Humes

Strength. Performance. Passion.

Precast arch systems

Issue 2

Contents

Introduction and product development

Humes manufactures an extensive range of precast concrete arch systems which may be used for bridges, underpasses, tunnels, mine portals and drainage culverts. The range of products available easily allows for the adoption of standard units to provide a choice of geometric envelopes to meet access and waterway area requirements.

The elements of the Humes arch system are primarily:

- precast arch units
- precast spandrel walls
- precast wing walls.

The arches are installed on an in-situ concrete strip foundation and are placed end-to-end to form the desired structure length.

Where large expanses are to be crossed, for example a flood plain, multiple arch spans are placed side by side and provide an aesthetically pleasing structure.

The spandrel walls run parallel to the arch, retaining the backfill at each end of the structure, enhancing its appearance (refer to Figures 1 and 2 on the following page).

Precast concrete wing walls, placed at each end of the spandrel wall, not only retain the backfill and support the spandrel walls but can also act as training walls for waterways. All of these elements may be finished in either conventional concrete or a variety of applied finishes to suit the specific environment.

In 1984 Humes entered into an exclusive agreement with BEBO Arch International AG (BEBO) for the manufacture of BEBO® arches in Australia. Humes has a commitment to technical excellence and consistent with this it was mandatory to ensure the first arch installed was instrumented and design theories validated.

Since that time Humes has undertaken development work in consultation with the BEBO group and has extended the BEBO concept into a unique portfolio of arches which were initially marketed as the Classic arch series.

When BEBO commenced operations the original arch was developed from small flat slab elements, which were joined together to form the arch profile, similar to a block and keystone arrangement. This in turn led to the one piece BEBO® arch. The ongoing development work at Humes has produced a product range which consists of a mix of one and two piece arches.

Humes continues to undertake the development and refinement of the design methodology, using both the original BEBO "finite displacement model" and the more recently available design methodology of "finite element analysis", which was used to confirm the designs of our Classic arch range. This work ensures refinement to product design adopting sound engineering practices and at the same time ensuring compliance to Australasian Standards and user specifications.

In both the installation of the first BEBO® arch and the first Classic arch, Humes engaged Adelaide and Sydney universities to fully instrument the structures and to validate the design methodology and its suitability to Australian conditions and requirements.

As the development work continues the soil structure relationship for all arches will be defined using the finite element methodology, which is more commonly used in general engineering, and allows greater scope for the analysis of structure response to site specific conditions.

All of Humes' arches will continue to be offered as either one or two piece elements. The number of pieces is generally dependent on the span required, the transportability of the pieces, or the loadings imposed on the structure.

The naming convention for Humes' arches is based on horizontal span, vertical height and number of pieces. The first number (or two numbers when the span is 10 metres or greater) is the span dimension expressed in metres. The next three numbers are the height expressed in centimetres. The final letter is either a "T" for a two piece arch or an "S" for a one piece arch. For example, an arch with an 18 m span and an internal vertical height of 6 m designed in two pieces is an 18600T.

This convention reduces the risk of confusion between our customers and sales consultants and then internally between our sales, design and production centres. See Table 1 – Standard arch data, on page 6 for details.

Figure 1 – General assembly, one piece arches

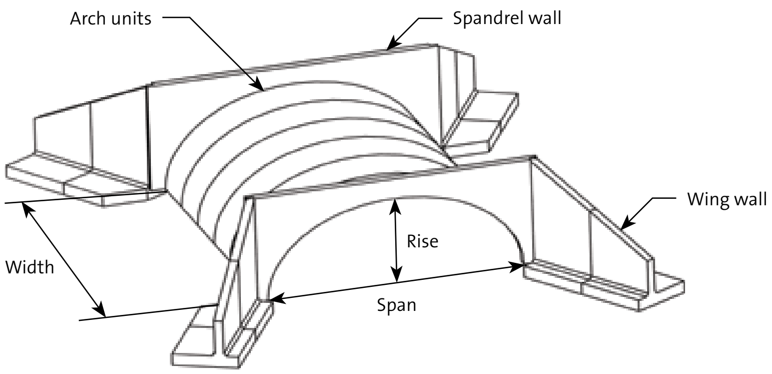
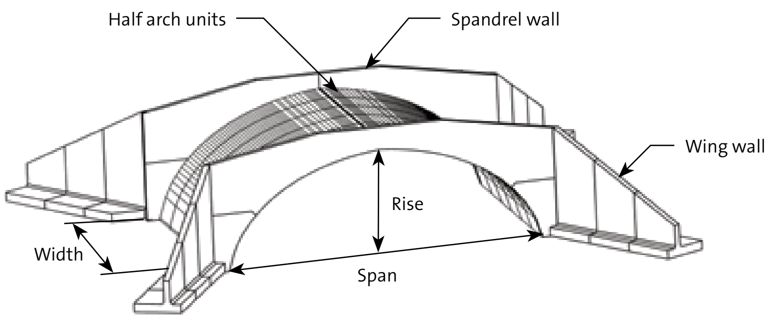


Figure 2 – General assembly, two piece arches



Features and benefits

There are many benefits of using Humes’ precast arches to all stakeholders when compared with conventional bridge or culvert construction. We have detailed these by specific market sector and end use application.

Asset owner

- **Cost**
  The cost of the project is reduced by quick installation, minimal design cost and low maintenance.
- **Durability**
  The use of high strength concrete efficiently compacted during manufacture at the factory ensures a high strength durable product produced under a stringent quality assurance system.
- **Appearance**
  The graceful appearance of the arch complements the environment and is aesthetically pleasing. Surface treatment can be tailored to suit specific applications.
- **Environmental impact**
  The arches can be sized to span most waterways without midstream support thus preserving the natural stream bed and providing a fish friendly environment. Land based fauna requirements may also be readily accommodated.
- **Maintenance**
  The high quality concrete ensures a maintenance free life with minimal inspections required by the owner throughout the life of the structure.

