Enabel

Design Tables and Standard Drawings

Stone Arch Bridges

Belgian development agency

enabel.be

Historical Empirical Equations to the initial arch thickness Design

Rankine advocated that the barrel thickness, d, for a segmental arch of radius R should be:

$d = 0.19\sqrt{R}$ (single span)

$d = 0.226\sqrt{R}$ (multi-span)

Heinzerling suggested:

$d = 0.4 + 0.025R$ (dressed stone)

$d = 0.4 + 0.028R$ (brickwork)

$d = 0.4 + 0.032R$ (random rubble stone)

Trautwine suggested (for span $= L$):

$d = 1.0[0.061 + 0.138\sqrt{(R + 0.5L)}]$ (first class cut stone)

$d = 1.13[0.061 + 0.138\sqrt{(R + 0.5L)}]$ (second class cut stone)

$d = 1.13[0.061 + 0.138\sqrt{(R + 0.5L)}]$ (brickwork)

Rennie and Stephenson related arch barrel thickness to span and radius, respectively.

$d = span/30 \rightarrow span/33$ (Rennie)

$d = R/26 \rightarrow R/30$ (Stephenson)

Historically, the addition of haunches to the arch ring at the abutments has been considered good practice (and in keeping with the usual assumption for two-hinged arch analysis that the second moment of area of the barrel varies as the secant of the tangent to the centreline).

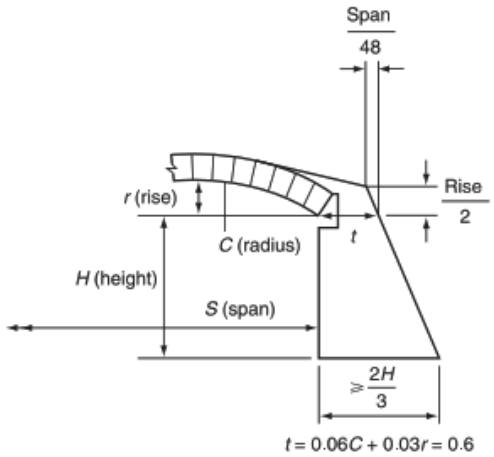
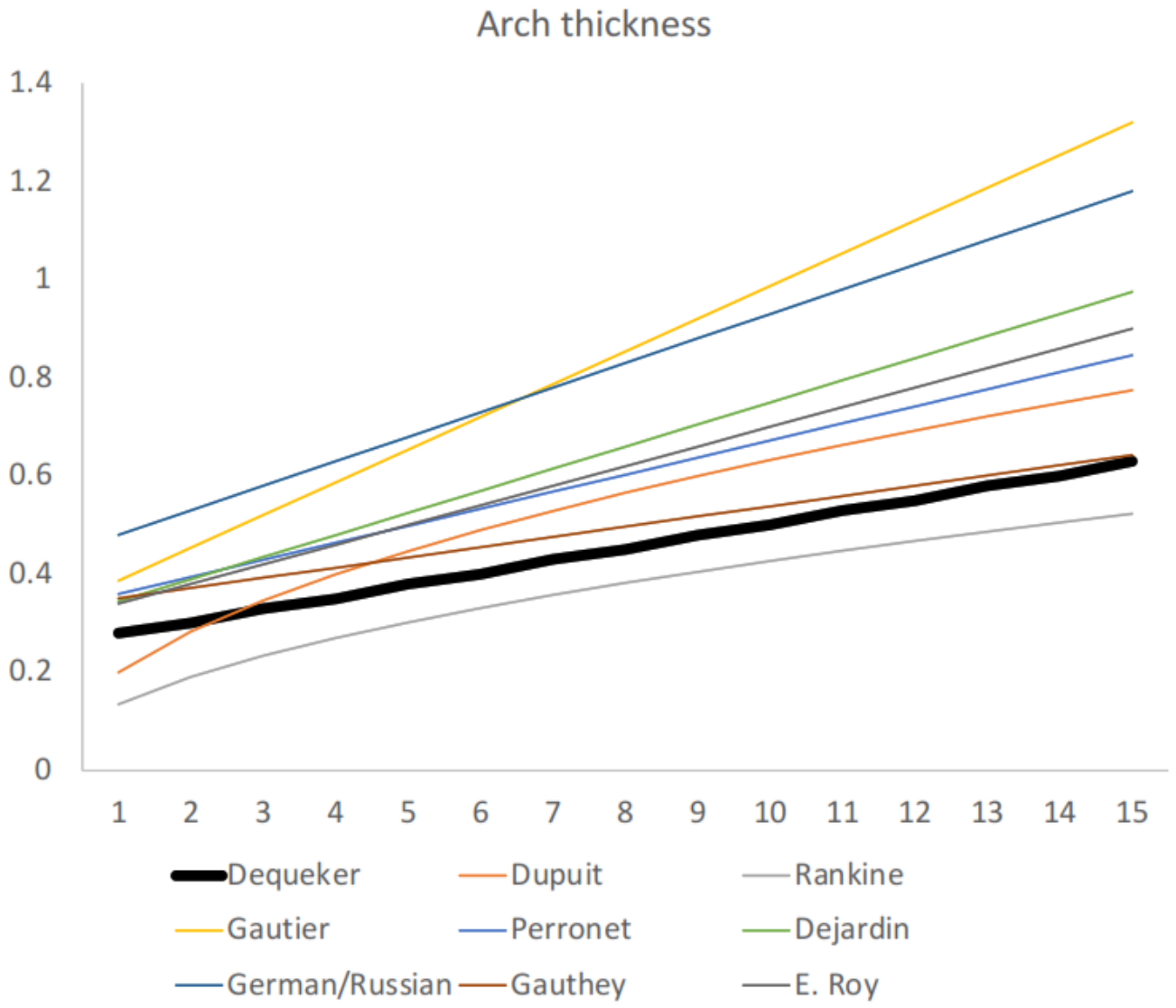


Figure 41 Empirical rule for abutment sizes

The suggested ratio of springing to crown thickness varied from 1.2 to 2. In stonework and concrete this is relatively easy to achieve but in brickwork the haunching is usually concrete and there is a reliance upon the bond between it and the brickwork.

Abutment sizes for a 'gravity' solution (as opposed to a reinforced concrete or masonry solution) have been suggested by Baker (1909) where the abutment thickness, t, in metres is given by:

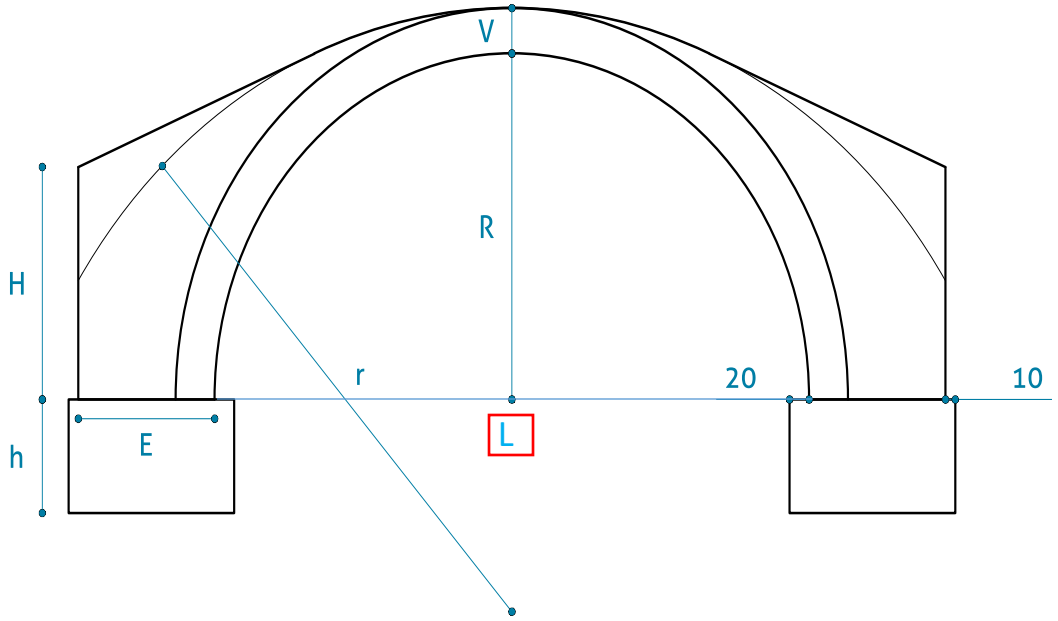
$t = 0.012(5L + 4H) + 0.3$


Arch thickness
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Dequeker
Dupuit
Rankine
Gautier
Perronet
Dejardin
German/Russian
Gauthey
E. Roy

