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Experimental research on wall-slab connections

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Task

Experimental research on wall-slab connections

1 BACKGROUND

When multi-storey concrete buildings are made of bearing wall elements and prestressed hollow core slabs, the ends of the slab elements, together with the jointing concrete or mortar, transfer the loads from the upper wall element to the lower one. Simultaneously, the slab ends are subjected to a negative bending moment until they crack. To avoid unfavourable cracking modes of the slab end, different types of joint have been proposed [1] and used in different countries. Fig. 1 illustrates two alternatives with hypothetical cracking patterns.

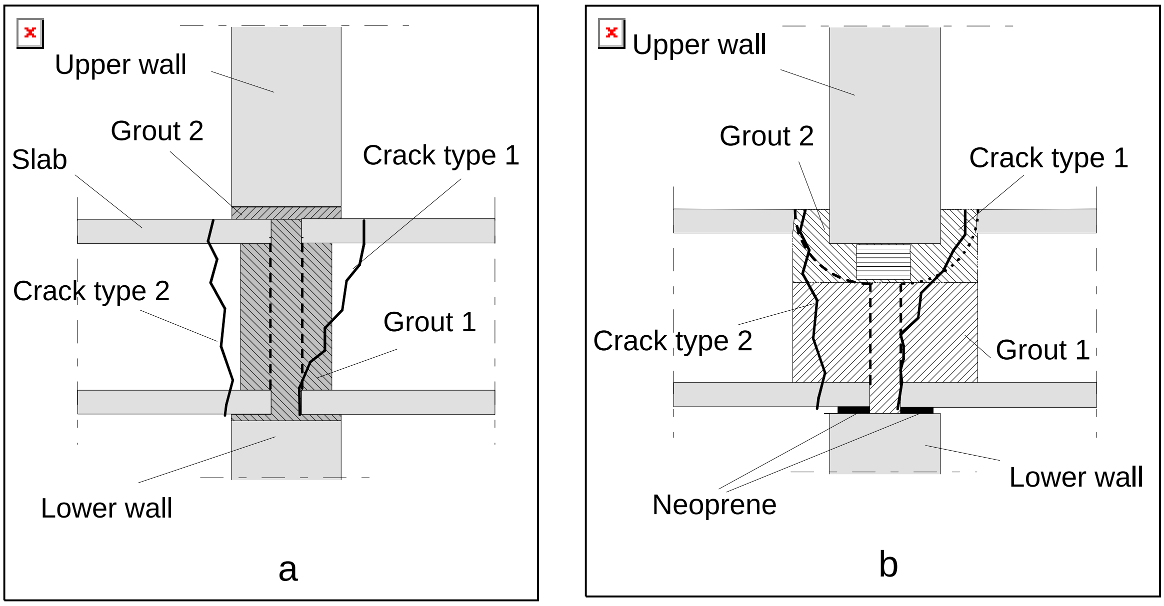

Fig. 1. Different joints with possible favourable (type 1) and unfavourable (type 2) cracking modes. a) Finnish BES joint. b) Joint with notched slab ends.

Crack type 1 represents a favourable mode with a slight or no effect on the load-bearing resistance of the slab. Crack type 2 can be considered unfavourable because it results in a reduction in the shear resistance of the slab end.

In 1978, several load tests on BES-joints similar to that in Fig. 1.a were carried out by VTT in Finland [2] in order to measure the vertical resistance of the joint between prefabricated concrete walls and hollow core slabs. The test layout is shown in Fig. 2. The weakness of these tests is obvious. The loads P_2 on the cantilevered slabs had to be small in order to prevent a premature collapse of the slabs. Despite the small value of P_2 , the slabs collapsed in numerous tests far before the vertical loads P_1 had achieved their ultimate value. The scatter of the results was great. It is likely that the results obtained using this test setup considerably underestimated the real vertical resistance of the joint.

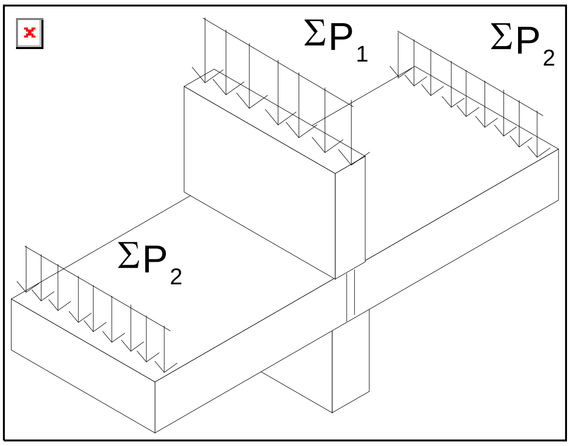

Fig. 2. Layout in tests of VTT in 1978.

There is a demand for higher buildings, longer spans, thicker floors and thicker walls. For these reasons, full employment of the vertical resistance of the joint has become actual. New tests, simulating the real behaviour of the joint more accurately than the old ones, have been considered necessary.

2 TEST ARRANGEMENTS

2.1 General

A new test layout shown in Fig. 3 was planned and three tests were carried out. One test (BES1) simulated a BES joint, two tests (N1 and N2) a joint with notched slab ends. Table 3 gives additional data about the tests.

The slabs were 10 m in length. The loads on the slabs were located at a distance of 3 m from the joint in order to create a rotation at the slab end and to simulate a realistic cracking at the joint. The maximum value of the load was determined to give a bending moment equal to 80 % of the flexural resistance of the slab but not higher. It was evaluated that the corresponding maximum shear force of the slab, equal to 108 kN, was too small to cause a shear failure, but high enough to simulate the typical shear force in residential buildings at the ultimate limit state.

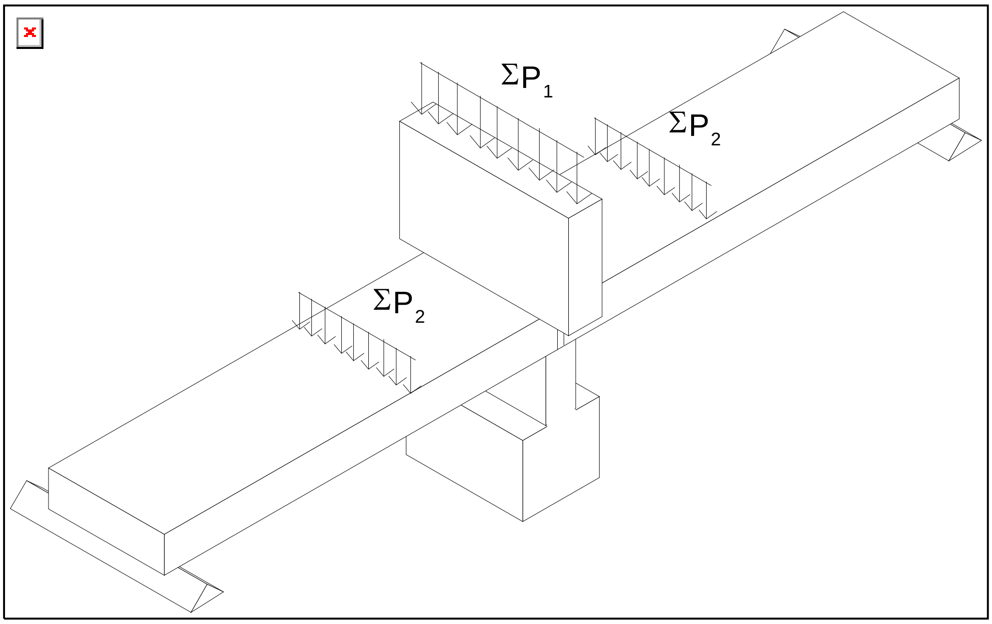

Fig. 3. General view on test layout.

Table 1. Basic data about tests. For numbering of slabs and their ends, see App. 1.

Test	Slab ends	Slab /slab end in joint		Jointed	Tested
		East side	West side		
BES1	Vertical	5 / 1	6 / 2	23-24 Oct	5 Nov
N1	Notched	2 / 2	1 / 1	23-24 Oct	9 Nov
N2	Notched	3 / 2	4 / 1	14-15 Nov	26 Nov

The notches in slabs 1 – 4 were made before hardening of the concrete using a special screw. For the notches see App. 1, Fig. 1.b and App. 7, Fig. 2.

2.2 Test specimens

The test specimens were made of slab elements and wall elements made by Parma Betonila Oy and Specifinn Oy, respectively.

The slab elements with four hollow cores were 320 mm in depth and provided with 9 12.5 mm strands (A_p = 93 mm^2). They were cast on 19th of September and delivered to VTT on 28th of September 2001. The nominal and measured cross-sectional data of the slabs are given in App. 1.

The wall elements were cast on week 39 and delivered to VTT on 4th of October 2001. They are depicted in Figs 4 – 7. The upper wall elements were identical in all three tests. The geometry of the lower wall element was the same in all tests but the reinforcement in tests N1 and N2 was different from that in test BES1.

The design of the test specimens is given in Figs 4 – 9. The specimens are illustrated in Appendices 6 and 7 in Figs 1 – 5 and 1 – 4, respectively.

In all figures of this report, symbol TXY refers to a reinforcing bar with diameter XY and made of reinforcing steel A500HW. All measures are given in millimetres.

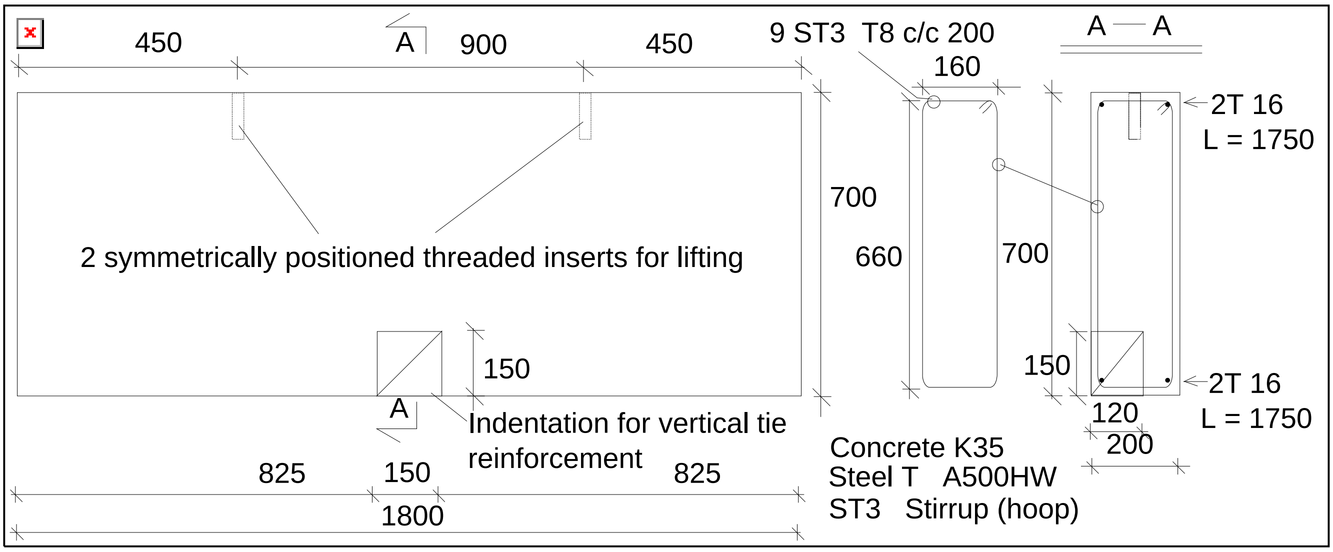

Fig. 4. N1 and N2. Upper wall element WU1.

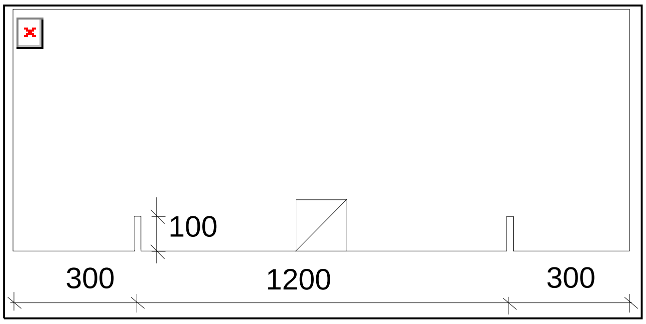

Fig. 5. BES1. Sawn notches in upper wall element WU0. Otherwise WU0 is identical with element WU1.

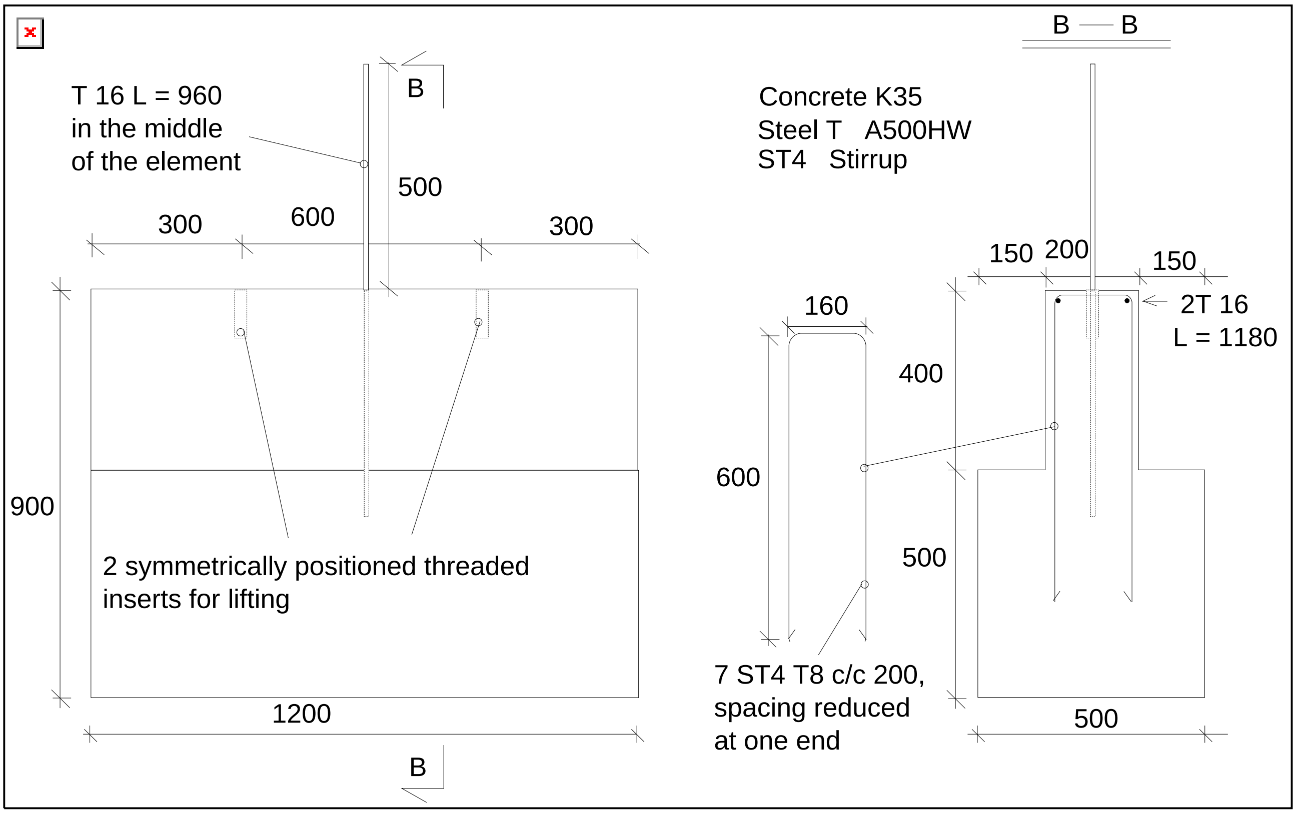

Fig. 6. BES1. Lower wall element LW0.

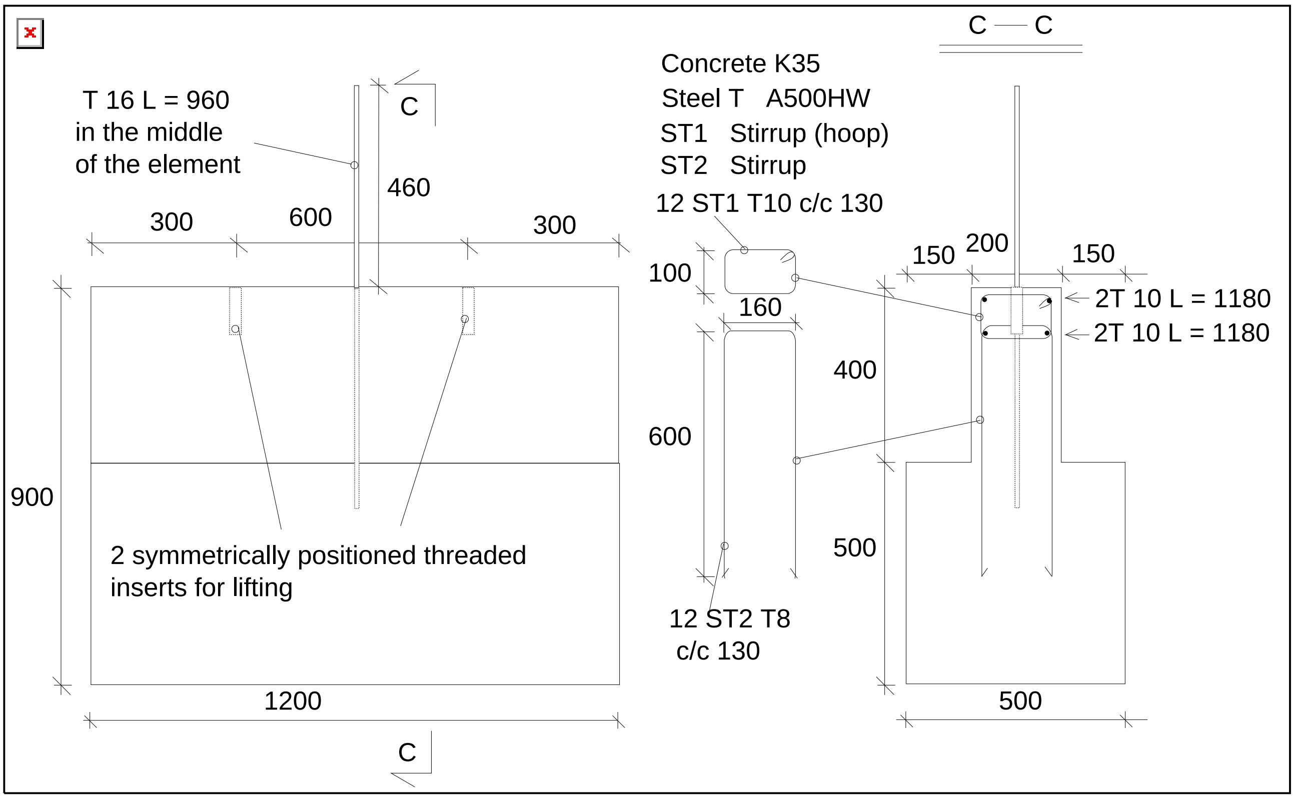

Fig. 7. N1 and N2. Lower wall element WL1.

