On the Use of Horizontal Reinforcement in Masonry Lintels

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ABSTRACT

The paper describes the results of an investigation carried out on reinforced single- or double-leaf masonry lintels.
The type of bricks and the mortar mix were kept constant throughout the testing.
The tests have proved that a reinforced masonry lintel has good performances and can be used to replace the classical concrete and/or iron lintels.
A design method is being developed by Ir. Smits, IWONL-Researcher.

1. INTRODUCTION

The common practice in constructing lintels is to put either a concrete lintel (precast or poured in situ) or an iron lintel.
Both solutions have several disadvantages, as there are:

- corrosion (iron lintels)
- necessity of formwork (in situ poured lintels)
- a linear thermal expansion modulus that differs from the masonry modulus (this leads to the classical 45° cracks starting from the contact surface lintel-masonry)
- thermal bridges when the in situ poured lintel is in contact with the outer leaf of a two-leaf wall.

Several tests have been carried out during a research program sponsored by the "Belgische groepering van de kleinijverheid" - "Fabrimetal" - "FeBe" and the Belgian government.
One of the purposes of this research program was to investigate the behaviour of reinforced masonry lintels.

2. PROPERTIES OF MATERIALS AND TEST PROGRAM

The test program consisted of six lintel constructions. All lintels had an overall length of 3800 mm, a height of 600 mm and a free span of 3000 mm.

2.1. Lintel V_1A (see fig. 1)

- single leaf
- bricks: perforated clay bricks 290 x 140 x 140 mm³
  average compressive strength = 10,1 N/mm²
- mortar: C_{300} (i.e. 300 kg P_{30} cement pro m³ of sand)
  average flexural tensile strength = 1,8 N/mm²
  average compressive strength = 9,4 N/mm²
- reinforcement: Ø 4 mm - width 100 mm in the lower two mortar joints

2.2. Lintel V_1B (see fig. 1)

This lintel is identical to V_1A except for:

- mortar: C_{300}
  average compressive strength: 10,2 N/mm²
  average flexural tensile strength: 2,4 N/mm²

2.3. Lintel V_5A (see fig. 2)

- double leaf
- bricks
  - inner leaf: perforated clay bricks 290 x 140 x 140 mm³
    average compressive strength: 10,1 N/mm²

- outer leaf: clay bricks 190 x 90 x 65 mm³
  average compressive strength: 16,0 N/mm²
- mortar C_{300}
  average compressive strength: 10,4 N/mm²
  average flexural tensile strength: 2,0 N/mm²
- reinforcement: Ø 4,75 mm - width 250 mm
  in the lower two mortar joints

2.4. Lintel V_5B (see fig. 2)

This lintel is identical to V_5A

2.5. Lintel V_8 (see fig. 3)

- single leaf
- bricks: perforated clay bricks 290 x 190 x 140 mm³
  average compressive strength: 15,7 N/mm²
- mortar: C_{300}
  average compressive strength: 11,0 N/mm²
  average flexural tensile strength: 2,5 N/mm²
- reinforcement: ɸ 10 x 7,1 mm² - width 150 mm
  in each mortar joint

2.6. Lintel V_9 (see fig. 4)

- double-leaf lintel constructed in such a way that we had immediately the classical rabbet for incorporating a window
- bricks:
  - inner leaf: perforated clay bricks: 290 x 190 x 140 mm³
    average compressive strength: 15,7 N/mm²
  - outer leaf: clay bricks: 190 x 90 x 65 mm³
    average compressive strength: 16,0 N/mm²
- mortar: C_{300}
  average compressive strength: 11,7 N/mm²
  average flexural tensile strength: 2,1 N/mm²
- reinforcement: ɸ 10 x 7,1 mm² - width 250 mm
  in each mortar joint

All lintels were loaded by a local charge at mid-span.
The double-leaf lintels V_5A an V_5B were loaded at both leaves, the double-leaf lintel V_9 was loaded at the inner leaf only.

The reinforcement used was of the MURFOR type (see fig. 5).
The characteristics are given in fig. 6 for the Ø 4 mm and in fig. 7 for the ɸ 10 x 7,1 mm².

3. INSTRUMENTATION AND TESTING

The local load was applied at mid-span by a flexure machine of a maximum capacity of 200 kN.

The strain in the masonry was measured by a 8" mechanical extensometer. (See fig. 1-4, Demec points indicated by ⇔).

The strain in the reinforcement was measured by electrical strain gages (see fig. 1-4, strain gages indicated by ■).
For measuring the deflection of the lintel dial gauges were used (see fig. 1-4, dial gauges indicated by ↓).

The load was applied incrementally from zero load to a small load and back to zero loading and then from zero load to failure.
The load at which first crack(s) appeared was noted.

4. SOME TEST RESULTS

(The complete detailed test results are obtainable from the authors).

4.1. First-crack load, ultimate load

Lintel	Load at first crack P_c kN	Ultimate load P_u kN	Mode of failure
V_1A	5	15	(1)
V_1B	7,5	15	(1)
V_5A	8	22,5	(2)
V_5B	8	22,7	(2)
V_8	8	48	(3)
V_9	12	48	(3)

(1) compression of masonry
(2) fracture of the reinforcement
(3) shear failure

4.2. Crack patterns

Fig. 8, 9 and 10 give the crack pattern of respectively V_1B, the inner and the outer leaf of V_5B and V_8.

4.3. Deflections

The measured deflections as a function of load are given in the

fig. 11, 12 and 13 for respectively V_1B, V_5B, V_9 (inner and outer leaf).

4.4. Strain in masonry

The figures 14, 15 and 16 give the strain distribution for the mid-section at crack load for respectively V_1A, V_5A (inner and outer leaf) and V_9 (inner and outer leaf).

4.5. Strain in reinforcement

Some typical strain evolutions are given in the figures 17, 18 and 19 for the lintels V_1B, V_5A and V_8 respectively.

5. DISCUSSION OF TEST RESULTS

The failure load of the normally reinforced lintels is about three times the first-crack load.
Taking the tensile strength of the masonry as a design strength for the reinforced lintel gives a security against failure of about 3 for normally reinforced lintels and even 4 for heavily reinforced lintels.

The strain and deflection measurements on lintel V_9 show that 70% of the applied load is taken by the inner (loaded) leaf and 30% is taken by the outer leaf. This means that the zig-zag wire of the reinforcement really transfers load from the inner leaf to the outer leaf.