Span L

Distance of the opening of the arch from the Left bottom part of the intrados to the right one

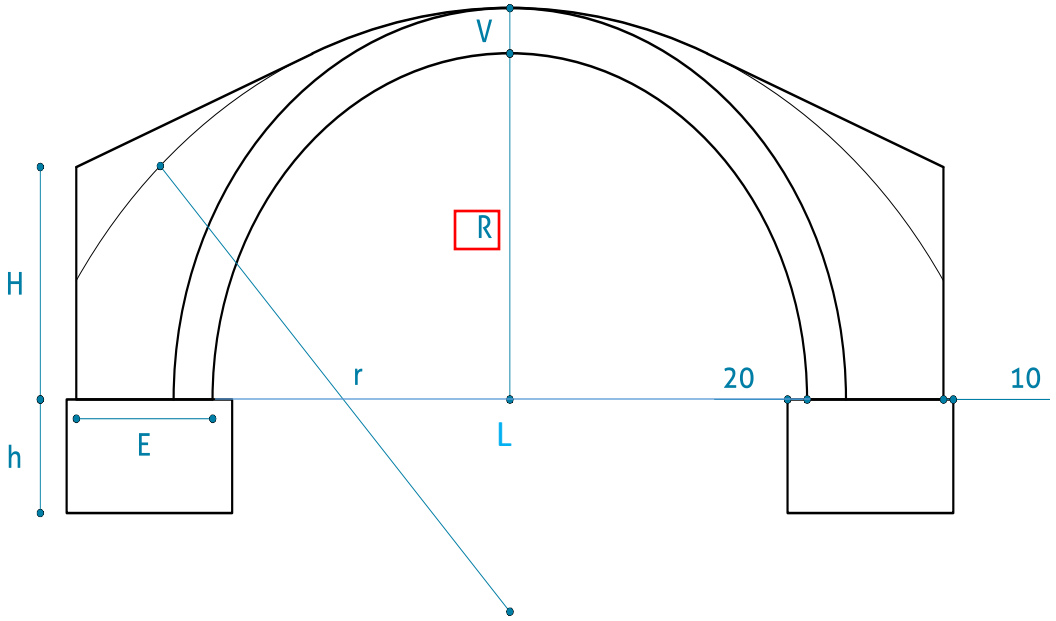
Roman arch									
Span	Radius intrados	Thickness keystone	Radius extrados	Thickness abutments	Thickness pier	Height abutments	Height foundations	Unitary volume	Bags of cement
L	R	V	r	E	E'	H	h	m³/m	bags/m
1	0.50	0.28	4.00	0.44	0.56	0.63	0.50	2.32	5
2	1.00	0.30	3.38	0.63	0.61	0.91	0.60	3.79	8
3	1.50	0.33	3.70	0.83	0.80	1.19	0.70	5.40	11
4	2.00	0.35	4.19	1.02	0.97	1.48	0.80	7.16	14
5	2.50	0.38	4.74	1.21	1.14	1.76	0.90	9.07	18
6	3.00	0.40	5.32	1.40	1.30	2.05	1.00	11.13	22
7	3.50	0.43	5.91	1.59	1.46	2.33	1.10	13.33	26
8	4.00	0.45	6.51	1.78	1.61	2.61	1.20	15.69	30
9	4.50	0.48	7.11	1.98	1.77	2.90	1.30	18.20	35
10	5.00	0.50	7.72	2.17	1.91	3.18	1.40	20.85	40
11	5.50	0.53	8.33	2.36	2.05	3.47	1.50	23.66	45
12	6.00	0.55	8.94	2.55	2.18	3.75	1.60	26.61	51
13	6.50	0.58	9.56	2.74	2.31	4.04	1.70	29.71	57
14	7.00	0.60	10.17	2.93	2.44	4.32	1.80	32.97	63
15	7.50	0.63	10.79	3.13	2.57	4.60	1.90	36.37	70



Radius Intrados

The Radii of the inner part of the Arch.

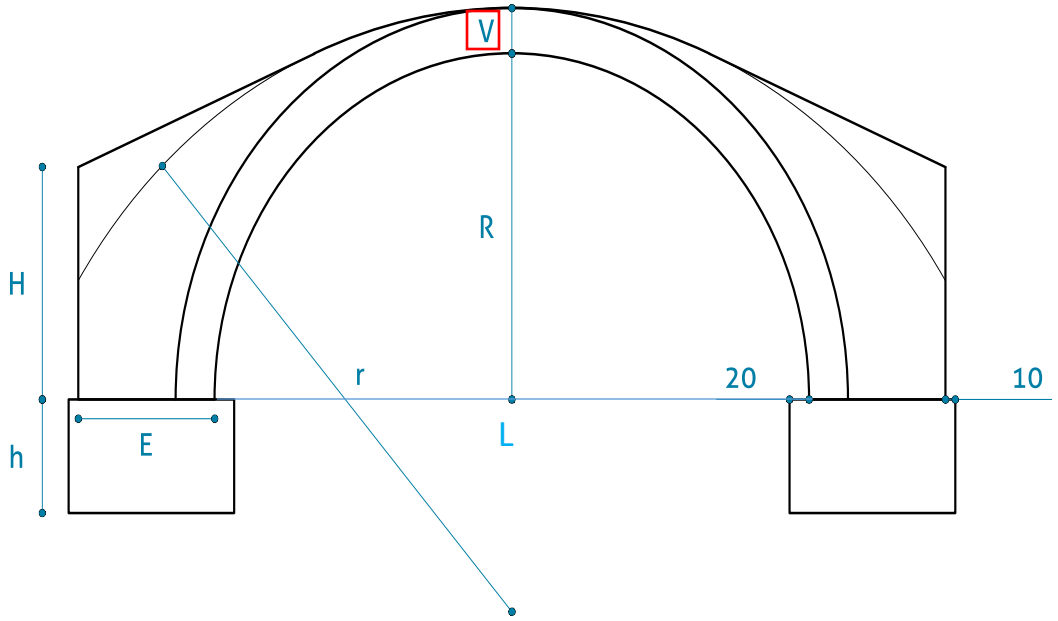
Roman arch									
Span	Radius intrados	Thickness keystone	Radius extrados	Thickness abutments	Thickness pier	Height abutments	Height foundations	Unitary volume	Bags of cement
L	R	V	r	E	E'	H	h	m³/m	bags/m
1	0.50	0.28	4.00	0.44	0.56	0.63	0.50	2.32	5
2	1.00	0.30	3.38	0.63	0.61	0.91	0.60	3.79	8
3	1.50	0.33	3.70	0.83	0.80	1.19	0.70	5.40	11
4	2.00	0.35	4.19	1.02	0.97	1.48	0.80	7.16	14
5	2.50	0.38	4.74	1.21	1.14	1.76	0.90	9.07	18
6	3.00	0.40	5.32	1.40	1.30	2.05	1.00	11.13	22
7	3.50	0.43	5.91	1.59	1.46	2.33	1.10	13.33	26
8	4.00	0.45	6.51	1.78	1.61	2.61	1.20	15.69	30
9	4.50	0.48	7.11	1.98	1.77	2.90	1.30	18.20	35
10	5.00	0.50	7.72	2.17	1.91	3.18	1.40	20.85	40
11	5.50	0.53	8.33	2.36	2.05	3.47	1.50	23.66	45
12	6.00	0.55	8.94	2.55	2.18	3.75	1.60	26.61	51
13	6.50	0.58	9.56	2.74	2.31	4.04	1.70	29.71	57
14	7.00	0.60	10.17	2.93	2.44	4.32	1.80	32.97	63
15	7.50	0.63	10.79	3.13	2.57	4.60	1.90	36.37	70



Thickness Keystone V

The distance from the intrados to the extrados of the keystone of the Arch.