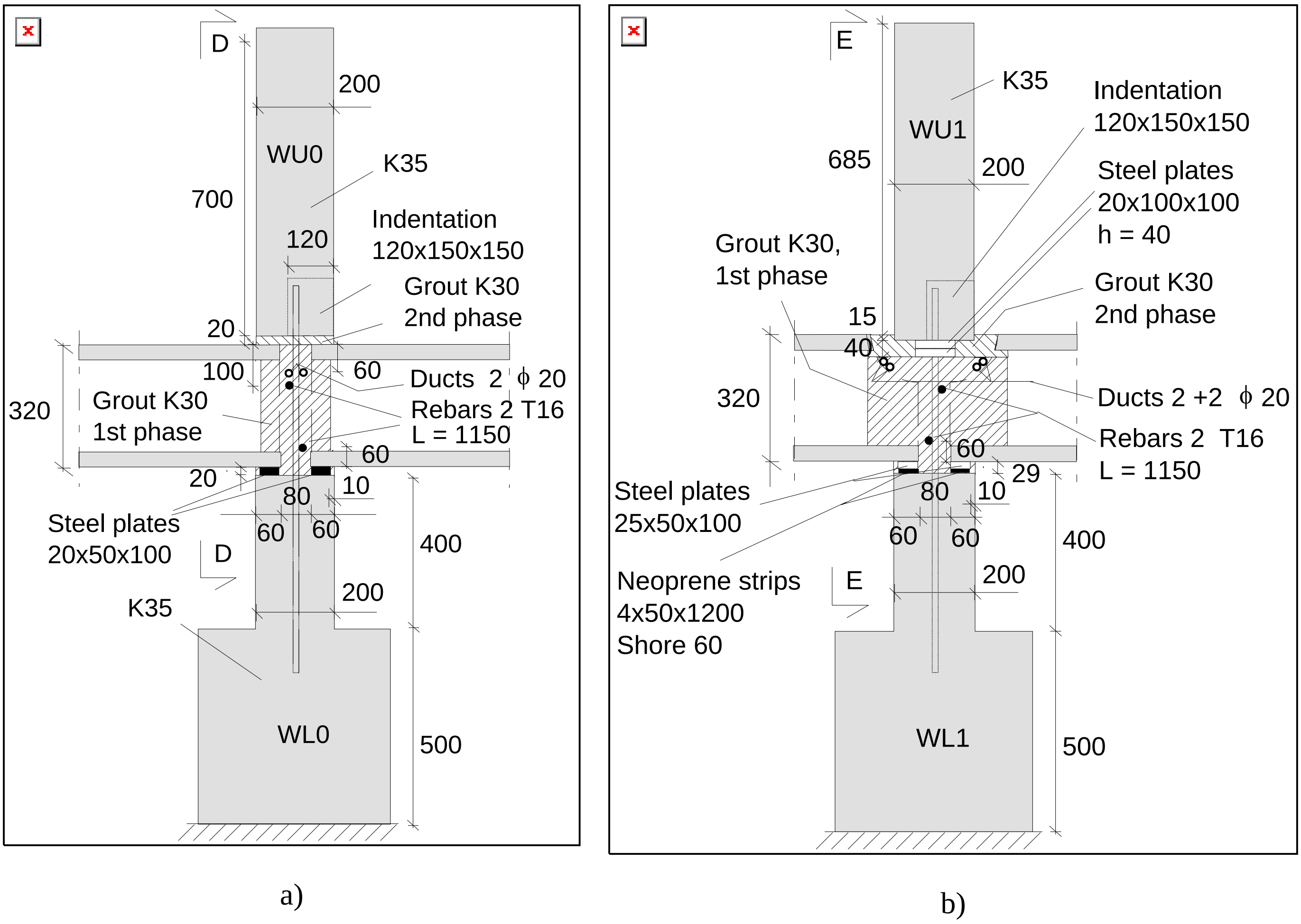

Fig. 8. Details of joint. a) BES1. b) N1 and N2. For sections D – D and E – E see Fig. 9.

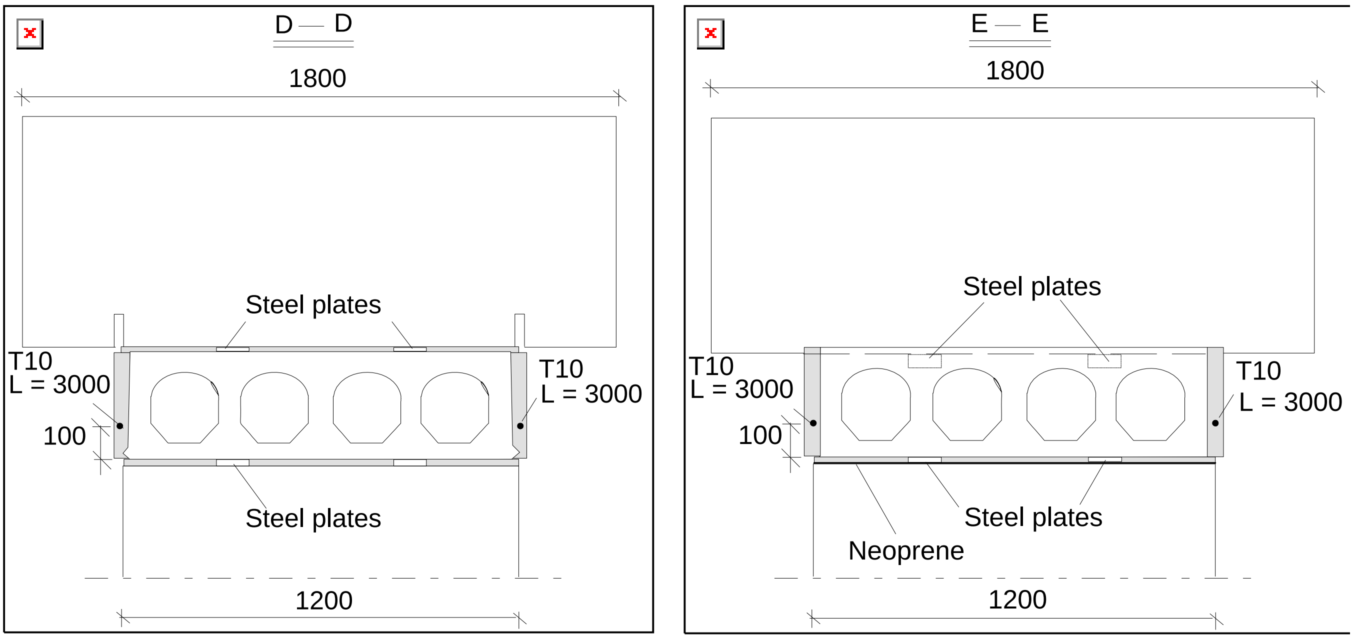

Fig. 9. Sections D – D and E – E, see Fig. 8.

In Table 2, material data are given.

Table 2. Nominal strength of steel and target grade and maximum aggregate size of concrete.

	Strength MPa	Grade	Aggregate size mm
Reinforcing steel A500HW	500		
Prestressing steel	1570		
Concrete in wall element		K35	18
Grout in joints		K30	8
Concrete in slabs		K60	16

2.3 Loading arrangements

In Fig. 10 the location of the actuators and supports is given. In tests N1 and N2 there were two steel plates 50x275x480 mm^3 above the upper wall element and under the outermost actuators in order to even out local stress concentrations.

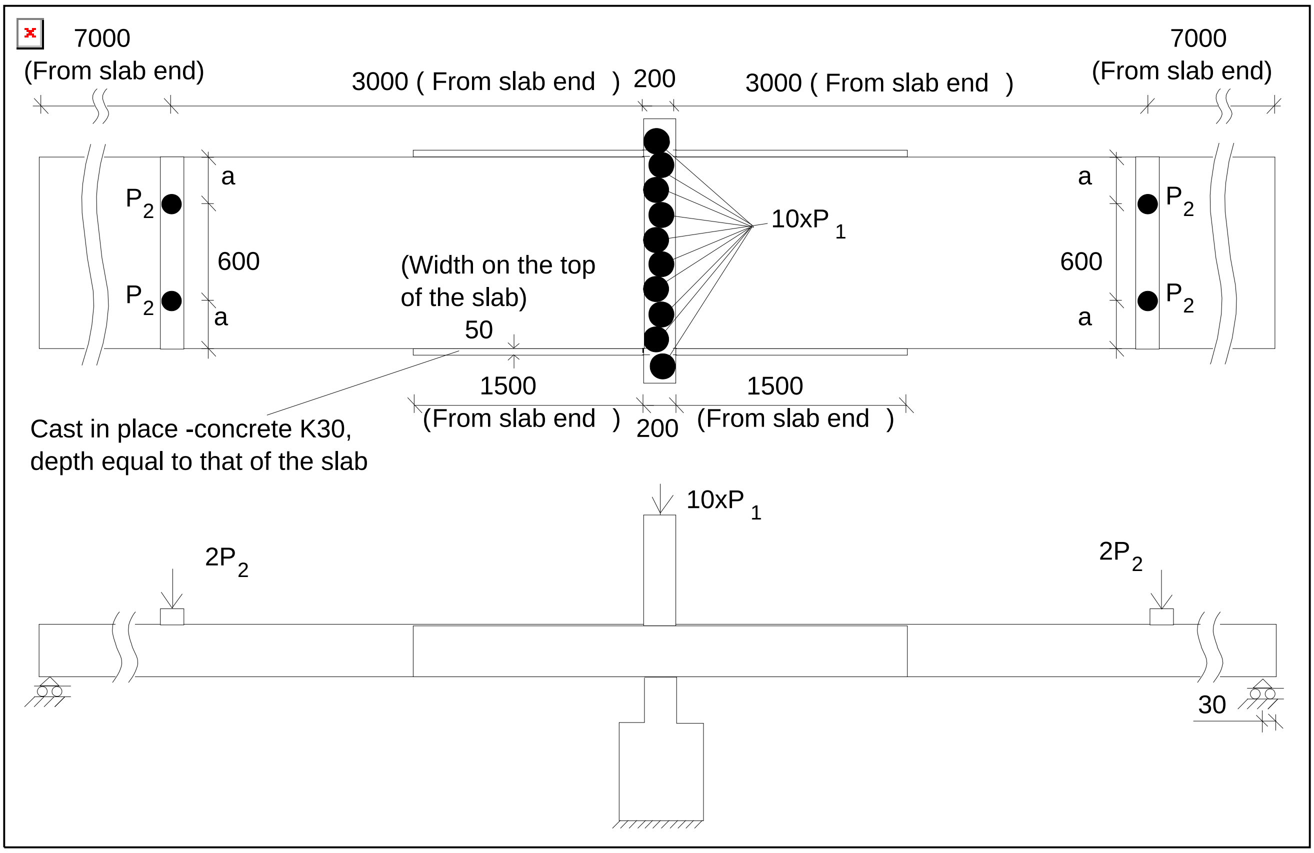

Fig. 10. Loads.

The total load F_1 on the joint is obtained from

$$F_1 = \Sigma P_1 + \text{weight of upper wall} + \text{weight of loading equipment}$$

$= \Sigma P_1 + 8.4$ kN in test BES1

$= \Sigma P_1 + 9.5$ kN in tests N1 and N2

and the total load F_2 on a slab from

$$F_2 = 2P_1 + 0.27 \text{ kN}$$

Fig. 11 illustrates the chosen loading strategy. It consists of several steps. The steps 1 - 30 tend to simulate the service loads during construction and use of the building. The steps from 31 on simulate a way to find out the ultimate vertical resistance of the joint, but not the shear resistance of the slab ends. The different stages are described in Table 3.

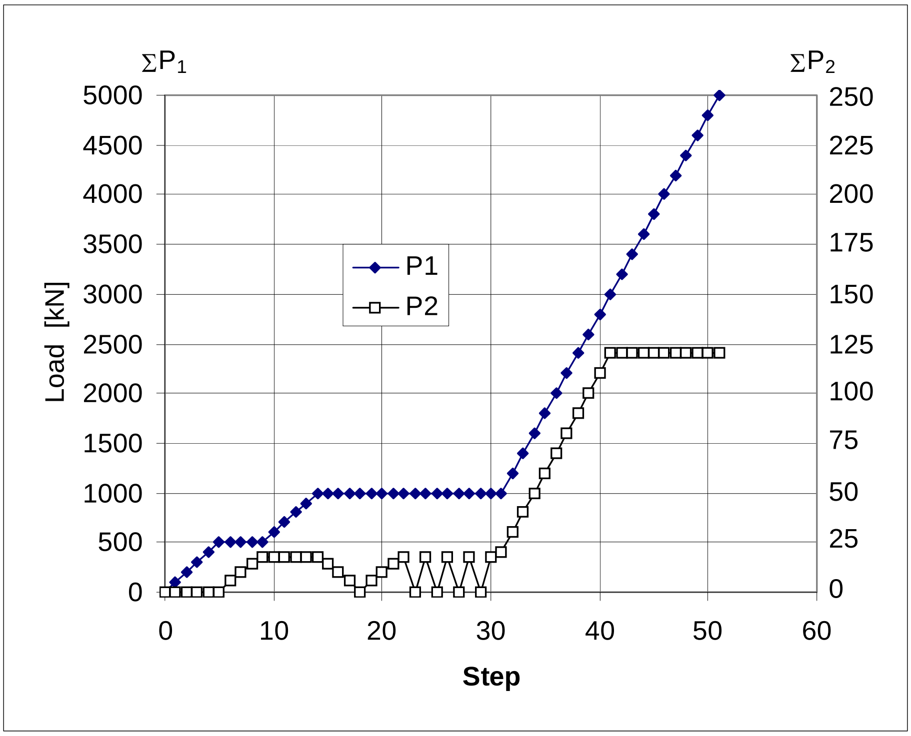

Fig. 11. Loading strategy.

Table 3. Stages simulated by loading.

Steps	Stage
0 - 5	Erection of lower stories
6 - 9	Service load on 1st floor
10 - 14	Erection completed
15 - 30	Varying service load on 1st floor, joint subjected to constant load
31 - 41	Search for ultimate resistance of the joint
42 - 51	Search for ultimate resistance of the joint, floor loads constant (bending moment = 80 % of flexural resistance)

2.4 Measurements

Loads, settlement of the upper wall element and the supports of the outer ends of the slabs as well as the deflection of the slabs and rotation of the slab ends next to the joint were measured. Location of the measuring devices is given in Fig. 12. See also Fig. 5 in App. 6 for illustration of inductive transducers.

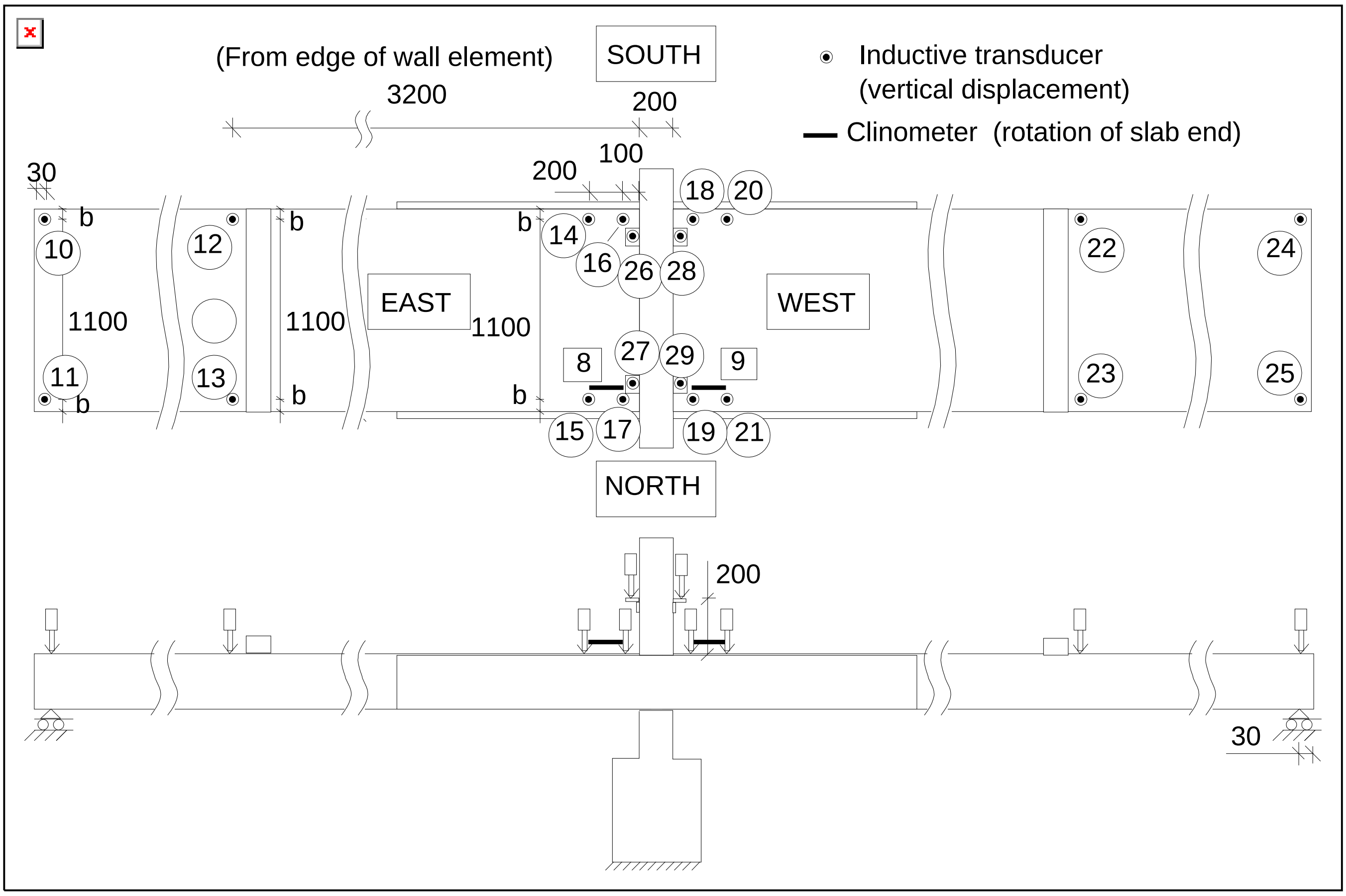

Fig. 12. Measurements.

3 RESULTS OF LOAD TESTS

3.1 Test BES1

The loading strategy given in Fig. 11 was followed. After load step 44 the upper wall element cracked vertically outside the slabs, see Fig. 3 in App. 6. After this, the load steps were renumbered starting from 100. Three actuators of 10 were removed from the top of the upper wall element and the loading was continued. After load step 106 the loads P_1 were reduced to zero, one actuator was added and all eight actuators on the top of the wall element were rearranged. The loads were increased again until the joint failed.

The observations during the test are listed in Table 4. Photographs of the test are shown in App. 6. The measured data are given in App. 3 and illustrated in Figs 13 - 18.

As can be seen in Fig. 14 , the east face of the upper wall element moved down faster than the west face. Eventually, the east upper edge of the lower wall element and the west lower edge of the upper wall element failed at the same time as the global failure took place (see Figs 7 -13 in App. 6). The failure was rather brittle.

Despite unfavourable cracking mode (vertical cracks outside the wall), the slabs could carry the shear force of 108.7 kN. The failure of the eastern slab was caused mainly by the failure of the vertical joint, not by the shear force of the slab.

Table 4. Observations made during test BES1.