The comparison of lintel V_8 and V_9 shows that the first crack moments are in proportion to the thicknesses of the lintel.
This leads to the same statement as mentioned above.
The dotted lines in the figures 17, 18 and 19 give the calculated strain in the reinforcement. The design methode used is the same as the one normally applied for the elastic design of reinforced concrete.
All this goes to show that this design method can be an approximation for designing reinforced masonry lintels.

6. CONCLUSIONS

Given the results of these tests and the wellknown disadvantages of normally used lintels we can conclude that reinforced masonry lintels offer a much better solution for this problem.

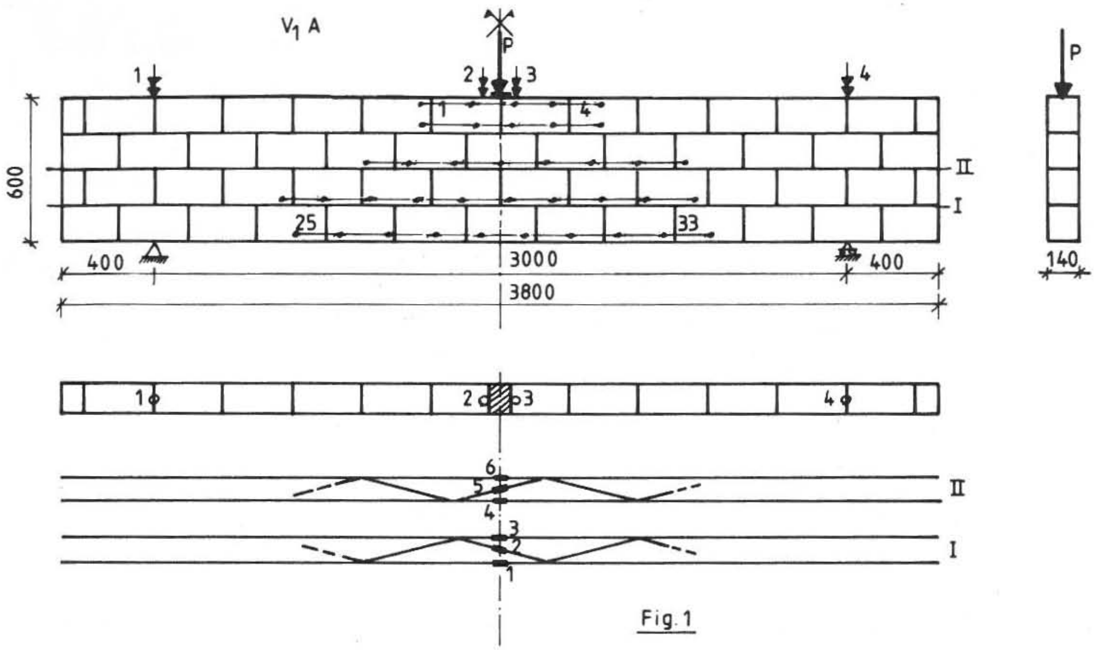

V1 A
P
1
2
3
4
II
I
600
25
33
400
3000
400
3800
140
6
5
4
3
2
1

Fig. 1

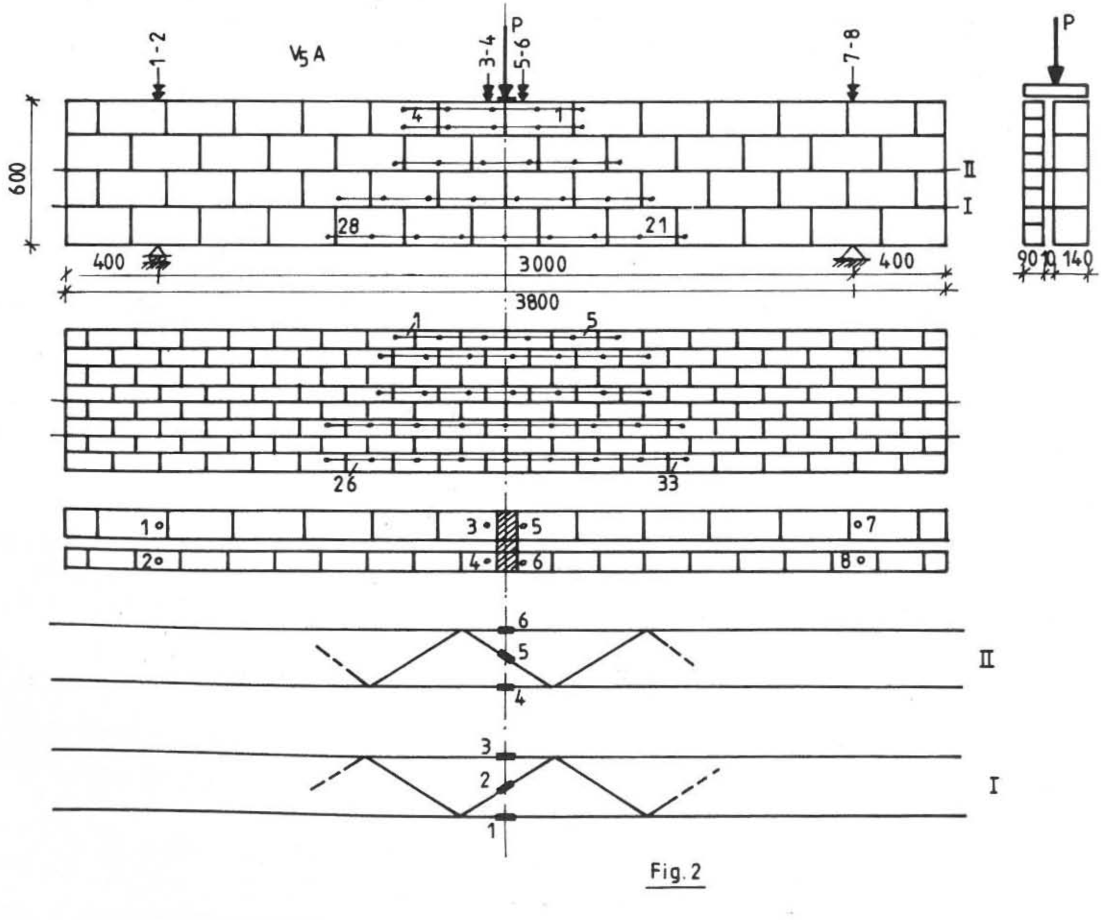

V5 A
P
1-2
3-4
5-6
7-8
II
I
600
28
21
400
3000
400
3800
90 10 140
26
33
6
5
4
3
2
1

Fig. 2

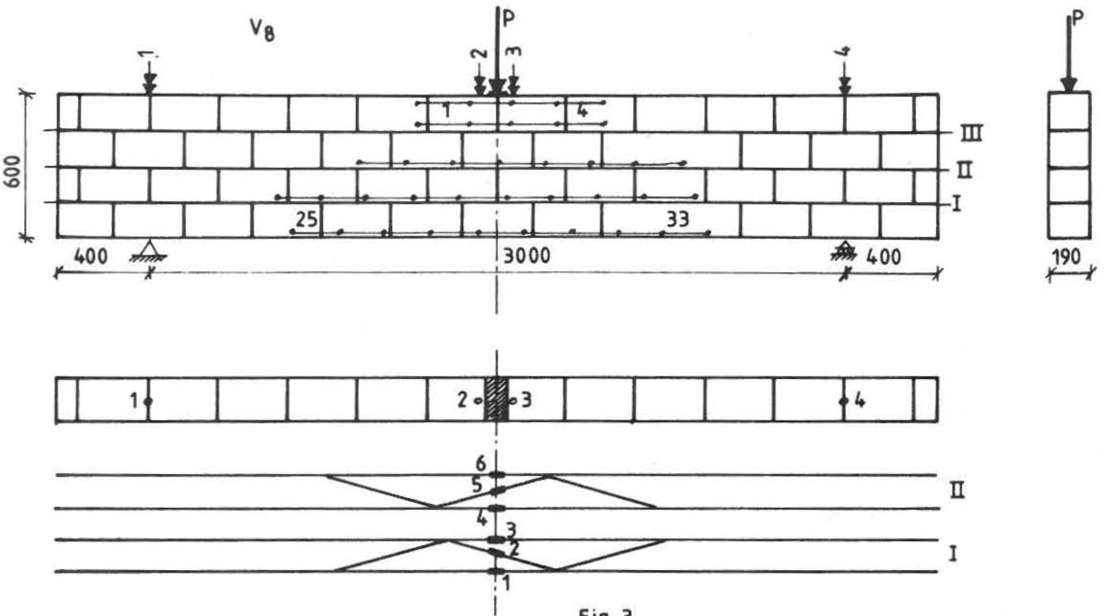

V8
P
1
2
3
4
600
III
II
I
25
33
400
3000
400
190
1
2
3
4
6
5
4
3
2
1
II
I

Fig. 3

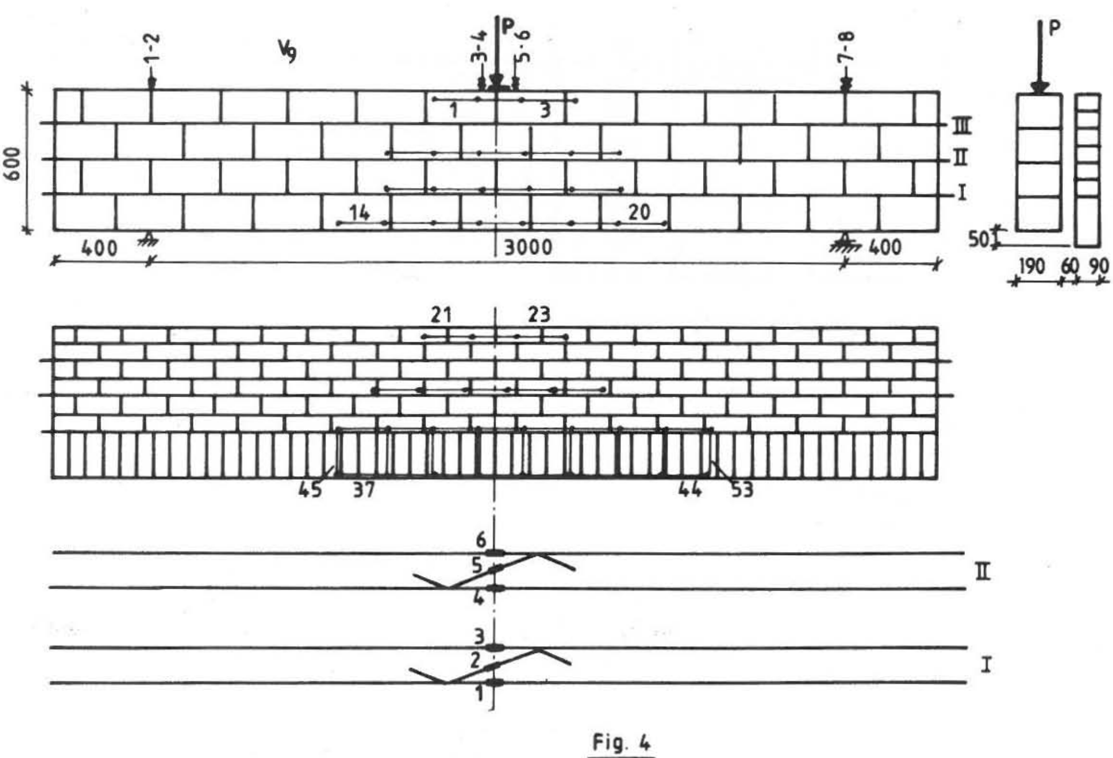

V9
P
1-2
3-4
5-6