Roman arch									
Span	Radius intrados	Thickness keystone	Radius extrados	Thickness abutments	Thickness pier	Height abutments	Height foundations	Unitary volume	Bags of cement
L	R	V	r	E	E'	H	h	m³/m	bags/m
1	0.50	0.28	4.00	0.44	0.56	0.63	0.50	2.32	5
2	1.00	0.30	3.38	0.63	0.61	0.91	0.60	3.79	8
3	1.50	0.33	3.70	0.83	0.80	1.19	0.70	5.40	11
4	2.00	0.35	4.19	1.02	0.97	1.48	0.80	7.16	14
5	2.50	0.38	4.74	1.21	1.14	1.76	0.90	9.07	18
6	3.00	0.40	5.32	1.40	1.30	2.05	1.00	11.13	22
7	3.50	0.43	5.91	1.59	1.46	2.33	1.10	13.33	26
8	4.00	0.45	6.51	1.78	1.61	2.61	1.20	15.69	30
9	4.50	0.48	7.11	1.98	1.77	2.90	1.30	18.20	35
10	5.00	0.50	7.72	2.17	1.91	3.18	1.40	20.85	40
11	5.50	0.53	8.33	2.36	2.05	3.47	1.50	23.66	45
12	6.00	0.55	8.94	2.55	2.18	3.75	1.60	26.61	51
13	6.50	0.58	9.56	2.74	2.31	4.04	1.70	29.71	57
14	7.00	0.60	10.17	2.93	2.44	4.32	1.80	32.97	63
15	7.50	0.63	10.79	3.13	2.57	4.60	1.90	36.37	70

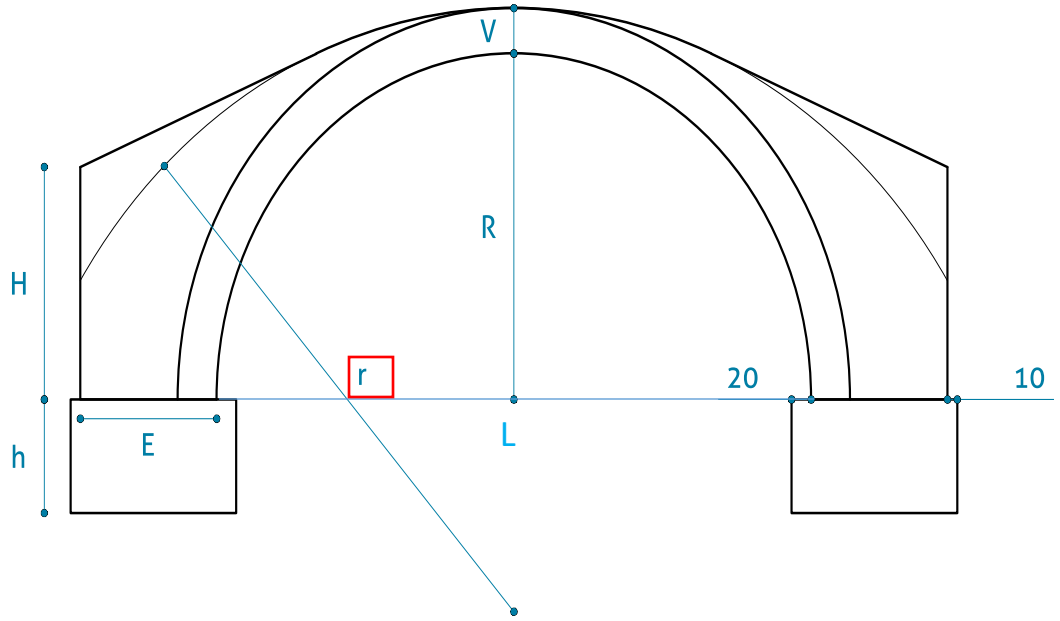


Thickness Keystone V

Radius Extrados

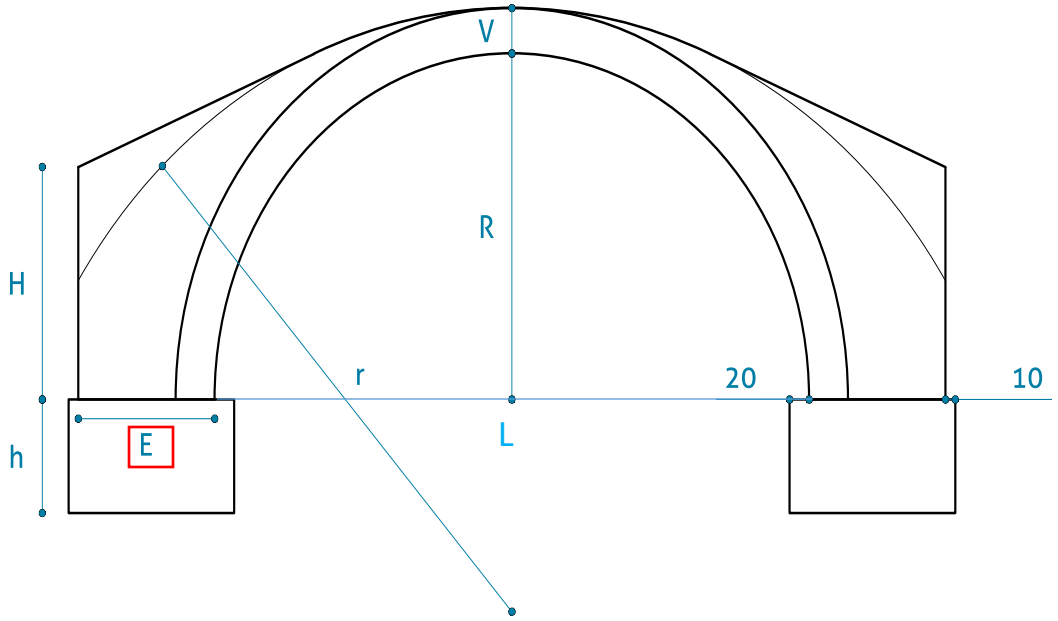
Radius of the larger outer curve of the Arch bridge,

Roman arch									
Span	Radius intrados	Thickness keystone	Radius extrados	Thickness abutments	Thickness pier	Height abutments	Height foundations	Unitary volume	Bags of cement
L	R	V	r	E	E'	H	h	m³/m	bags/m
1	0.50	0.28	4.00	0.44	0.56	0.63	0.50	2.32	5
2	1.00	0.30	3.38	0.63	0.61	0.91	0.60	3.79	8
3	1.50	0.33	3.70	0.83	0.80	1.19	0.70	5.40	11
4	2.00	0.35	4.19	1.02	0.97	1.48	0.80	7.16	14
5	2.50	0.38	4.74	1.21	1.14	1.76	0.90	9.07	18
6	3.00	0.40	5.32	1.40	1.30	2.05	1.00	11.13	22
7	3.50	0.43	5.91	1.59	1.46	2.33	1.10	13.33	26
8	4.00	0.45	6.51	1.78	1.61	2.61	1.20	15.69	30
9	4.50	0.48	7.11	1.98	1.77	2.90	1.30	18.20	35
10	5.00	0.50	7.72	2.17	1.91	3.18	1.40	20.85	40
11	5.50	0.53	8.33	2.36	2.05	3.47	1.50	23.66	45
12	6.00	0.55	8.94	2.55	2.18	3.75	1.60	26.61	51
13	6.50	0.58	9.56	2.74	2.31	4.04	1.70	29.71	57
14	7.00	0.60	10.17	2.93	2.44	4.32	1.80	32.97	63
15	7.50	0.63	10.79	3.13	2.57	4.60	1.90	36.37	70