Step	
33	Vertical cracks at slab ends on both sides of the joint outside the joint
34	Vertical crack within the joint, obviously along the grout between slab ends
39	Flexural cracks in soffit of slabs in the loaded zone
44	After this step, upper wall element failed locally outside the joint, see fig. 13 in App. 6, unloading, 3 actuators removed, reloading
106 (F_1=3.82 MN)	After this step unloading, one actuator added and all actuators rearranged on the wall element, reloading
110 (F_1=3.84 MN)	Failure of the joint

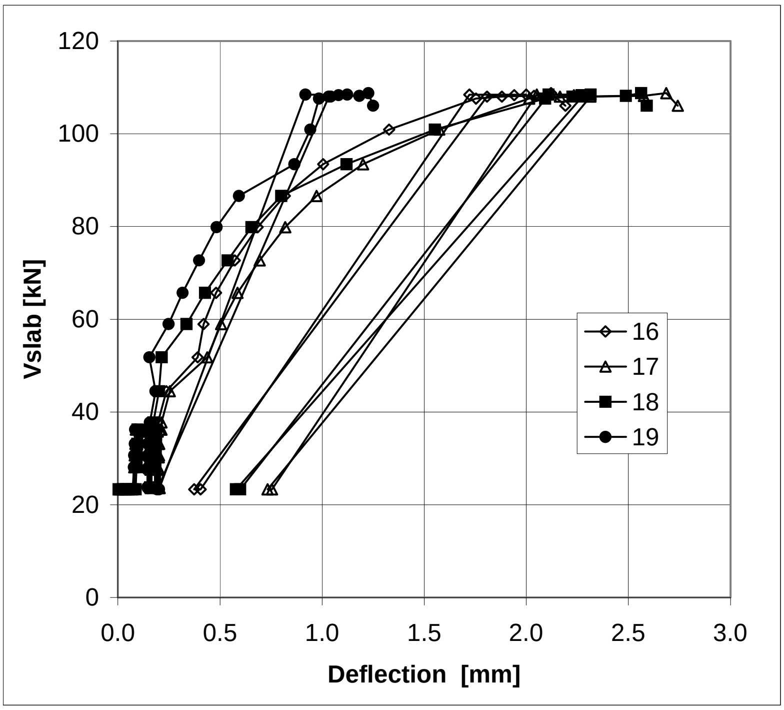

Fig. 13. BES1. Vertical displacement of slab ends at the joint measured by transducers 16 – 19.

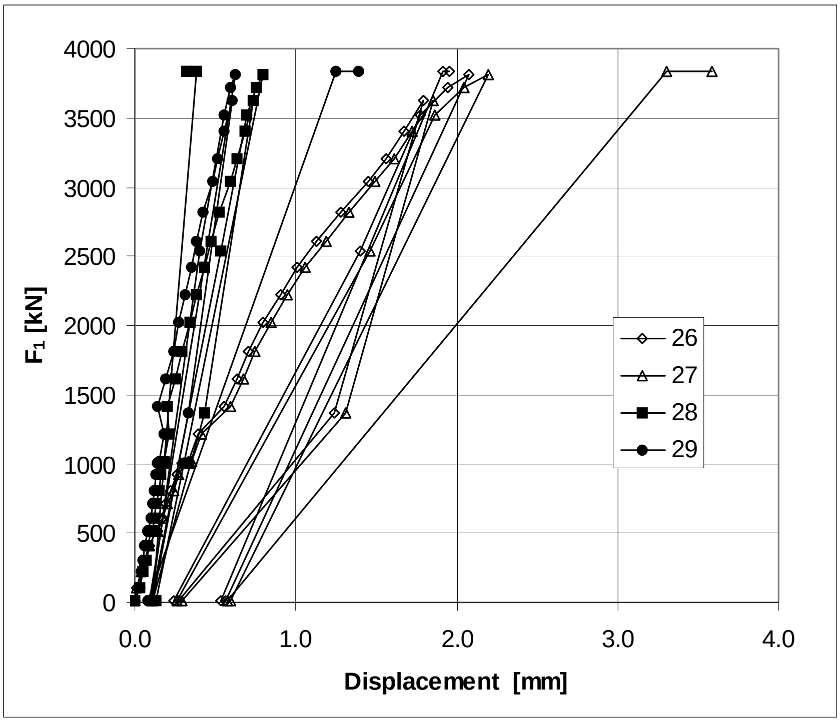

Fig. 14. BES1. Vertical displacement of upper wall element measured by transducers 26 – 29.

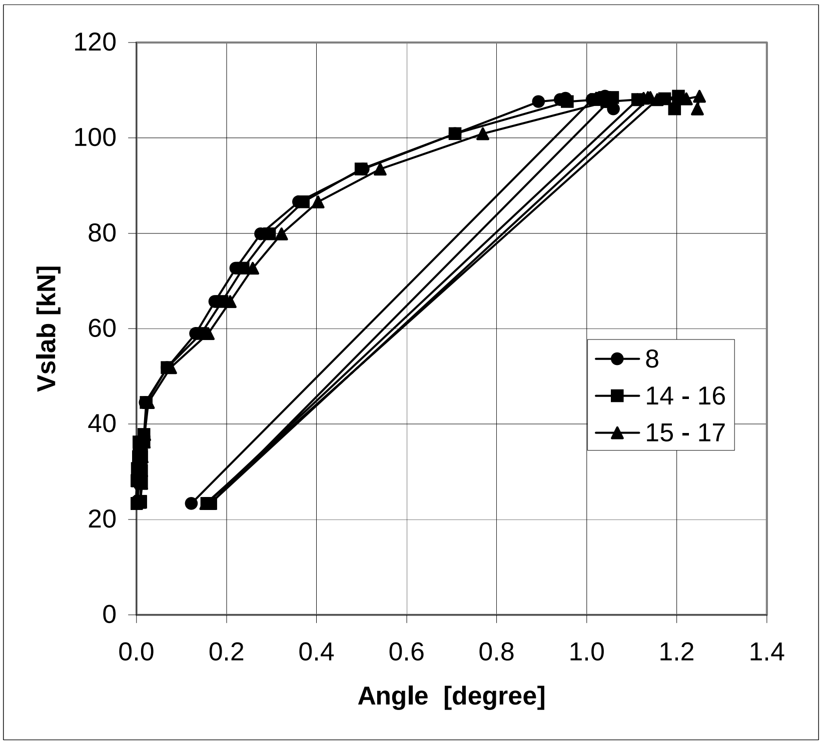

Fig. 15. BES1. Rotation of slab end on the east side of the joint measured by clinometer 8 and transducers 14 – 17.

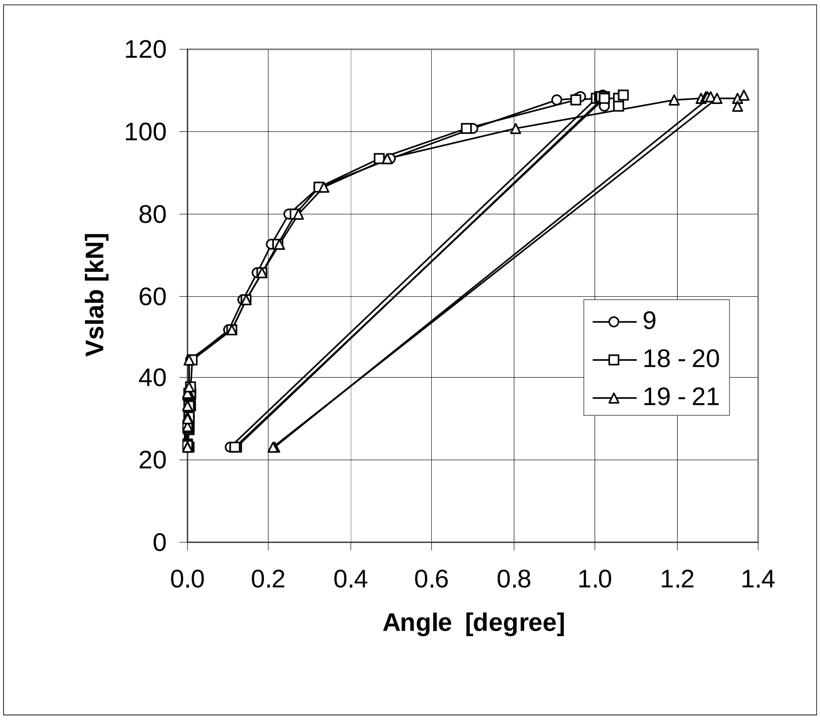

Fig. 16. BES1. Rotation of slab end on the west side of the joint measured by clinometer 9 and transducers 18 – 21.

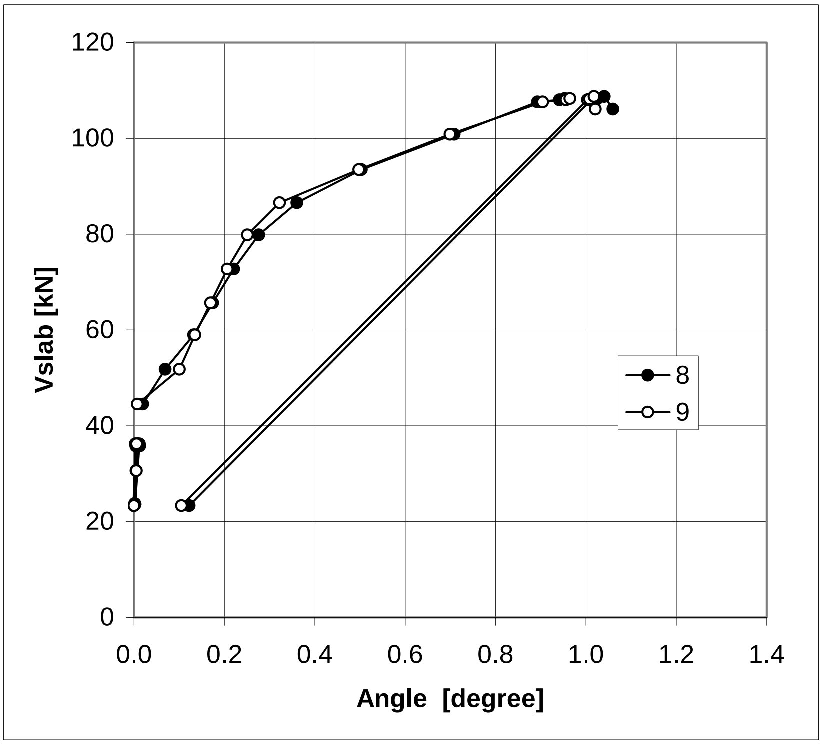

Fig. 17. BES1. Rotation of slab ends on both sides of the joint measured by clinometers 8 and 9.

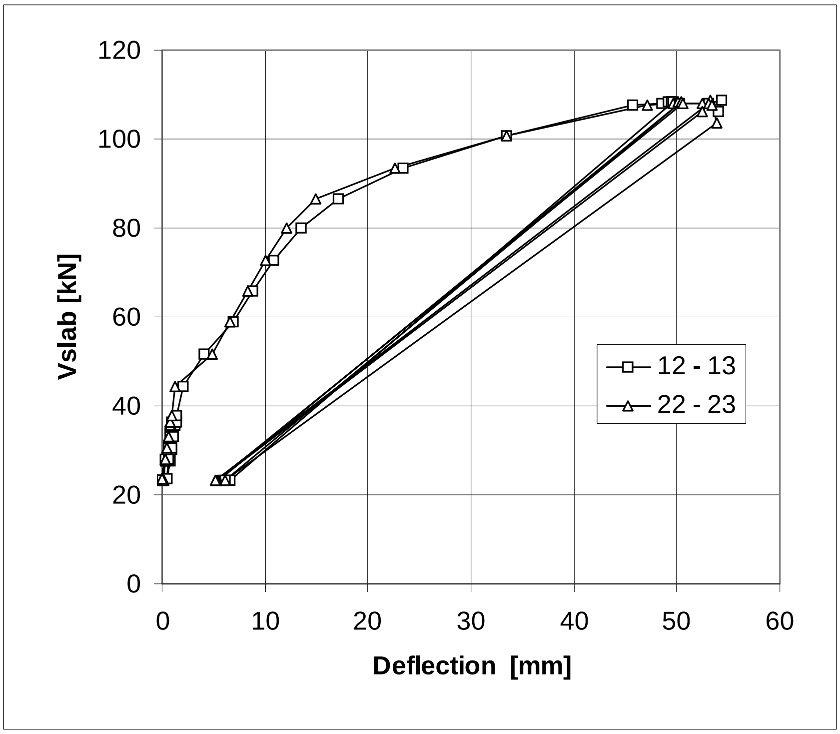

Fig. 18. BES1. Deflection of slab. The plotted curves represent the mean of the values measured by transducers 12 & 13 and 22 & 23.

3.2 Test N1

The loading strategy specified in Fig. 11 was followed, but measurements were not carried out at all steps. After step 46 the increments of loads P_1 were halved in order to measure the failure load more accurately. The new steps were called 46.5, 47.5, ... After step 48.5 there was a leakage in the hydraulic system. After unloading, the machinery was repaired and the test specimen reloaded.

The observations during the test are listed in Table 5 . Photographs of the test are shown in App. 7. The measured data are given in App. 4 and illustrated in Figs 19 - 24.

As can be seen in Fig. 20, the west side of the upper wall element moved down faster than the east side. At failure, the upper edge of the lower wall element on the west side and the lower edge of the upper wall element on the east side failed simultaneously (see Figs 4 and 14 in App. 7). The failure was rather brittle.

Despite unfavourable cracking mode (vertical cracks outside the wall), the slabs could carry the shear force of 108.7 kN. The failure took place in the joint. The shear resistance of the slab end was not exceeded.

Table 5. Observations made during test N1.

Step	
32	Vertical crack at slab end on east side of the joint, outside the joint
34	Vertical crack at slab end on west side of the joint outside the joint
36	Vertical crack within the joint between slab ends
39	Flexural cracks in soffit of slabs
44	Strong deformation in neoprene, peeling of concrete in lower wall element outside the neoprene strip, see Fig. 7 in App. 7
48.5	After this step unloading and reloading due to problems in hydraulic system
110 (F_1=4.95 MN)	Failure of the joint

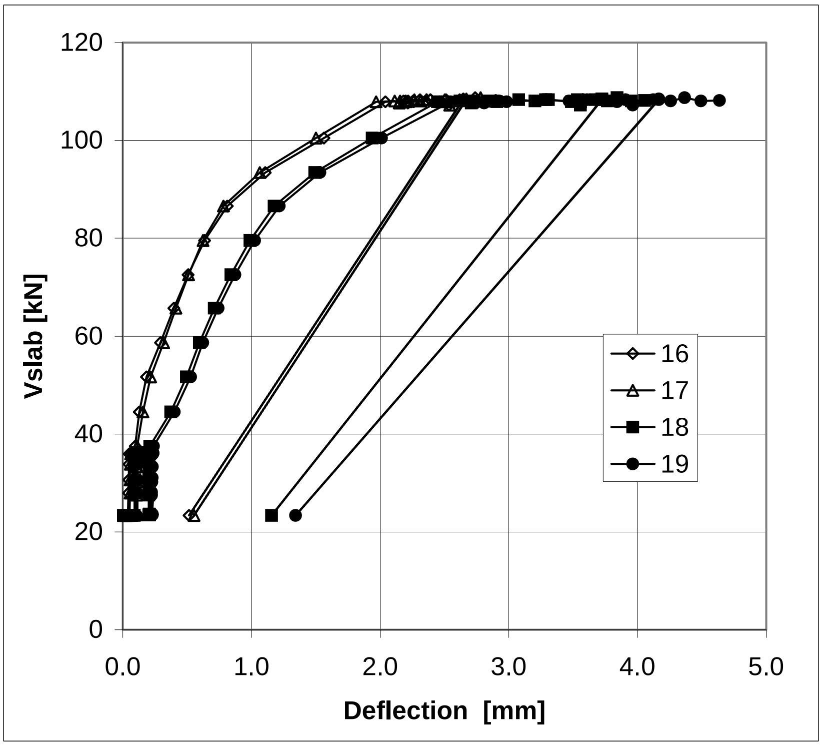

Fig. 19. N1. Vertical displacement of slab ends at the joint measured by transducers 16 – 19.

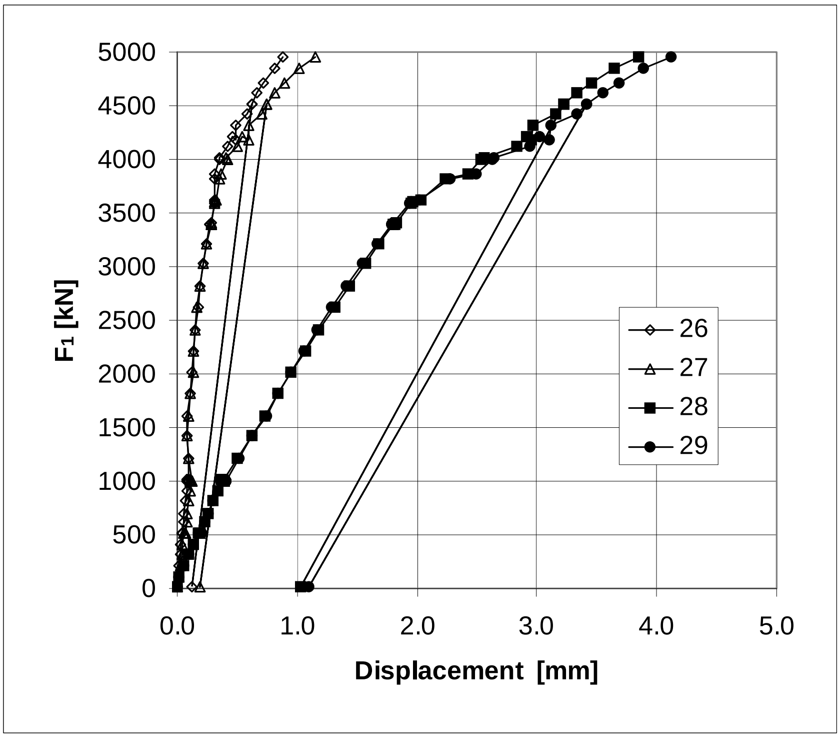

Fig. 20. N1. Vertical displacement of upper wall element measured by transducers 26 – 29.

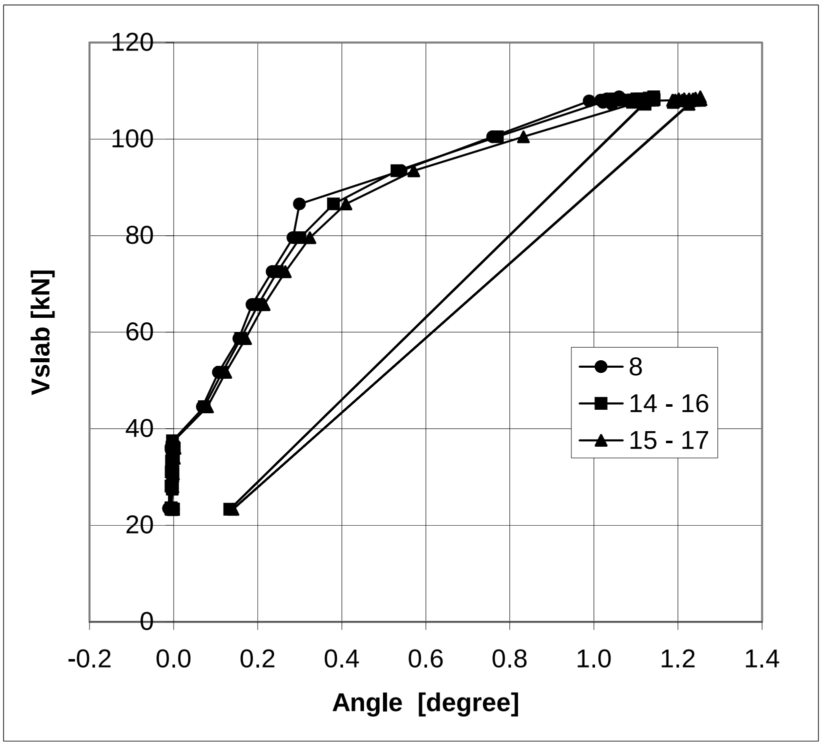

Fig. 21. N1. Rotation of slab end on the east side of the joint measured by clinometer 8 and transducers 14 – 17.