7-8
600
III
II
I
1
3
14
20
400
3000
400
50
190
60
90
21
23
45
37
44
53
6
5
4
3
2
1
II
I

Fig. 4

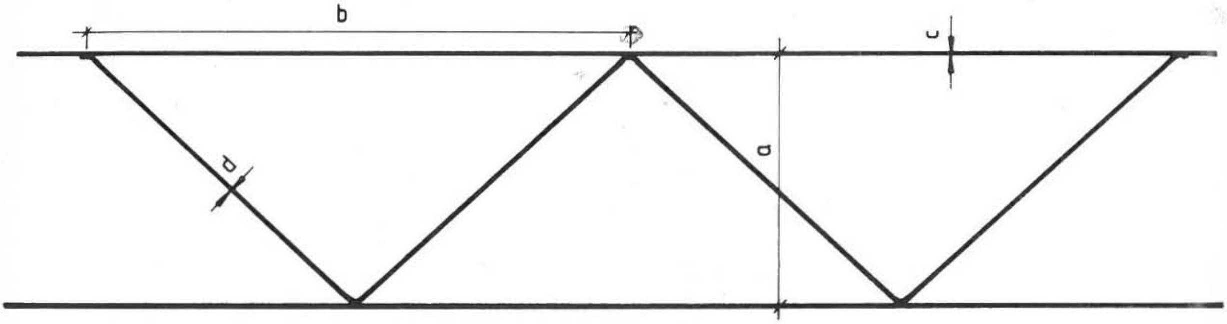


Fig. 5

Lintel	a mm	b mm	c	d Ø (mm)
V_1A	100	406	Ø 4 mm	3,75
V_1B	100	406	Ø 4 mm	3,75
V_5A	250	406	Ø 4,75 mm	3,75
V_5B	250	406	Ø 4,75 mm	3,75
V_8	150	406	■ 10 x 7,1 mm²	3,75
V_9	250	406	■ 10 x 7,1 mm²	3,75

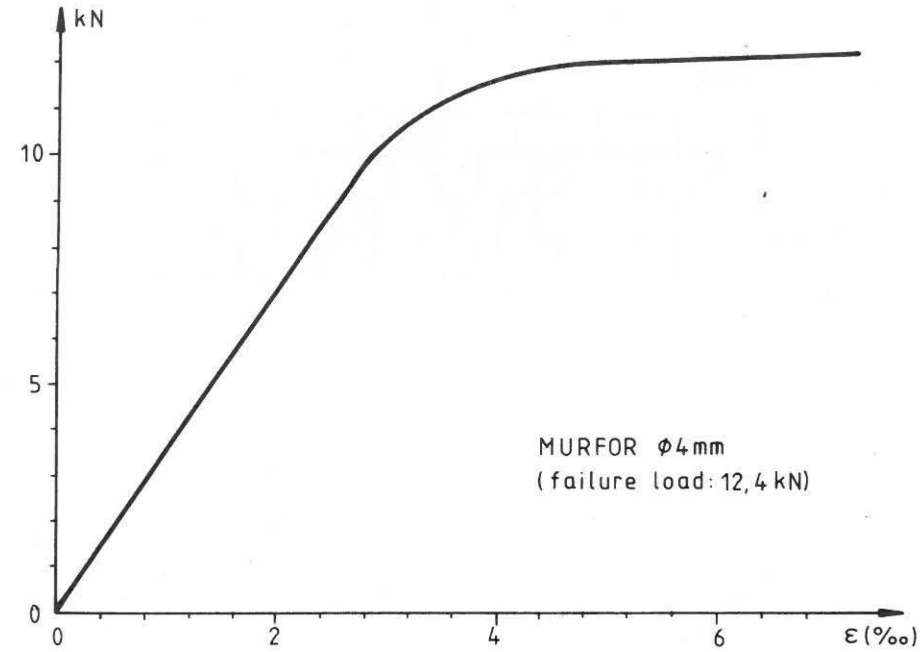

kN
10
5
0
0
2
4
6
ε (‰)
MURFOR Φ4mm
(failure load: 12,4 kN)

Fig. 6

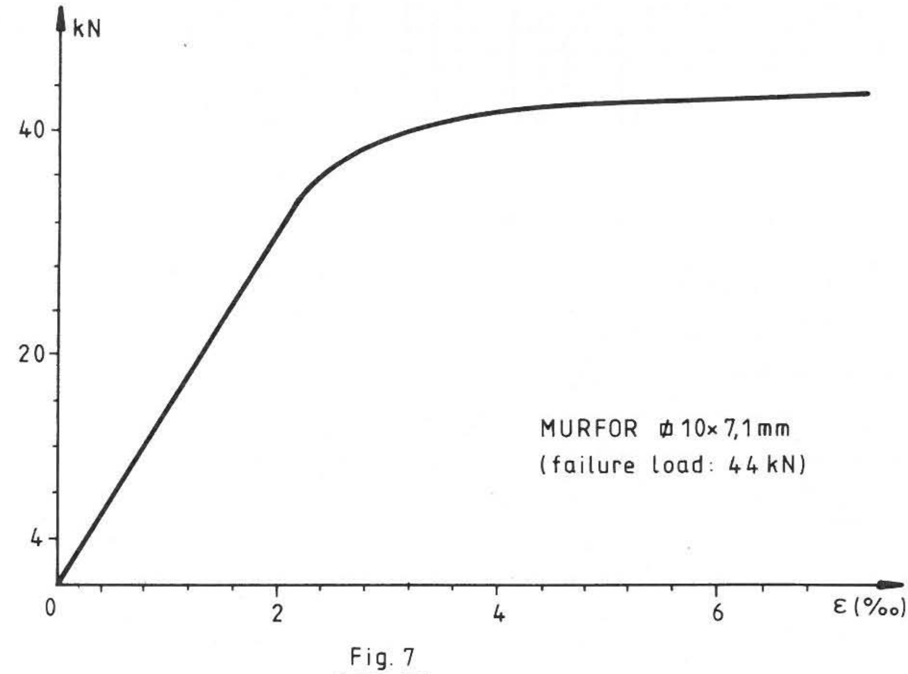

kN
40
20
4
0
2
4
6
ε (‰)
MURFOR Φ 10× 7,1 mm
(failure load: 44 kN)