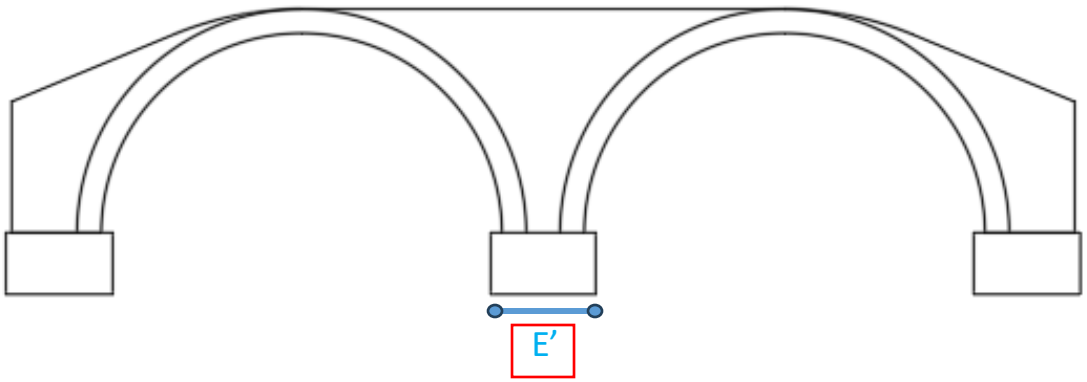
Thickness of the Shoulders/Backings

Roman arch									
Span	Radius intrados	Thickness keystone	Radius extrados	Thickness abutments	Thickness pier	Height abutments	Height foundations	Unitary volume	Bags of cement
L	R	V	r	E	E'	H	h	m³/m	bags/m
1	0.50	0.28	4.00	0.44	0.56	0.63	0.50	2.32	5
2	1.00	0.30	3.38	0.63	0.61	0.91	0.60	3.79	8
3	1.50	0.33	3.70	0.83	0.80	1.19	0.70	5.40	11
4	2.00	0.35	4.19	1.02	0.97	1.48	0.80	7.16	14
5	2.50	0.38	4.74	1.21	1.14	1.76	0.90	9.07	18
6	3.00	0.40	5.32	1.40	1.30	2.05	1.00	11.13	22
7	3.50	0.43	5.91	1.59	1.46	2.33	1.10	13.33	26
8	4.00	0.45	6.51	1.78	1.61	2.61	1.20	15.69	30
9	4.50	0.48	7.11	1.98	1.77	2.90	1.30	18.20	35
10	5.00	0.50	7.72	2.17	1.91	3.18	1.40	20.85	40
11	5.50	0.53	8.33	2.36	2.05	3.47	1.50	23.66	45
12	6.00	0.55	8.94	2.55	2.18	3.75	1.60	26.61	51
13	6.50	0.58	9.56	2.74	2.31	4.04	1.70	29.71	57
14	7.00	0.60	10.17	2.93	2.44	4.32	1.80	32.97	63
15	7.50	0.63	10.79	3.13	2.57	4.60	1.90	36.37	70



Thickness of the Piers

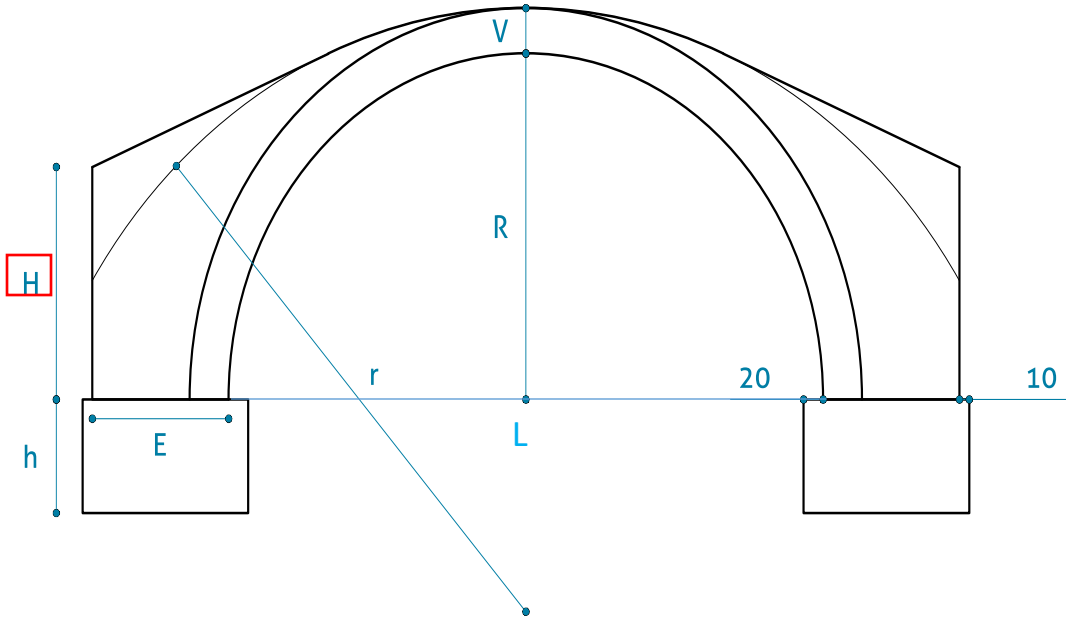
Roman arch									
Span	Radius intrados	Thickness keystone	Radius extrados	Thickness abutments	Thickness pier	Height abutments	Height foundations	Unitary volume	Bags of cement
L	R	V	r	E	E'	H	h	m³/m	bags/m
1	0.50	0.28	4.00	0.44	0.56	0.63	0.50	2.32	5
2	1.00	0.30	3.38	0.63	0.61	0.91	0.60	3.79	8
3	1.50	0.33	3.70	0.83	0.80	1.19	0.70	5.40	11
4	2.00	0.35	4.19	1.02	0.97	1.48	0.80	7.16	14
5	2.50	0.38	4.74	1.21	1.14	1.76	0.90	9.07	18
6	3.00	0.40	5.32	1.40	1.30	2.05	1.00	11.13	22
7	3.50	0.43	5.91	1.59	1.46	2.33	1.10	13.33	26
8	4.00	0.45	6.51	1.78	1.61	2.61	1.20	15.69	30
9	4.50	0.48	7.11	1.98	1.77	2.90	1.30	18.20	35
10	5.00	0.50	7.72	2.17	1.91	3.18	1.40	20.85	40
11	5.50	0.53	8.33	2.36	2.05	3.47	1.50	23.66	45
12	6.00	0.55	8.94	2.55	2.18	3.75	1.60	26.61	51
13	6.50	0.58	9.56	2.74	2.31	4.04	1.70	29.71	57
14	7.00	0.60	10.17	2.93	2.44	4.32	1.80	32.97	63
15	7.50	0.63	10.79	3.13	2.57	4.60	1.90	36.37	70



Height of the Shoulders

For structural purpose it should be loaded.

Roman arch									
Span	Radius intrados	Thickness keystone	Radius extrados	Thickness abutments	Thickness pier	Height abutments	Height foundations	Unitary volume	Bags of cement
L	R	V	r	E	E'	H	h	m³/m	bags/m
1	0.50	0.28	4.00	0.44	0.56	0.63	0.50	2.32	5
2	1.00	0.30	3.38	0.63	0.61	0.91	0.60	3.79	8
3	1.50	0.33	3.70	0.83	0.80	1.19	0.70	5.40	11
4	2.00	0.35	4.19	1.02	0.97	1.48	0.80	7.16	14
5	2.50	0.38	4.74	1.21	1.14	1.76	0.90	9.07	18
6	3.00	0.40	5.32	1.40	1.30	2.05	1.00	11.13	22
7	3.50	0.43	5.91	1.59	1.46	2.33	1.10	13.33	26
8	4.00	0.45	6.51	1.78	1.61	2.61	1.20	15.69	30
9	4.50	0.48	7.11	1.98	1.77	2.90	1.30	18.20	35
10	5.00	0.50	7.72	2.17	1.91	3.18	1.40	20.85	40
11	5.50	0.53	8.33	2.36	2.05	3.47	1.50	23.66	45
12	6.00	0.55	8.94	2.55	2.18	3.75	1.60	26.61	51
13	6.50	0.58	9.56	2.74	2.31	4.04	1.70	29.71	57
14	7.00	0.60	10.17	2.93	2.44	4.32	1.80	32.97	63
15	7.50	0.63	10.79	3.13	2.57	4.60	1.90	36.37	70