Consulting engineer

- **Structural design systems**
  All arches, spandrels and wing walls are designed by Humes in accordance with the Australian Concrete Structures Standard AS 3600 and AS 5100 - Bridge Design. Humes can also advise on the design of the cast in-situ strip footings.
- **Hydraulic efficiency**
  The large span-to-height ratio for standard profiles minimises hydraulic disturbance for wide low flow streams and channels. Other profiles with various span to height ratios can be supplied to accommodate other stream or channel flow requirements.
- **Versatility of profile**
  Several basic arch shapes and the option of using multiple cell arches allows easy application to most site configurations. Various spandrel wall and wing wall options at the bridge ends compliment the choice. Pedestal footings may be used if necessary to increase headroom clearances.

Contractor

- **Fast construction**
  Humes’ arches are simple to assemble which results in very fast erection times. The ability to manufacture and deliver the arches simultaneously with site works reduces overall project time and allows quick construction access across the spanned distance.
- **Minimal waste**
  BEBO® and Classic arches only require simple strip footings to resist vertical and horizontal forces. No moment is transferred to the footings simplifying their design and construction details. Precast foundations are an option.

- **Backfill protocol defined**

  The inherent strength of high quality concrete used in the precast concrete arches provides many backfilling advantages:

  – Only the first 300 mm of fill, adjacent to the arch, requires hand compaction. This applies to one piece arches. For two piece in-service arches the first 300 mm of fill is not compacted. The majority of the backfill can be compacted with vibratory rollers.

  – The maximum difference in the levels of fill on opposite sides of the arch can be as high as 600 mm for the majority of the backfill.

  – The use of precast concrete spandrels and wing walls allows backfill operations to commence sooner than if in-situ concrete structures were used.

  Construction traffic that is within highway traffic weight limits can cross over the arches with compacted earth covers as low as 300 mm for one piece arches and 500 mm for two piece arches. Where a two piece in-service (3-pin) arch is used then this minimum earth cover increases to 1,500 mm.

- **Eliminates scaffolding**

  All arches are free standing and require no scaffolding for temporary support during erection. Precast spandrel and wing walls may require temporary bracing.

End user

- **Differential settlement reduced**

  Precast arch bridges are completely backfilled overcoming the traditional bump experienced when driving over conventional bridges which is caused by differential settlement between the concrete abutment and adjacent fill.

Details of arch elements

Standard arches

Right:
BEBO® arch

The standard arch data below covers a broad range of spans and heights to accommodate a wide range of applications including bridges, tunnels and drainage culverts. All these shapes have been designed to comply with AS 5100 - Bridge Design, design loadings as well as a maximum 3 m of overlying fill.

Table 1 – Standard arch data (refer Figures 3, 4 and 5)

Profile	Dimensions					No. of pieces	Unit mass (t)	Total mass (t)	Old designation
	Internal Span 'S'	Internal Height 'H'	Dimension 'A'	Thickness 'T'	Unit length (mm)				
6210S	6.0	2.1	0	200	2,500	One	11.9	11.9	Classic 621
6310S	6.0	3.1	1.0	200	2,500	One	13.2	13.2	Classic 631
9300S	9.0	3.0	0	250	1,800	One	14.2	14.2	BEBO® L9
9400S	9.0	4.0	1.0	250	1,800	One	16.5	16.5	BEBO® M9
12300S	12.0	3.0	0	250	1,800	One	16.8	16.8	BEBO® L12
12400S	12.0	4.0	0	250	1,800	One	18.9	18.9	BEBO® M12
15500T	15.0	5.0	0	350	1,800	Two	15.6	31.1	Classic 155
18600T	18.0	6.0	0	350	1,800	Two	18.8	37.6	Classic 186
21700T	21.0	7.0	0	350	1,800	Two	22.7	45.3	Classic 217
25900T*	25.6	9.0	1.0	450	1,200	Two	25.5	50.1	N/A

Notes:
- Standard two piece arches may be configured with either a concrete interlocking joint or an in-situ concrete joint and this detail is of extreme importance to the installer. Humes' designers will detail in the drawings the type of connection that will be required.
- * Contact Humes for technical data on this profile.