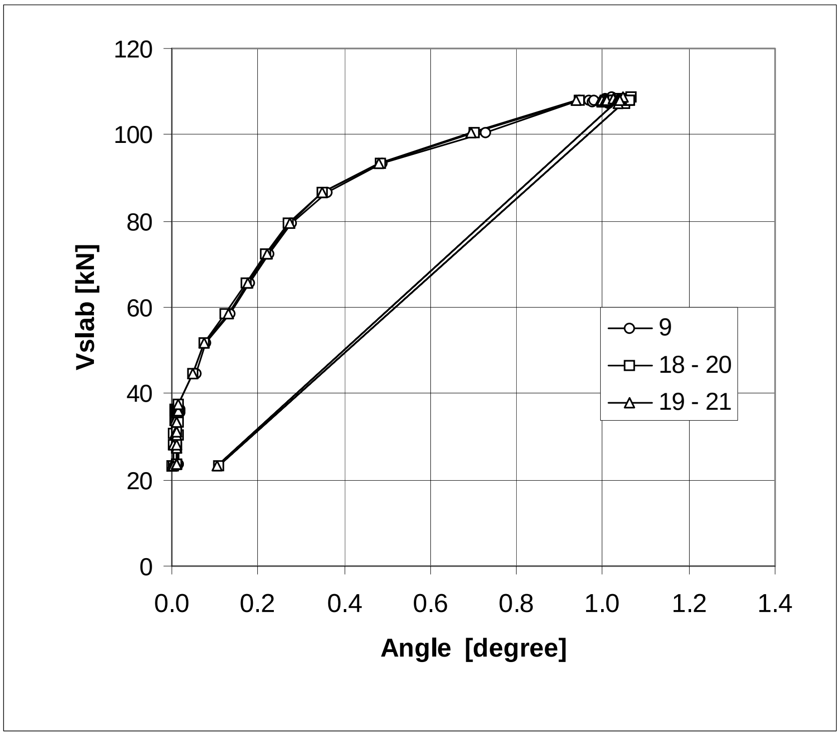

Fig. 22. N1. Rotation of slab end on the west side of the joint measured by clinometer 9 and transducers 18 – 21.

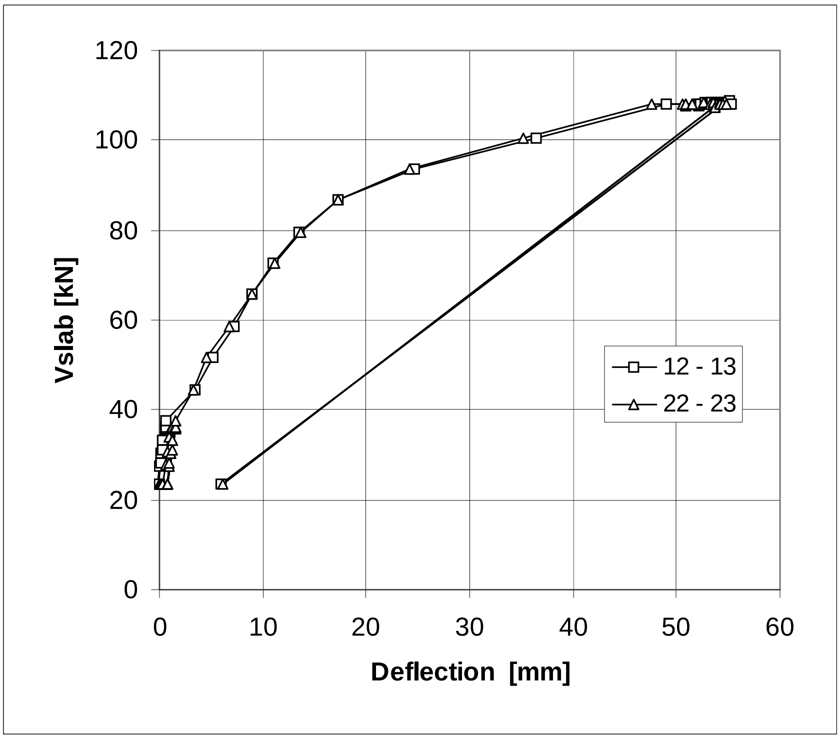

Fig. 23. N1. Deflection of slab. The plotted curves represent the mean of the values measured by transducers 12 & 13 and 22 & 23.

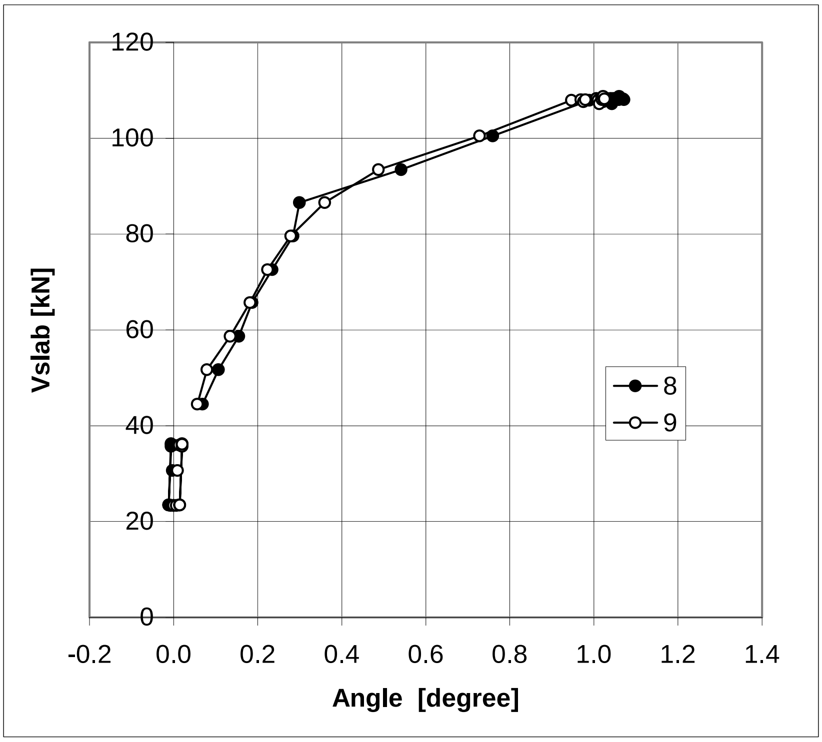

Fig. 24. N1. Rotation of slab ends on both sides of the joint measured by clinometers 8 and 9.

The failure mode of the lower wall element (uncracked between the slab ends, cracked below the neoprene) suggests that the load was mainly transmitted by the slab ends and neoprene, not by the jointing grout between the slab ends. This observation is supported by the strong deformation of the neoprene illustrated in Figs 20 and 21 in App. 7.

The cracking mode of the slab ends shown in Figs 22 -25 in App. 7 was of the unfavourable type.

3.3 Test N2

The loading strategy specified in Fig. 11 was followed, but measurements were not carried out at all steps.

The observations during the test are listed in Table 6. Photographs of the test are shown in App. 8. The measured data are given in App. 5 and illustrated in Figs 25 - 30.

As can be seen in Fig. 26, the west face of the upper wall element moved down faster than the east face. At failure, the upper edge of the lower wall element on the east side and the lower edge of the upper wall element on the west side failed simultaneously, see Figs 3, 4 and 7 – 11 in App. 8. The failure was rather brittle.

Despite unfavourable cracking mode (vertical cracks outside the wall), the slabs could carry the shear force of 108.5 kN. The failure took place in the joint. The shear resistance of the slab ends was not exceeded.

Table 6. Observations made during test N2.

Step	
14	Vertical crack at slab end on east side of the joint, outside the joint
35	Vertical crack at slab end on west side of the joint outside the joint
36	Vertical crack inside the joint between slab ends along the inner edge of neoprene strip
38	Flexural cracks in soffit of slab, east side
39	Flexural cracks in soffit of slab, west side
40	Peeling of concrete in lower wall element outside the neoprene strips. The neoprene strongly deformed.
110 (F_1 = 4.41 MN)	Failure of the joint

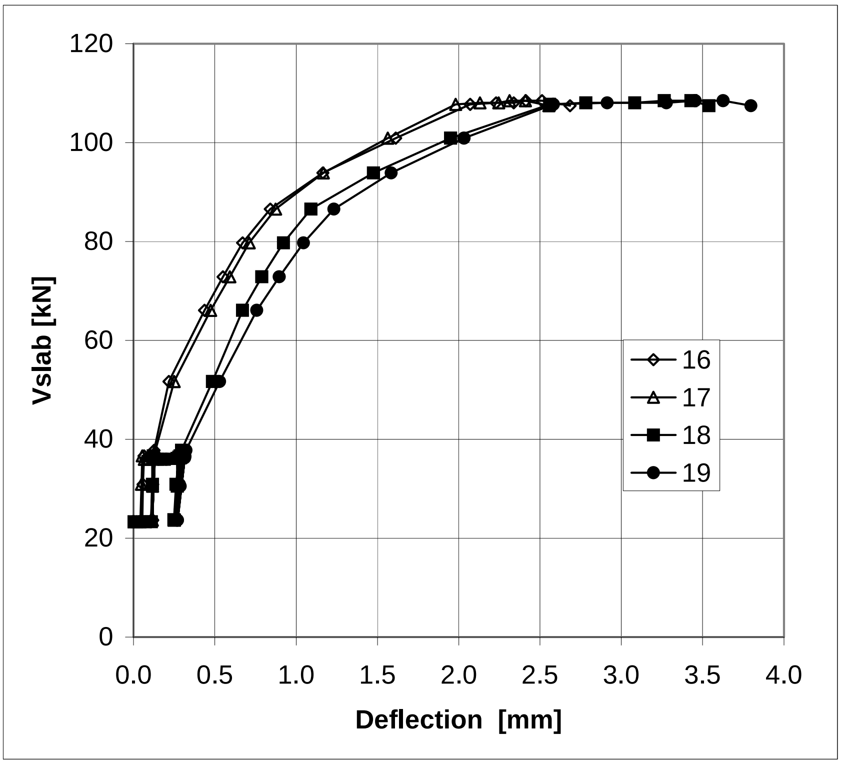

Fig. 25. N2. Vertical displacement of slab ends at the joint measured by transducers 16 – 19.

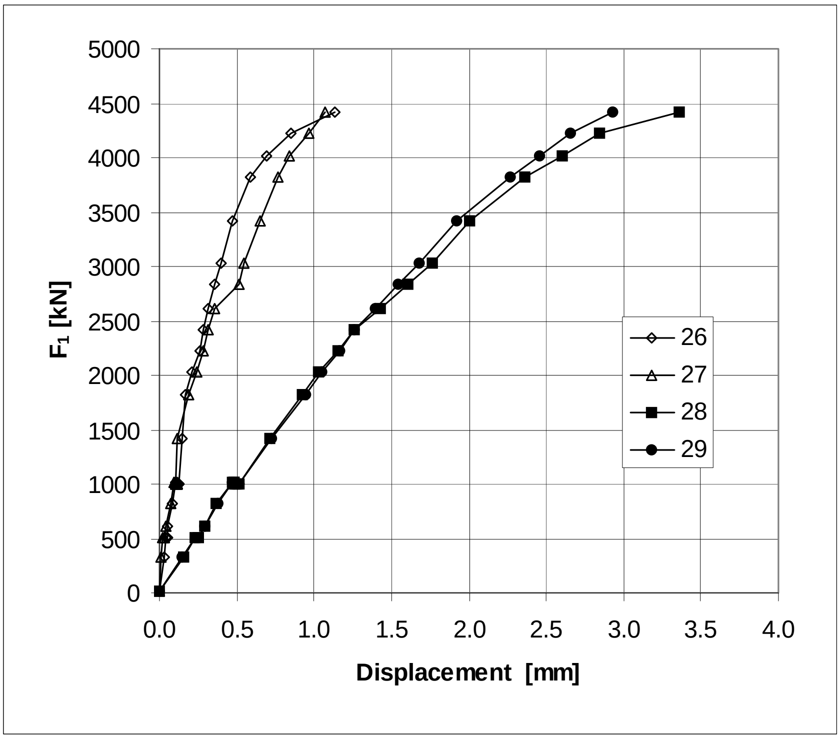

Fig. 26. N2. Vertical displacement of upper wall element measured by transducers 26 – 29.

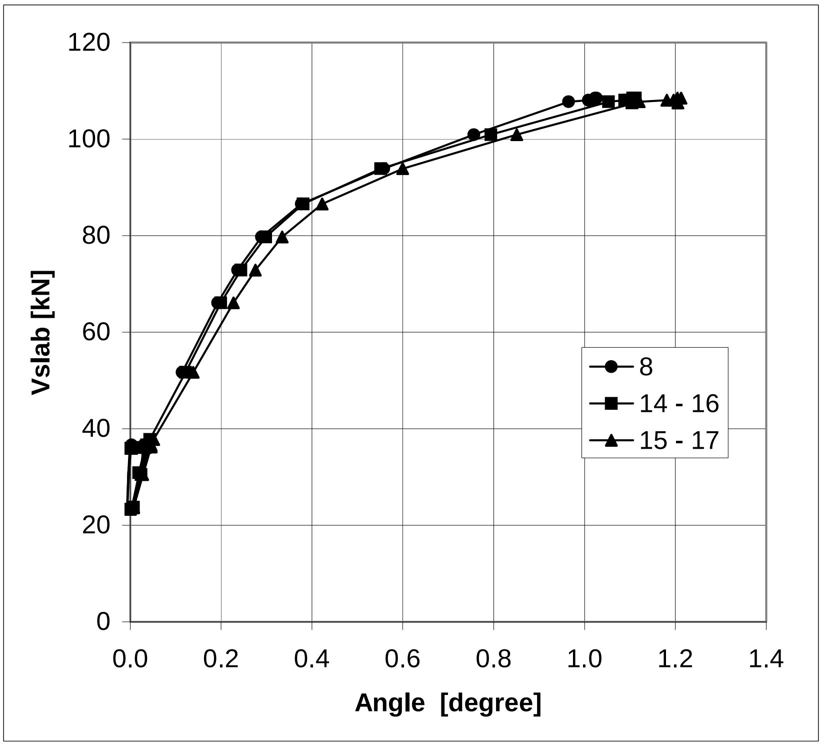

Fig. 27. N2. Rotation of slab end on the east side of the joint measured by clinometer 8 and transducers 14 – 17.

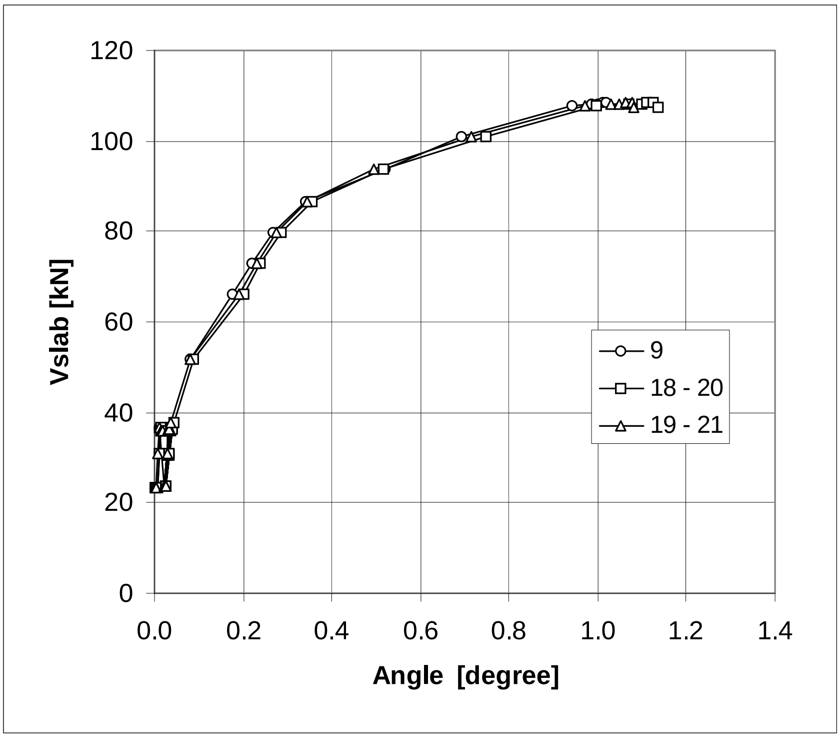

Fig. 28. N2. Rotation of slab end on the west side of the joint measured by clinometer 9 and transducers 18 – 21.

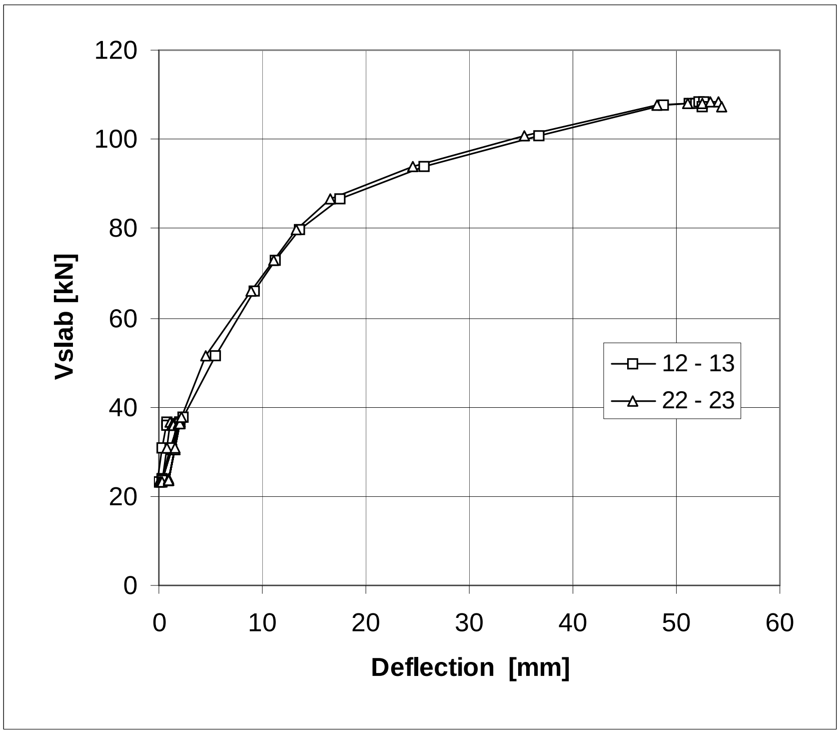

Fig. 29. N2. Deflection of slab. The plotted curves represent the mean of the values measured by transducers 12 & 13 and 22 & 23.

