

# **BubbleDeck Voided Flat Slab Solutions**



**Technical Paper**

**BubbleDeck<sup>®</sup> 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<sup>2</sup>, dead load 1.5 kN/m<sup>2</sup> 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<sup>2</sup> 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 <sup>2</sup>	m <sup>3</sup> /m <sup>2</sup>
<b>BD230</b>	230	Ø 180	5 – 8.3	≤ 2.8	5 – 6.5	4.34	0.109
<b>BD280</b>	280	Ø 225	7 – 10.1	≤ 3.3	6 – 7.8	5.17	0.142
<b>BD340</b>	340	Ø 270	9 – 12.5	≤ 4.0	7 – 9.5	6.25	0.186
<b>BD390</b>	390	Ø 315	11 – 14.4	≤ 4.7	9 – 10.9	6.93	0.213
<b>BD450</b>	450	Ø 360	13 – 16.4	≤ 5.4	10 – 12.5	7.94	0.245
<b>BD510 *</b>	510	Ø 410	15 – 18.8	≤ 6.1	11 – 13.9	9.06	0.291
<b>BD600 *</b>	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) \*<sup>1</sup>**

**L/d ≤ 41 for continuously supported floors (Multiple Spans) \*<sup>2</sup>**



**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**

\*<sup>1</sup> Single Bay Rows refers to primary single span in one direction with multiple spans in other direction. \*<sup>2</sup> 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<sup>†</sup>); 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							
Version	Slab Thickness	BubbleDeck Slabs Total Concrete Cover (c <sup>†</sup> )			BubbleDeck Slabs Effective Depth (d)		
		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
<b>BD230</b>	230	34	39	44	196	191	186
<b>BD280</b>	280	34	39	44	246	241	236
<b>BD340</b>	340	36	41	46	304	299	294
<b>BD390</b>	390	44	49	54	346	341	336
<b>BD450</b>	450	49	54	59	401	396	391
<b>BD510</b>	520	49	54	59	461	456	451
<b>BD600</b>	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<sup>†</sup>) 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 ( $c^{\dagger}$ ) 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  $41x d$  indicates a maximum 9.88 metre continuously supported (multiple bay) span;  $30x d$  indicates a maximum 7.23 metre simply supported (single bay) span, and  $12.5x d$  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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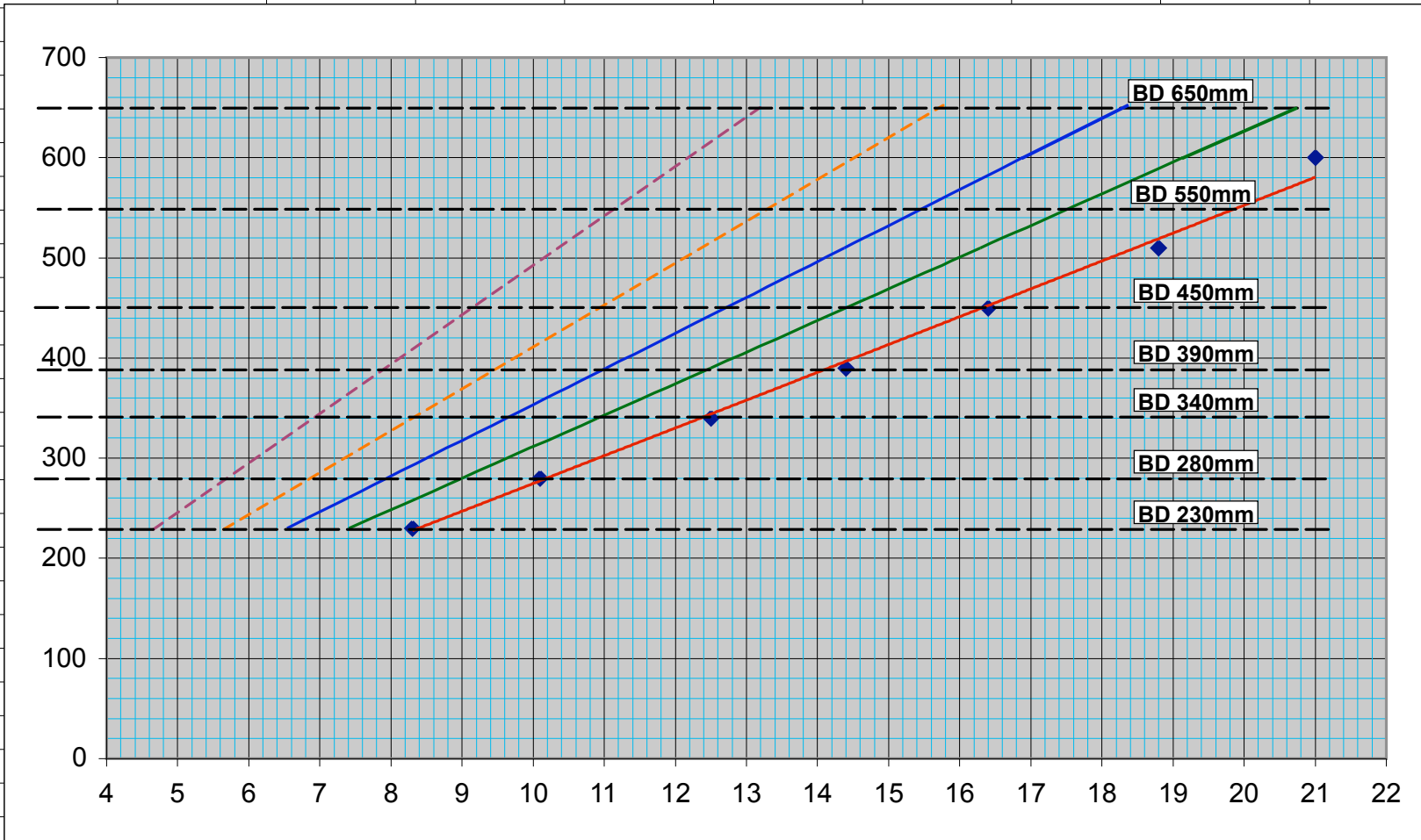
## BubbleDeck Maximum Span Guide Span - Depth Summary Table For Multiple (Continuous) Span Condition