Figure 3 – Arch profiles 6310S and 9400S

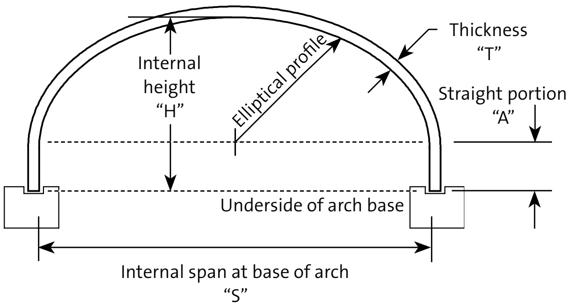


Figure 4 – Arch profiles 6210S, 9300S, 12300S and 12400S

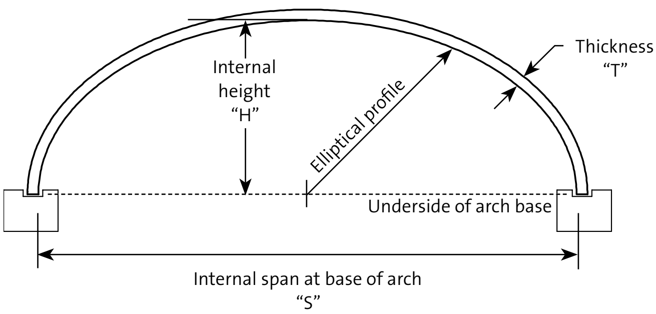


Figure 5 – Arch profiles 15500T, 18600T, 21700T and 25900T

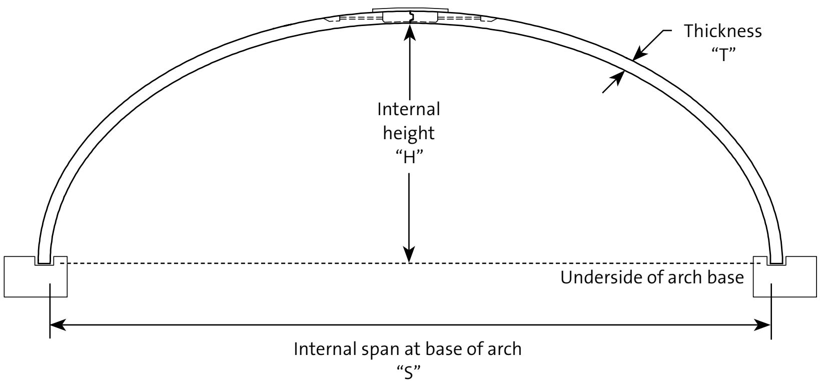
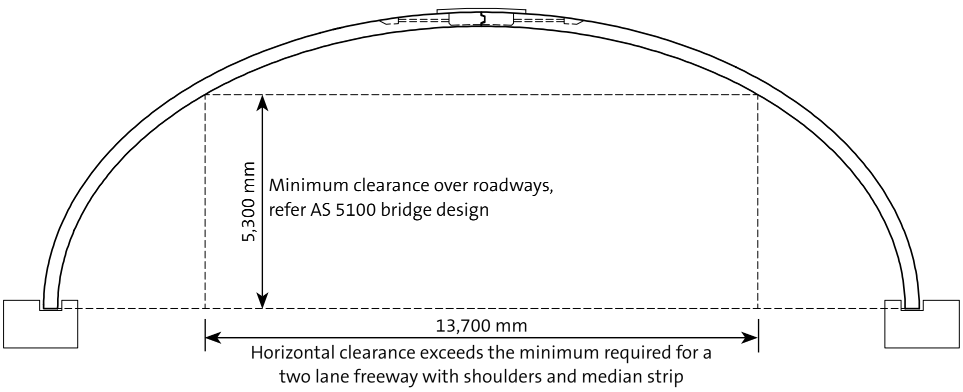


Figure 6 – Two lane road passing under a 21700T profile arch



Right:
3-pin arches in a mining application

Depth of fill

The minimum depth of fill required over the crown is 0.3 m for BEBO® arches, 0.5 m for Classic arches and up to 1.5 m for 3-pin arches.

For standard BEBO® and Classic arches the maximum depth of compacted fill is 3 to 5 m, at 21 kN/ cu.m.

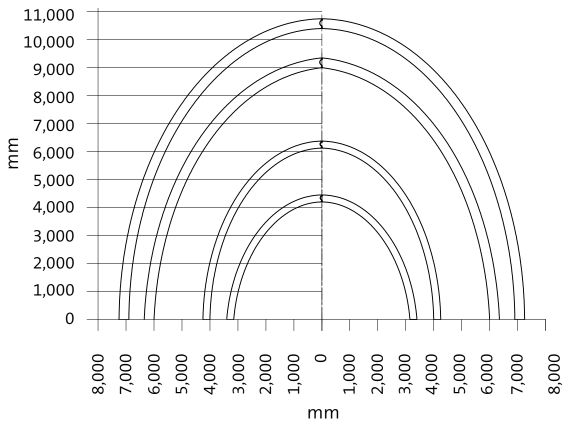
Larger fill heights (up to 50 m) have been achieved for coal stockpiles and other lighter materials.
Our engineers should be consulted where fill heights are in excess of the maximum nominated depth for standard units. In these cases project specific designs will be recommended.

3-pin arches

Humes can adapt the shapes and/or portions of our standard arches to produce a large range of custom designed 3-pin (two piece) arch solutions to meet a variety of heavy/complex loading and internal clearance criteria. The 3-pin arch solution has been widely used in mining applications for reclaim tunnels designed to cater for coal stockpiles up to 50 m depending on the arch profile, cover depths and backfill material.

Figure 7 below details our most commonly requested 3-pin arch profiles. These arch profiles can be further customised to meet specific clearance envelopes. Other profiles are also available and Humes' engineers are able to provide custom solutions using varying configurations.

Figure 7 – 3-pin arch profiles



Footings

BEBO® and Classic arches are designed to act in service as structures with pinned base supports. The hinge at the foundation is achieved by providing a keyway into which the arches are placed. This keyway is then grouted to form a lateral restrained pin connection.

Actual rotations at the hinge are very small during backfilling operations and for all practical purposes zero once backfilling is complete. There are essentially no special requirements when designing footings for BEBO® and Classic arch structures. Where underlying soils do not have adequate bearing capacity the structure may be supported by piles. Humes will provide advice on the footing reaction for the design and should always be consulted during the early design stages.

Final footing design is the responsibility of the project structural engineer. Humes are able to supply precast concrete footings if the designer wants to consider this option.

Humes can provide specific advice where greater fill depth or user defined live loads are encountered such as railway and heavy construction equipment.

Hydraulics

The hydraulic analysis is most commonly carried out by treating the flow through the arch as an open conduit and using Manning's formula to determine velocity of flow. By selecting the appropriate profile the designer can ensure the backwater will be within the accepted limits of hydraulic design principles. The flat elliptical profile of the arch ensures the optimum hydraulic performance compared to pipe or box culvert structures.

Table 2 below shows the maximum waterway areas for each arch profile. Also shown is the periphery length of the underside of the arch to assist with determination of the hydraulic radius required when using Manning's formula.

Curves of waterway area and periphery for varying water depths are plotted in Figures 8-11 and Tables 4-7 on pages 10-13. Table 3 above gives typical values of Manning's roughness coefficient, which will vary between arch surface and stream bed. The overall roughness coefficient should be proportioned for the amount of wetted perimeter of stream channel and arch soffit.

Table 2 – Water area and periphery

Arch profile	Maximum waterway area (m^2)	Maximum periphery of arch soffit (m)
6210S	9.9	8.1
6310S	15.9	10.1
9300S	21.2	11.9
9400S	30.2	13.9
12300S	26.7	14.2
12400S	38.9	16.2
15500T	55.5	19.3
18600T	82.5	23.5
21700T	115.5	27.8

Notes:
- The waterway area assumes a flat stream bed between strip footings at the same level as the bottom of the arch.
- The waterway area will be influenced by the shape of the stream bed.
- Larger waterway areas are possible if the arches are placed on pedestal footings.