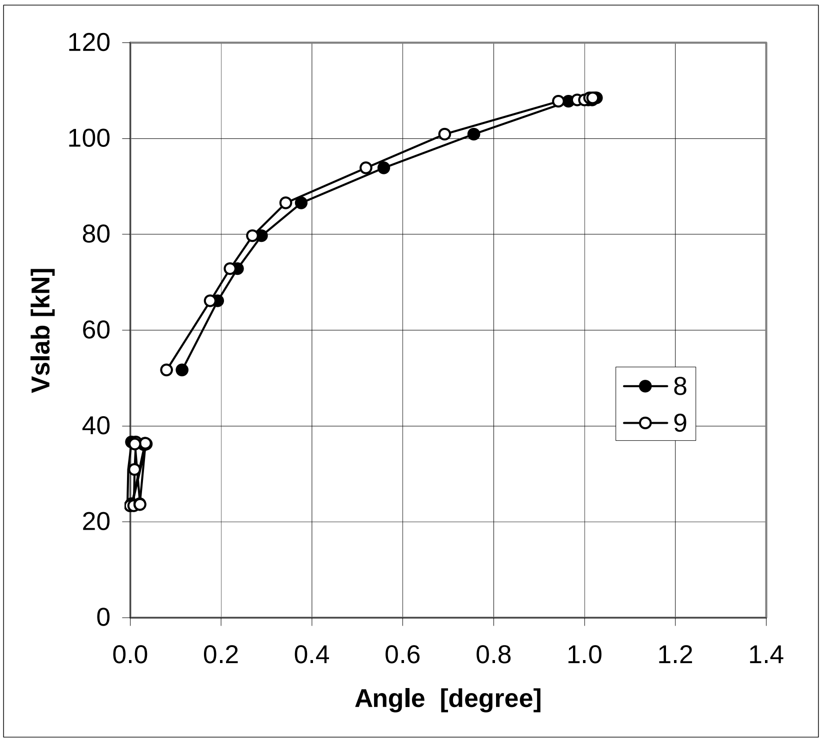

Fig. 30. N2. Rotation of slab ends on both sides of the joint measured by clinometers 8 and 9.

Observations were similar to those made for test N1, See App. 9, Figs 12 - 22.

4 RESULTS OF MATERIAL TESTS

The measured density and strength of concrete measured from 150 mm test cubes and 50 or 100 mm cores are given in Appendix 2. Table 7 summarizes the results. T

The youngest wall element was 38 days old in the load tests, but the strength of concrete of all wall elements was tested at the age of 70 or 71 days. Despite this the obtained strengths are representative for the time at load tests because the concrete was made of rapidly hardening cement and the elements were stored in room temperature. The concrete in wall elements was considerably stronger than the target strength 35 MPa.

The 1st phase grout was a bit stronger and the 2nd phase grout weaker than the target strength 30 MPa. The target strength of the slab concrete 60 MPa was also exceeded. The cement in slabs was also rapidly hardening.

It is likely that the strength of the 2nd phase grout had no effect on the observed failure resistance or failure mode. On the other hand, the strength of the 1st phase grout and slab concrete has to be taken into account when assessing the results.

Table 7. Measured mean (f_{cm}) and characteristic strength (f_{ck}) transformed into strength of 150 mm cubes.

Test	Material	Number of specimens	$f_{cm,K150}$ MPa	$f_{ck,K150}$ MPa
BES	Lower wall	3	49.7	
N1	Lower wall	3	52.7	
N2	Lower wall	3	44.6	
BES, N1	Grout (1st phase)	3	37.7	
N2	Grout (1st phase)	6	36.5	35.5
BES,N1	Grout (2nd phase)	3	28.7	
	Grout (2nd phase)	6	22.8	21.7
All	Upper wall	3	48.7	
BES, N1	Slab 6, slab2	6	71.0	67.5

5 SUMMARY AND CONCLUSIONS

5.1 Vertical stiffness of joint

The vertical displacement of the upper wall element was measured by symmetrically positioned transducers 26 – 29. The measured maximum values before failure were of the order of 3 – 4 mm, i.e. of the order of the thickness of the neoprene strips in tests N1 and N2. The mean of the measured values can be regarded as the average displacement of the element. Fig 31 shows that virtually no difference can be seen in the vertical stiffness of the two tested joint types.

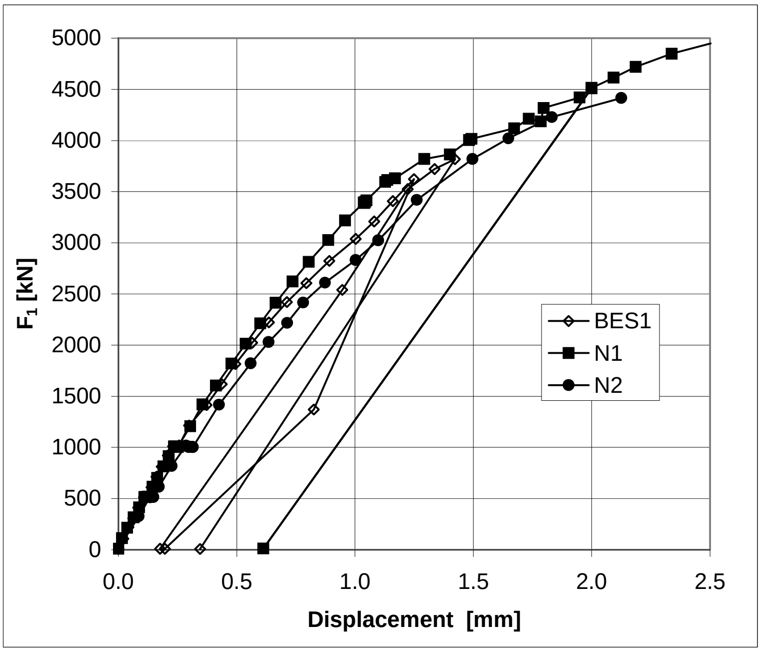

Fig. 31. Vertical displacement of upper wall element (mean of values measured by transducers 26 – 29).

5.2 Cracking before failure

The first cracks in the slabs, see Fig. 32, were of the unfavourable type presented in Fig. 1. The high vertical compression across the slab end prevented the crack from inclining under the wall element.

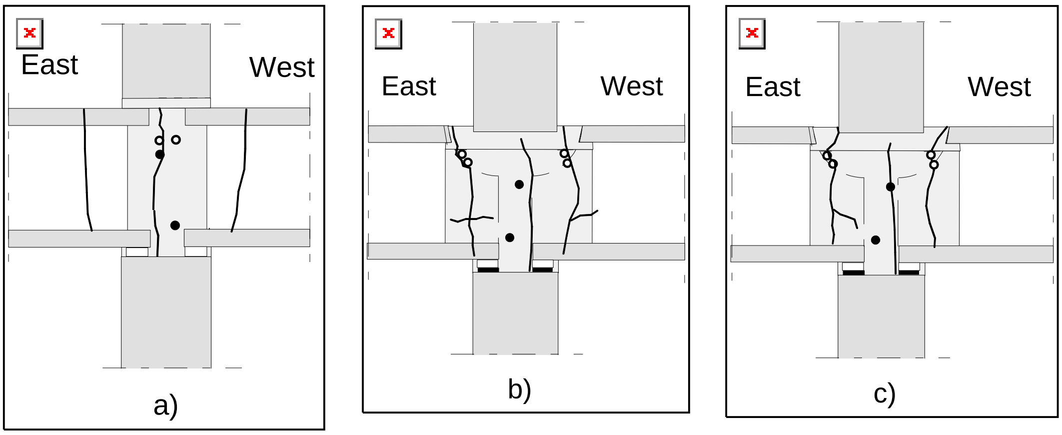

Fig. 32. Cracking pattern in the joint seen from north before failure. a) BES1. b) N1. c) N2.

The neoprene strips, the aim of which was to reduce the vertical compression of slab ends in tests N1 and N2, did not work as effectively as expected.

The first vertical cracks in the slabs appeared at load level given in Table 8. To give an impression about the slab loads, a uniformly distributed load p on the slabs, giving the same support moment as the line loads P_2 in the tests, is also given in Table 8. When calculating p, the joint was assumed to be completely rigid.

Table 8. Vertical force F_1 in the joint, shear force of slab V_{slab} and corresponding uniformly distributed load p at first cracking of slab.

Test	Number of cracked slabs	V_{slab} kN	F_1 kN	p kN/m^2
BES1	2	51.8	1414	6.2
N1	1	44.5	1207	5.3
	2	58.7	1605	7.0
N2	1	36.1	1017	4.3
	2	66.1	1823	7.9

In Table 8 the values of F_1 are within the range of imposed service loads in 10 – 20 storey residential buildings with long floor spans. At the same time, the values of p are a bit higher than the typical service loads. This means that if one of the lowest floors in such a building, provided with joints like those in the present tests, is uniformly loaded until failure, the cracking of the slab end is likely to be similar to that observed in the tests. This in its turn means that the shear resistance of the slabs is reduced and has to be considered.

The aim of the tests was not to measure the shear resistance of the slabs. However, it can be concluded that the shear resistance was at least equal to the highest shear force 108 kN observed. From this, using the total safety factor of 2.5, it can be calculated that the maximum uniformly distributed service load on the slab, in addition to the self-weight of the slab, is equal to 3.5 kN/m^2. This suggests that in some cases the shear resistance of the slab ends may be critical.

There is experimental evidence [3,4] that with a lower vertical load on the joint the cracking mode of the slab ends may be of the favourable type shown in Fig. 1. Due to such cracking the shear resistance of the slab is only slightly reduced or is not reduced at all.

5.3 Failure modes and failure loads

Fig. 33 depicts the failure modes in detail. The failure modes were similar in all tests and can be presented in a simplified form shown in Fig. 34.

In all tests the failure took place when a corner of the lower wall element failed. This confirms that a major part of the vertical load was transferred via the slab ends and in tests N1 and N2 via the neoprene strips. In test BES1 this was an expected result but not in tests N1 and N2.

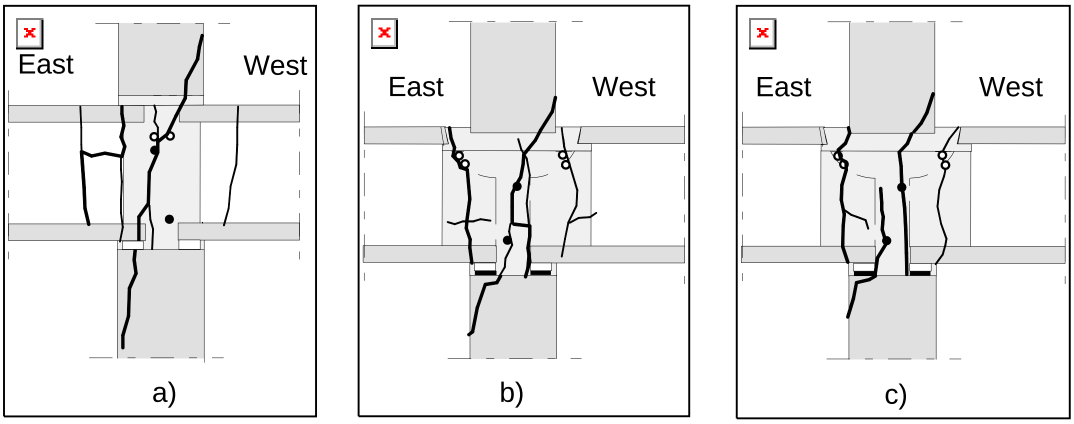

Fig. 33. Cracking pattern after failure seen from north. a) BES1. b) N1. c) N2.

It has been proposed that the grout between the slab ends is in an essentially three-dimensional stress state and, therefore, has a compressive strength of the order of 2.5 times its uniaxial strength. The vertical cracks in the middle of the joint and on both sides of the joint did not support this hypothesis. On the other hand, a ridge of the grout survived the failure uncracked, see Figs 15 – 19, 19 - 20 and 16 - 18 in Appendices 6, 7 and 8, respectively. Obviously either the strength of the grout at the root of the ridge was high, or the grout was not subjected to a high vertical stress.

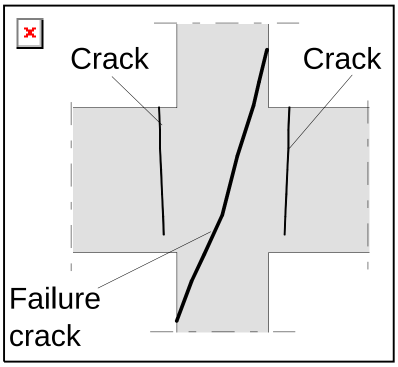

Fig. 34. Simplified cracking pattern after failure in all tests.

The ultimate vertical load on the joint is given in Table 9 for all tests. In tests N1 and N2 the failure load was clearly higher than in test BES1.

Table 9. F_1 at failure.

Test	F_1 at failure MN
BES1	3.84
N1	4.95
N2	4.41

In tests N1 and N2 the stirrups in the upper part of the lower wall element were stronger and more closely spaced than the stirrups in test BES1, see Figs. 6 and 7. On the other hand the longitudinal corner bars in test BES1 were thicker and closer to the corner than those in tests N1 and N2. These differences may have had an effect on the obtained results but a quantitative evaluation is difficult.

To give an impression about the obtained failure loads, concrete stresses calculated in some hypothetical situations are listed in Table 10.

Table 10. Stress in concrete at failure load in some hypothetical situations.

Assumed situation	Stress MPa		
	BES1	N1	N2
1. Uniform stress over whole joint (width = 200 mm)	16.0	20.6	18.4
2. Only grout between slab ends effective (width = 80 mm)	40.0	51.5	45.9
3. Only webs of slabs effective	123.0	-	-

From Table 10 and from the previous considerations the following conclusions can be drawn

1. The stress distribution was not uniform, because a uniform stress of the order 20 MPa would not have cracked the lower wall element with strength of the order of 45 MPa or more.

2. In test BES1 the failure load was far above the value which could be carried by the slab ends only.

3. The load-carrying role of the grout was very important in all tests, not only between the slab ends but also in the hollow cores. The grout between the slab ends alone could not carry the whole failure load.

Espoo, 1.2.2002

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APPENDICES

1	Nominal and measured cross-section of slab units
2	Measured strength of concrete
3	Measured displacements and angles, test BES1
4	Measured displacements and angles, test N1
5	Measured displacements and angles, test N2
6	Photographs, test BES1
7	Photographs, test N1
8	Photographs, test N2

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1 FIP Recommendations "Precast prestressed hollow core floors". London: Thomas Telford, 1988. 31 p.

2 Technical Research Centre of Finland (VTT). Compression tests on crosswise joint of Variax elements (Variax-elementtien poikittaissauman puristuskokeet). Research report B8805/78. Espoo 1978.8 p. + App. 4 p. Not published. (In Finnish)

3 Delvaux, C. Restrained hollow core floors, shear resistance. CBR, Department Development Service Studies and Research on Prefabrication. August 1976. Translated by AVA 10.6.2001. 13 p. + App. 12 p. Not published.

4 Pajari, M. Effect of clamping on shear resistance of prestressed hollow core slab. Manuscript, March 1993. 7 p. Not published.

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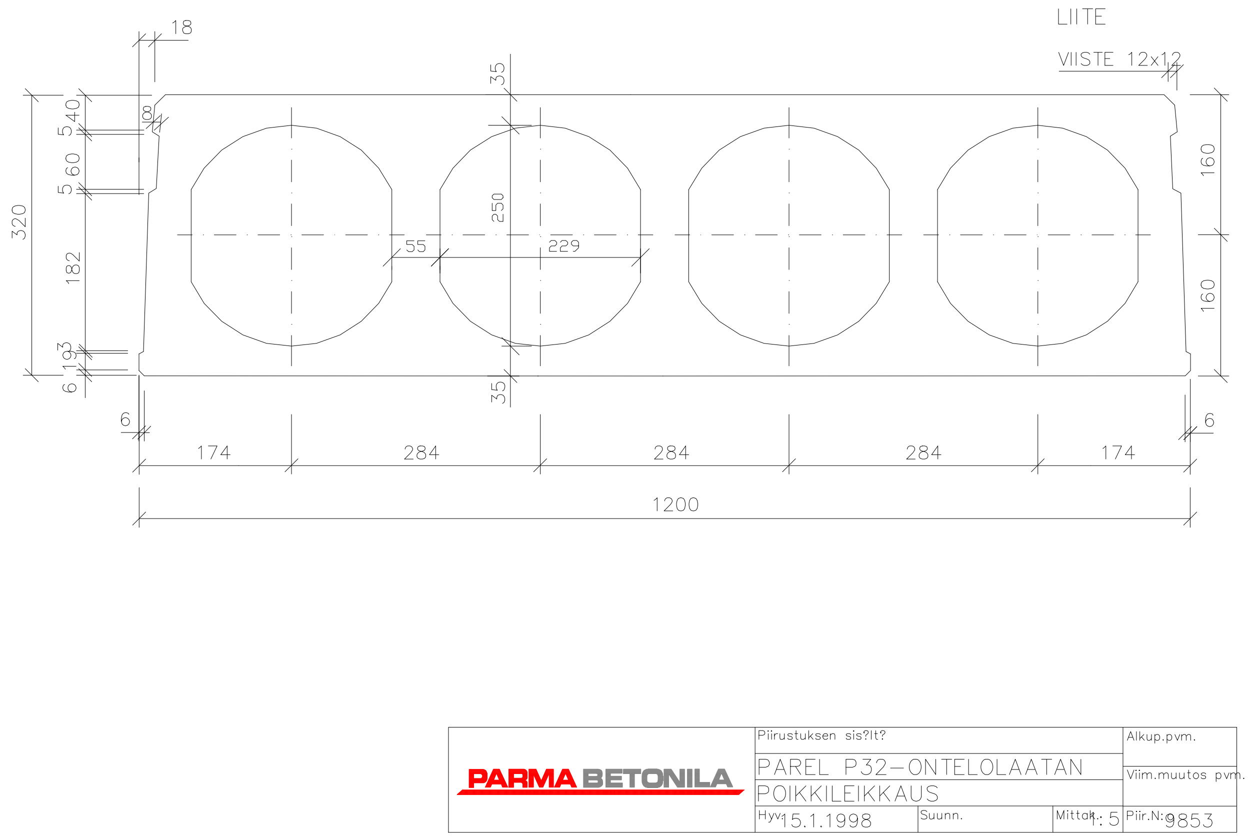
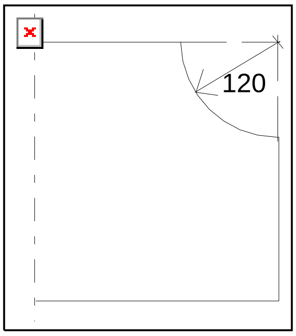
	VTT	Original

NOMINAL AND MEASURED CROSS-SECTION OF SLAB UNITS



a)



b)

Fig. 1. a) Nominal cross-section. b) Nominal size of notch.

In the following figures *prestress* refers to the nominal prestress in the strands after pretensioning (initial prestress). The underlined values refer to initial slippage of the strands.