**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 <sub>2.5</sub>	L <sub>5</sub>	L <sub>7.5</sub>	L <sub>10.0</sub>	L <sub>12.5</sub>	
(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

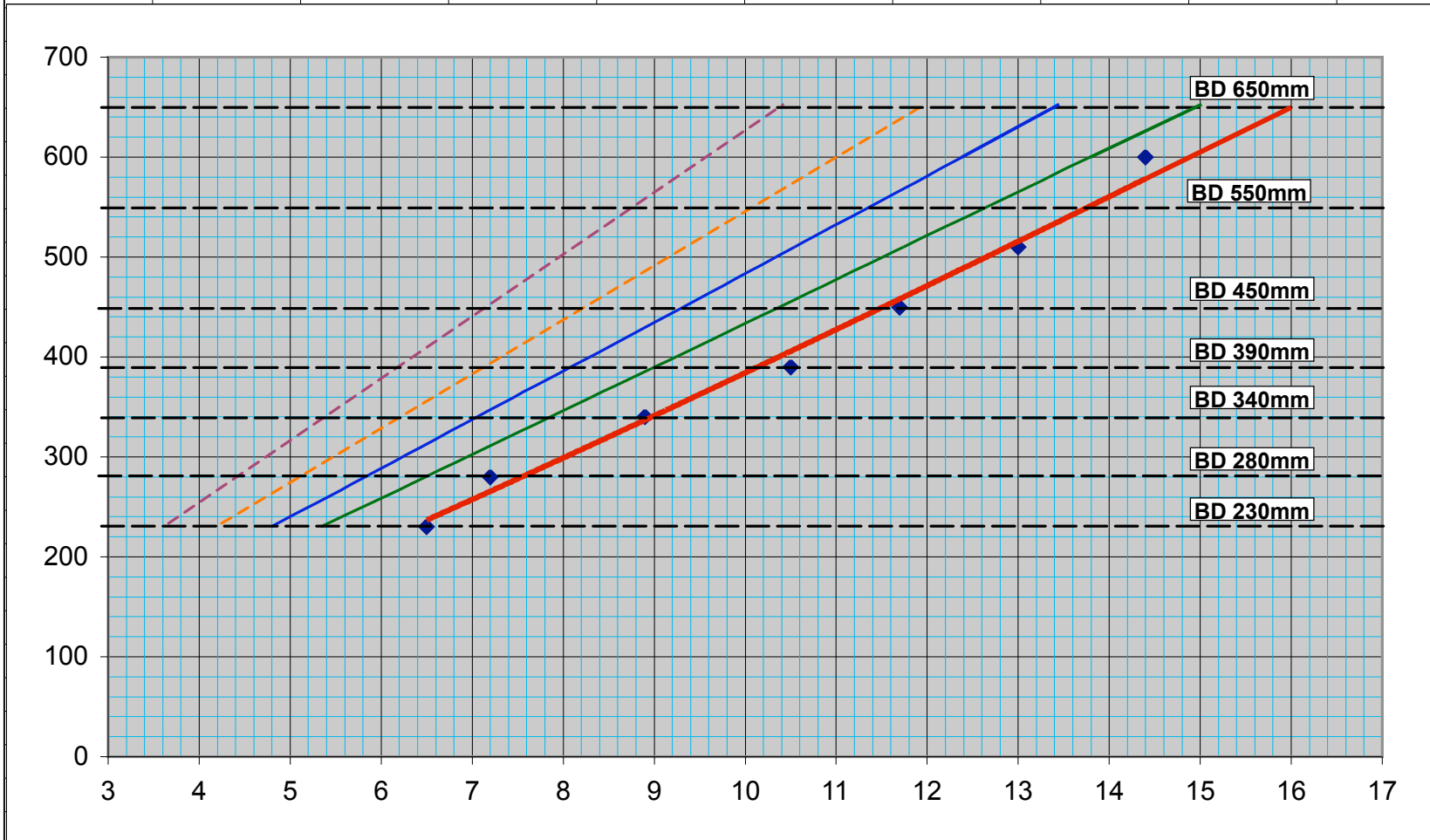


## BubbleDeck Maximum Span Guide Span - Depth Summary Table For Single (One Bay) Span Condition

### 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 <sub>2.5</sub>	L <sub>5</sub>	L <sub>7.5</sub>	L <sub>10.0</sub>	L <sub>12.5</sub>	
(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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# BubbleDeck Maximum Span Guide Simple & FE Calculation Results (Continuous Spans)