Table 3 – Values of Manning's roughness coefficient (n)

Surface description	n
Inside surface of concrete arch	0.013
Stone pitching	0.017
Earth, smooth, no weeds	0.020
Earth, some stones and weeds	0.025
Concrete, untrowelled	0.015
Rockfill mattresses or gabions, un-grouted	0.022 to 0.027
Rockfill mattresses or gabions, grouted	0.016 to 0.020
Natural river channels: – Clean and straight – Winding with pools – Very weedy, winding and overgrown	 0.025 to 0.030 0.033 to 0.040 0.075 to 0.150

Figure 8 – Hydraulic curves for BEBO® arches (waterway area)

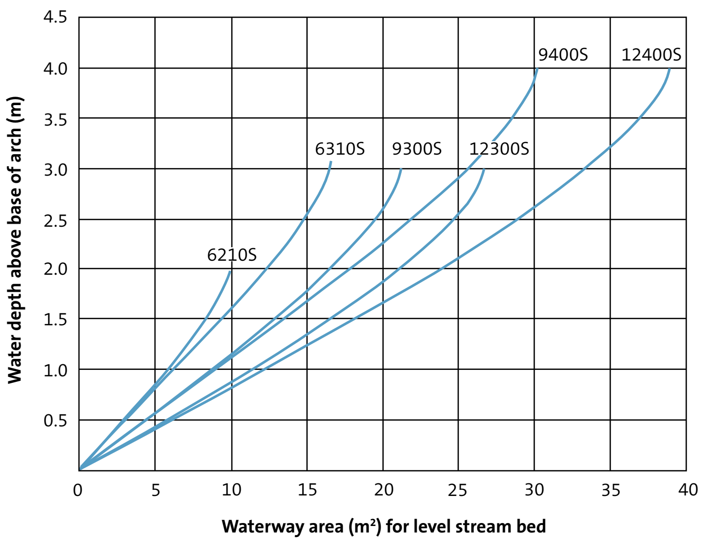


Table 4 – (See Figure 8)

Depth (m)	Waterway area (m²)					
	Arch 6210S	Arch 6310S	Arch 9300S	Arch 12300S	Arch 9400S	Arch 12400S
0.2	1.198	1.200	1.799	2.383	1.800	2.478
0.4	2.385	2.400	3.589	4.727	3.600	4.950
0.6	3.550	3.600	5.364	7.025	5.400	7.409
0.8	4.681	4.800	7.114	9.269	7.200	9.849
1.0	5.765	6.000	8.830	11.450	9.000	12.265
1.2	6.786	7.198	10.505	13.559	10.799	14.648
1.4	7.728	8.385	12.126	15.587	12.589	16.992
1.6	8.566	9.550	13.685	17.522	14.364	19.290
1.8	9.268	10.681	15.167	19.350	16.114	21.533
2.0	9.773	11.765	16.560	21.057	17.830	23.714
2.2		12.786	17.844	22.622	19.505	25.824
2.4		13.728	18.998	24.022	21.126	27.852
2.6		14.566	19.991	25.220	22.685	29.786
2.8		15.269	20.772	26.157	24.167	31.615
3.0		15.773	21.206	26.675	25.560	33.320
3.1		15.896				
3.2					26.844	34.887
3.4					27.998	36.286
3.6					28.991	37.484
3.8					29.772	38.421
4.0					30.206	38.940

Note:
Graphs do not include the wetted perimeter of the stream bed.

Figure 9 – Hydraulic curves for BEBO® arches (wetted perimeter)

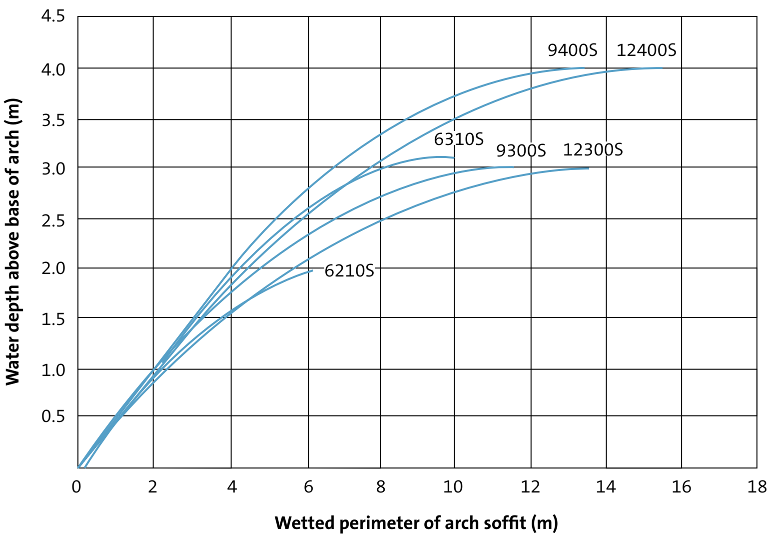


Table 5 – (See Figure 9)

Depth (m)	Wetted perimeter (m)					
	Arch 6210S	Arch 6310S	Arch 9300S	Arch 12300S	Arch 9400S	Arch 12400S
0.2	0.400	0.400	0.400	0.438	0.400	0.400
0.4	0.810	0.800	0.806	0.890	0.800	0.804
0.6	1.234	1.200	1.218	1.364	1.200	1.210
0.8	1.683	1.600	1.644	1.858	1.600	1.626
1.0	2.166	2.000	2.086	2.380	2.000	2.050
1.2	2.700	2.402	2.550	2.934	2.400	2.488
1.4	3.303	2.810	3.044	3.524	2.806	2.942
1.6	4.013	3.234	3.574	4.162	3.218	3.414
1.8	4.905	3.682	4.150	4.858	3.644	3.908
2.0	6.229	4.166	4.784	5.624	4.086	4.430
2.2		4.700	5.496	6.484	4.550	4.984
2.4		5.304	6.318	7.476	5.044	5.576
2.6		6.014	7.314	8.672	5.574	6.214
2.8		6.904	8.634	10.256	6.150	6.908
3.0		8.230	11.899	14.155	6.784	7.674
3.1		10.074				
3.2					7.496	8.534
3.4					8.318	9.526
3.6					9.314	10.722
3.8					10.634	12.306
4.0					13.899	16.205

Figure 10 – Hydraulic curves for Classic arches (waterway area)