Fig. 7

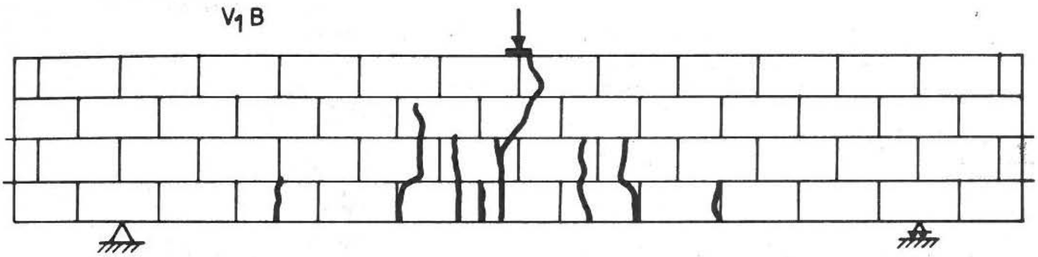


Fig. 8

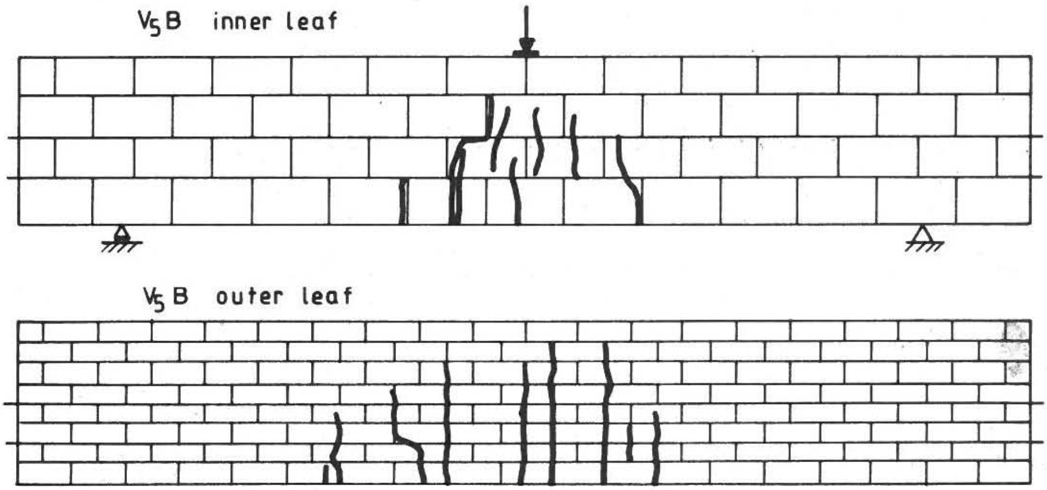


Fig. 9

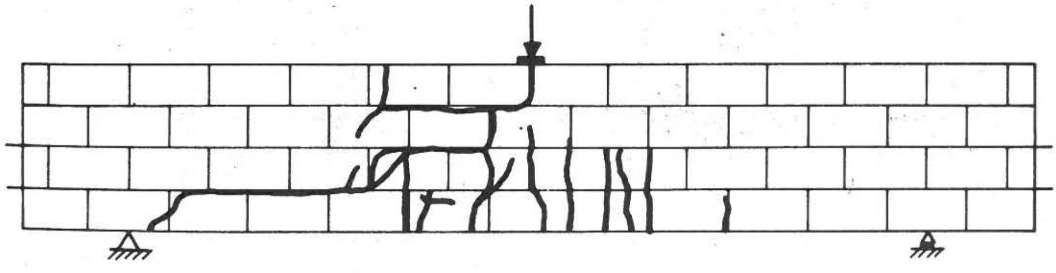
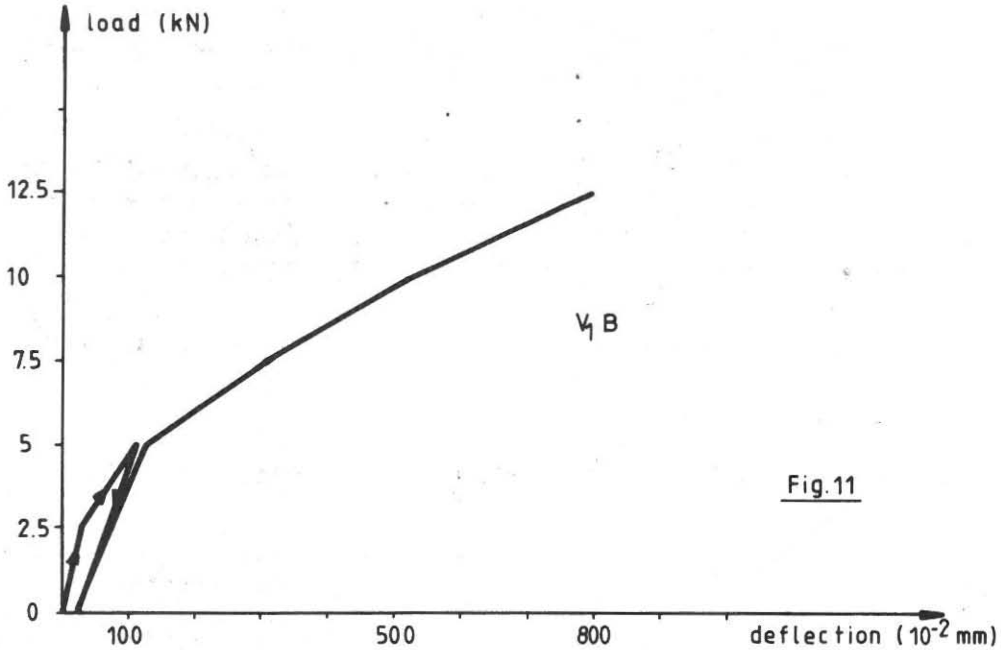
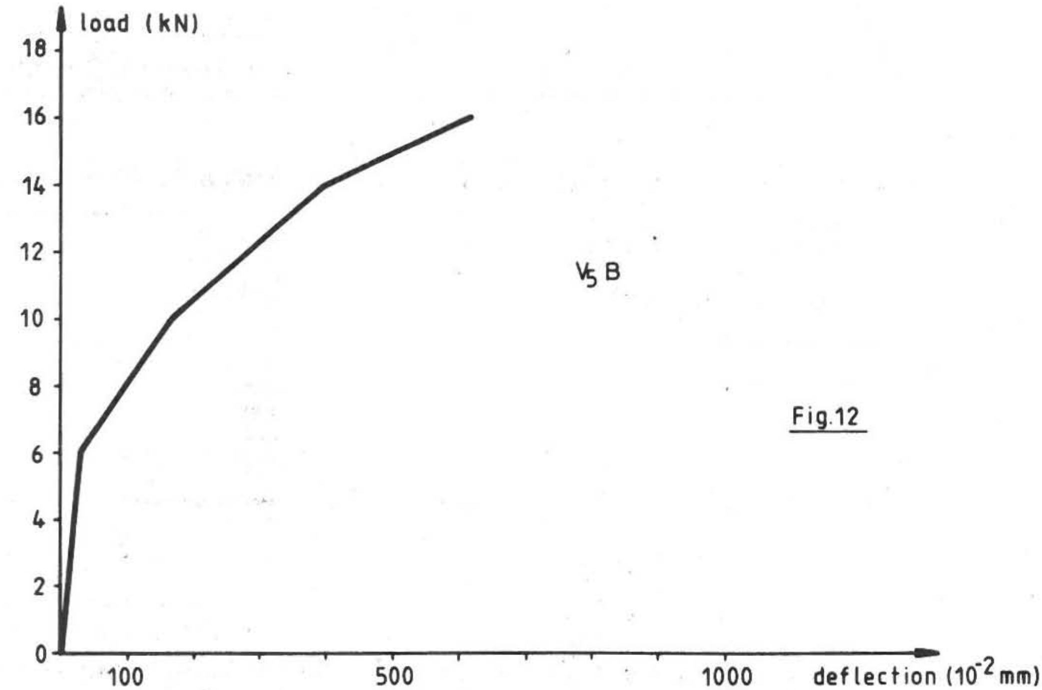