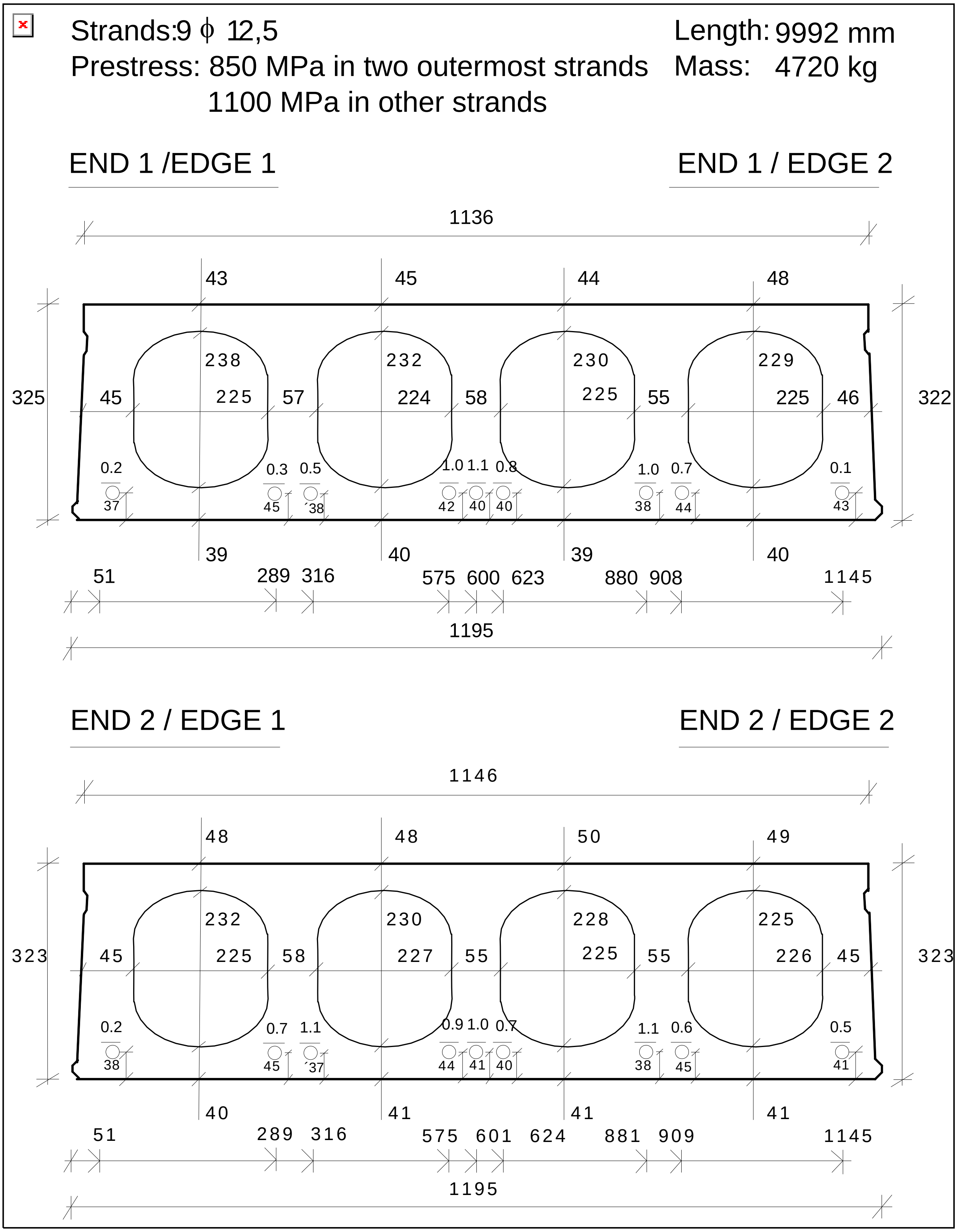


Fig. 2. Measured geometry and weight. Slab 1.

Strands: 9 ϕ 12,5 Length: 9990 mm
Prestress: 850 MPa in two outermost strands Mass: 4700 kg
1100 MPa in other strands

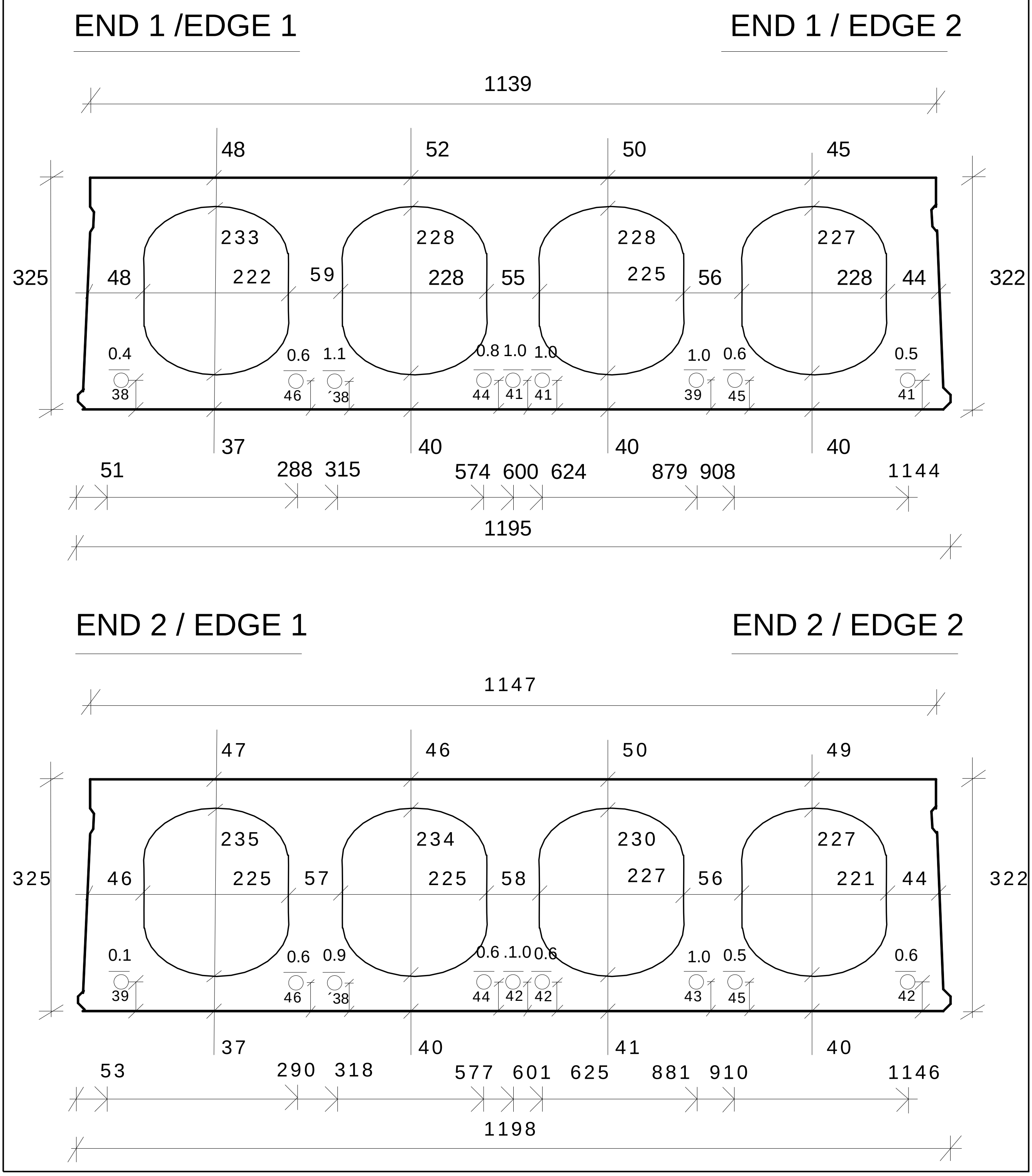


Fig. 3. Measured geometry and weight. Slab 2.

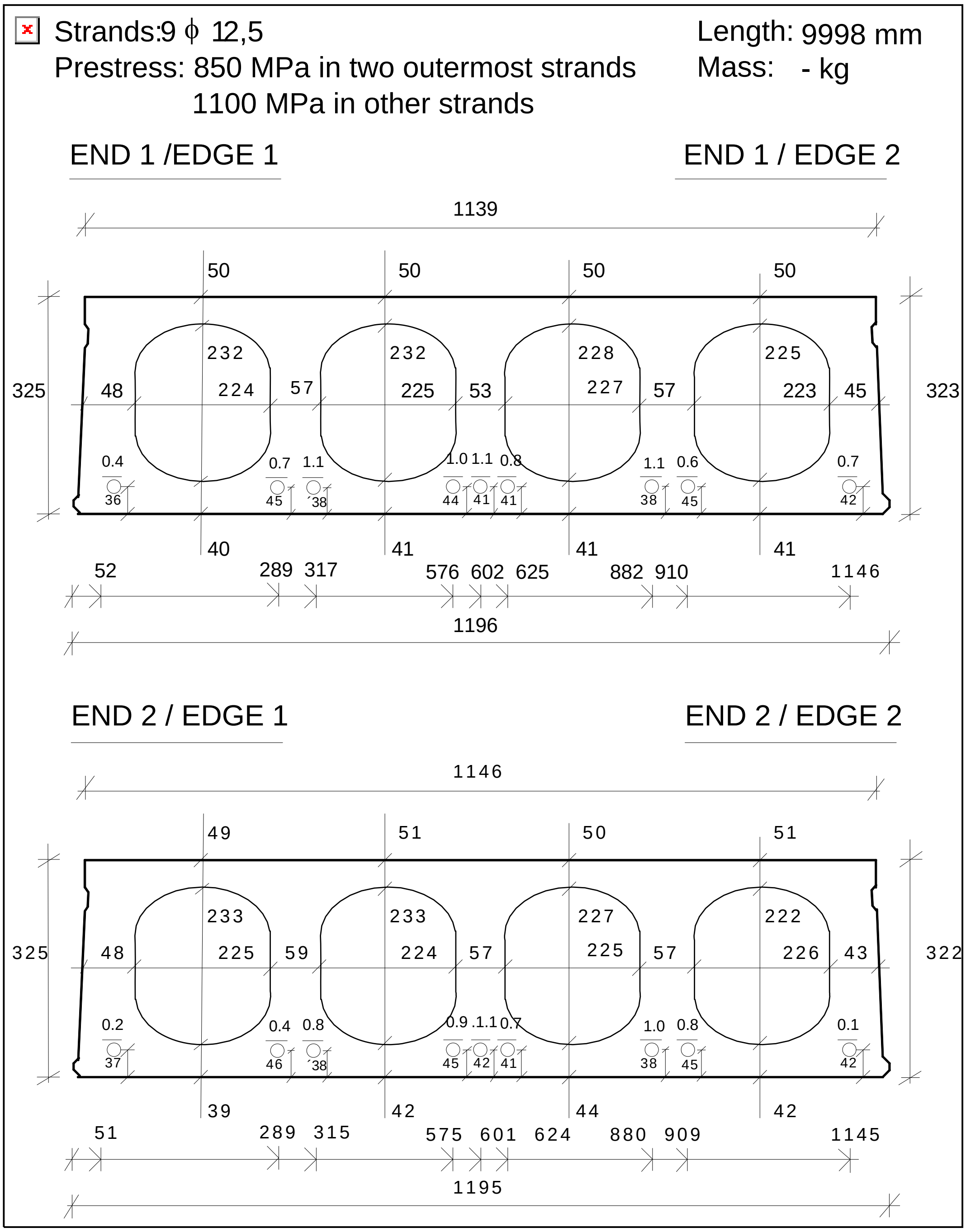


Fig. 4. Measured geometry and weight. Slab 3.

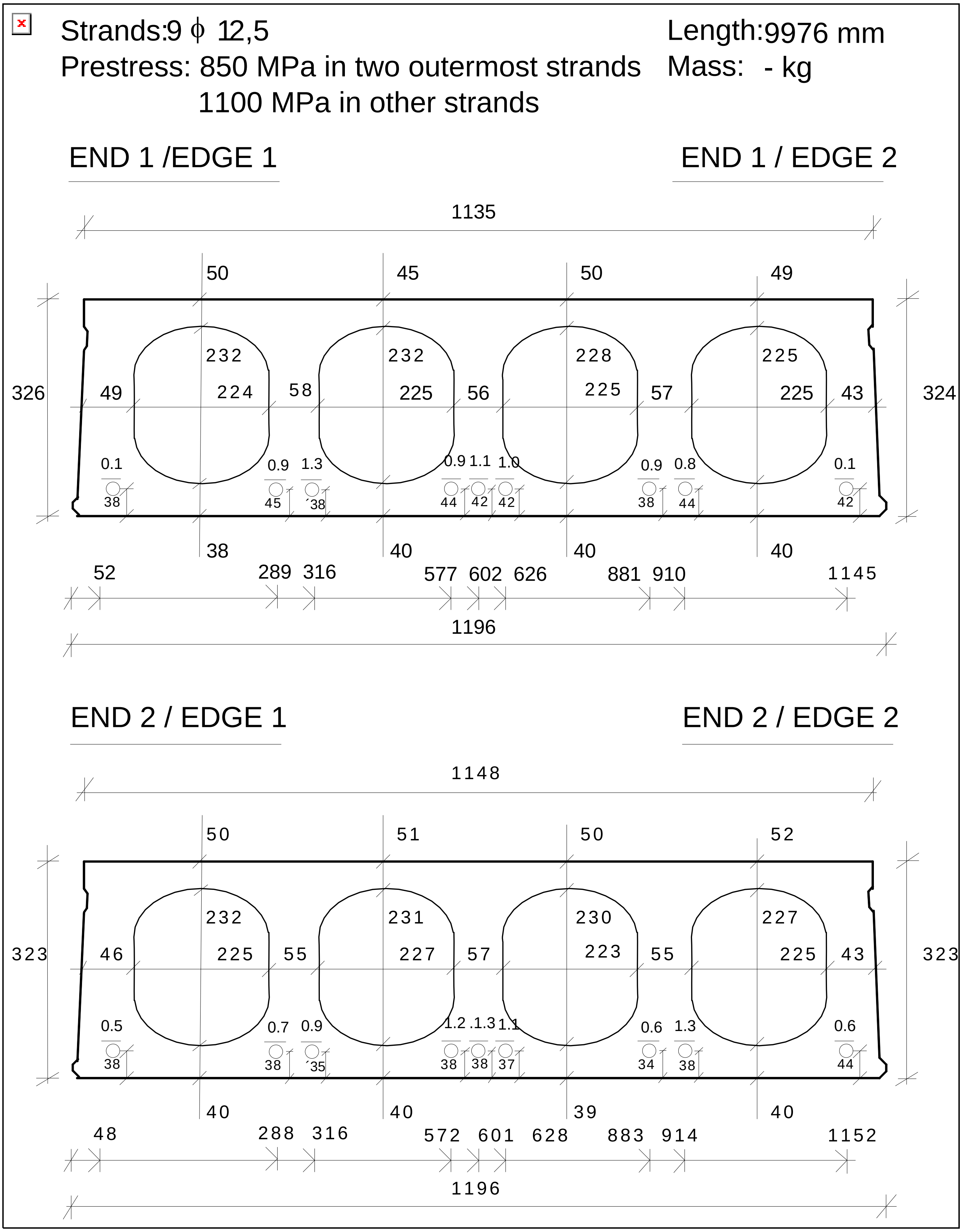


Fig. 5. Measured geometry and weight. Slab 4.

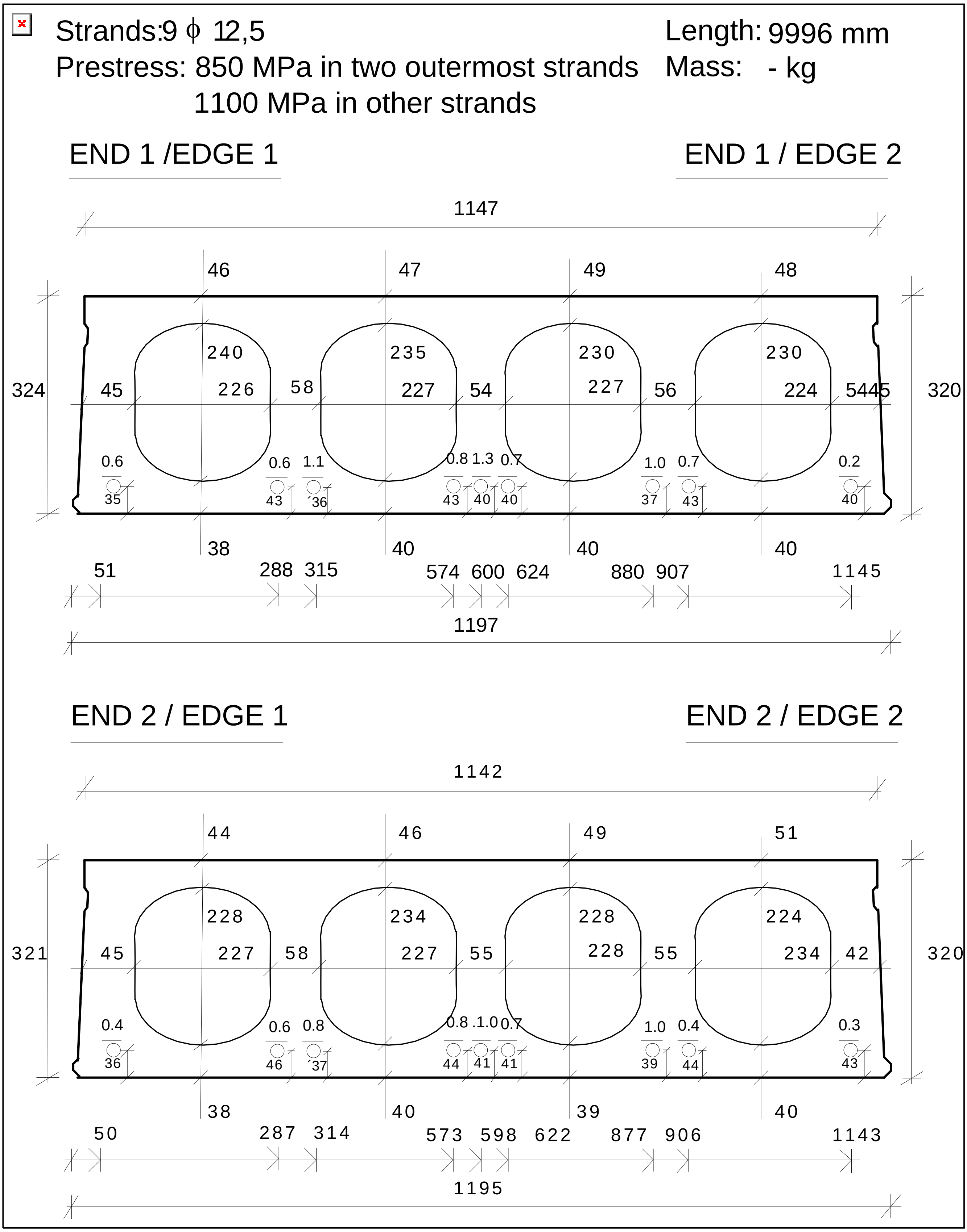


Fig. 6. Measured geometry and weight. Slab 5.