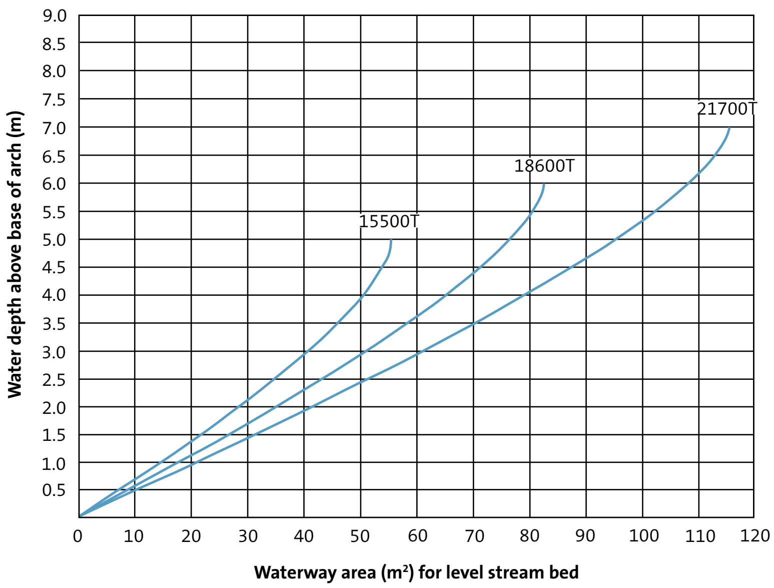


Table 6 – (See Figure 10)

Depth (m)	Waterway area (m²)		
	Arch 15500T	Arch 18600T	Arch 21700T
0.2	2.991	3.597	4.199
0.4	5.963	7.184	8.395
0.6	8.190	10.755	12.585
0.8	11.828	14.272	16.763
1.0	14.715	17.838	20.928
1.2	17.565	21.342	25.076
1.4	20.374	24.816	29.203
1.6	23.138	28.256	33.305
1.8	25.850	31.658	37.379
2.0	28.507	35.018	41.421
2.2	31.102	38.331	45.428
2.4	33.630	41.592	49.394
2.6	36.083	44.797	53.317
2.8	38.455	47.940	57.192
3.0	40.738	51.016	61.014
3.1			
3.2	42.923	54.018	64.780
3.4	45.000	56.942	68.484
3.6	46.957	59.779	72.121
3.8	48.781	62.522	75.686
4.0	50.456	65.163	79.173
4.2	51.961	67.692	82.577
4.4	53.270	70.099	85.891
4.6	54.344	72.372	89.108
4.8	55.123	74.497	92.220
5.0	55.465	76.456	95.219
5.2		78.227	98.096
5.4		79.782	100.839
5.6		81.097	103.436
5.8		82.048	105.873
6.0		82.515	108.133
6.2			110.192
6.4			112.021
6.6			113.577
6.8			114.787
7.0			115.454

Note:
Graphs do not include the wetted perimeter of the stream bed.

Figure 11 – Hydraulic curves for Classic arches (wetted perimeter)

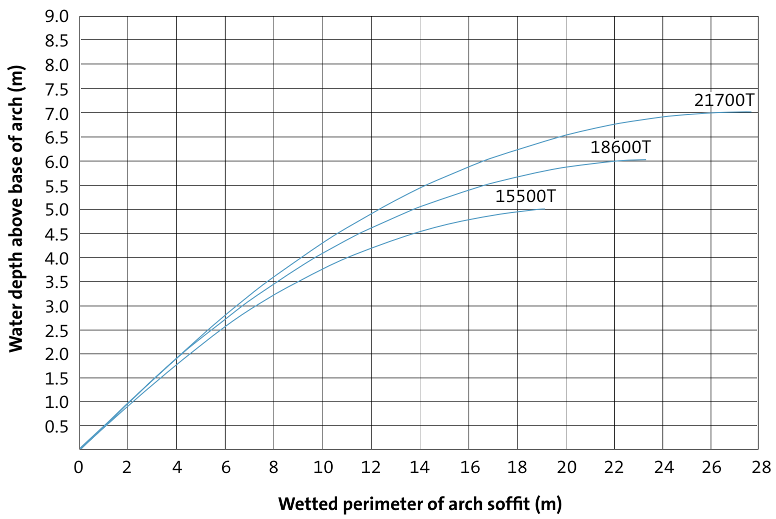


Table 7 – (See Figure 11)

Depth (m)	Wetted perimeter (m) Arch 15500T	Arch 18600T	Arch 21700T
0.2	0.410	0.402	0.400
0.4	0.826	0.808	0.800
0.6	1.246	1.218	1.204
0.8	1.674	1.630	1.608
1.0	2.110	2.048	2.016
1.2	2.554	2.472	2.426
1.4	3.008	2.902	2.842
1.6	3.476	3.340	3.264
1.8	3.956	3.788	3.690
2.0	4.452	4.246	4.126
2.2	4.966	4.716	4.568
2.4	5.500	5.200	5.018
2.6	6.058	5.696	5.480
2.8	6.642	6.210	5.952
3.0	7.258	6.742	6.438
3.2	7.908	7.294	6.934
3.4	8.604	7.906	7.448
3.6	9.350	8.472	7.967
3.8	10.158	9.104	8.524
4.0	11.046	9.772	9.092
4.2	12.040	10.478	9.682
4.4	13.178	11.232	10.296
4.6	14.534	12.042	10.940
4.8	16.292	12.920	11.614
5.0	19.308	13.886	12.326
5.2		14.966	13.080
5.4		16.204	13.882
5.6		17.688	14.744
5.8		19.634	15.676
6.0		23.486	16.698
6.2			17.840
6.4			19.144
6.6			20.706
6.8			22.760
7.0			27.765

Top:
Arches subjected to high flows require scour protection

Bottom:
BEBO® arch on concrete strip footing

Scour protection

Often BEBO® and Classic arches are used to span waterways and are subjected to the dynamic forces of rapidly flowing water. It is essential that the designer not only considers hydraulic criteria but the probability of scour caused by turbulent flow conditions.

BEBO® and Classic arches are normally founded on concrete strip footings. The probability of scour therefore becomes an important consideration in the overall design.

