
# (Cantilevers)

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**Cantilever - simple calculation for L/d=10:**

| h | L | Ly | d | L/d | L/h |
|---|---|---|---|---|---|
| 230 | | 0 | N/A | | 0.0 |
| 280 | | 0 | N/A | | 0.0 |
| 340 | | 0 | N/A | | 0.0 |
| 390 | | 0 | N/A | | 0.0 |
| 450 | | 0 | N/A | | 0.0 |
| 510 | | 0 | N/A | | 0.0 |
| 600 | | 0 | N/A | | 0.0 |

**Cantilever - FE calculation for L/h= 10**

| h | Lc* | L | Ly | d | L/d | L/h | $\Delta_{QP}$ | $\Delta_{P+I}$ | $\Delta_{P}$ | $\Delta_{I=(P+I)-P}$ | $L/\Delta_{QP}$ | $L/\Delta_{I}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 230 | 2.3 | 6.5 | 4.5 | 196 | 11.7 | 10.0 | 9 | 7 | 5 | 2 | 707 | 3824 |
| 280 | 2.8 | 7.2 | 4.8 | 244 | 11.5 | 10.0 | 7 | 3 | 4 | -1 | 1068 | 7273 |
| 340 | 3.4 | 8.9 | 5.9 | 309 | 11.0 | 10.0 | 8 | 6 | 4 | 3 | 1184 | 3450 |
| 390 | 3.9 | 10.5 | 7 | 360 | 10.8 | 10.0 | -12 | -8 | -5 | -2 | 890 | 4730 |
| 450 | 4.5 | 11.7 | 7.8 | 410 | 11.0 | 10.0 | -10 | -7 | -6 | -1 | 1181 | 15395 |
| 510 | 5.1 | 13 | 8.7 | 469 | 10.9 | 10.0 | -8 | -4 | -5 | 1 | 1582 | 10833 |
| 600 | 6 | 14.4 | 9.6 | 562 | 10.7 | 10.0 | -16 | -9 | -10 | 0 | 918 | 180000 |

*Lc taken from column centre

Creep included. Shrinkage excluded.
Cracked section, non linear analysis.
All results comfortably within limits for L/h=10

**Cantilever - FE calculation for L/h= 12**

| h | Lc* | L | Ly | d | L/d | L/h | $\Delta_{QP}$ | $\Delta_{P+I}$ | $\Delta_{P}$ | $\Delta_{I=(P+I)-P}$ | $L/\Delta_{QP}$ | $L/\Delta_{I}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 230 | 2.76 | 6.5 | 4.5 | 196 | 14.1 | 12.0 | 26 | 22 | 16 | 6 | 248 | 1009 |
| 280 | 3.36 | 7.2 | 4.8 | 244 | 13.8 | 12.0 | 23 | 22 | 16 | 7 | 307 | 1070 |
| 340 | 4.08 | 8.9 | 5.9 | 309 | 13.2 | 12.0 | 30 | 27 | 18 | 9 | 296 | 947 |
| 390 | 4.68 | 10.5 | 7 | 360 | 13.0 | 12.0 | 11 | 10 | 6 | 4 | 993 | 2471 |
| 450 | 5.4 | 11.7 | 7.8 | 410 | 13.2 | 12.0 | 19 | 18 | 11 | 8 | 617 | 1550 |
| 510 | 6.12 | 13 | 8.7 | 469 | 13.0 | 12.0 | 29 | 29 | 18 | 12 | 455 | 1117 |
| 600 | 7.2 | 14.4 | 9.6 | 562 | 12.8 | 12.0 | 24 | 26 | 15 | 11 | 599 | 1328 |

*Lc taken from column centre

Creep included. Shrinkage excluded.
Cracked section, non linear analysis.
Absolute value of deflection is becoming more important.
Rebar concentration becoming critical.