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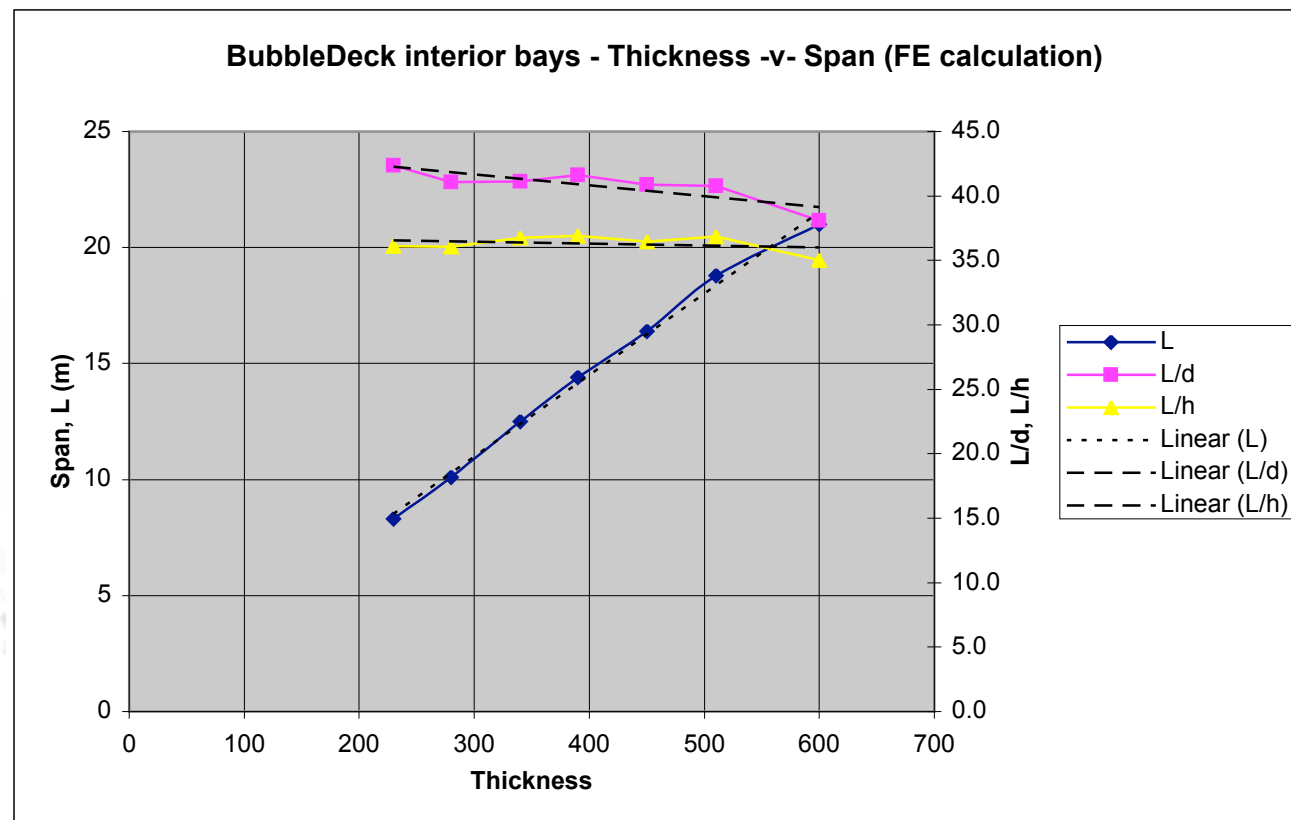
