Study on the Bearing Capacity of Autoclaved Fly Ash Masonry Short Column

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Abstract. According to the plane cross-section assumption and static equilibrium, the formulas for the bearing capacity of autoclaved fly ash masonry short column (AFAMC) can be deduced. And in the deducing process, we should consider the stress-strain relations of the various masonry materials. In this paper, the experimental values of bearing capacity of the short column are compared with those from the theoretical formulas. The data coincidence will verify the reasonability of the formulas deduced by the author. The experimental values of bearing capacity are also compared with the values calculated under the formula of *Code for Design of Masonry Structures (GB50003-2011)*. It can be found the theoretical values are higher than experimental values. So the compression bearing capacity of AFAMC based on the code is overestimated which leads to insecurity.

Introduction

At present, the formula of the bearing capacity N of masonry column is the product of section area A, compressive strength f and eccentric influence coefficient φ. Researche shows that axial offset e and component of high thickness ratio β are the main factors affecting the coefficient of eccentric compression member φ. The influence coefficient is the major factor that affects the bearing capacity [6].

In this paper, different formulas of AFA bearing capacity and eccentricity influence coefficient expressions were deduced and the theoretical value were calculated according to the stress-strain relationship of the masonry. And the theoretical data were compared with experimental data [1], the data comparison results in good agreement, it shows that the method of derivation is desirable and the stress-strain relationship is reasonable in the compression of masonry structures in this paper. Finally, it is verified that the calculation formula of the load bearing capacity of the standard is reasonable or not by experimental data.

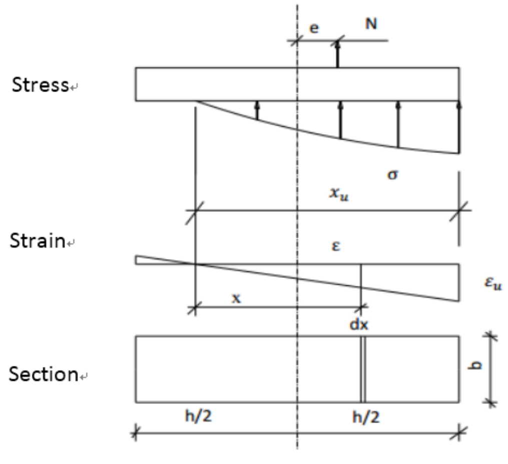

Fig. 1 Stress curve distribution section analysis

The stress-strain relations of AFAMC

According to the experimental data of the strain in the cross section with AFA masonry specimen [1]: the stress in the cross section of AFAMC isn't linear until it is destroyed and it can be accorded with the plane cross-section assumption well. At the same time, since the tensile strength of masonry structure is very low, the horizontal cracks will be immediately out of work. Thus the tensile strength of the AFA masonry can be neglected. Due to high stress gradient in the eccentric compression section, the plastic zone development is greater than the axial pressure. Therefore, the stress-strain curve of eccentric compression is replaced by the stress-strain curve of axial compression [2] is on the safe side, as shown in **Fig. 1**.

The peak pressure strain ε_0 refers to the masonry compressive stress reached the peak of the longitudinal strain values; masonry structure is one of the important parameters of stress-strain curve. References [3] provide the peak compressive strain is between 0.0026 and 0.0049. It also lists several groups of masonry under uniaxial compressive stress-strain curve, comprehensive analysis of ε_0 value 0.003. References [3] points out that the disparity of the rise of various types of stress-strain curves is not big, the disparity of various types of brick masonry is big, and the ratio of the ultimate compressive strain to the peak pressure strain $\varepsilon_u/\varepsilon_0$ for all kinds of AFA masonry is 1.6.

Formula of compressive bearing capacity for AFAMC

Depending on the stress - strain relations, derivation the formula of compression capacity N and eccentricity influence coefficient φ, also lists the formula given in the specification [6].
Krishna Naraine, Sachchidanand Sinha proposed the model of stress-strain relationship [3]:

$$\frac{\sigma}{f_m}=\frac{\varepsilon}{\varepsilon_0}\cdot e^{(1-\frac{\varepsilon}{\varepsilon_0})} \tag{1}$$

From Fig. 1, the above conditions can be:

$$\frac{\varepsilon_u}{\varepsilon_0}=1.6 \tag{2}$$

Obtained by the proportional relationship:

$$\frac{\varepsilon_0}{\varepsilon_u}=\frac{x_0}{x_u}=\frac{1}{1.6}=0.625 \tag{3}$$

$$\frac{\varepsilon_0}{x_0}=\frac{\varepsilon_u}{x_u}=\frac{\varepsilon}{x} \tag{4}$$

