Experimental Investigation on the Modulus of Elasticity of Brickwork

Ir. J.C. Keller

Vereniging De Nederlandse Baksteenindustrie, De STEEG, Netherlands

Introduction: In literature many figures are produced for the modulus of elasticity. In some cases it is stated, that there is substantial difference between these values in horizontal and vertical direction. In most cases it is not clear from what kind of experiment the value is derived and we may expect, that almost all figures are found somewhere in said literature.

In most countries it is taken for granted, that the modulus of elasticity is 1000 x the assumed compressive strength.

As the calculation of non-loadbearing walls, that should withstand the windload only, largely depends on the E-value in two directions, we feel, that the assumption $E = 1000.f'_m$ is nothing but a rule of thumb.

Preliminary experiments on test-walls by TNO (The National Institute for applied scientifical research) have shown, that the flexural strength and modulus of elasticity strongly deviate from the values calculated from values found under compression and tension only.

Experiments: Appendix 1 shows the different walls and elements used for tests. Three types of brick were combined with four different types of mortar. The results are shown on appendix 2 and 3.

The main conclusions were:

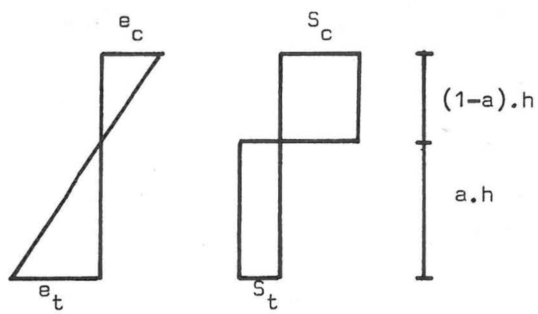
1. The E found in bending is roughly 0,75 x the E found under compression.
2. The flexural tensile strength is roughly 3 x the stress found on single elements under tension.

Discussion: As in both experiments the value of E decreased at higher loads, the value of E has been taken at 0,3 x the ultimate load.

The small number of tests limits the reliability of the results.

The size of the walls used for bending-tests makes it doubtful wether we may assume "pure" bending. As such the high values of flexural tensile strength may be exaggerated. A rule of thumb syas, that the ratio should be around 2 instead of 3.

A possible explanation for the above mentioned deviations could be the following proposition:
Assuming that under bending the section is plain and remains plain, but that the neutral axis is not the mathematical centre of the section we can calculate as follows:



$$E_c = \frac{S_c}{e_c}$$

$$E_t = \frac{S_t}{e_t}$$

Further: $\frac{e_t}{e_c} = \frac{a}{1-a}$

$$a.S_t = (1-a).S_c$$

$$M = a.S_t.\tfrac{1}{2}.b.h^2$$

$$d\phi = \frac{e_t}{a.h}$$

This leads to: $a = \frac{E_c - \sqrt{E_c.E_t}}{E_c - E_t}$ and thus to:

$S_t = \frac{M}{3.a.W}$ instead of $\frac{M}{W}$

$S_c = \frac{M}{3(1-a)W}$ instead of $\frac{M}{W}$

$d\phi = \frac{M}{6.a^2.E_t I} = \frac{M}{6.(1-a)^2.E_c I}$ instead of $\frac{M}{E_f.I}$

$$\frac{E_c}{E_t} = \frac{(1-a)^2}{a^2}$$

Assuming that $E_f = 0,75.E_c$, we have to use

$6.(1-a)^2 = 0,75$ and thus: $a = 0,65$, which leads to $3.a = 2$.
Thus S_t seems to be two times higher; while S_c remains on the expected level, as $3.(1-a) = 1$.
Than we have to accept, that $E_c = 4.E_t$

Conclusions: We wish to stress, that the explanation is based on a small number of experiments and that as such it is not more than an attempt to explain or better the result of "speculative thinking".
However it would be advisable to distinguish the several types of E; to undertake further research in this field (which is executed by TNO at the moment) and to reconsider the possibility, that the behaviour of mortar in the wall might be different from the behaviour of mortar-prisms in the laboratory.