Absolute velocities beyond which erosion will occur are difficult to determine due to unknown variables such as the amount and nature of debris discharged and frequency of peak velocity. However, commonly adopted values based on experience are listed in Table 8.

Where underlying soils do not have adequate bearing the BEBO® and Classic arch structures may be supported on piles, in which case scour is less of a potential problem.

Table 8 – Maximum recommended flow velocities for various materials

Material	Maximum velocity (m/s)
Arch soffit	8.0
In-situ concrete	6.0
Hard packed rock (300 mm minimum size)	6.0
Beaching or boulders (250 mm minimum size)	5.0
Stones (100-150 mm size)	3.0
Grass covered surface	1.8
Coarse gravel	1.8
Stiff, sand clay	1.5
Coarse sand	0.7
Fine sand	0.5

End treatment

Precast concrete spandrel walls and wing walls can be provided at the ends of BEBO® and Classic arches to retain the backfill. In waterway crossings the wing walls assist in training the water through the arch and reduce entrance losses.

For arches with spans up to 12 m

Spandrel walls

The precast concrete spandrel wall is placed adjacent to the end arches to retain the fill covering the arch. The spandrel is placed to overlap the end arch. The spandrel is supported horizontally by the wing walls or by tie rods between spandrels where wing walls are not required. Erection tie backs are provided for supporting the spandrel from the end arch during installation.

Spandrel walls are available for all of our arches with spans of 6 m, 9 m and 12 m. The 6310S, 9400S and the 12400S spandrel walls are supported on one metre high pedestals cast with the in-situ footings.

The standard finish for spandrel walls is plain concrete however vertical flutes and a range of architectural finishes are also available. The dimensions of the spandrel walls are given in Table 9.

Figure 12 – Spandrel wall dimensions

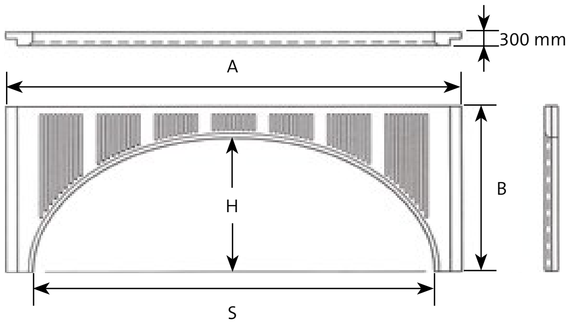


Table 9 – Spandrel walls dimensions and masses (see Figure 12)

Arch profile	Dimensions (m)				Unit mass (t)
	S	H	A	B	
6210S	5.9	2.05	7.5	2.75	8.2
6310S	5.9	3.05	7.5	3.75	9.3
9300S	8.9	2.95	10.1	3.7	12.2
9400S	8.9	2.95	10.1	3.7	12.2
12300S	11.9	2.95	13.3	3.7	17.2
12400S	11.9	2.95	13.3	3.7	17.2

Notes:
- The top level of the spandrel wall is 450 mm higher than the external top level of the arch.
- The top of the spandrel is at the same height as the top of the wing wall.
- Spandrel walls 9400S and 12400S are placed on pedestals. Top of pedestal is 1 m above top of levelling pad for arches.
- The foundation level for spandrel walls 9300S and 12300S is identical to the arches.
- The spandrel wall internal ellipse profile overlaps the arch by 50 mm.

Wing walls

Right:
Light type wing wall

The precast concrete wing walls adjacent to the spandrel wall retain earth fill and support the spandrel wall. Additional wing walls serve only to retain earth fill and direct the water flow. Wing walls are provided with weep holes to relieve hydrostatic pressure.

Two wing wall types are available - the light type shaped like an inverted 'T' and the heavy type shaped like an 'L'.

- Light type wing walls:
  Must be placed on and connected to an in-situ concrete footing designed to resist vertical and horizontal loads from the wall. Alternatively Humes can supply precast footings. Sliding resistance is provided by grouted-in-place galvanised N20 dowels which connect the wall to the in-situ footing. Details of light type wing walls are shown in Table 10.

Figure 13 – Light type wing wall dimensions

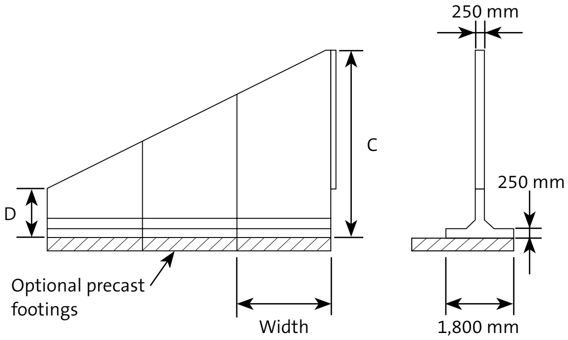
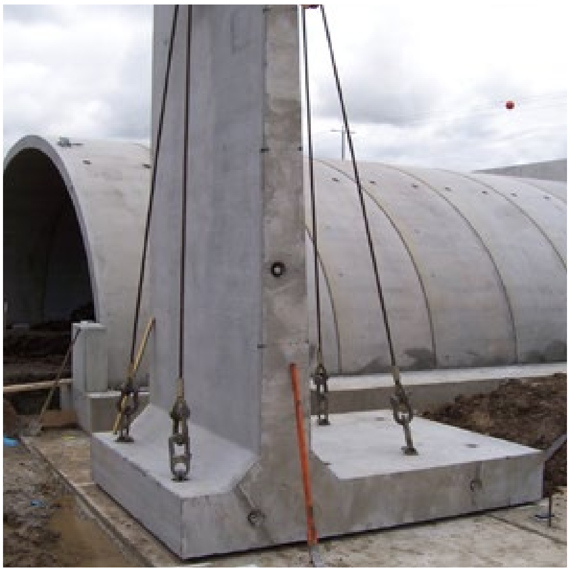


Table 10 – Light type wing walls dimensions and masses (see Figure 13)

Arch profile	Light type wing wall element	Standard height dimensions (mm)		Unit mass (t)
		C	D	
6210S	W10	3,000	2,725	6.9
6310S, 9300S, 12300S	W5 W6	4,000 2,795	2,825 1,570	8.4 6.4
9400S, 12400S	W1 W2 W3	5,000 3,795 2,540	3,825 2,570 1,315	9.7 7.9 5.9

Note:
Maximum width of light type wing walls is 2,500 mm.