Fig. 10



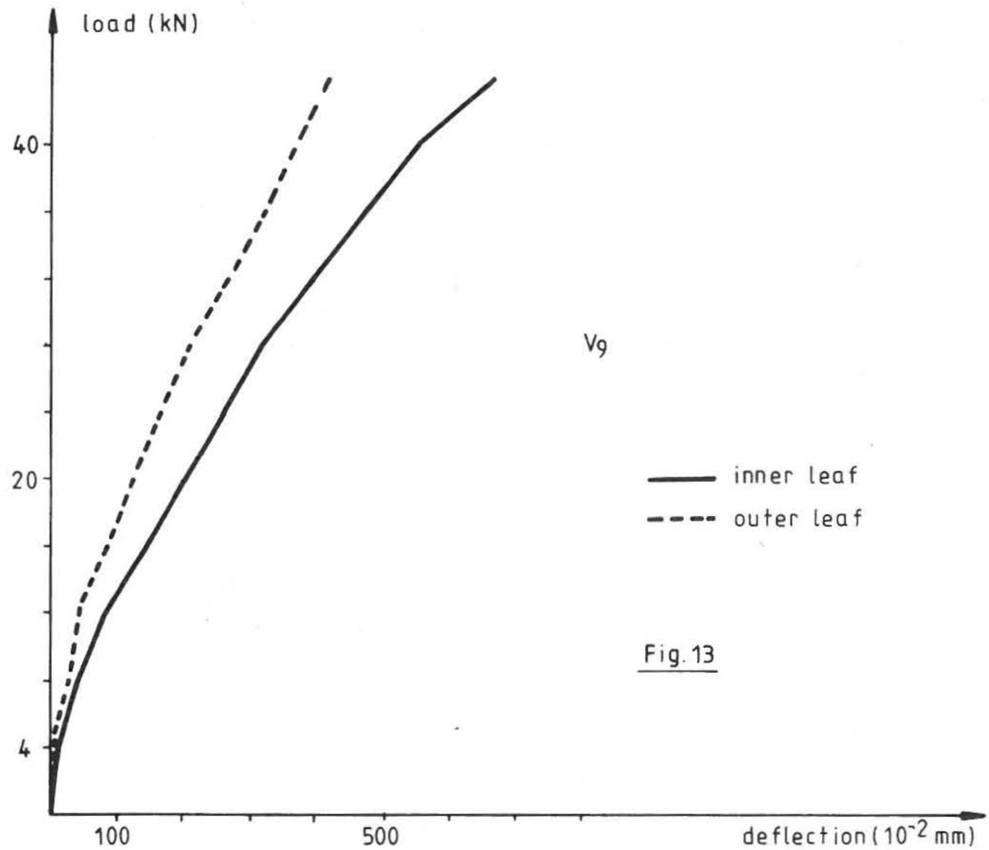
load (kN)
12.5
10
7.5
5
2.5
0
100
500
800
deflection (10^{-2} mm)
V_1 B