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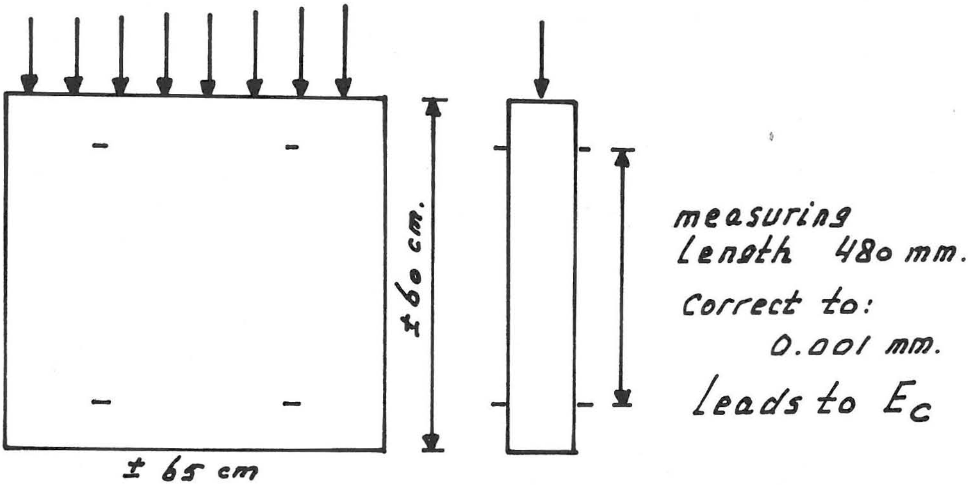
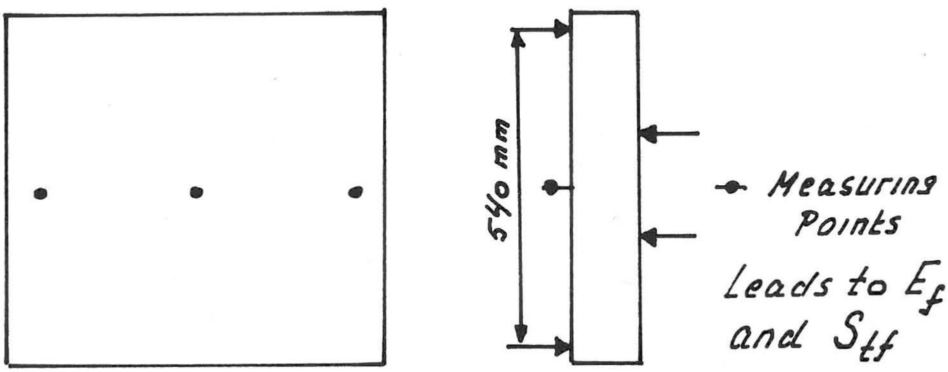