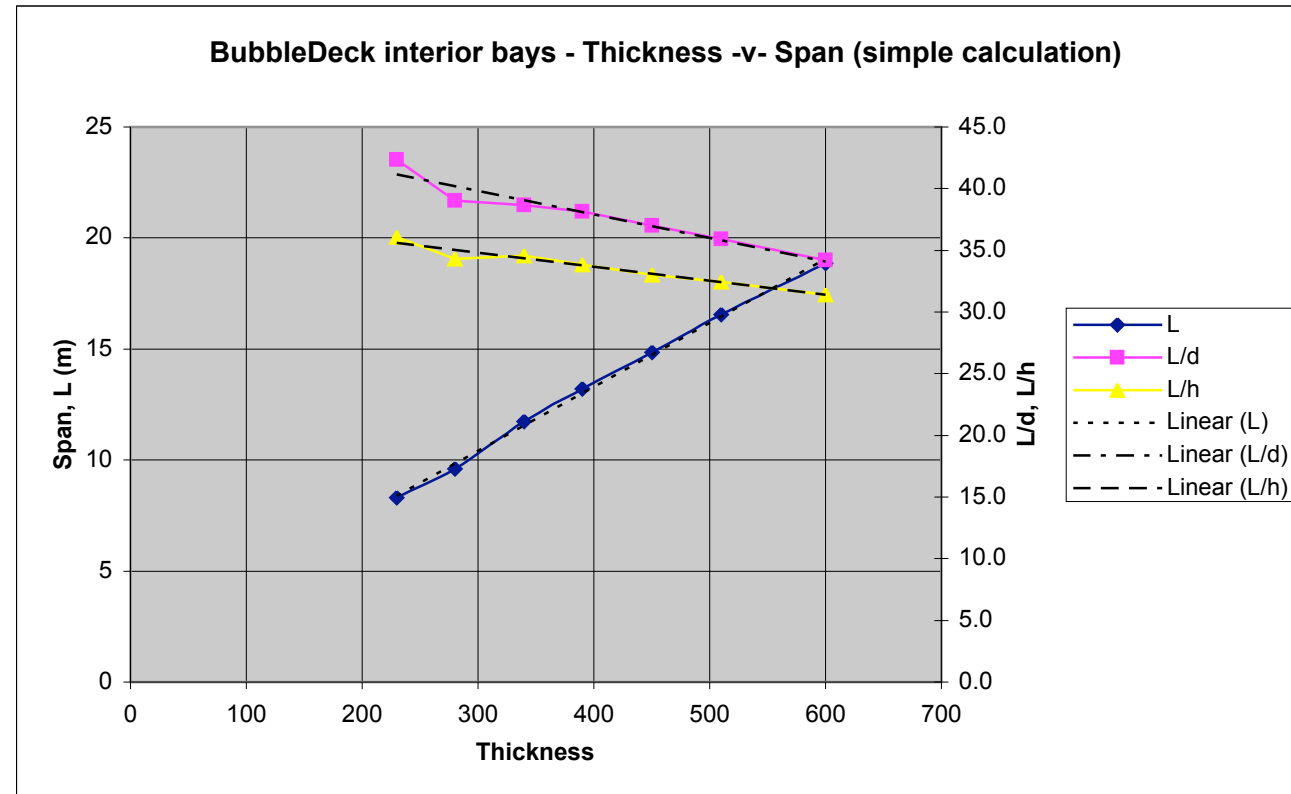
**Inner bays - simple calculation:**