It's derived from static equilibrium condition of the cross section:

$$N_1=\int_0^{x_u} f_m\cdot\frac{\varepsilon}{\varepsilon_0}e^{(1-\frac{\varepsilon}{\varepsilon_0})}\cdot b\cdot dx \tag{5}$$

$$N_1(\frac{h}{2}+e)=\int_0^{x_u} f_m\cdot\frac{\varepsilon}{\varepsilon_0}e^{(1-\frac{\varepsilon}{\varepsilon_0})}\cdot b\cdot(h-x_u+x)dx \tag{6}$$

From Eq. 3, Eq. 4, Eq. 5, Eq. 6:

$$N_1=\varphi_1 f_m bh \qquad \varphi_1=0.8100(1-\frac{2e}{h}) \tag{7}$$

In the formula:

f_m —Average compressive strength of masonry;

ε_0 —Strain of f_m;

h —The length of rectangular cross-section eccentric axial force direction, When the axial compression of the column cross-section smaller side length;

b —Sectional width;

e —Axial force eccentricity

N_1 —Compressive bearing capacity;

φ_1 —Eccentric influence coefficient.

Stress - strain relation model proposed by Professor Shi Chuxian of Hunan University [4]:

$$\frac{\sigma}{f_m}=\frac{9}{10}(1-e^{-2.3\frac{\varepsilon}{\varepsilon_0}}) \tag{8}$$

It's derived from static equilibrium condition of the cross section:

$$N_2 = \int_0^{x_u} f_m \frac{9}{10}(1-e^{-2.3\frac{\varepsilon}{\varepsilon_0}})b \cdot dx \qquad \varphi_2 = 8\,0\,1\,(1-0\frac{2e}{h}) \tag{9}$$

From Eq. 2, Eq. 3, Eq. 4, Eq. 9, Eq. 10

$$N_2 = \varphi_2 f_m bh \qquad \varphi_2 = 8\,0\,1\,(1-0\frac{2e}{h}) \tag{10}$$

0In the formula:

N_2—Compressive bearing capacity;

φ_2—Eccentric influence coefficient.

Turnsek and Cacovic proposed model of stress-strain relationship [5]:

$$\frac{\sigma}{f_m} = 6.4\left(\frac{\varepsilon}{\varepsilon_0}\right) - 5.4\left(\frac{\varepsilon}{\varepsilon_0}\right)^{1.17} \tag{11}$$

It's derived from static equilibrium condition of the cross section:

$$N_3 = \int_0^{x_u} f_m \left[6.4\left(\frac{\varepsilon}{\varepsilon_0}\right) - 5.4\left(\frac{\varepsilon}{\varepsilon_0}\right)^{1.17}\right] bdx \tag{12}$$

$$N_3\left(\frac{h}{2}+e\right) = \int_0^{x_u} f_m \left[6.4\left(\frac{\varepsilon}{\varepsilon_0}\right) - 5.4\left(\frac{\varepsilon}{\varepsilon_0}\right)^{1.17}\right] \cdot b \cdot (h - x_u + x)dx \tag{13}$$

From Eq. 2, Eq. 3, Eq. 4, Eq. 9, Eq. 10, Eq. 15, Eq. 16:

$$N_3 = \varphi_3 f_m bh \qquad \varphi_3 = 9\,0\,4\,(1-0\frac{2e}{h}) \tag{14}$$

In the formula:

N_3—Compressive bearing capacity;

φ_3—Eccentric influence coefficient.

The formula of the pressure bearing capacity and the eccentric influence factor according to the specification [6]:

$$N_4 = \varphi_4 fbh \tag{15}$$

When $\beta \le 3$ When $\beta \ge 3$

$$\varphi_4 = \frac{1}{1+12\left(\frac{e}{h}\right)^2} \qquad \varphi_4 = \frac{1}{1+12\left[\frac{e}{h}+\sqrt{\frac{1}{12}\left(\frac{1}{\varphi_0}-1\right)}\right]^2} \tag{16}$$

$$\varphi_0 = \frac{1}{1+\alpha\beta^2} \tag{17}$$

In the formula:

N_4—Compressive bearing capacity;

φ_4—Eccentric influence coefficient

φ_0—The stability coefficient of axially loaded members;

α—Coefficient related to the strength of mortar;

β—Component of high thickness ratio;

Experimental Verification

The eccentric compression force is one of the main forms of masonry structures. Eccentric compression test of 52 masonry specimens of the AFA brick in reference [1] and recorded the failure load and sectional stress distribution under different loads. According to the needs of this article, only selected 24 experiment result values and analyzed.

