A COMPARISON OF THREE LABORATORY TEST METHODS USED TO DETERMINE THE SHEAR RESISTANCE OF MASONRY WALLS

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SUMMARY

Three laboratory test methods, the Dynamic, Static and Brazilian, for the determination of the referential tensile strength of masonry walls provide statistically congruent results.

1.0 DESCRIPTION OF TESTS AND RESULTS

The tests were carried out according to a programme jointly agreed upon between two institutes, ICPS of the University of Padova, Italy and ZRMK Ljubljana, Yugoslavia. The direct initiative for these tests was given by the "Laterizio Alveolato Poroton" Association of brick manufacturers.

Three kinds of tests were carried out on masonry wall elements of aspect ratio h:d $\cong$ 1.1 built of two different kinds of bricks: ceramic bricks designated "Doppio UNI" and light-weight ceramic bricks designated "Poroton". The following three test methods were used: 1) the wall was subjected to a constant vertical load and a cyclically changing, increasing, horizontal load produced by programmed, horizontal, cyclic displacements at a frequency of 1 c.p.s. (Method D - Ljubljana), 2) the wall was subjected to a constant vertical load and a one-way acting, static, increasing horizontal load (Method S - Padova) and 3) the wall was subjected to an increasing, diagonally-acting load-the Brazilian method (Method B - Padova).

When analysing the results of the tests the hypothesis was assumed that for a shear failure limit state τ_o = H/F the referential stress is the maximum tensile stress in the panel. This gives for narrower walls of aspect ratio h/d $\geq$ 1.5 the equation:

$$\sigma_n = -\sigma_o/2 + \sqrt{(1.5\tau_o)^2 + (\sigma_o/2)^2} \qquad \ldots (1)$$

In the case of walls where h:d $\cong$ 1:1, photoelasticity measurements have shown that at greater eccentricities the maximum tensile stress is less than the value that is obtained by using Eq.1. For this reason the principal stresses were calculated by ICPS of Padova for the aspect ratios 1:1.04 (Doppio UNI) and 1:1.07 (Poroton) by means of linear elastic finite element models for different ratios of the horizontal and vertical loads H and V. The results of these calculations and of the photoelasticity measurements are shown in Fig.1.

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The tensile stress at the middle-point of the panel is given, in general, by the expression:

$$\sigma_n = -(\sigma_x + \sigma_y)/2 \quad + \sqrt{\tau_{xy}^2 \quad + \quad (\sigma_x - \sigma_y)^2/4} \qquad \ldots (2)$$

If the obtained stress σ_n is to be expressed in terms of the parameters $\tau_o = H/F$ and $\sigma_o = V/F$, then a coefficient "b" must be introduced for the calculation of σ_n:

$$\sigma_n = -\sigma_o/2 \quad + \sqrt{b^2 \cdot \tau_o^2 \quad + \quad (\sigma_o/2)^2} \qquad \ldots (3)$$

Two possible equations of straight-line regression between σ_n/σ_o and τ_o/σ_o follow from the calculated results presented in Fig.1. The equations are given in the same figure.

The values of $\tau_{o\ max}$ experimentally obtained for different vertical loadings σ_o are shown for walls built of the two different types of ceramic bricks and for the three different test methods in Table 1. For each of these results the corresponding maximum tensile stress has been calculated according to both equations of regression. In the case of the Brazilian method the maximum tensile stress has been calculated using a finite element model and taking into account the dimensions of the enclosing steel corner blocks.

In Fig.2 the values of σ_{n1}/σ_o from Table 1 for methods "D" in "S" have been introduced into the dimensionless shear interaction diagram. The variance coefficient, which typifies the deviation of individual results from the theoretical relation, amounts to 8%, and the validity of the hypothesis about a referential tensile strength is confirmed.