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

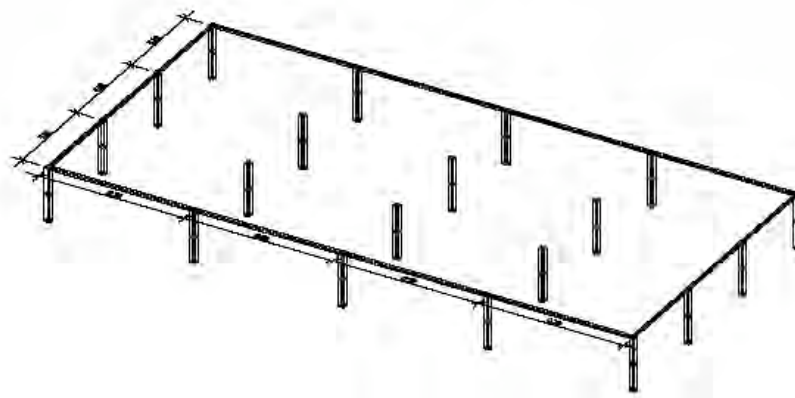
**Inner bays - FE calculation:**

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:

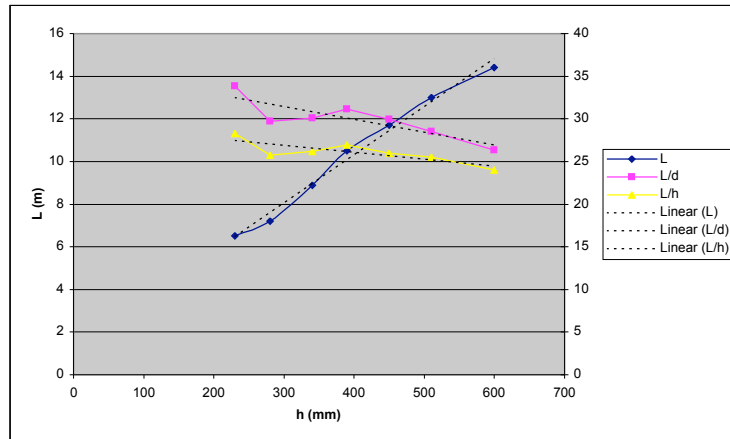
h	L	Ly	d	L/d	L/h
230		0	192	0.0	0.0
280		0	242	0.0	0.0
340		0	296	0.0	0.0
390		0	337	0.0	0.0
450		0	391	0.0	0.0
510		0	456	0.0	0.0
600		0	546	0.0	0.0