Table 1 Eccentric compression of AFA solid masonry bearing capacity test comparison with the theoretical value

Test value (Failure load)		Formula（7）		Formula（12）		Formula（17）		Formula（19）	
$\frac{e}{h}$	N_u kN	N_1 kN	$\frac{N_1}{N_u}$	N_2 kN	$\frac{N_2}{N_u}$	N_3 kN	$\frac{N_3}{N_u}$	N_4 kN	$\frac{N_4}{N_u}$
0	757. 0	710.9	0.939	613.3	0.810	712.5	0.941	747.7	0.988
0	713. 5	670.2	0.939	578.2	0.863	671.7	0.941	704.9	0.988
0	721. 3	676.9	0.938	584.7	0.811	679.2	0.942	712.8	0.988
0.1	581. 0	542.2	0.933	467.8	0.805	542.7	0.934	592.7	1.020
0.1	565. 8	546.2	0.965	471.1	0.834	546.5	0.967	596.8	1.055
0.1	567. 0	546.8	0.964	471.8	0.832	547.3	0.965	597.7	1.054
0.2	411 .4	406.1	0.987	350.4	0.852	407.1	0.990	433.9	1.055
0.2	454. 5	409.0	0.900	352.8	0.776	409.9	0.902	437.0	0.961
0.2	406. 0	405.5	0.999	349.9	0.862	406.5	1.001	433.3	1.067
0.3	285. 8	270.4	0.946	233.2	0.816	271.1	0.949	307.0	1.074
0.3	277. 5	272.7	0.983	235.2	0.848	273.3	0.985	309.6	1.116
0.3	309. 1	271.9	0.880	234.5	0.759	272.5	0.882	308.7	0.999
Average			0.948		0.822		0.950		1.030
Coefficient of variation			0.037		0.040		0.037		0.045

Table 2 AFA porous masonry bearing capacity of eccentric compression test and the comparison between theoretical values

Test value(Failure load)		Formula（7）		Formula（12）		Formula（17）		Formula（19）	
$\frac{e}{h}$	N_u kN	N_1 kN	$\frac{N_1}{N_u}$	N_2 kN	$\frac{N_2}{N_u}$	N_3 kN	$\frac{N_3}{N_u}$	N_4 kN	$\frac{N_4}{N_u}$
0	524.4	492.1	0.938	424.8	0.810	492.9	0.940	516.0	0.984
0	500.0	469.4	0.939	405.2	0.810	470.2	0.940	492.2	0.984
0	553.4	518.9	0.938	448.0	0.810	519.9	0.939	544.2	0.983
0.1	385.6	394.2	1.022	340.1	0.882	395.1	1.025	428.6	1.112
0.1	432.5	395.3	0.914	341.1	0.789	396.2	0.916	429.8	0.994
0.1	387.9	398.1	1.026	343.4	0.885	399.0	1.029	432.8	1.116
0.2	274.2	297.3	1.084	256.5	0.935	298.0	1.087	315.4	1.150
0.2	344.0	296.9	0.863	256.1	0.745	297.5	0.865	315.0	0.916
0.2	328.8	298.1	0.907	257.2	0.782	298.8	0.909	316.3	0.962
0.3	234.7	197.1	0.840	170.1	0.725	197.6	0.842	222.3	0.947
0.3	280.1	198.2	0.708	171.0	0.610	198.7	0.709	223.5	0.798
0.3	204.7	197.1	0.963	170.1	0.831	197.6	0.965	222.3	1.086
Average			0.929		0.801		0.931		1.003
Coefficient of variation			0.105		0.106		0.106		0.099

The average value of the single brick compressive strength were 16.77MPa and 10.46MPa which the AFA solid brick and porous brick were choosed in the experiment. Measuring the compressive strength of the mortar respectively 13.69MPa and 19.08MPa. Solid brick masonry outer contour size specimens are 240mm×365mm ×746mm, β = 3.108; perforated brick is 240mm×365mm× 790mm, β =3.290.Up and down with the top surface of 10mm thick cement mortar. Eccentricity value e/h respectively 0, 0.1, 0.2 and 0.3. Numerical experiments with the carrying capacity of such as **Table 1**, **Table 2**.

The analysis of the data in the table shows that load capacities for AFAMC e/h increases as decreases, from the perspective of the average, the use of the bearing capacity of theory and experimental method derived herein determined value better fit, while bearing capacity of the theoretical value of the use of standardized methods of seeking larger than the experimental values, both in the coefficient of variation are relatively stable.

Summary

Based on the study of 24 AFAMCs, the experiment result show that masonry columns under compression and effects of various factors on bearing capacity of its situation. Under the same assumption, depending on the different stress-strain constitutive relations derived different formulas about compressive bearing capacity and eccentric influence coefficients. By comparing the theoretical data and experimental data of bearing capacity, the results are as follows:

(1) The calculation of Eq. 7, Eq. 12, Eq. 17 compressive bearing capacity values are close to experimental values and the coefficient of variation is stable. In order to verify the correctness of the method and the rationality of the stress-strain relationship of the three kinds of masonry structures.

(2) According to the the current code formula (19), the calculated compression bearing capacity is slightly larger than the experimental values. Aiming at AFAMC, from the calculation of the average can be drawn, the calculation of the load bearing capacity in code is overestimated, may have some defects in the design, and is expected to further revise. It may lead to some flaw in the design, look further amended

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