- Heavy type wing walls:
  Designed to resist overturning and sliding without reliance on an in-situ footing. Typically they are placed on compacted gravel material 500 mm thick and the top surface levelled with a 50 mm thick blinding layer of 15 MPa concrete. The bearing pressure needs to be checked to ensure the foundation has adequate capacity. Typically a foundation capacity of 250 kPa is required to accommodate working loads. Dimensions of heavy type wing walls are given in Table 11. Note that the assessment of the strength and settlement potential of the foundation material and global stability is the responsibility of the client's geotechnical engineer.



Left:
Heavy type wing wall

Figure 14 – Heavy type wing wall dimensions

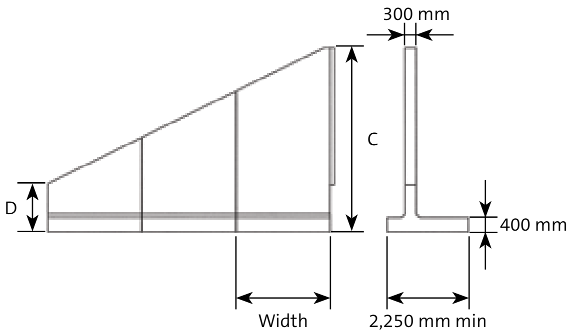


Table 11 – Heavy type wing walls dimensions and masses (see Figure 14)

Arch profile	Heavy type wing wall element	Standard height dimensions (mm)		Unit mass* (t)
		C	D	
9300S, 1200S	HL1	4,000	2,825	11.3
	HL2	2,795	1,570	9.6
9400S, 12400S	HM1	5,000	3,825	13.3
	HM2	3,795	2,570	11.5
	HM3	2,540	1,315	9.1

Notes:
- Maximum width of heavy type wing walls is 2,500 mm.
- *Unit mass based on 2,250 mm base.
- For wing wall heights greater than 5 m, contact your local Humes sales representative.

Wing wall angle options

Top:
120° wing wall

Bottom:
180° wing wall

Wing walls can be placed at 90°, 120° or 180° to the spandrel face. It is possible for a structure to have a combination of wing wall angles to suit the geometry of the stream bed.

180° wing walls run parallel to the spandrel wall and hence do not support the wall. To overcome this, the spandrel walls are restrained by tie rods spanning across the structure. This method of construction is also used when precast spandrels are used without precast wing walls.

Typically wing walls running at a skew angle to road alignment are not subject to roadway traffic loading. As a result standard wing wall designs do not consider roadway loadings.

Where wing walls are to run parallel with the roadway (180°) our engineers need to be advised so that roadway loads can be considered and the standard wing walls evaluated for the suitability of application.

For arches with spans greater than 12 m

Spandrel walls

Spandrel walls for arches with spans greater than 12 m are typically made up of a number of elements as shown in Figures 15-17 on the following page. The spandrel walls are placed adjacent to the end arches. Table 12 sets out the masses of the spandrel wall units and Figures 15-17 show the dimensions. All spandrels are supported by galvanised steel tie backs to the end arch and by the wing wall units.

Spandrel walls can be plain concrete or veneered using stones, bricks and other architectural finishes.

Wing walls

Wing walls for arches with spans greater than 12 m are designed to resist sliding and overturning without relying on an in-situ concrete footing. Typically they are placed on compacted gravel material 150 mm thick and the top surface levelled with a 50 mm thick blinding layer of 15 MPa concrete. The bearing capacity of the foundation needs to be assessed to ensure it is adequate for a 250 kPa working load.

Wing walls can be placed at either 90° or 120° to the spandrel face. Dimensions and masses of the wing walls are given in Table 13.

Table 12 – Spandrel wall masses

Arch profile	Spandrel wall unit mass (t)					
	S1	S2	S4	S5	S8	S9
15500T					3.2	10.8
18600T			5.8	11.6		
21700T	7.1	14.4				

= Not typically supplied.

Table 13 – Wing walls dimensions and masses (see Figures 15-17)

Arch profile	Wing wall type	Standard height dimensions (mm)						Unit mass (t)
		C	D	W	T1	T2	L	
21700T	W1	7,325	6,330	3,500	450	450	2,500	22.7
21700T	W2	6,278	5,223	3,000	450	450	2,500	20.9
21700T, 18600T	W3	5,170	4,115	2,500	400	355	2,500	14.7
21700T, 18600T	W4	4,063	3,008	2,000	400	355	2,500	11.5
21700T, 18600T	W5	2,955	1,900	1,500	400	250	2,500	7.6
18600T	W2a	6,245	5,223	3,000	450	450	2,500	20.0
15500T	HC1	5,000	3,825	2,250	400	300	2,580	13.5
15500T	HM2	3,795	2,570	2,250	400	300	2,580	11.5
15500T	HM3	2,540	1,315	2,250	400	300	2,580	9.1