### Single row continuous bays - FE calculation

h	L	Ly	L/d	L/h	$\Delta_{OP}$	$\Delta_{P+I}$	$\Delta_P$	$\Delta_{H(P+I)P}$	$L/\Delta_{OP}$	$L/\Delta_I$										
230	6.5	4.5	192	33.9	28.3	24	26	13	15	275	446	26	23	18	12	13	12	15	10	5
280	7.2	4.8	242	29.8	25.7	28	27	15	12	261	591	27	25	19	15	15	13	12	10	5
340	8.9	5.9	296	30.1	26.2	31	32	19	14	284	637	32	29	24	18	19	19	14	11	5
390	10.5	7	337	31.2	26.9	45	42	27	16	232	672	42	40	32	26	27	25	16	13	6
450	11.7	7.8	391	29.9	26.0	48	43	29	15	245	804	43	41	33	28	29	27	15	12	6
510	13	8.7	456	28.5	25.5	53	47	32	15	246	869	47	45	37	32	32	31	15	13	6
600	14.4	9.6	546	26.4	24.0	63	57	40	17	227	829	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	$\Delta_{OP}$	$\Delta_{P+I}$	$\Delta_P$	$\Delta_{H(P+I)P}$	$L/\Delta_{OP}$	$L/\Delta_I$
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:

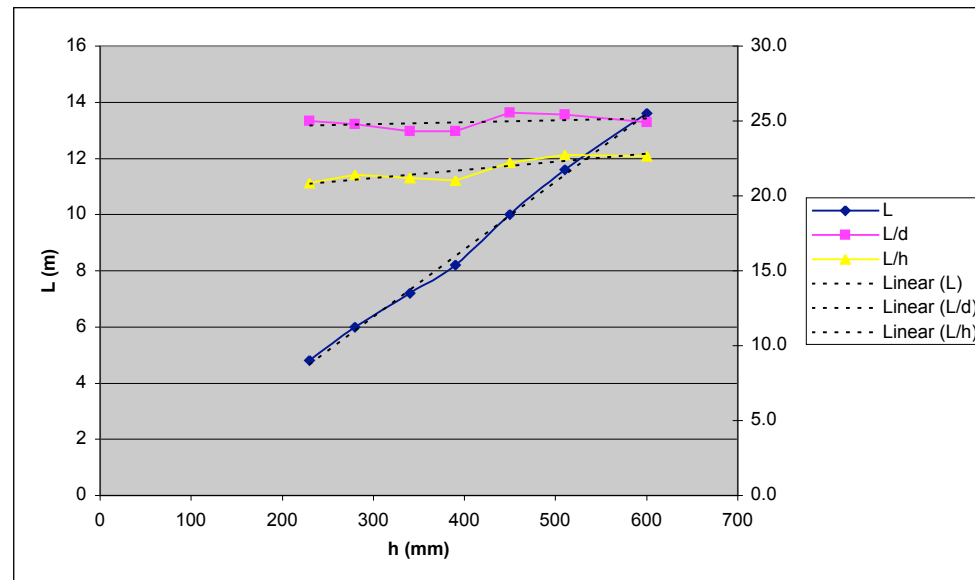
h	L	Ly	d	L/d	L/h
230	4.8	4.8	192	25.0	20.9
280	6	6	242	24.8	21.4
340	7.2	7.2	296	24.3	21.2
390	8.2	7.2	337	24.3	21.0
450	9.3	7.2	391	23.8	20.7
510	10.6	7.2	456	23.2	20.8
600	12.8	7.2	546	23.4	21.3

### Single bay - FE calculation:

h	L	Ly	d	L/d	L/h	$\Delta_{OP}$	$\Delta_{P+I}$	$\Delta_P$	$\Delta_{I=(P+I)-P}$	$L/\Delta_{OP}$	$L/\Delta_I$	$\Delta_{Age}$	Precamb.	$\Delta'_{OP}$	$\Delta'_{P+I}$
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.