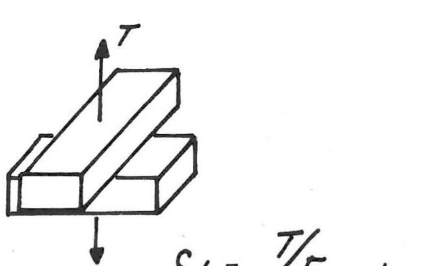
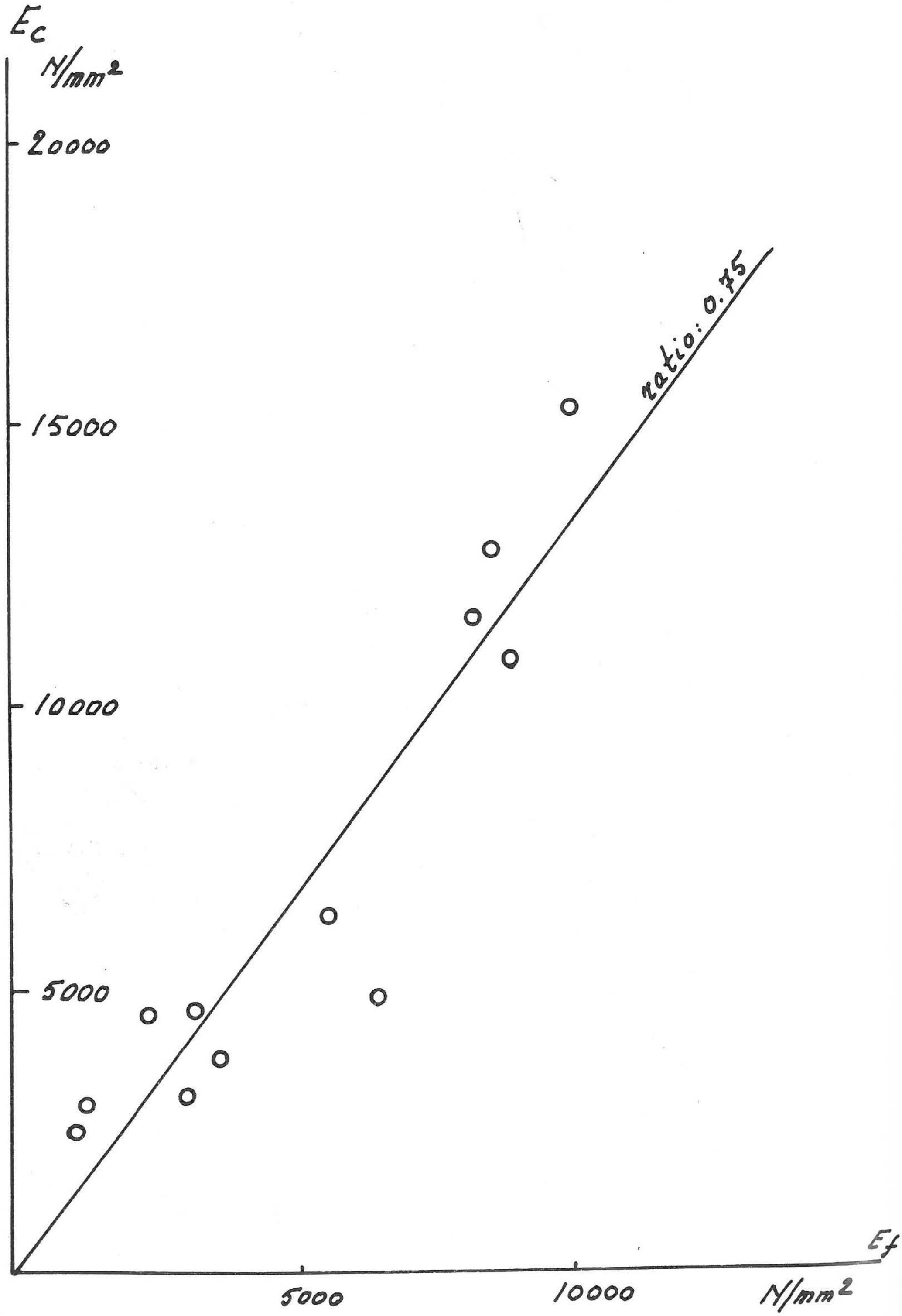
APPENDIX 1