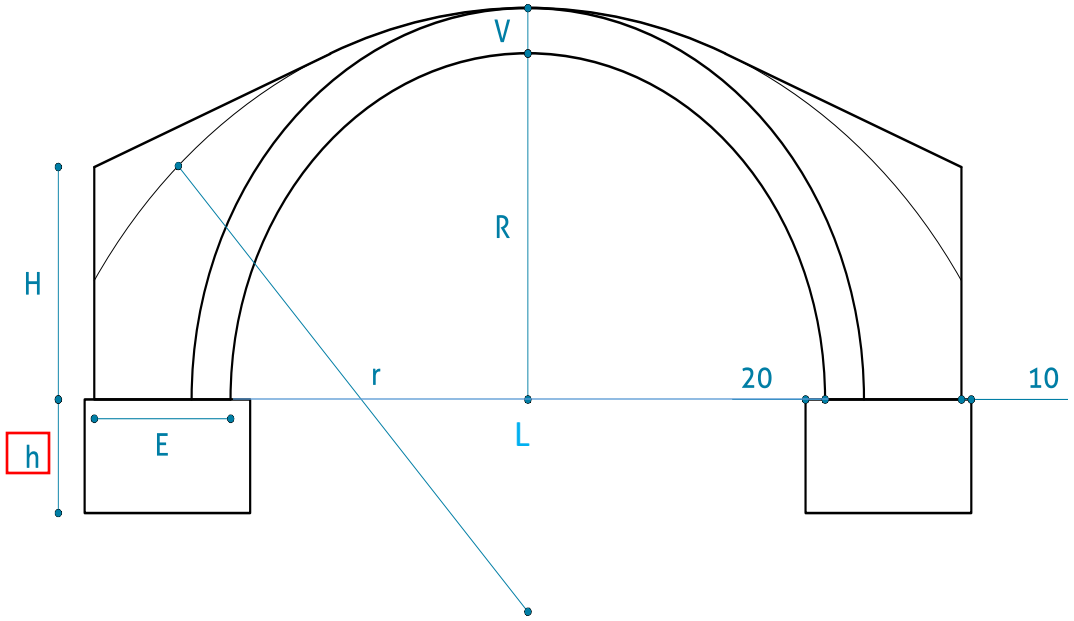


Height of the shoulders

To the
Foundation level

Height of the abutments

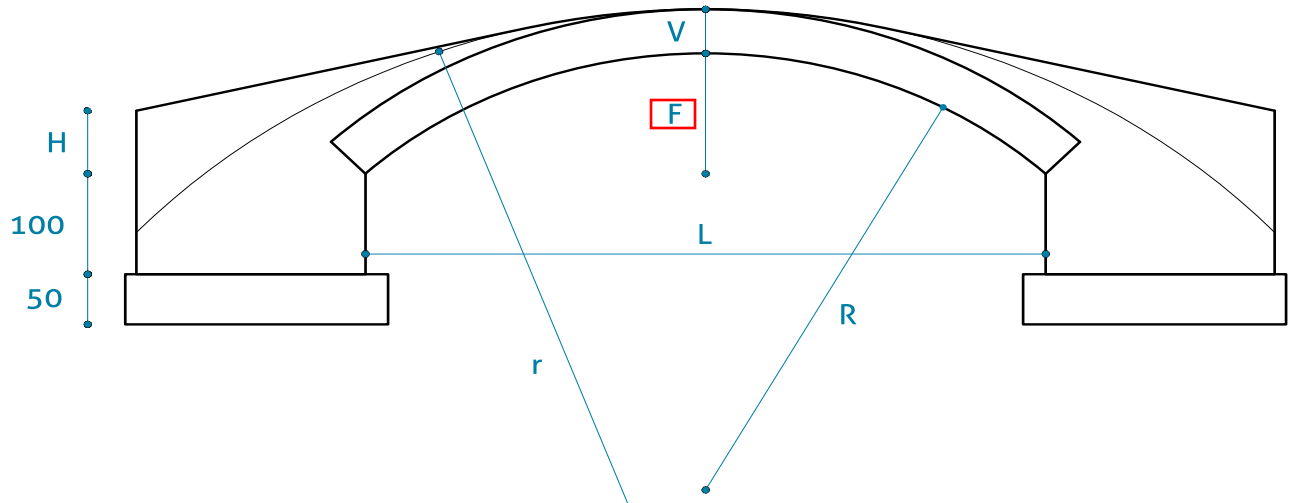
Roman arch									
Span	Radius intrados	Thickness keystone	Radius extrados	Thickness abutments	Thickness pier	Height abutments	Height foundations	Unitary volume	Bags of cement
L	R	V	r	E	E'	H	h	m³/m	bags/m
1	0.50	0.28	4.00	0.44	0.56	0.63	0.50	2.32	5
2	1.00	0.30	3.38	0.63	0.61	0.91	0.60	3.79	8
3	1.50	0.33	3.70	0.83	0.80	1.19	0.70	5.40	11
4	2.00	0.35	4.19	1.02	0.97	1.48	0.80	7.16	14
5	2.50	0.38	4.74	1.21	1.14	1.76	0.90	9.07	18
6	3.00	0.40	5.32	1.40	1.30	2.05	1.00	11.13	22
7	3.50	0.43	5.91	1.59	1.46	2.33	1.10	13.33	26
8	4.00	0.45	6.51	1.78	1.61	2.61	1.20	15.69	30
9	4.50	0.48	7.11	1.98	1.77	2.90	1.30	18.20	35
10	5.00	0.50	7.72	2.17	1.91	3.18	1.40	20.85	40
11	5.50	0.53	8.33	2.36	2.05	3.47	1.50	23.66	45
12	6.00	0.55	8.94	2.55	2.18	3.75	1.60	26.61	51
13	6.50	0.58	9.56	2.74	2.31	4.04	1.70	29.71	57
14	7.00	0.60	10.17	2.93	2.44	4.32	1.80	32.97	63
15	7.50	0.63	10.79	3.13	2.57	4.60	1.90	36.37	70



For segmental

Arch Height

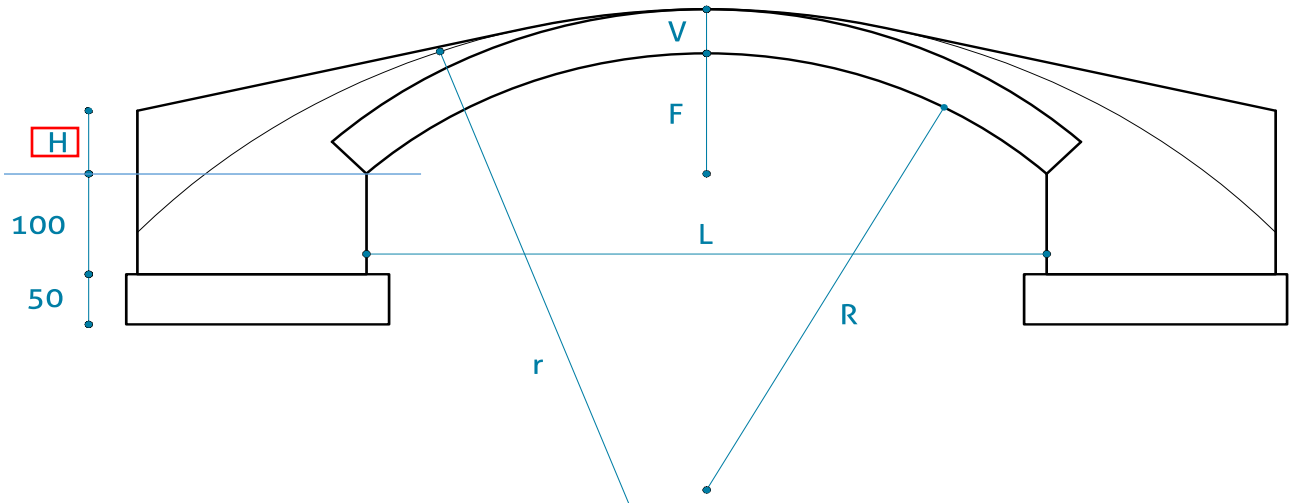
Segmental arch									
Span	Arch height	Radius intrados	Thickness keystone	Radius extrados	Thickness abutments	Thickness pier	Height abutments	Unitary volume	Bags of cement
L	F	R	V	r	E	E'	H	m³/m	bags/m
1	0.2	0.72	0.28	3.37	0.64	0.63	0.38	2.77	6
2	0.4	1.45	0.31	3.59	0.94	0.92	0.43	4.54	9
3	0.6	2.17	0.34	4.29	1.23	1.19	0.48	6.36	13
4	0.8	2.90	0.38	5.09	1.50	1.43	0.53	8.28	16
5	1.0	3.62	0.41	5.93	1.76	1.65	0.58	10.33	20
6	1.2	4.35	0.44	6.78	2.02	1.87	0.63	12.50	24
7	1.4	5.07	0.47	7.65	2.28	2.09	0.67	14.80	29
8	1.6	5.80	0.51	8.52	2.54	2.30	0.72	17.25	33
9	1.8	6.52	0.54	9.39	2.79	2.49	0.77	19.83	38
10	2.0	7.25	0.57	10.26	3.05	2.68	0.81	22.55	43
11	2.2	7.97	0.61	11.14	3.30	2.86	0.86	25.41	49
12	2.4	8.70	0.64	12.02	3.56	3.05	0.91	28.42	54
13	2.6	9.42	0.67	12.90	3.81	3.22	0.95	31.57	60
14	2.8	10.15	0.70	13.78	4.06	3.38	1.00	34.86	67
15	3.0	10.87	0.74	14.66	4.32	3.54	1.04	38.29	73
16	3.2	11.60	0.77	15.54	4.57	3.69	1.09	41.86	80
17	3.4	12.32	0.80	16.42	4.82	3.84	1.18	45.65	87
18	3.6	13.05	0.83	17.30	5.08	3.98	1.18	49.43	94
19	3.8	13.77	0.87	18.19	5.33	4.11	1.23	53.44	102
20	4.0	14.50	0.90	19.07	5.58	4.24	1.28	57.58	110