Strands:9 ϕ 12,5 Length: 9993 mm
Prestress: 850 MPa in two outermost strands Mass: - kg
1100 MPa in other strands

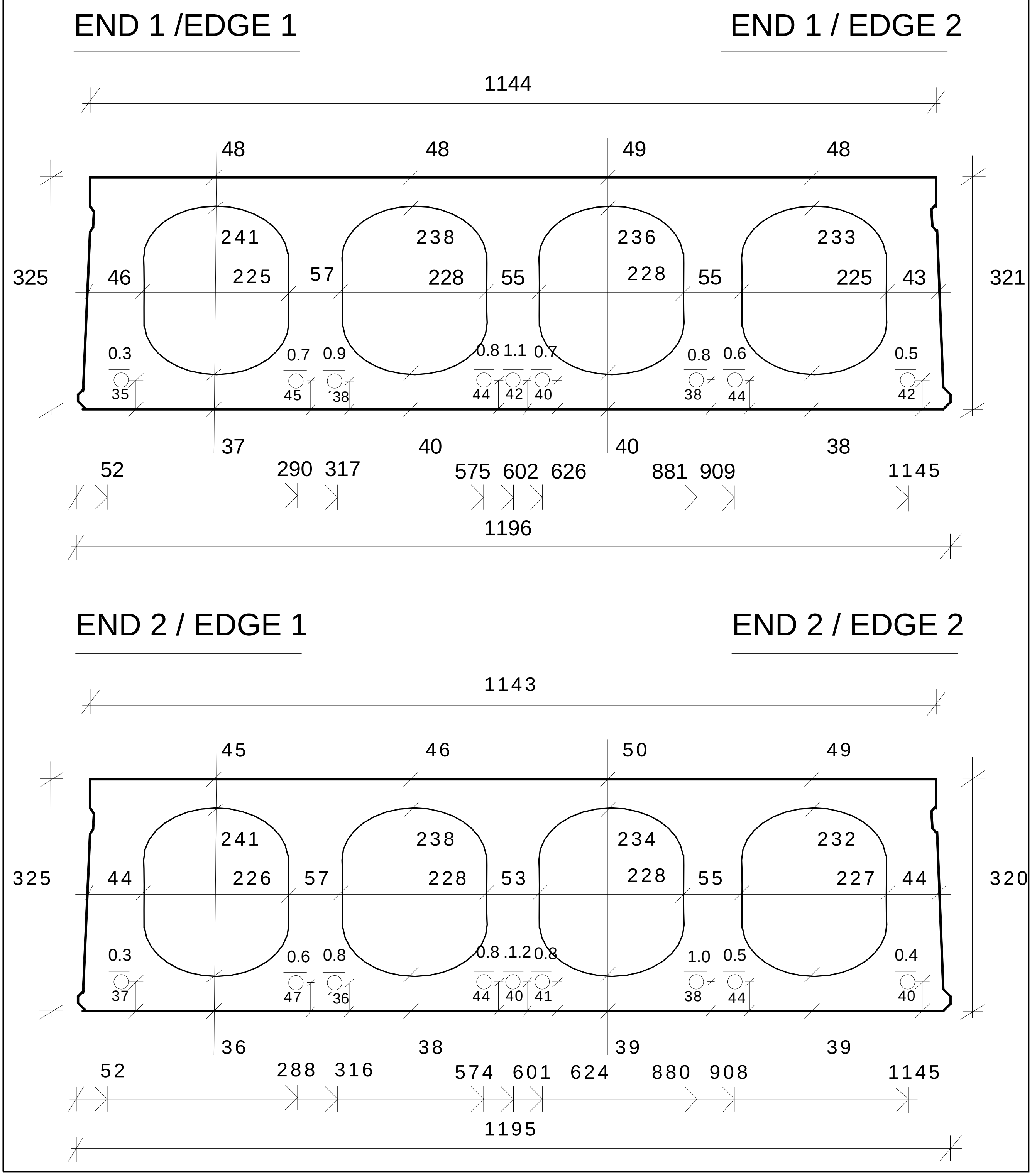


Fig. 7. Measured geometry and weight. Slab 6.

MEASURED STRENGTH OF CONCRETE

Table 1. BES1 and N1, grouting phase 1. Strength and density of 150 mm cubes cast on 23rd of October and tested on 5th of November 2001.

Specimen	Strength MPa	Density kg/m^3
S1	37.5	2220
S2	38.0	2210
S3	38.0	2210
Mean *x*	37.7	2213

Table 2. BES1 and N1, grouting phase 2. Strength and density of 150 mm cubes cast on 24th of October and tested on 5th of November 2001.

Specimen	Strength MPa	Density kg/m^3
J1	30.0	2230
J2	28.0	2220
J3	28.0	2220
Mean *x*	28.7	2223

Table 3. BES1, lower wall element. Strength and density of 100 mm cores tested on 7th of December. The element was cast on 27th or 28th of September 2001.

Specimen	Strength MPa	Density kg/m^3
V1	47.0	2310
V2	47.0	2300
V3	48.0	2310
Mean *x*	47.3	2367
Mean strength $f_{cm,K150}$	49.7	

Table 4. N1, lower wall element. Strength and density of 100 mm cores tested on 7th of December. The element was cast on 27th or 28th of September 2001.

Specimen	Strength MPa	Density kg/m^3
1U1	51.5	2290
1U2	49.0	2300
1U3	50.0	2300
Mean x	50.2	2297
Mean strength $f_{cm,K150}$	52.7	

Table 5. N2, upper wall element. Strength and density of 100 mm cores tested on 7th of December. The element was cast on 27th or 28th of September 2001.

Specimen	Strength MPa	Density kg/m^3
Y1	47.5	2290
Y2	49.0	2300
Y3	42.5	2300
Mean x	46.3	2297
Mean strength $f_{cm,K150}$	48.7	

Table 6. N2, lower wall element. Strength and density of 100 mm cores tested on 7th of December. The element was cast on 27th or 28th of September 2001.

Specimen	Strength MPa	Density kg/m^3
2U1	43.0	2290
2U2	42.5	2280
2U3	42.0	2280
Mean x	42.5	2297
Mean strength $f_{cm,K150}$	44.6	

Table 7. N2, grouting phase 1. Strength and density of 150 mm cubes cast on 14th and tested on 26th of November 2001.

Specimen	Strength MPa	Density kg/m^3
S7	37.5	2250
S8	36.0	2210
S9	37.0	2210
S10	36.0	2210
S11	36.5	2220
S12	36.0	2200
Mean *x*	36.5	2217
Standard deviation *s*	0.6	
Characteristic strength $f_{ck,K150} = x - 1.65s$	35.5	

Table 8. N2, grouting phase 2. Strength and density of 150 mm cubes cast on 15th and tested on 26th of November 2001.

Specimen	Strength MPa	Density kg/m^3
J7	22.5	2200
J8	24.0	2200
J9	23.0	2200
J10	23.0	2210
J11	22.5	2190
J12	22.0	2170
Mean *x*	22.8	2195
Standard deviation *s*	0.7	
Characteristic strength $f_{ck,K150} = x - 1.65s$	21.7	

Table 9. Hollow core slabs. Strength and density of 50 mm cores tested on 19th of December 2001. The slabs were cast on 19th of September 2001.

Specimen	Strength MPa	Density kg/m^3
L21 (slab 2)	64.5	2360
L22 (slab 2)	62.0	2360
L23 (slab 2)	66.5	2390
L61 (slab 6)	65.0	2350
L62 (slab 6)	62.5	2390
L63 (slab 6)	66.5	2370
Mean x	64.5	2370
Standard deviation s	1.9	
Characteristic strength $f_{ck,C50} = x - 1.65s$	61.3	
Characteristic strength $f_{ck,K150} = 1.1(x - 1.65s)$	67.5	

MEASURED DISPLACEMENTS AND ANGLES, TEST BES1

Table 1. Loads and displacements measured by transducers 10 – 17.

Step	$2P_2$	ΣP_1	Displacement mm							
	kN	kN	10	11	12	13	14	15	16	17
0	0.0	0.0	0.000	0.000	0.00	0.00	0.000	0.000	0.000	0.000
1	0.0	100.0	0.002	-0.001	-0.05	-0.06	0.005	0.000	0.010	0.008
2	0.0	211.0	0.002	-0.001	-0.05	0.01	0.018	0.014	0.027	0.022
3	0.0	299.0	0.003	-0.001	-0.01	-0.01	0.035	0.029	0.044	0.037
4	0.0	402.0	0.002	-0.001	0.02	0.07	0.053	0.047	0.061	0.054
5	0.0	507.0	0.000	-0.001	0.06	0.07	0.075	0.071	0.079	0.074
6	6.8	502.0	0.001	0.000	0.38	0.40	0.086	0.087	0.082	0.080
7	10.4	503.0	0.001	0.008	0.53	0.58	0.093	0.093	0.085	0.082
8	14.0	502.0	0.000	0.017	0.73	0.76	0.102	0.103	0.086	0.085
9	18.4	501.0	0.001	0.028	0.96	0.98	0.109	0.111	0.089	0.088
10	17.8	603.0	0.003	0.030	0.99	1.01	0.127	0.131	0.105	0.107
11	17.8	705.0	0.001	0.034	1.04	1.06	0.147	0.158	0.123	0.128
12	18.2	802.0	0.001	0.038	1.09	1.14	0.171	0.183	0.142	0.150
13	18.0	914.0	0.001	0.044	1.16	1.21	0.193	0.210	0.161	0.174
14	17.8	1002.0	0.001	0.048	1.21	1.23	0.215	0.236	0.178	0.195
15	14.0	1001.0	0.001	0.048	1.07	1.10	0.223	0.244	0.183	0.200
16	9.8	1000.0	0.003	0.040	0.88	0.91	0.223	0.241	0.182	0.200
17	6.0	1000.0	0.001	0.031	0.73	0.73	0.223	0.239	0.182	0.199
18	0.6	999.0	0.001	0.020	0.45	0.46	0.215	0.228	0.183	0.197
19	6.4	1002.0	0.002	0.024	0.69	0.72	0.214	0.231	0.182	0.199
20	10.4	1003.0	0.003	0.033	0.88	0.91	0.218	0.237	0.182	0.201
21	14.0	1002.0	0.004	0.041	1.04	1.10	0.223	0.245	0.183	0.203
22	18.4	1002.0	0.003	0.050	1.23	1.27	0.229	0.252	0.186	0.205
23	0.4	998.0	0.003	0.022	0.49	0.49	0.217	0.231	0.187	0.201
24	18.4	999.0	0.005	0.052	1.27	1.31	0.237	0.261	0.189	0.209
25	0.4	999.0	0.005	0.021	0.47	0.49	0.223	0.236	0.190	0.205
26	18.4	996.0	0.009	0.060	1.37	1.41	0.256	0.273	0.197	0.213
31	20.6	1012.0	0.012	0.064	1.47	1.51	0.256	0.277	0.197	0.213
32	30.2	1205.0	0.014	0.089	2.01	2.09	0.313	0.347	0.237	0.254
33	40.6	1406.0	0.079	0.175	3.98	4.13	0.630	0.704	0.390	0.438
34	50.8	1609.0	0.107	0.304	6.69	7.00	0.922	1.061	0.420	0.505
35	60.4	1807.0	0.135	0.380	8.60	8.97	1.144	1.313	0.481	0.586
36	70.4	2015.0	0.154	0.451	10.66	11.07	1.400	1.595	0.573	0.694
37	80.6	2213.0	0.171	0.525	13.35	13.82	1.718	1.944	0.685	0.820
38	90.2	2412.0	0.177	0.627	16.90	17.48	2.111	2.381	0.817	0.973
39	100.0	2597.0	0.178	0.793	22.91	23.77	2.746	3.091	1.005	1.200
40	110.6	2815.0	0.176	0.991	32.82	34.02	3.798	4.260	1.328	1.574
41	120.2	3030.0	0.178	1.148	44.91	46.38	5.095	5.661	1.754	2.014
42	120.8	3201.0	0.177	1.247	47.76	49.31	5.444	6.048	1.880	2.165
43	121.2	3400.0	0.179	1.258	48.34	49.90	5.545	6.164	1.940	2.233
44	121.4	3615.0	0.180	1.265	48.74	50.32	5.630	6.268	2.000	2.302

Table 1. Continued.

Step	$2P_2$ kN	ΣP_1 kN	Displacement mm 10	11	12	13	14	15	16	17
100	121.4	1361.0	0.207	1.293	48.77	50.35	5.413	6.035	1.721	2.052
101	0.0	0.0	0.155	0.619	6.33	6.89	0.981	1.328	0.405	0.755
102	0.0	0.0	0.140	0.604	5.89	6.45	0.920	1.272	0.374	0.733
103	120.8	2532.6	0.221	1.236	49.49	51.10	5.695	6.352	1.808	2.314
104	121.0	3517.5	0.216	1.315	52.22	53.88	6.134	6.839	2.038	2.576
105	121.8	3712.8	0.216	1.329	53.43	55.13	6.323	7.051	2.121	2.685
106	118.0	3808.0	0.218	1.343	53.18	54.87	6.364	7.092	2.191	2.742
107	0.0	0.0	0.141	0.695	6.00	6.69	1.046	1.522	0.517	0.993
108	0.0	0.0	0.136	0.681	5.75	6.44	1.002	1.481	0.493	0.973
109	120.8	3824.8	0.190	1.355	53.94	56.01	6.505	7.727	2.052	3.289
110	120.0	3827.2	0.190	1.387	54.82	56.96	6.612	7.928	2.063	3.407
111	114.4	362.4	0.130	1.143	57.83	59.63	7.432	8.324	2.877	3.572

Table 2. Displacements measured by transducers 18 – 25.

Step	$2P_2$	ΣP_1	Displacement mm							
	kN	kN	18	19	20	21	22	23	24	25
0	0.0	0.0	0.000	0.000	0.000	0.000	0.00	0.00	0.000	0.000
1	0.0	100.0	0.024	0.021	0.028	0.022	0.09	0.07	-0.003	-0.003
2	0.0	211.0	0.041	0.033	0.045	0.033	0.09	0.06	-0.002	0.001
3	0.0	299.0	0.056	0.047	0.064	0.045	0.11	0.05	0.000	0.002
4	0.0	402.0	0.072	0.060	0.076	0.055	0.13	0.04	0.001	0.003
5	0.0	507.0	0.087	0.074	0.091	0.068	0.10	0.06	-0.001	0.002
6	6.8	502.0	0.092	0.078	0.103	0.078	0.41	0.26	0.000	0.000
7	10.4	503.0	0.093	0.079	0.111	0.083	0.57	0.36	0.001	-0.001
8	14.0	502.0	0.095	0.083	0.116	0.089	0.74	0.51	0.004	0.000
9	18.4	501.0	0.097	0.084	0.125	0.098	0.98	0.66	0.007	0.005
10	17.8	603.0	0.110	0.097	0.136	0.109	0.95	0.64	0.010	0.004
11	17.8	705.0	0.123	0.109	0.147	0.118	0.93	0.62	0.009	0.000
12	18.2	802.0	0.135	0.122	0.157	0.129	0.94	0.66	0.009	0.006
13	18.0	914.0	0.150	0.136	0.168	0.140	0.91	0.61	0.008	0.007
14	17.8	1002.0	0.160	0.146	0.177	0.150	0.90	0.63	0.009	0.013
15	14.0	1001.0	0.161	0.147	0.180	0.147	0.75	0.47	0.010	0.014
16	9.8	1000.0	0.162	0.147	0.174	0.141	0.53	0.35	0.010	0.009
17	6.0	1000.0	0.160	0.146	0.170	0.136	0.34	0.20	0.009	0.010
18	0.6	999.0	0.158	0.145	0.159	0.125	0.11	0.03	0.007	0.009
19	6.4	1002.0	0.159	0.145	0.163	0.134	0.33	0.20	0.008	0.007
20	10.4	1003.0	0.161	0.147	0.169	0.139	0.52	0.33	0.007	0.009
21	14.0	1002.0	0.161	0.147	0.175	0.144	0.69	0.46	0.009	0.010
22	18.4	1002.0	0.164	0.150	0.180	0.150	0.90	0.60	0.008	0.009
23	0.4	998.0	0.161	0.147	0.162	0.128	0.12	0.02	0.007	0.008
24	18.4	999.0	0.166	0.153	0.184	0.154	0.92	0.62	0.010	0.012
25	0.4	999.0	0.163	0.150	0.162	0.128	0.08	0.06	0.007	0.009
26	18.4	996.0	0.174	0.157	0.195	0.163	0.98	0.66	0.025	0.020
31	20.6	1012.0	0.174	0.157	0.196	0.165	1.09	0.75	0.025	0.020
32	30.2	1205.0	0.201	0.184	0.235	0.200	1.53	1.11	0.026	0.022
33	40.6	1406.0	0.214	0.154	0.594	0.528	4.99	4.73	0.098	0.074
34	50.8	1609.0	0.336	0.248	0.838	0.750	6.75	6.54	0.155	0.110
35	60.4	1807.0	0.427	0.317	1.061	0.957	8.38	8.15	0.179	0.128
36	70.4	2015.0	0.537	0.398	1.312	1.190	10.23	9.95	0.209	0.151
37	80.6	2213.0	0.655	0.483	1.583	1.439	12.32	11.97	0.244	0.177
38	90.2	2412.0	0.800	0.593	1.928	1.758	15.12	14.70	0.278	0.199
39	100.0	2597.0	1.120	0.864	2.762	2.576	22.82	22.32	0.313	0.225
40	110.6	2815.0	1.552	0.943	3.936	3.752	33.79	33.24	0.347	0.208
41	120.2	3030.0	2.092	0.985	5.419	5.155	47.43	46.88	0.351	0.212
42	120.8	3201.0	2.226	1.042	5.726	5.443	49.95	49.40	0.349	0.218
43	121.2	3400.0	2.271	1.081	5.800	5.515	50.37	49.83	0.349	0.218
44	121.4	3615.0	2.315	1.123	5.861	5.578	50.65	50.10	0.348	0.223

Table 2. Continued.

Step	$2P_2$ kN	ΣP_1 kN	Displacement mm							
			18	19	20	21	22	23	24	25
100	121.4	1361.0	2.109	0.919	5.674	5.396	50.68	50.12	0.335	0.262
101	0.0	0.0	0.599	0.201	1.022	0.950	5.59	5.40	0.095	0.089
102	0.0	0.0	0.579	0.193	0.986	0.920	5.36	5.17	0.069	0.064
103	120.8	2532.6	2.275	1.033	5.840	5.568	50.87	50.33	0.328	0.239
104	121.0	3517.5	2.488	1.183	6.184	5.889	52.79	52.23	0.332	0.246
105	121.8	3712.8	2.562	1.227	6.300	5.998	53.46	52.91	0.337	0.247
106	118.0	3808.0	2.590	1.250	6.280	5.968	52.74	52.17	0.336	0.249
107	0.0	0.0	0.659	0.292	1.051	0.994	5.38	5.19	0.086	0.089
108	0.0	0.0	0.637	0.277	1.019	0.966	5.19	5.02	0.075	0.082
109	120.8	3824.8	2.485	1.569	6.211	6.361	53.20	52.98	0.260	0.353
110	120.0	3827.2	2.500	1.639	6.247	6.458	53.42	53.24	0.259	0.367
111	114.4	362.4	2.942	2.587	6.699	6.733	54.19	53.70	0.342	0.322

Table 3. Displacements measured by transducers 26 – 29, angles measured by clinometers 8 – 9 and time from the beginning of the test.