Figure 15 – Spandrel and wing wall for 15500T profile

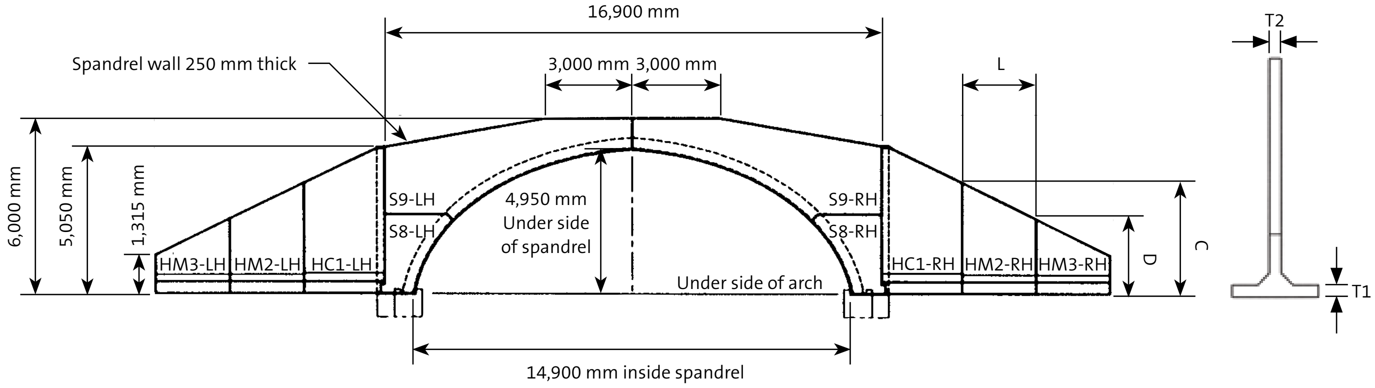


Figure 16 – Spandrel and wing wall for 18600T profile

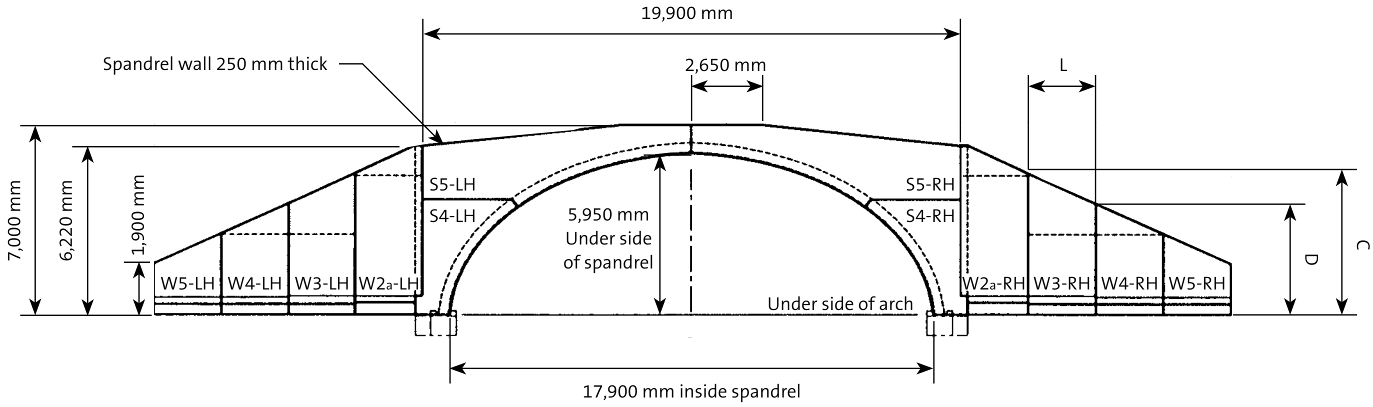
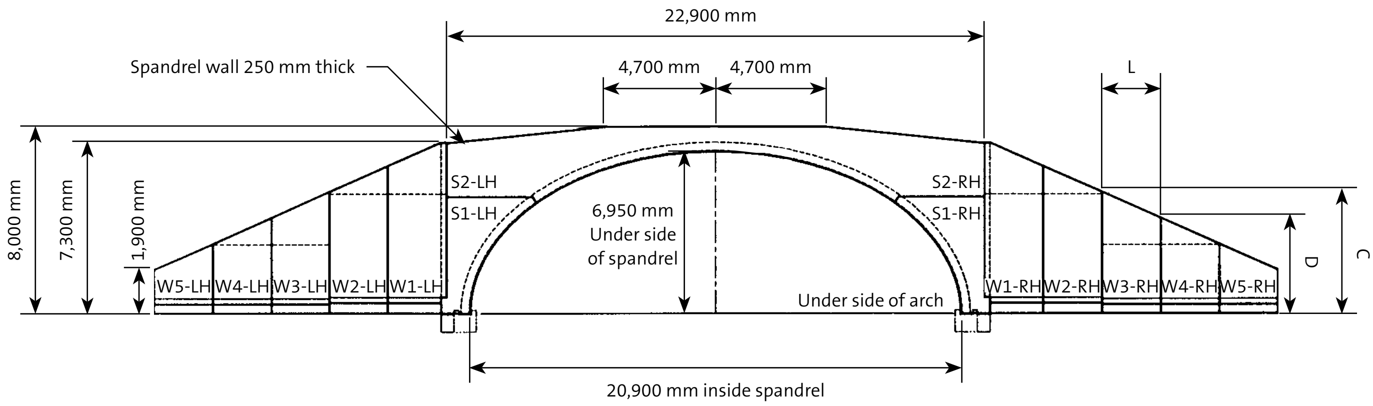


Figure 17 – Spandrel and wing wall for 21700T profile



Multi-cell installations

Double, triple or multiple cell installations can be constructed to cross large expanses of water, flood plains or low lying ground. It is possible to combine BEBO® arches with Classic arches in multiple installations.

The support of the centre spandrel walls in multiple installations is achieved by using galvanised steel tie rods connecting opposite end spandrels to each other. This is identical to the spandrel support recommended for 180° wing walls. Alternatively, tie bars raked back to the in-situ footing may be used.

Top:
Combination of Classic and BEBO® arches

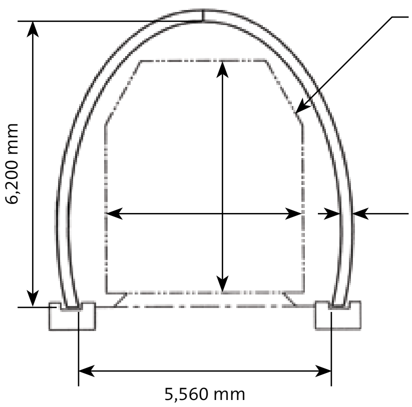
Bottom:
Multi-cell BEBO® structure

Special installations

Top:
Mitred BEBO® arches to accommodate a skewed application

Often customer requirements result in special installations. Humes can offer advice and provide practical solutions to the special needs of the customer. An example of a non-standard installation is shown in Figure 19.

Figure 19 – Concept for 3-pin arch railway tunnel



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