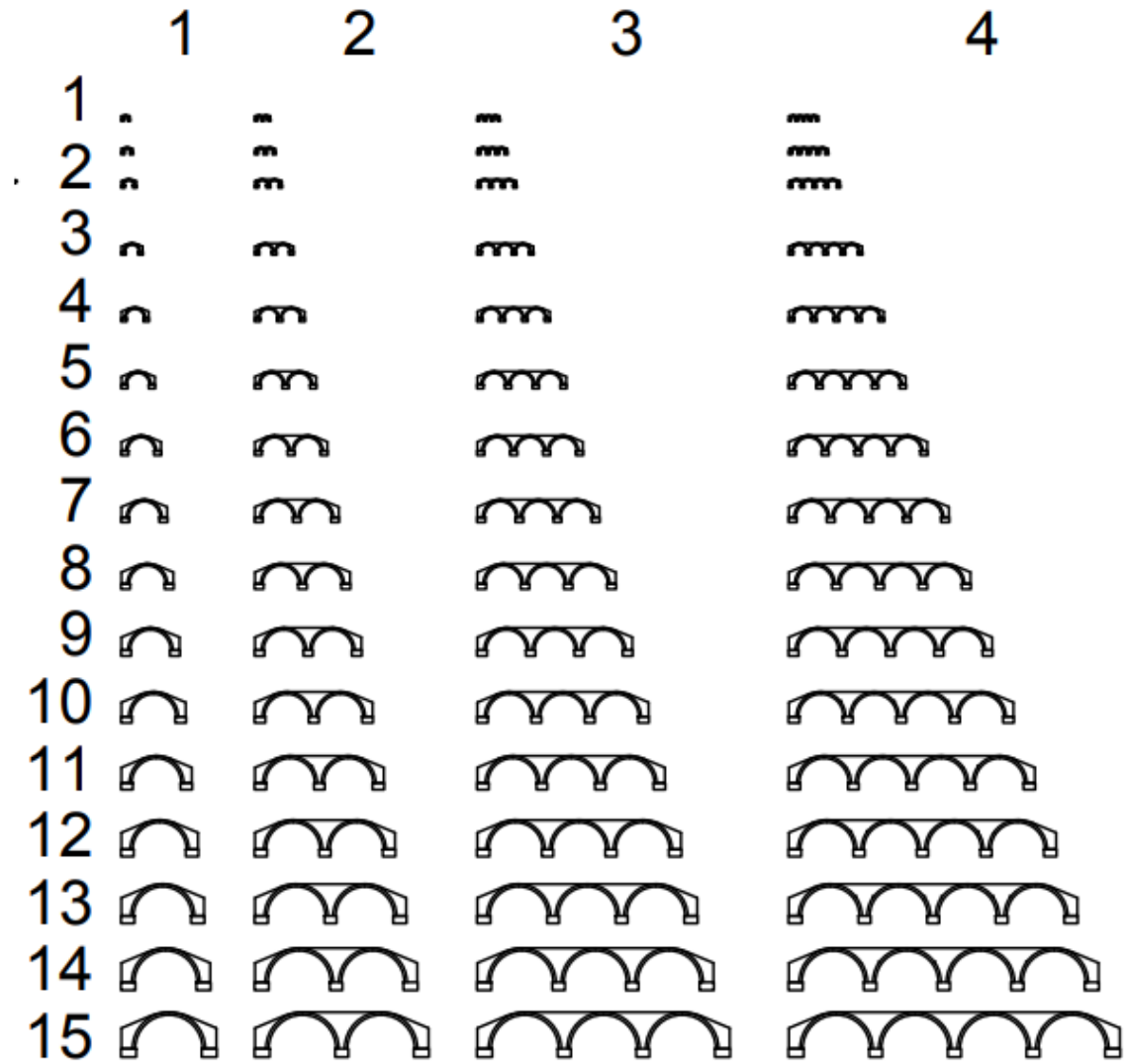
Arch Height

Shoulder/Backing Height

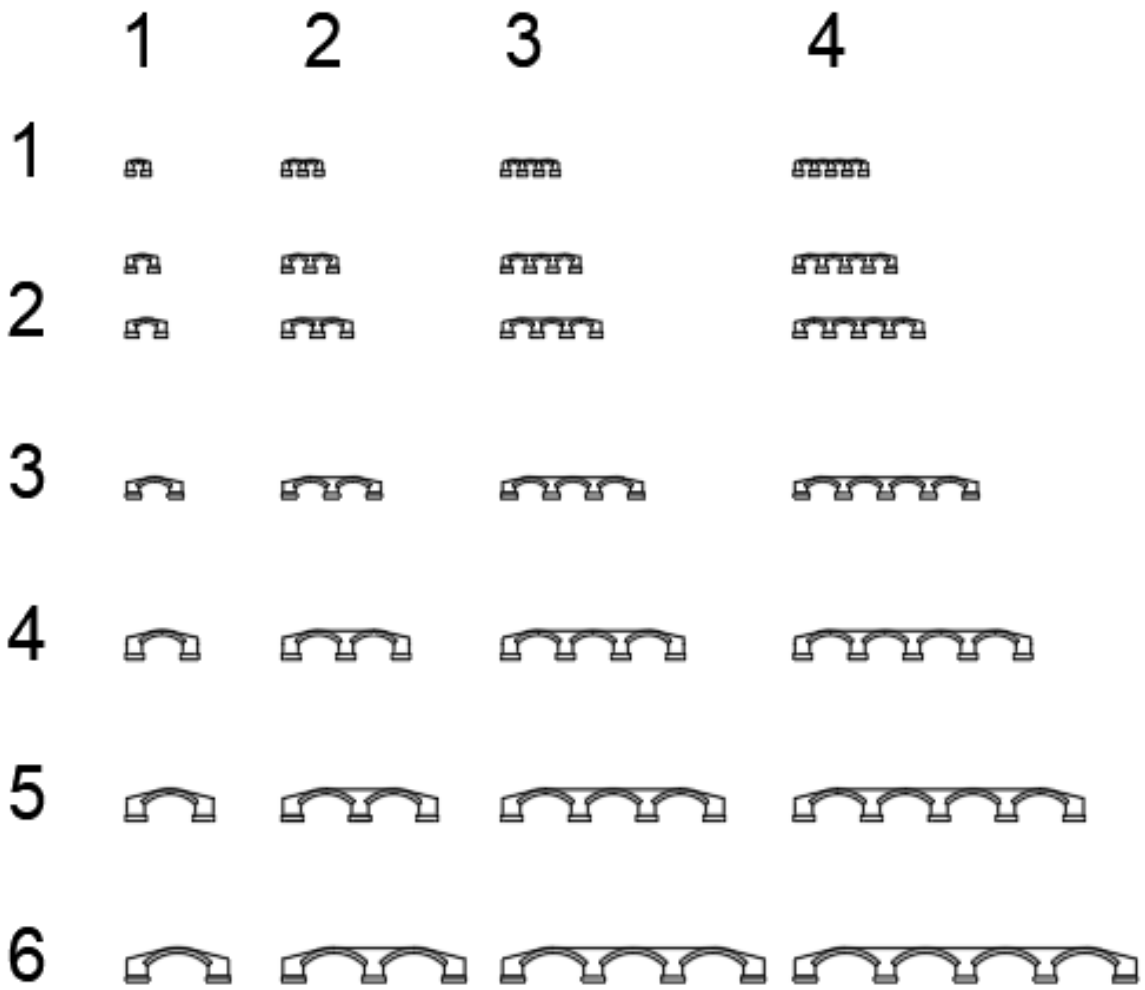
Segmental arch									
Span	Arch height	Radius intrados	Thickness keystone	Radius extrados	Thickness abutments	Thickness pier	Height abutments	Unitary volume	Bags of cement
L	F	R	V	r	E	E'	H	m³/m	bags/m
1	0.2	0.72	0.28	3.37	0.64	0.63	0.38	2.77	6
2	0.4	1.45	0.31	3.59	0.94	0.92	0.43	4.54	9
3	0.6	2.17	0.34	4.29	1.23	1.19	0.48	6.36	13
4	0.8	2.90	0.38	5.09	1.50	1.43	0.53	8.28	16
5	1.0	3.62	0.41	5.93	1.76	1.65	0.58	10.33	20
6	1.2	4.35	0.44	6.78	2.02	1.87	0.63	12.50	24
7	1.4	5.07	0.47	7.65	2.28	2.09	0.67	14.80	29
8	1.6	5.80	0.51	8.52	2.54	2.30	0.72	17.25	33
9	1.8	6.52	0.54	9.39	2.79	2.49	0.77	19.83	38
10	2.0	7.25	0.57	10.26	3.05	2.68	0.81	22.55	43
11	2.2	7.97	0.61	11.14	3.30	2.86	0.86	25.41	49
12	2.4	8.70	0.64	12.02	3.56	3.05	0.91	28.42	54
13	2.6	9.42	0.67	12.90	3.81	3.22	0.95	31.57	60
14	2.8	10.15	0.70	13.78	4.06	3.38	1.00	34.86	67
15	3.0	10.87	0.74	14.66	4.32	3.54	1.04	38.29	73
16	3.2	11.60	0.77	15.54	4.57	3.69	1.09	41.86	80
17	3.4	12.32	0.80	16.42	4.82	3.84	1.18	45.65	87
18	3.6	13.05	0.83	17.30	5.08	3.98	1.18	49.43	94
19	3.8	13.77	0.87	18.19	5.33	4.11	1.23	53.44	102
20	4.0	14.50	0.90	19.07	5.58	4.24	1.28	57.58	110