Fig. 11



load (kN)
18
16
14
12
10
8
6
4
2
0
100
500
1000
deflection (10^{-2} mm)
V_5 B

Fig. 12



load (kN)
40
20
4
100
500
deflection (10^{-2} mm)
V9
inner leaf
outer leaf

Fig. 13

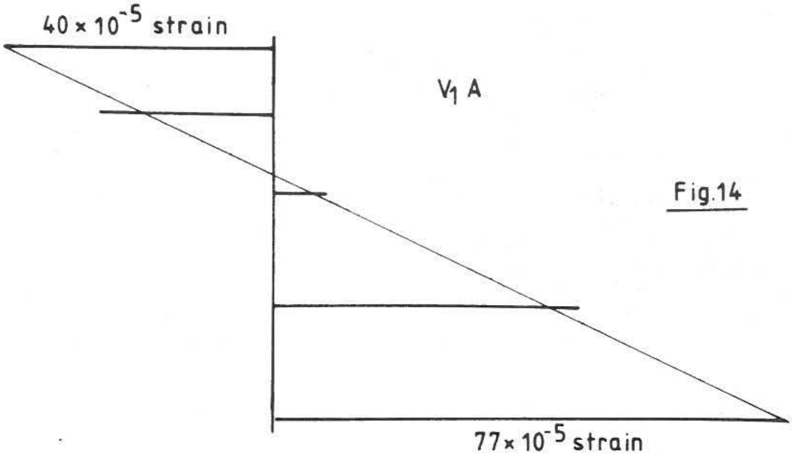

40×10^{-5} strain
V_1 A
77×10^{-5} strain

Fig.14

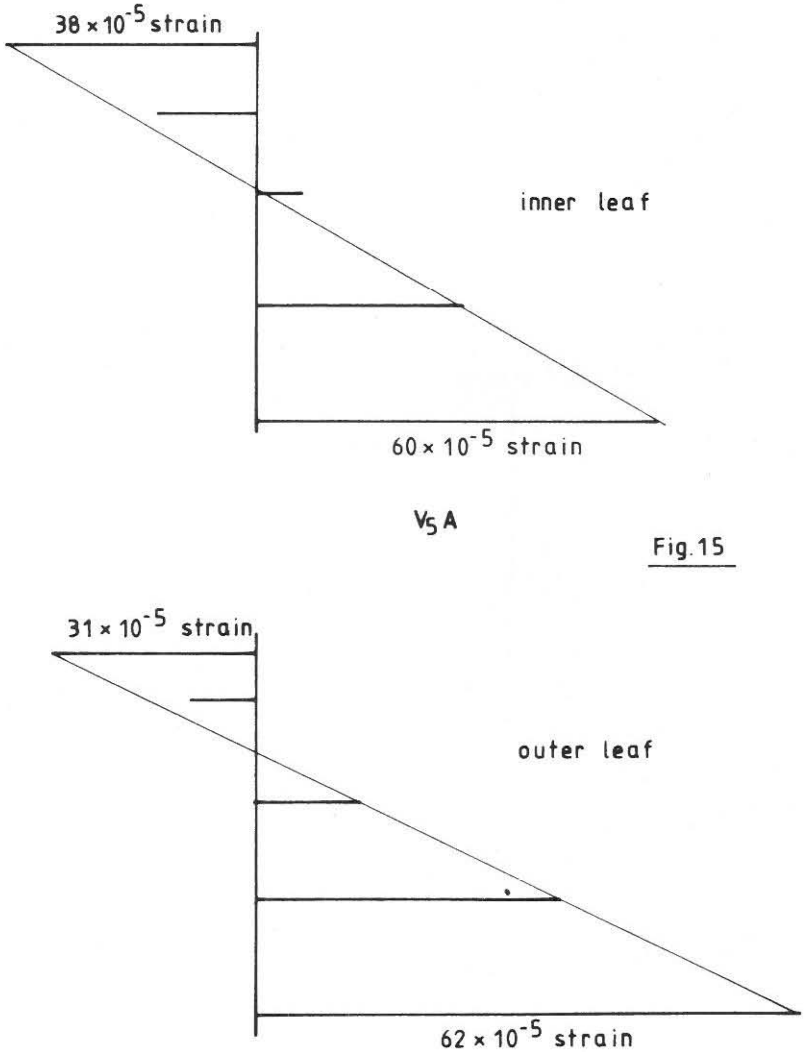
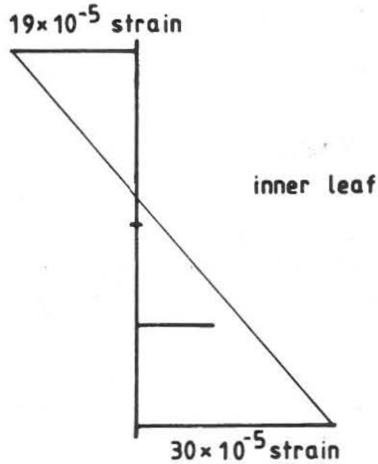
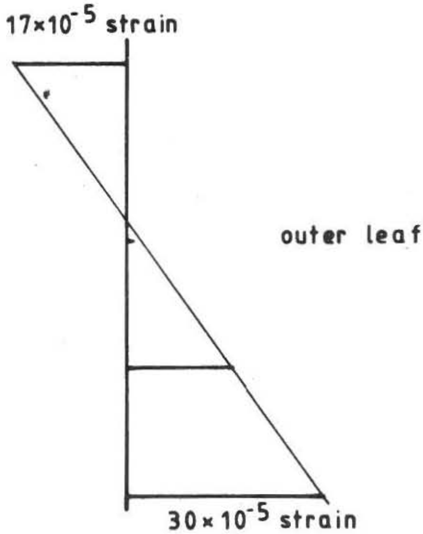

38×10^{-5} strain
inner leaf
60×10^{-5} strain
V_5 A
31×10^{-5} strain
outer leaf
62×10^{-5} strain

Fig.15


19×10^{-5} strain
inner leaf
30×10^{-5} strain

V.9

Fig.16


17×10^{-5} strain
outer leaf
30×10^{-5} strain

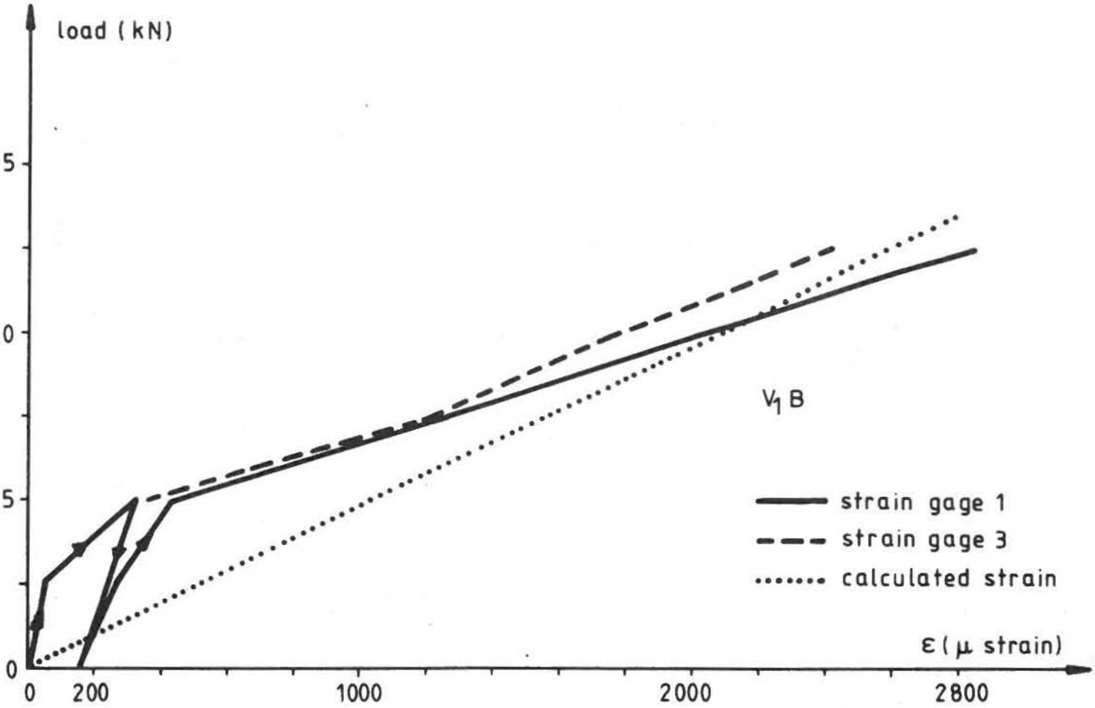

load (kN)
15
10
5
0
0
200
1000
2000
2800
ε (μ strain)
V1 B
strain gage 1
strain gage 3
calculated strain