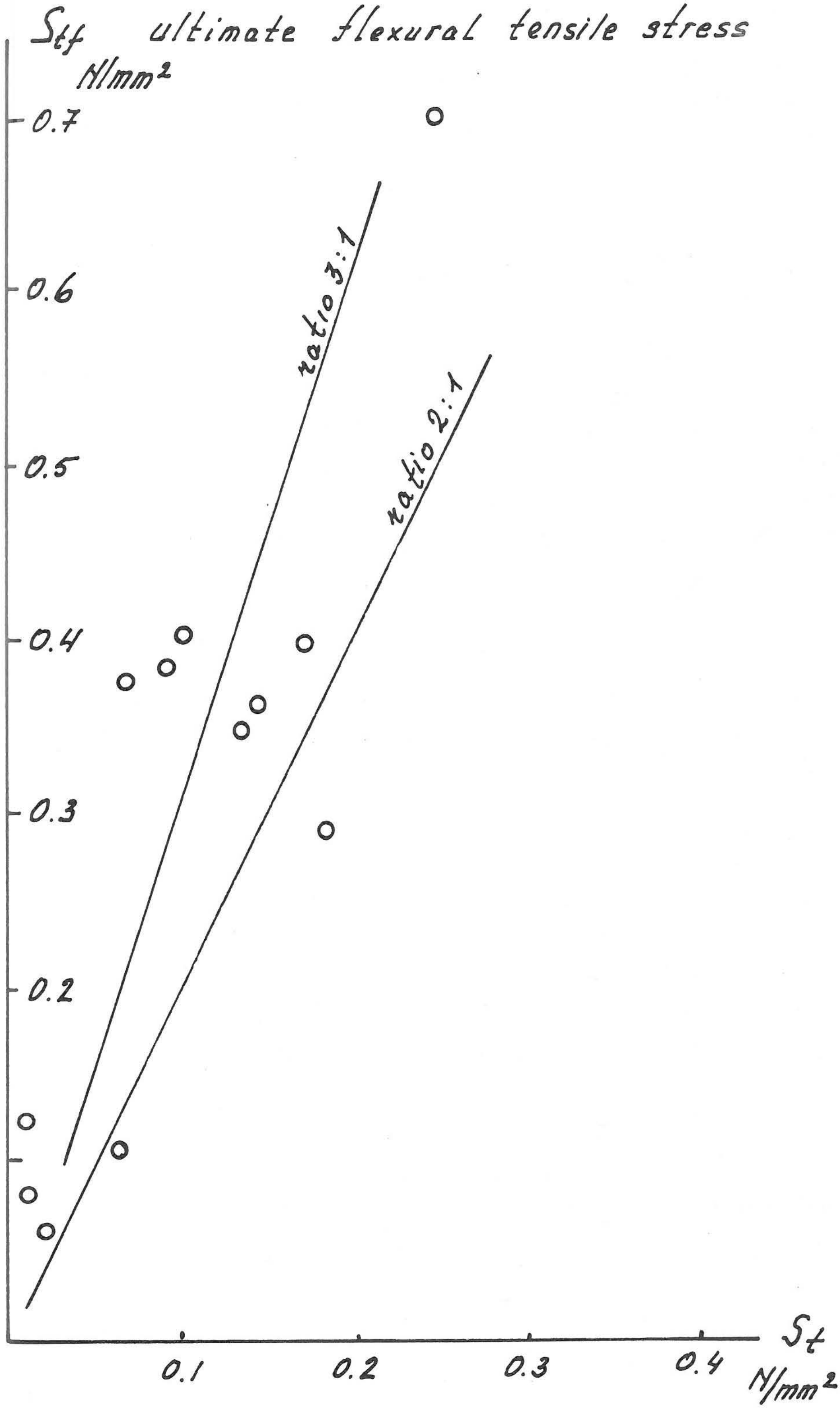




$S_t = T/F_{mortar}$.


E_c
N/mm²
20000
15000
10000
5000
ratio: 0.75
E_f
5000
10000
N/mm²

APPENDIX 3



S_{tf} ultimate flexural tensile stress
N/mm²
0.7
0.6
0.5
0.4
0.3
0.2
ratio 3:1
ratio 2:1
0.1
0.2
0.3
0.4
S_t
N/mm²