Segmental Arch Standard Drawings

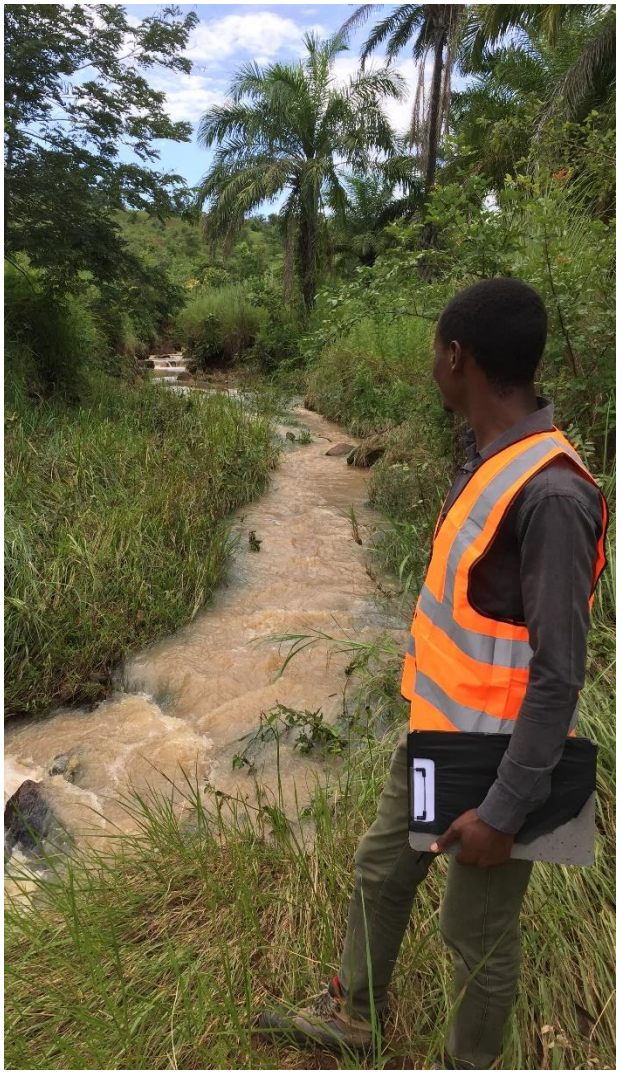


Semental Arch Standard Drawings

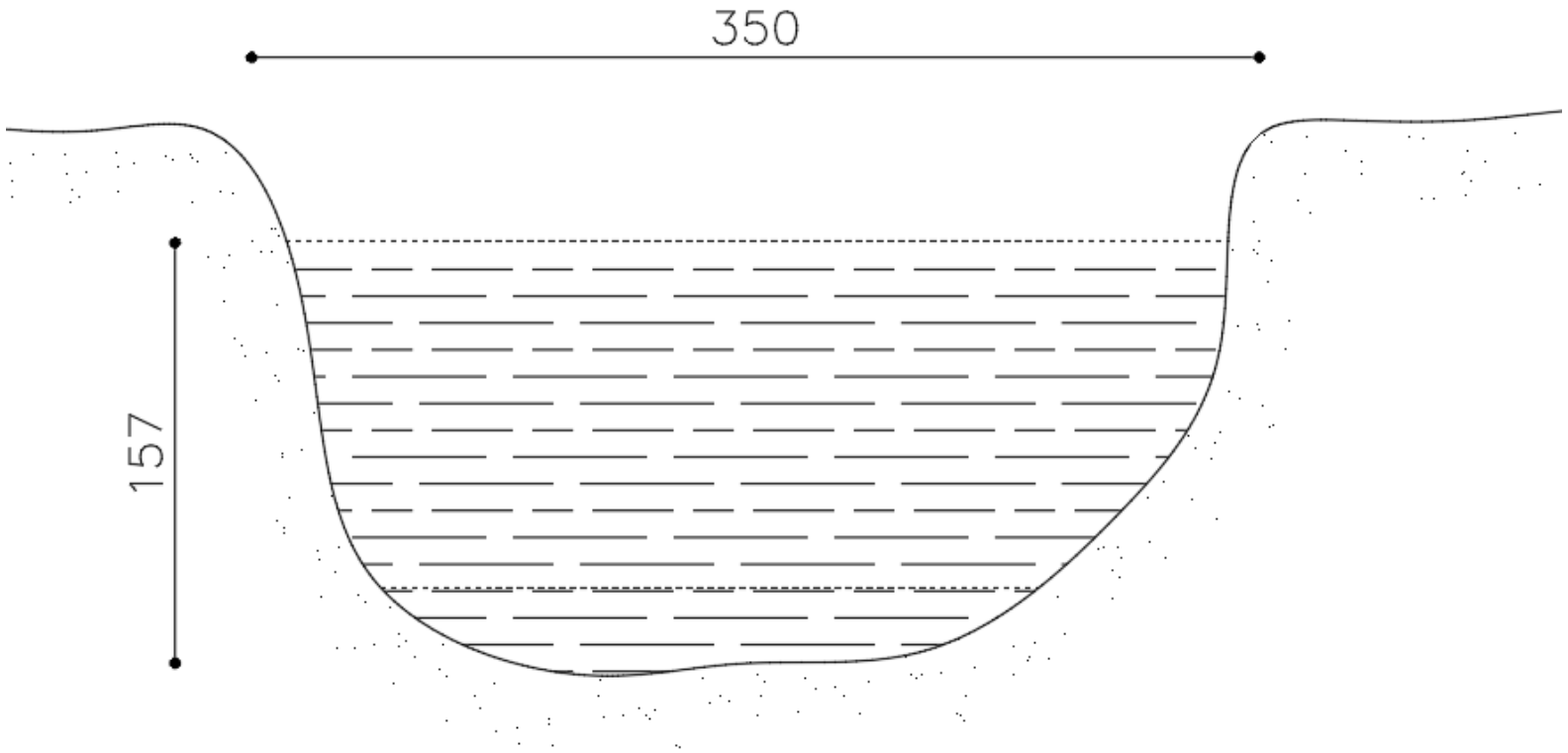


Design Consideration, Dimensioning

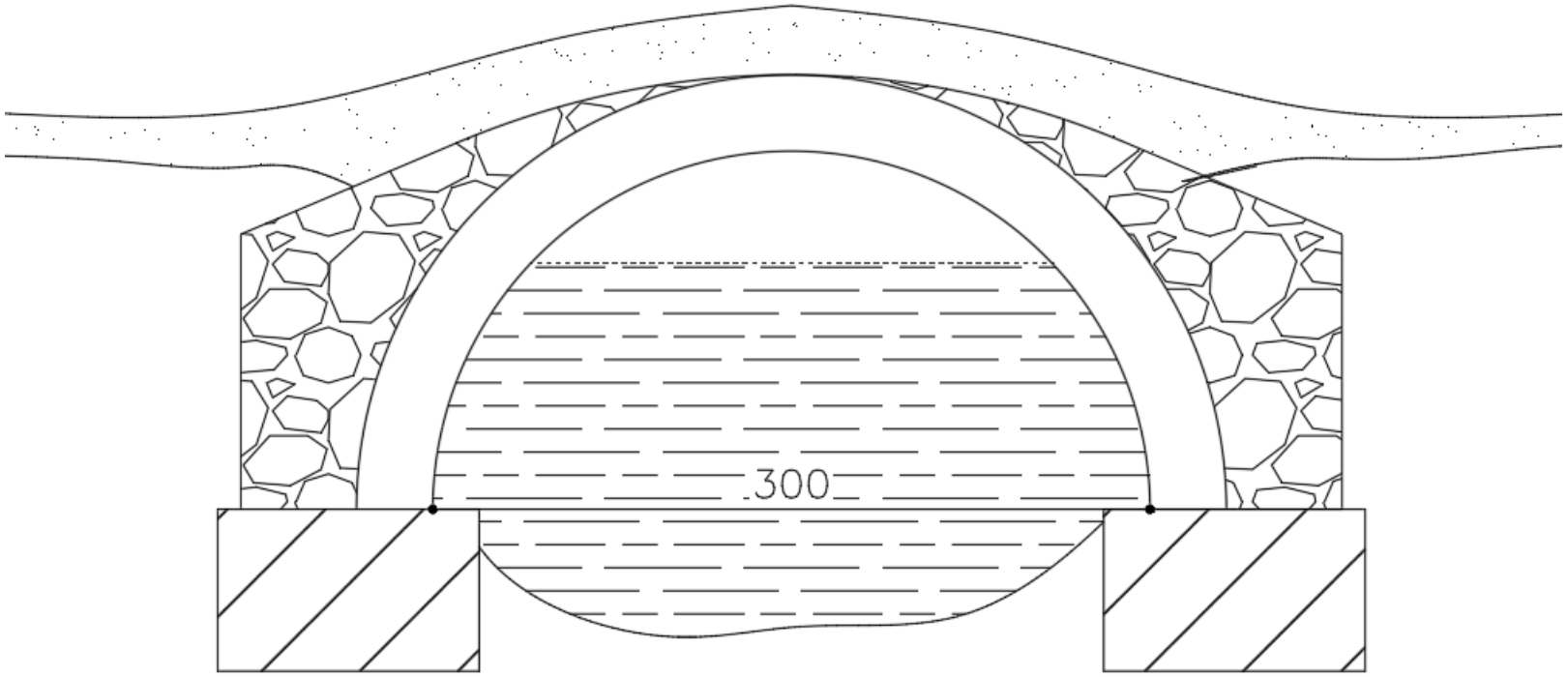
River bed and location



River Profile



Placing a reasonable Arch with respect to typology.



Extracting the Dimensions of the Bridge From the Table

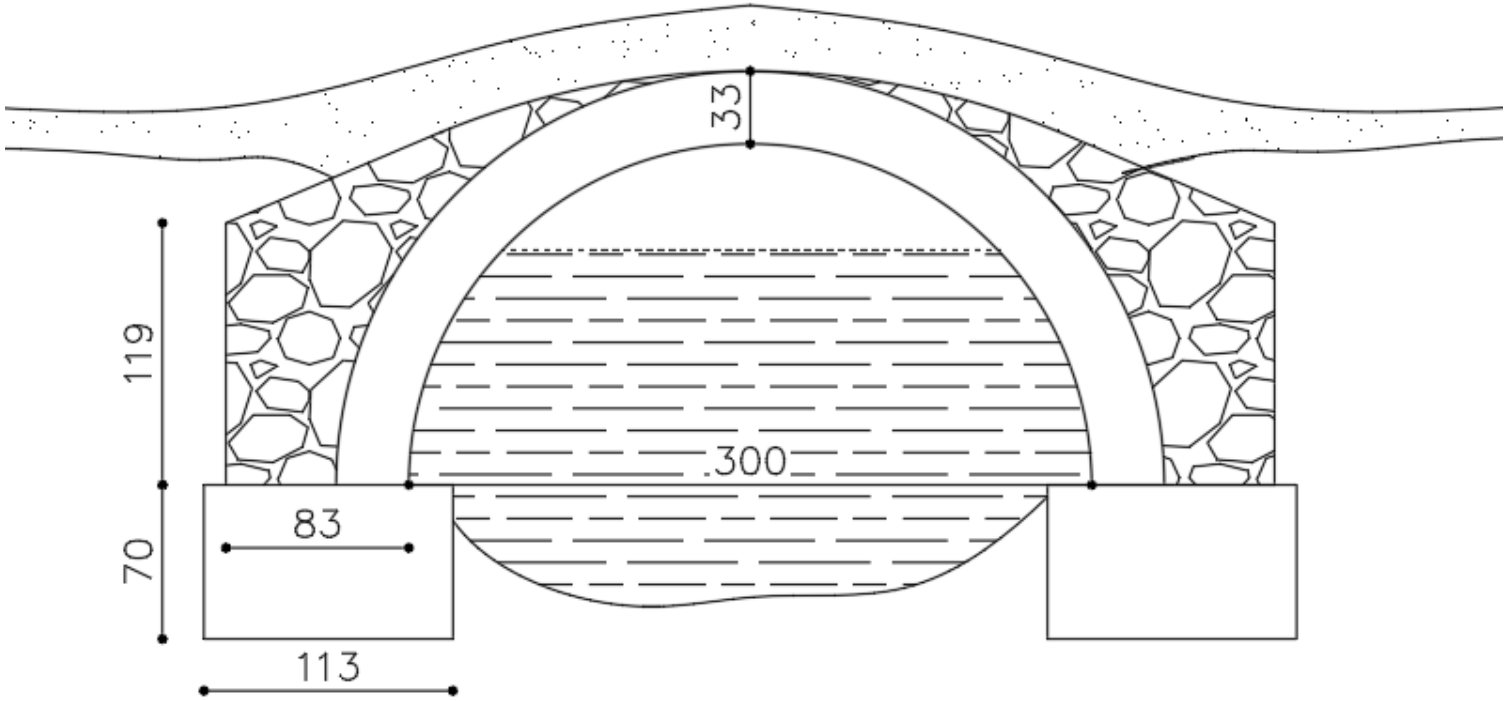
For L = 3

R = 1.5
V = 0.33
r = 3.7
E=0.83
H = 1.19
h = 0.7

Roman arch

Span	Radius intrados	Thickness keystone	Radius extrados	Thickness abutments	Thickness pier	Height abutments	Height foundations	Unitary volume	Bags of cement
L	R	V	r	E	E'	H	h	m³/m	bags/m
1	0.50	0.28	4.00	0.44	0.56	0.63	0.50	2.32	5
