THE INFLUENCE OF JOINT THICKNESS AND THE WATER ABSORPTION OF BRICKS ON COMPRESSIVE STRENGTH OF BRICKWORK

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ABSTRACT Based on the domestic experimental data of 1075 test prisms, the calculation formula for the compressive strength of brickwork is proposed. Based on the experimental results at home and abroad, the influence of the mortar bed joint thickness and the water absorption of bricks on the compressive strength of brickwork is clarified. This paper has provided the basis for the further research of reliability of brick masonry structures, and for definited standard of the normal quality when the compressive strength of brickwork is determined.

1. COMPRESSIVE STRENGTH OF BRICKWORK

Mainly based on the statistical analysis of the experimental results, the calculation formula for the compressive strength (f) of brickwork in the current Chinese Code is determined. The values (f) calculated by the formula of the said code [1] have been compared with the experimental values (f'). The mean value of f/f' is 0.943 and the coefficient of variation is 0.179.

According to the domestic experimental data of 1075 test prisms, we have analysed and compared relative formulas in China and other countries [2, 3, 4, 5, 6] . The compressive strength of brickwork may be calculated by the following polynomial formula:

$$f = a f_1 + b f_2 + c\sqrt{f_1} + d\sqrt{f_2}$$

where

f_1 = the compressive strength of brick (kPa)
f_2 = the compressive strength of mortar (kPa).

The values of a, b, c and d are constant. On the basis of the statistical results, we get a = 0.1, b = 0.2, c = 4 and d = 14. Then

$$f = 0.1\, f_1 + 0.2\, f_2 + 4\sqrt{f_1} + 14\sqrt{f_2} \quad (kPa) \qquad (1)$$

The calculation values (f) by formula (1) have been compared with the experimental values (f'). The mean value of f/f' is 0.971 and the coefficient of variation is 0.136. The formula (1) is closer to the experimental results than the formula of our current national code. It is rather simple in computation and it is convenient to be used. In addition, we derive an approximate formula determining the mean value (f_m) and coefficient of variation (δ) of brickwork, using the average compressive strength of brick and mortar (f_{1m} and f_{2m}) and the coefficient of variation of brick and mortar (δ_1 and δ_2) are used as the cardinal quantity.

The formula (1) is developed according to Taylor's series and the first-order term is only taken. We can transform the compressive strength of brickwork into the function of the average value of the compressive strength of brick and motar.

Then according to the principle of "Statistics", we get:

$$f_m^2 = \alpha f_{1m} + \beta f_{2m} + \gamma \qquad (2)$$

$$\delta^2 = \frac{\alpha^2 f_{1m}^2 \delta_1^2 + \beta^2 f_{2m}^2 \delta_2^2}{\alpha f_{1m} + \beta f_{2m} + \gamma} \qquad (3)$$

where

$$\alpha = a + \frac{1}{2}\frac{c}{\sqrt{f_{1m}}}$$

$$\beta = b + \frac{1}{2}\frac{d}{\sqrt{f_{2m}}}$$

$$\gamma = a f_{1m} + b f_{2m} + c\sqrt{f_{1m}} + d\sqrt{f_{2m}} - \alpha f_{1m} - \beta f_{2m} .$$

2. THE INFLUENCE OF THE MORTAR BED JOINT THICKNESS

When the brickwork is compressed, in the brickwork the tensile stress, bending stress and shearing stress are formed, the brickwork exists in the state of complex stresses. The influence of

the motar bed joint thickness on the compressive strength of brickwork is essentially the improving degree of the unadvisable influence of the said state.

Based on the experimental results in our country [7,8] and in abroad [9] , the calculation formula of coefficient of the motar bed joint thickness t (mm) effect on the compressive strength of brickwork is:

$$\psi_t = \frac{1.4}{1 + 0.04t} \tag{4}$$

The calculated values (ψ_t) by formula (4) have been compared with the experimental values (ψ'_t) (See Fig. 1 and Table 1).