Fig. 17

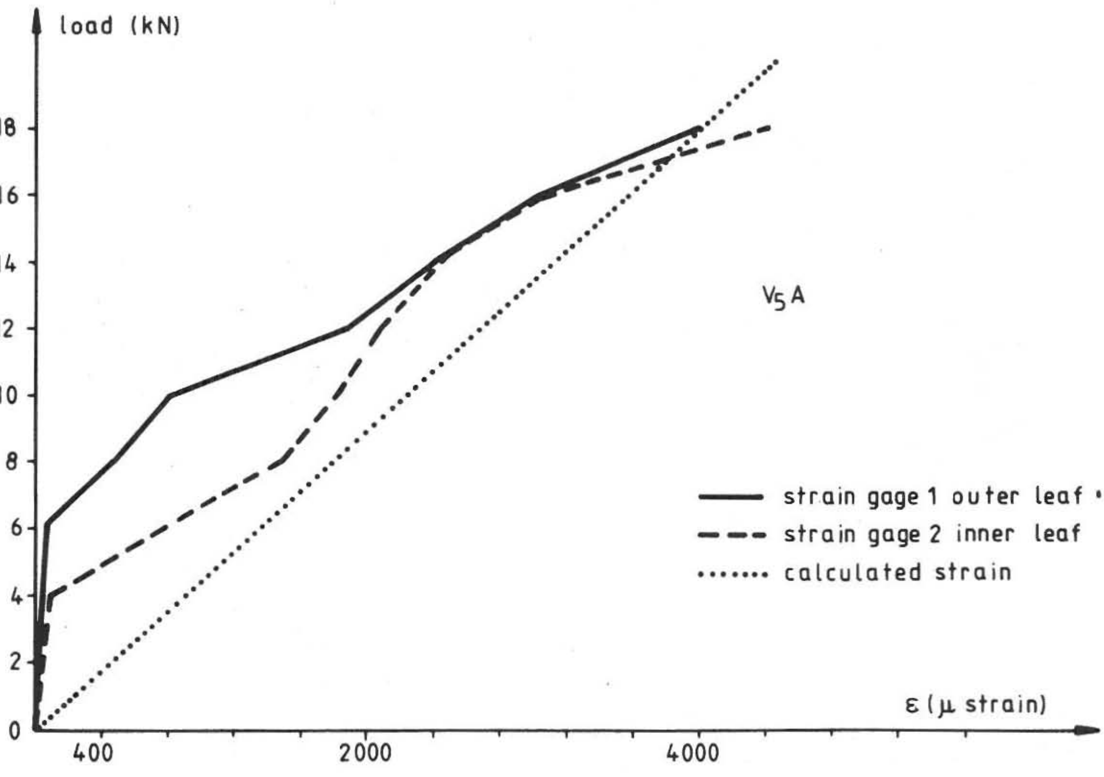

load (kN)
18
16
14
12
10
8
6
4
2
0
400
2000
4000
ε (μ strain)
V5 A
strain gage 1 outer leaf
strain gage 2 inner leaf
calculated strain

Fig. 18

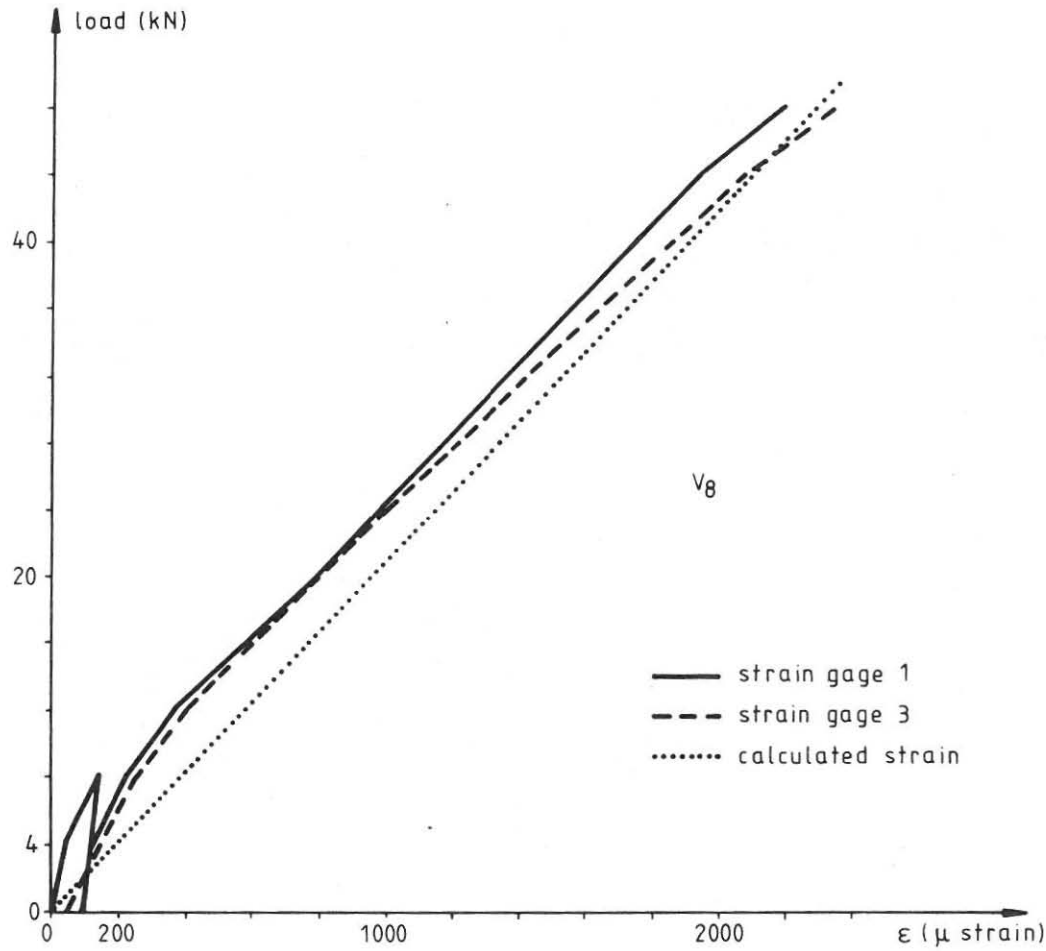

load (kN)
40
20
4
0
0
200
1000
2000
ε (μ strain)
V8
strain gage 1
strain gage 3
calculated strain

Fig. 19