2.0 CONCLUSIONS

Firstly, all three test methods provide statistically congruent results within limits defined by a variance coefficient of wall quality of 11%. Secondly, the good agreement obtained between the Brazilian method and the other two test methods provides additional proof of the hypothesis concerning a referential tensile strength, as the edge loading distribution used in this method is essentially different.

T A B L E 1

CALCULATED PRINCIPAL TENSILE STRESSES AT ULTIMATE STATE - "POROTON" (POR) WALLS

$$\frac{\sigma_n^{①}}{\sigma_o} = -\frac{1}{2} + \sqrt{b^2\left(\frac{\tau_o}{\sigma_o}\right)^2 + \frac{1}{4}} \; ; \quad \frac{\sigma_n^{②}}{\sigma_o} = -0'078 + 0'789 \frac{\tau_o}{\sigma_o}$$

$$b = 1'543 - 0'478 \left(\frac{\tau_o}{\sigma_o}\right) \; ;$$

Group of walls	LJUBLJANA "D" σ_o kp/cm²	τ_o kp/cm²	b /	$\sigma_n^{①}$ kp/cm²	$\sigma_n^{②}$ kp/cm²	PADOVA "S" σ_o kp/cm²	τ_o kp/cm²	b /	$\sigma_n^{①}$ kp/cm²	$\sigma_n^{②}$ kp/cm²	PADOVA "B" σ_n kp/cm²
I	4'35	4'08	1'09	2'79	2'88	4'00	4'00	1'07	2'72	2'84	2'17
	4'57	3'73	1'15	2'58	2'59	4'70	3'90	1'15	2'71	2'71	2'61
	4'55	4'11	1'11	2'83	2'89	3'90	3'90	1'07	2'66	2'77	2'70
			$\bar{x}_I$ = 2'73		2'79				2'70	2'77	
II	8'4	4'6	1'28	3'04	2'97	8'1	3'6	1'33	2'22	2'21	$\bar{x}_B$ = 2'49
	8'4	4'9	1'26	3'26	3'21	8'7	3'8	1'33	2'33	2'32	s = 0'28
	8'4	4'9	1'26	3'26	3'21	8'4	4'4	1'29	2'82	2'82	v = 0'11
			$\bar{x}_{II}$ = 3'19		3'13			$\bar{x}_{II}$ = 2'47		2'45	
III		$\bar{x}_D$ = 2'96				12'9	4'6	1'37	2'58	2'62	
		s = 0'27				13'9	4'9	1'37	2'73	2'76	
		v = 0'09				14'7	5'5	1'36	3'15	3'19	
								$\bar{x}_{III}$ = 2'82		2'86	

$\bar{x}_S$ = 2'66; s = 0'28; v = 0'10

Testing of groups of results D:S : n = 15 - 2 = 13 ; t = 2'04; 0'05 < P < 0'10.

Statistical parameters of results (D+S+B) - interval estimate: $\bar{x}$ = 2'73; s = 0'31 ; v = 0'11.

CALCULATED PRINCIPAL TENSILE STRESSES AT ULTIMATE STATE - "DOPPIO UNI" (D.U.) WALLS

$$\frac{\sigma_n^{①}}{\sigma_o} = -\frac{1}{2} + \sqrt{b^2\left(\frac{\tau_o}{\sigma_o}\right)^2 + \frac{1}{4}} \; ; \quad \frac{\sigma_n^{②}}{\sigma_o} = -0'078 + 0'789 \frac{\tau_o}{\sigma_o}$$

$$b = 1'543 - 0'478 \left(\frac{\tau_o}{\sigma_o}\right) \; ; \quad 12 \cdot \frac{e}{d} = 6 \left(\frac{\tau_o}{\sigma_o}\right)$$