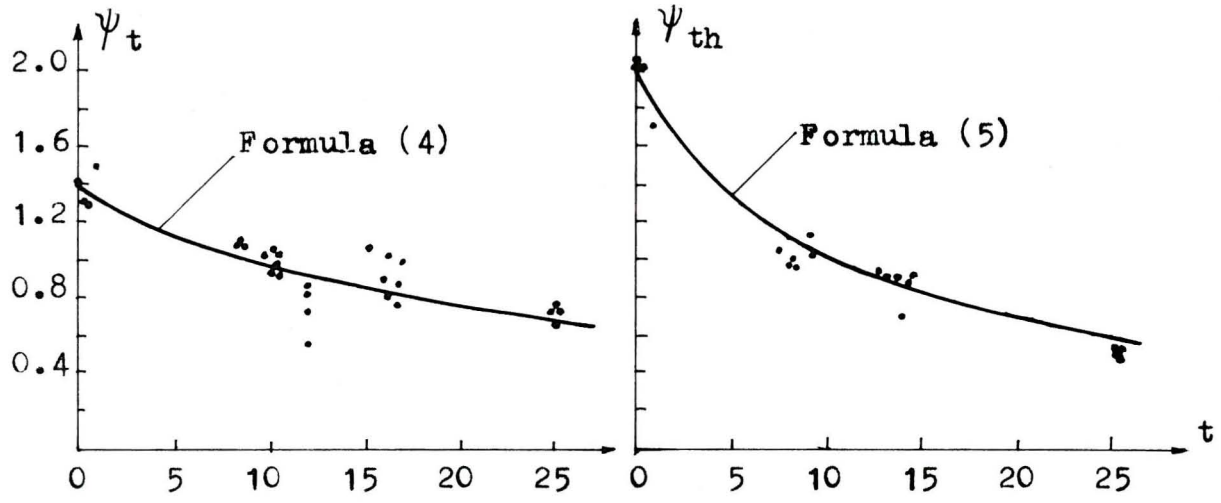

Fig.1 The influence coefficient ψ_t

Fig. 2 The influence coefficient ψ_{th}

Based on the experimental results in abroad [9], the calculation formula of the coefficient of the motar bed joint thickness t (mm) effect on the compressive strength of hollow-brick masonry is:

$$\psi_{th} = \frac{2}{1 + 0.1t} \tag{5}$$

The values (ψ_{th}) calculated by formula (5) have been also compared with the experimental values (ψ'_{th}) (See Fig. 2 and Table 2).

The formulas (4) and (5) can numerically determine the degree of influence of the motar bed joint thickness on the compressive strength of brickwork. In order to define the standard of the

Table 1. The Influence of joint thickness on the compressive strength of brickwork

Joint thickness (mm)	Compressive strength (kPa)	ψ_t	ψ'_t	$\frac{\psi_t}{\psi'_t}$
8.5	6080	1.045	1.060	0.986
8.5	5980	1.045	1.043	1.002
10.0	5740	1.000	1.000	1.000
12.0	4120	0.946	0.718	1.318
12.0	4610	0.946	0.804	1.177
8.5	7750	1.045	1.106	0.945
8.5	7450	1.045	1.063	0.983
10.0	7010	1.000	1.000	1.000
12.0	6180	0.946	0.882	1.073
12.0	3730	0.946	0.532	1.778
0	29100	1.400	1.416	0.989
0.51	27240	1.372	1.326	1.035
0.51	27720	1.372	1.349	1.017
1.27	31720	1.332	1.544	0.863
10.67	20130	0.981	0.980	1.001
10.41	21720	0.988	1.057	0.935
10.16	19930	0.995	0.970	1.026
10.41	19380	0.988	0.943	1.048
9.65	20890	1.010	1.017	0.993
10.16	21240	0.995	1.034	0.962
17.02	15860	0.833	0.772	1.079
16.00	18340	0.854	0.893	0.956
16.51	16890	0.843	0.822	1.026
16.26	21510	0.848	1.047	0.810
17.02	20550	0.833	1.000	0.833
15.75	21930	0.859	1.067	0.805
17.27	17720	0.828	0.862	0.961
25.40	14690	0.694	0.715	0.971
25.40	15790	0.694	0.768	0.904
25.40	15100	0.694	0.735	0.944
25.40	13930	0.694	0.678	1.024
			mean value	1.014

Table 2. The Influence of joint thickness on the compressive strength of Hollow-brick masonry