2	1.00	0.30	3.38	0.63	0.61	0.91	0.60	3.79	8
3	1.50	0.33	3.70	0.83	0.80	1.19	0.70	5.40	11
4	2.00	0.35	4.19	1.02	0.97	1.48	0.80	7.16	14
5	2.50	0.38	4.74	1.21	1.14	1.76	0.90	9.07	18
6	3.00	0.40	5.32	1.40	1.30	2.05	1.00	11.13	22
7	3.50	0.43	5.91	1.59	1.46	2.33	1.10	13.33	26
8	4.00	0.45	6.51	1.78	1.61	2.61	1.20	15.69	30
9	4.50	0.48	7.11	1.98	1.77	2.90	1.30	18.20	35
10	5.00	0.50	7.72	2.17	1.91	3.18	1.40	20.85	40
11	5.50	0.53	8.33	2.36	2.05	3.47	1.50	23.66	45
12	6.00	0.55	8.94	2.55	2.18	3.75	1.60	26.61	51
13	6.50	0.58	9.56	2.74	2.31	4.04	1.70	29.71	57
14	7.00	0.60	10.17	2.93	2.44	4.32	1.80	32.97	63
15	7.50	0.63	10.79	3.13	2.57	4.60	1.90	36.37	70

Detailed Structure



Nyabwenzi Bridge 3m