Group of walls	LJUBLJANA "D" σ_o kp/cm²	τ_o kp/cm²	b /	$\sigma_n^{①}$ kp/cm²	$\sigma_n^{②}$ kp/cm²	PADOVA "S" σ_o kp/cm²	τ_o kp/cm²	b /	$\sigma_n^{①}$ kp/cm²	$\sigma_n^{②}$ kp/cm²	PADOVA "B" σ_n kp/cm²
I	8'5	6'9	1'15	4'78	4'78						4'63
	7'3	6'0	1'15	4'16	4'16						4'02
	7'1	5'8	1'15	4'02	4'02						4'84
			$\bar{x}_I$ = 4'32		4'32						
II	15	7'9	1'29	5'16	5'06	16'6	7'9	1'32	5'00	4'94	$\bar{x}_B$ = 4'50
	15	8'0	1'29	5'24	5'14	14'1	6'7	1'32	4'24	4'15	s = 0'43
	15	7'3	1'31	4'66	4'93	13'6	5'9	1'34	3'61	3'59	v = 0'10
			$\bar{x}_{II}$ = 5'02		4'93			$\bar{x}_{II}$ = 4'28		4'23	
III		$\bar{x}_D$ = 4'67				23'2	8'0	1'38	4'40	4'50	
		s = 0'50				23'2	7'8	1'38	4'24	4'34	
		v = 0'1				25'4	9'1	1'37	5'11	5'20	
								$\bar{x}_{III}$ = 4'58		4'68	
IV						34'4	10'8	1'39	5'65	5'84	
						33'7	10'3	1'40	5'31	5'50	
						31'0	10'2	1'39	5'48	5'63	
								$\bar{x}_{IV}$ = 5'48		5'66	

$\bar{x}_S$ = 4'85 ; s = 0'76 ; v = 0'16

Testing of groups of results D:S : n = 15 - 2 = 13 t = - 0'34 , P > 0'50

Statistical parameters of results (D+S+B)-interval estimate x = 4'70 s = 0'5[illegible] v = 0'[illegible]2

RESULTS OF ANALYSIS OF PANELS OF ASPECT $h/d \cong 1$ BY FINITE ELEMENT THEORY

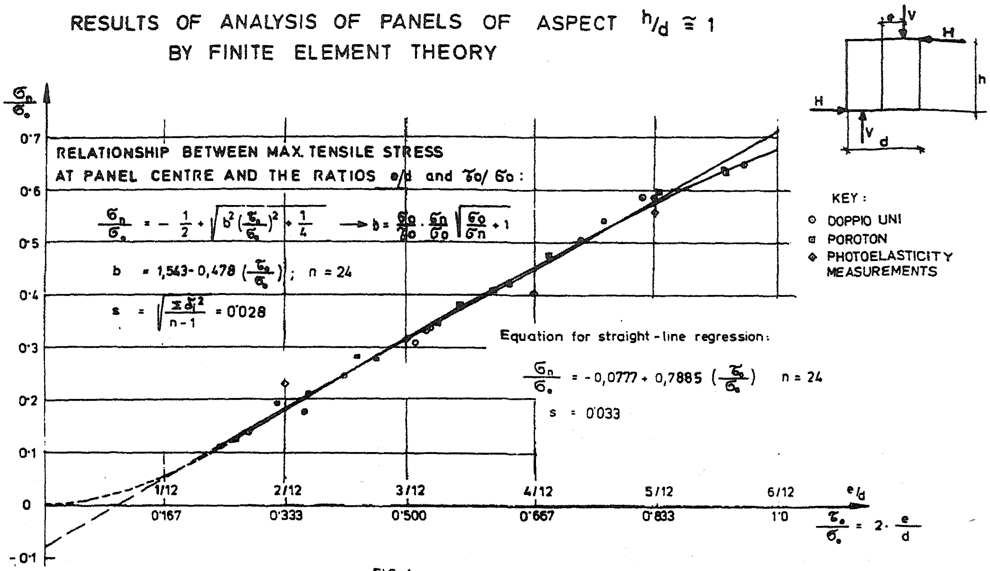

FIG. 1

FIG. 2