Joint thickness (mm)	Compressive strength (kPa)	ψ_{th}	ψ'_{th}	$\frac{\psi_{th}}{\psi'_{th}}$
0	37580	2.000	2.037	0.982
0	39780	2.000	2.156	0.928
0.51	37750	1.902	2.046	0.930
1.02	30680	1.815	1.663	1.091
8.89	20480	1.059	1.110	0.954
8.89	18960	1.059	1.028	1.030
8.38	16820	1.088	0.912	1.193
7.87	16960	1.119	0.919	1.218
8.13	18100	1.103	0.981	1.124
7.87	19380	1.119	1.050	1.066
13.72	15890	0.843	0.861	0.979
14.48	15260	0.817	0.827	0.988
14.22	12270	0.826	0.665	1.242
14.48	17440	0.817	0.945	0.864
13.46	15890	0.853	0.861	0.991
13.87	16690	0.834	0.905	0.922
25.40	7780	0.565	0.422	1.339
25.40	8650	0.565	0.469	1.205
25.40	8650	0.565	0.469	1.205
25.40	8490	0.565	0.460	1.228
			mean value	1.074

normal quality in construction [11], the mortar bed joint thickness will be controled in the range of 8 ~11 mm, then the amount of influence on the compressive strength of brickwork is less than 5%.

3. THE INFLUENCE OF THE WARTER ABSORPTION OF BRICKS IN CONSTRUCTION

3.1 The statistical curve of the water absorption of bricks in construction

The water absorption of bricks are measured in seven regions of China (Changsha, Tsinan, Hofei, Foochow, Chengtu, Kunming and Shenyang). Based on the measured results [10], we get the histogram (See Fig. 3) for the water absorption w (%) of bricks. The mean value is 9.2% and the coefficient of variation is 0.617. The water absorption of bricks in China can be accepted as the normal distribution in the ensuring rate of 95%.

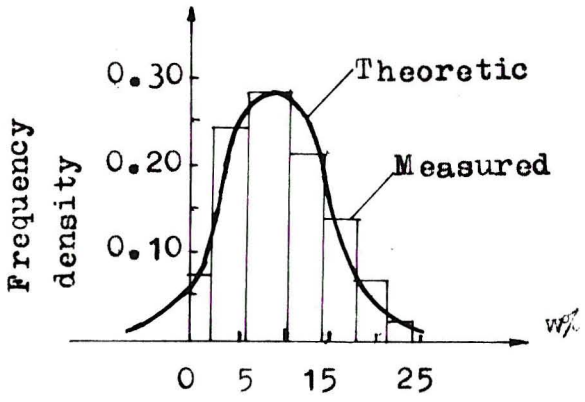

Fig. 3 Frequency distribution curve

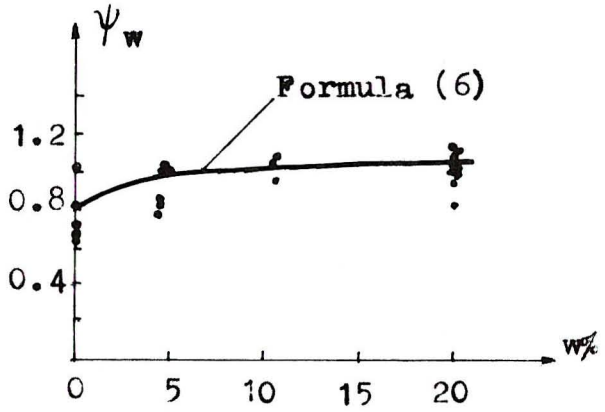

Fig. 4 Influence coefficient ψ_w

3.2 The influence of the water absorption of bricks on the compressive strength of brickwork

The same bricks and the same mortar in proportion are used for the making of the test prisms. There are four different values of the water absorption of the bricks. The w of the test prism of the third type is 10.8% (See Table 3). It approaches the mean value of the water absorption of bricks in our country. Therefore, we can take the third type of prism to be the brickwork that possesses the water absorption under the normal construction conditions. Based on the statistical results, the calculation formula of the coefficient of water absorption of bricks to the effect on the

Table 3. The Influence of the water absorption of bricks on the compressive strength of brickwork

Type	Ultimate load (kN)	Compressive strength (kPa)			w (%)	ψ_w	ψ'_w	$\frac{\psi_w}{\psi'_w}$
		brick	mortar	brickwork				
	118.7			1240			0.669	1.196
	112.8			1180			0.637	1.256
I	143.2	6910	3880	1490	0	0.800	0.804	0.995
	125.5			1310			0.717	1.116
	199.1			2080			1.122	0.713
	207.9			2100			1.133	0.854
	201.0			2030			1.095	0.884
II	191.2	6910	4300	1930	4.75	0.968	1.041	0.930
	147.1			1490			0.804	1.204
	134.4			1360			0.734	1.319
	148.1			1500			0.809	1.197
	154.9			1740			0.939	1.087
III	168.7	6910	2980	1300	10.8	1.021	1.025	0.996
	170.6			1920			1.036	0.986
	203.0			1970			1.063	0.941
	179.5			1740			0.939	1.141
	153.0			1480			0.800	1.339
	195.2			1890			1.020	1.050
IV	196.1	6910	4920	1950	20.0	1.071	1.052	1.018
	208.9			2030			1.095	0.978
	226.5			2200			1.187	0.902
	199.1			1930			1.041	1.029
	218.7			2120			1.144	0.936
							mean value	1.046

compressive strength of brickwork is:

$$\psi_w = 0.8 \frac{\sqrt[3]{w}}{10} \qquad (6)$$

where

w = the water absorption of bricks in construction.

The calculation values (ψ_w) by formula (6) have been compared with the experimental values (ψ_w') (See Table 3 and Fig. 4).

We can know from formula (6) that when w = 9.2%, ψ_w = 1.01, when w = 8～10%, ψ_w = 1.0～1.015, we get ψ_w = 1.0 . In order to define the standard of the normal quality in construction [11] , the water absorption of bricks will be controled in the range of 8～10%.

4. CONCLUSION

The compressive strength of brickwork can be calculated by formula (1). The formula possesses the characteristics, that is, the computation is simple and the application is also easy.

The coefficient of the mortar bed joint thickness effect on the compressive strength of brickwork can be calculated by formula (4) and (5). In order to define the standard of the normal quality in construction, the mortar bed joint thickness will be controled in the range of 8～11 (mm).

The coefficient of the water absorption of bricks in construction effect on the compressive strength of brickwork can be calculated by formula (6). In order to define the standard of the normal quality in construction, the water absorption of bricks will be controled in the range of 8～10%.

The research results presented in this paper have been adopted into "Construction and Acceptance Code of Masonry Engineering (GBJ 203-83)" and the Research Group of Reliability of Brick Masonry Structures of China.

5. REFERENCES

[1] Design Code of Brick Masonry Structures (GBJ3-73), Building Industry Publishing House of China, Beijing, 1973.

[2] Nanjing Institute of Technology, Brick Masonry Structures,

Building Industry Publishing House of China, Beijing, 1981.
[3] The Calculation of Load-bearing Wall, Building Translation, Published by Building Intelligence Research Division, Chinese Academy of Building Research, No. 6, 1965.
[4] Grimn, C.T., Strength and Related Properties of Brick Masonry, Proceedings ASCE, Structural Division, Vol. 101, No. STI, Janary 1975.
[5] Hendry, A.W., Structural Brickwork, John Wiley & Sons, Inc., New York, 1981.
[6] Poliakaofu, S.V. and Falieweiji, B.N., Masonry Structures, Building Industry Publishing House of U.S.S.R, Moscow, 1960.
[7] Cao Jiwen, The Effect of Joint Thickness on the Strength of Brickwork, Building Technology, Building Industry Publishing House of China, No. 11, 1980.
[8] Shi Chuxian, The Effect of Joint Thickness on the Compressive Strength of Brickwork, Building Technology, Building Industry Publishing House of China, No. 12, 1981.
[9] Francis, A.J., Horman C. B. and Jerems, L.E., The Effect of Joint Thickness and other factors on the Compressive Strength of Brickwork, SIBMaC Proceedings, England, 1971.
[10] Shi Chuxian, The Effect of Water Absorption of Bricks on the Compressive and Shearing Strength of Masonry, Building Technology, Building Industry Publishing House of China, No.3, 1983.
[11] Construction and Acceptance Code of Masonry Engineering (GBJ203-83), Building Industry Publishing House of China, Beijing, 1983.