Step	$2P_2$	ΣP_1	Displacement mm				Angle degree		Time
	kN	kN	26	27	28	29	8	9	min
0	0.0	0.0	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0
1	0.0	100.0	0.012	0.013	0.033	0.027			1.7
2	0.0	211.0	0.044	0.038	0.048	0.039			2.9
3	0.0	299.0	0.069	0.064	0.068	0.052			4.0
4	0.0	402.0	0.095	0.094	0.085	0.063			4.7
5	0.0	507.0	0.127	0.127	0.101	0.079	-0.0006	0.0003	5.6
6	6.8	502.0	0.132	0.132	0.103	0.078			9.4
7	10.4	503.0	0.134	0.134	0.105	0.080	0.0044	0.0050	10.1
8	14.0	502.0	0.137	0.137	0.106	0.083			12.4
9	18.4	501.0	0.139	0.140	0.109	0.083	0.0078	0.0061	14.3
10	17.8	603.0	0.168	0.171	0.123	0.096			16.2
11	17.8	705.0	0.196	0.205	0.136	0.108			17.0
12	18.2	802.0	0.225	0.239	0.148	0.123			18.0
13	18.0	914.0	0.260	0.277	0.165	0.134			18.6
14	17.8	1002.0	0.291	0.310	0.177	0.146	0.0128	0.0042	19.2
15	14.0	1001.0	0.301	0.320	0.179	0.148			21.7
16	9.8	1000.0	0.302	0.321	0.178	0.148			22.4
17	6.0	1000.0	0.302	0.321	0.177	0.146			23.2
18	0.6	999.0	0.302	0.321	0.177	0.147	0.0017	-0.0014	24.2
19	6.4	1002.0	0.312	0.326	0.176	0.150			26.8
20	10.4	1003.0	0.315	0.328	0.176	0.151			27.2
21	14.0	1002.0	0.316	0.330	0.178	0.148			27.8
22	18.4	1002.0	0.318	0.331	0.178	0.148	0.0081	0.0028	28.3
23	0.4	998.0	0.316	0.334	0.177	0.150	0.0022	-0.0014	31.3
24	18.4	999.0	0.327	0.341	0.183	0.155			36.2
25	0.4	999.0	0.326	0.342	0.182	0.152	0.0022	-0.0014	37.5
26	18.4	996.0	0.332	0.346	0.185	0.158	0.0122	0.0056	40.7
31	20.6	1012.0	0.334	0.350	0.184	0.156			43.0
32	30.2	1205.0	0.394	0.414	0.212	0.177	0.0194	0.0075	46.2
33	40.6	1406.0	0.552	0.598	0.201	0.140	0.0686	0.1006	51.7
34	50.8	1609.0	0.631	0.674	0.248	0.195	0.1319	0.1344	58.6
35	60.4	1807.0	0.702	0.746	0.291	0.237	0.1744	0.1697	66.0
36	70.4	2015.0	0.801	0.843	0.340	0.275	0.2208	0.2064	72.6
37	80.6	2213.0	0.904	0.945	0.384	0.311	0.2764	0.2508	77.5
38	90.2	2412.0	1.009	1.059	0.430	0.350	0.3603	0.3219	83.4
39	100.0	2597.0	1.132	1.184	0.476	0.384	0.5033	0.4975	90.4
40	110.6	2815.0	1.281	1.331	0.527	0.428	0.7081	0.6989	98.5
41	120.2	3030.0	1.447	1.493	0.591	0.480	0.8928	0.9044	105.3
42	120.8	3201.0	1.562	1.612	0.636	0.514	0.9417	0.9561	113.8
43	121.2	3400.0	1.677	1.725	0.682	0.556	0.9531	0.9644	117.8
44	121.4	3615.0	1.797	1.857	0.734	0.609			120.6

Table 3. Continued.

Step	$2P_2$	ΣP_1	Displacement mm				Angle degree		Time
	kN	kN	26	27	28	29	8	9	min
100	121.4	1361.0	1.235	1.309	0.429	0.329			120.8
101	0.0	0.0	0.270	0.296	0.114	0.106			124.2
102	0.0	0.0	0.239	0.266	0.103	0.098	0.1222	0.1050	136.6
103	120.8	2532.6	1.399	1.459	0.529	0.399	1.0119	1.0033	143.9
104	121.0	3517.5	1.772	1.868	0.700	0.551	1.0247	1.0078	148.8
105	121.8	3712.8	1.943	2.050	0.755	0.597	1.0408	1.0178	152.5
106	118.0	3808.0	2.076	2.197	0.791	0.626	1.0594	1.0208	156.8
107	0.0	0.0	0.562	0.598	0.129	0.094	0.0000	0.0000	160.4
108	0.0	0.0	0.537	0.574	0.107	0.079	0.1119	0.0981	163.1
109	120.8	3824.8	1.919	3.303	0.383	1.252		1.0331	173.5
110	120.0	3827.2	1.950	3.590	0.325	1.390			174.3
111	114.4	362.4	7.093	11.447	16.812	11.425			175.2

MEASURED DISPLACEMENTS AND ANGLES, TEST N1

Table 1. Loads and displacements measured by transducers 10 – 17.

Step	$2P_2$	ΣP_1	Displacement mm							
	kN	kN	10	11	12	13	14	15	16	17
0	0.0	0.0	0.000	0.000	0.00	0.00	0.000	0.000	0.000	0.000
1	0.0	103.0	0.000	0.000	0.03	0.02	0.013	0.013	0.014	0.013
2	0.0	205.0	-0.001	0.000	-0.02	0.01	0.015	0.019	0.020	0.022
3	0.0	306.0	0.002	0.001	-0.08	-0.04	0.017	0.024	0.025	0.032
4	0.0	404.0	0.001	0.001	-0.09	-0.10	0.017	0.032	0.032	0.043
5	0.0	505.0	0.004	0.001	-0.13	-0.11	0.024	0.035	0.040	0.053
6	6.6	508.0	-0.002	-0.001	0.15	0.15	0.036	0.050	0.045	0.057
7	10.4	508.0	-0.001	0.001	0.35	0.31	0.041	0.056	0.046	0.057
8	15.0	507.0	0.000	0.002	0.56	0.58	0.049	0.065	0.048	0.059
9	18.0	509.0	0.002	0.002	0.73	0.71	0.056	0.072	0.050	0.060
10	18.0	606.0	-0.002	0.002	0.73	0.71	0.063	0.077	0.059	0.069
11	18.4	692.0	0.002	0.003	0.70	0.68	0.069	0.082	0.068	0.078
12	18.2	804.0	-0.002	0.002	0.68	0.64	0.074	0.093	0.078	0.089
13	18.0	904.0	0.002	0.002	0.65	0.62	0.078	0.099	0.085	0.099
14	17.6	1002.0	-0.001	0.002	0.57	0.56	0.082	0.106	0.092	0.108
15	14.2	999.0	0.002	0.003	0.45	0.40	0.084	0.104	0.093	0.108
16	9.8	999.0	-0.002	0.002	0.21	0.21	0.083	0.102	0.092	0.108
17	6.0	998.0	0.002	0.001	0.05	0.05	0.082	0.098	0.092	0.108
18	0.2	998.0	-0.002	0.001	-0.24	-0.21	0.072	0.088	0.092	0.108
19	6.8	997.0	0.000	0.001	0.07	0.10	0.071	0.091	0.092	0.108
20	11.0	997.0	-0.002	0.000	0.24	0.26	0.074	0.095	0.092	0.108
21	14.2	997.0	0.001	0.001	0.39	0.38	0.075	0.100	0.092	0.109
22	18.4	997.0	-0.002	0.001	0.59	0.60	0.083	0.108	0.094	0.109
23	0.2	998.0	-0.002	0.002	-0.22	-0.20	0.075	0.088	0.093	0.110
24	18.2	997.0	-0.001	0.002	0.60	0.59	0.083	0.111	0.095	0.112
25	0.4	997.0	0.001	0.002	-0.23	-0.20	0.076	0.090	0.094	0.111
26	18.0	996.0	-0.003	0.000	0.57	0.56	0.084	0.108	0.095	0.112
27	0.2	996.0	-0.002	0.000	-0.23	-0.21	0.074	0.090	0.094	0.112
28	18.2	995.0	-0.002	0.000	0.59	0.56	0.085	0.109	0.096	0.113
29	0.2	996.0	-0.001	0.000	-0.22	-0.18	0.076	0.088	0.094	0.112
30	18.2	996.0	0.000	0.001	0.61	0.60	0.086	0.111	0.096	0.113
31	20.2	997.0	0.000	0.000	0.69	0.68	0.089	0.115	0.097	0.113
32	30.2	1197.0	0.028	0.019	3.51	3.52	0.383	0.438	0.128	0.157
33	40.4	1411.0	0.039	0.034	5.22	5.28	0.588	0.649	0.185	0.216
34	50.4	1595.0	0.064	0.049	7.11	7.26	0.851	0.916	0.293	0.317
35	60.4	1810.0	0.083	0.070	8.88	9.08	1.101	1.166	0.397	0.413
36	70.2	2004.0	0.101	0.087	10.90	11.13	1.369	1.438	0.507	0.511
37	80.2	2204.0	0.128	0.100	13.34	13.63	1.686	1.754	0.636	0.623
38	90.2	2403.0	0.150	0.117	17.12	17.44	2.139	2.213	0.811	0.781
39	100.0	2611.0	0.179	0.138	24.47	24.84	2.962	3.059	1.107	1.065

Table 1. Continued.

Step	$2P_2$ kN	ΣP_1 kN	Displacement mm							
			10	11	12	13	14	15	16	17
40	110.0	2804.0	0.216	0.155	36.15	36.80	4.254	4.407	1.564	1.502
41	120.6	3016.0	0.235	0.189	48.52	49.42	5.626	5.859	2.041	1.968
42	120.8	3209.0	0.243	0.199	51.67	52.63	5.994	6.258	2.181	2.113
43	120.2	3384.0	0.242	0.200	51.72	52.68	6.028	6.301	2.215	2.150
43	120.4	3380.0	0.245	0.199	51.72	52.68	6.027	6.301	2.214	2.150
43	120.6	3391.0	0.246	0.200	51.72	52.68	6.027	6.302	2.215	2.152
43	120.8	3406.0	0.242	0.199	51.72	52.68	6.030	6.304	2.217	2.155
44	120.8	3584.0	0.245	0.200	51.92	52.90	6.079	6.364	2.256	2.197
44	120.8	3603.0	0.246	0.200	51.92	52.90	6.082	6.368	2.258	2.200
44	120.6	3619.0	0.245	0.200	51.87	52.84	6.083	6.369	2.262	2.205
45	121.2	3809.0	0.247	0.202	52.30	53.28	6.158	6.460	2.309	2.265
45	120.8	3855.0	0.256	0.204	52.68	53.67	6.225	6.537	2.352	2.313
46	121.2	3994.0	0.259	0.205	52.85	53.86	6.271	6.600	2.389	2.360
46	121.2	4006.0	0.259	0.205	52.86	53.86	6.272	6.602	2.390	2.362
46.5	120.6	4110.0	0.264	0.208	53.25	54.27	6.381	6.729	2.480	2.462
47	121.2	4203.0	0.260	0.207	53.43	54.47	6.424	6.785	2.512	2.503
47	120.6	4177.0	0.266	0.208	53.36	54.41	6.452	6.823	2.534	2.535
47.5	119.6	4307.0	0.260	0.207	53.23	54.28	6.450	6.822	2.534	2.540
48	121.2	4411.0	0.263	0.208	53.80	54.86	6.551	6.951	2.618	2.638
48.5	121.2	4500.0	0.259	0.213	54.04	55.13	6.598	7.005	2.647	2.671
-	0.0	2.0	0.090	0.067	5.85	5.96	0.983	1.045	0.515	0.553
48.5	121.4	4503.0	0.259	0.213	54.04	55.13	6.598	7.005	2.647	2.671
49	120.8	4605.0	0.261	0.214	54.00	55.10	6.634	7.044	2.682	2.714
49.5	121.8	4710.0	0.257	0.217	54.58	55.69	6.727	7.156	2.739	2.780
50	120.8	4838.0	0.256	0.221	54.56	55.66	6.791	7.215	2.809	2.844
50.5	121.0	4938.0	0.263	0.219	54.74	55.82	6.888	7.279	2.895	2.900

Table 2. Displacements measured by transducers 18 – 25.

Step	$2P_2$	ΣP_1	Displacement mm							
	kN	kN	18	19	20	21	22	23	24	25
0	0.0	0.0	0.000	0.000	0.000	0.000	0.00	0.00	0.000	0.000
1	0.0	103.0	0.014	0.015	0.011	0.014	0.01	0.01	0.000	0.001
2	0.0	205.0	0.033	0.037	0.030	0.035	0.10	0.08	-0.005	-0.001
3	0.0	306.0	0.050	0.062	0.052	0.066	0.16	0.19	-0.006	-0.001
4	0.0	404.0	0.069	0.085	0.073	0.090	0.24	0.23	-0.005	-0.002
5	0.0	505.0	0.090	0.107	0.097	0.116	0.28	0.32	-0.006	-0.001
6	6.6	508.0	0.095	0.112	0.107	0.128	0.57	0.61	-0.003	-0.001
7	10.4	508.0	0.095	0.114	0.114	0.135	0.74	0.78	0.002	-0.002
8	15.0	507.0	0.098	0.115	0.120	0.143	0.98	0.99	0.007	0.000
9	18.0	509.0	0.100	0.118	0.127	0.153	1.14	1.16	0.007	-0.001
10	18.0	606.0	0.119	0.138	0.146	0.169	1.19	1.22	0.008	-0.001
11	18.4	692.0	0.135	0.156	0.167	0.190	1.28	1.28	0.010	-0.001
12	18.2	804.0	0.157	0.180	0.194	0.221	1.32	1.34	0.016	-0.001
13	18.0	904.0	0.178	0.202	0.217	0.243	1.40	1.40	0.021	0.000
14	17.6	1002.0	0.199	0.225	0.243	0.266	1.46	1.45	0.018	-0.002
15	14.2	999.0	0.202	0.227	0.247	0.271	1.32	1.35	0.020	-0.001
16	9.8	999.0	0.200	0.227	0.247	0.271	1.15	1.15	0.020	-0.002
17	6.0	998.0	0.202	0.225	0.247	0.270	0.95	0.97	0.017	-0.002
18	0.2	998.0	0.202	0.224	0.240	0.262	0.70	0.74	0.016	-0.002
19	6.8	997.0	0.202	0.225	0.240	0.264	0.98	1.01	0.020	0.000
20	11.0	997.0	0.202	0.228	0.245	0.269	1.19	1.18	0.021	0.000
21	14.2	997.0	0.203	0.230	0.249	0.274	1.32	1.32	0.017	-0.002
22	18.4	997.0	0.206	0.232	0.256	0.281	1.50	1.52	0.020	-0.002
23	0.2	998.0	0.204	0.228	0.241	0.263	0.71	0.71	0.017	0.000
24	18.2	997.0	0.208	0.234	0.257	0.282	1.49	1.51	0.021	-0.001
25	0.4	997.0	0.206	0.230	0.241	0.263	0.71	0.73	0.020	-0.001
26	18.0	996.0	0.208	0.235	0.258	0.283	1.49	1.51	0.021	-0.001
27	0.2	996.0	0.208	0.230	0.242	0.266	0.72	0.73	0.017	0.000
28	18.2	995.0	0.207	0.235	0.259	0.284	1.51	1.53	0.019	-0.001
29	0.2	996.0	0.208	0.231	0.242	0.266	0.72	0.72	0.018	-0.001
30	18.2	996.0	0.210	0.236	0.260	0.287	1.49	1.51	0.020	-0.001
31	20.2	997.0	0.210	0.238	0.263	0.289	1.59	1.62	0.018	-0.001
32	30.2	1197.0	0.373	0.400	0.539	0.569	3.24	3.26	0.028	-0.007
33	40.4	1411.0	0.495	0.527	0.752	0.793	4.53	4.56	0.023	-0.010
34	50.4	1595.0	0.596	0.622	1.032	1.075	6.73	6.73	0.030	-0.011
35	60.4	1810.0	0.711	0.742	1.320	1.361	8.99	8.95	0.050	-0.010
36	70.2	2004.0	0.840	0.873	1.606	1.651	11.15	11.10	0.078	-0.007
37	80.2	2204.0	0.989	1.024	1.937	1.980	13.67	13.59	0.100	-0.009
38	90.2	2403.0	1.177	1.217	2.392	2.436	17.38	17.29	0.133	-0.009
39	100.0	2611.0	1.491	1.531	3.175	3.206	24.19	24.05	0.176	-0.014
40	110.0	2804.0	1.938	2.011	4.388	4.438	35.33	35.07	0.247	-0.064

Table 2. Continued.

Step	$2P_2$	ΣP_1	Displacement mm							
	kN	kN	18	19	20	21	22	23	24	25
41	120.6	3016.0	2.445	2.549	5.753	5.826	47.73	47.45	0.305	-0.093
42	120.8	3209.0	2.620	2.732	6.129	6.209	50.76	50.48	0.328	-0.102
43	120.2	3384.0	2.709	2.809	6.230	6.292	50.98	50.68	0.331	-0.107
43	120.4	3380.0	2.714	2.809	6.234	6.293	50.99	50.70	0.329	-0.107
43	120.6	3391.0	2.723	2.816	6.248	6.303	51.05	50.75	0.332	-0.108
43	120.8	3406.0	2.732	2.821	6.258	6.311	51.09	50.79	0.335	-0.108
44	120.8	3584.0	2.832	2.913	6.387	6.429	51.60	51.29	0.344	-0.112
44	120.8	3603.0	2.840	2.926	6.396	6.442	51.63	51.32	0.341	-0.112
44	120.6	3619.0	2.907	2.984	6.478	6.508	51.74	51.42	0.340	-0.114
45	121.2	3809.0	3.077	3.291	6.712	6.866	52.78	52.56	0.341	-0.116
45	120.8	3855.0	3.203	3.469	6.865	7.069	53.34	53.14	0.342	-0.116
46	121.2	3994.0	3.285	3.578	6.964	7.193	53.63	53.46	0.343	-0.116
46	121.2	4006.0	3.307	3.609	6.985	7.226	53.69	53.52	0.343	-0.117
46.5	120.6	4110.0	3.486	3.842	7.187	7.488	53.98	53.87	0.349	-0.109
47	121.2	4203.0	3.532	3.907	7.232	7.552	54.06	53.97	0.354	-0.104
47	120.6	4177.0	3.559	3.958	7.246	7.585	53.87	53.80	0.355	-0.103
47.5	119.6	4307.0	3.557	3.964	7.231	7.577	53.68	53.61	0.357	-0.102
48	121.2	4411.0	3.671	4.123	7.361	7.746	54.19	54.15	0.353	-0.105
48.5	121.2	4500.0	3.722	4.166	7.422	7.801	54.28	54.23	0.356	-0.103
-	0.0	2.0	1.157	1.344	1.532	1.715	6.01	6.10	0.091	-0.036
48.5	121.4	4503.0	3.722	4.166	7.422	7.801	54.28	54.23	0.356	-0.103
49	120.8	4605.0	3.768	4.258	7.458	7.874	54.15	54.14	0.352	-0.103
49.5	121.8	4710.0	3.842	4.367	7.563	8.017	54.67	54.68	0.355	-0.103
50	120.8	4838.0	3.953	4.493	7.655	8.119	54.55	54.56	0.357	-0.102
50.5	121.0	4938.0	4.056	4.638	7.762	8.264	54.75	54.79	0.359	-0.101

Table 3. Displacements measured by transducers 26 – 29, angles measured by clinometers 8 – 9 and time from the beginning of the test.

Step	$2P_2$	ΣP_1	Displacement mm				Angle degree		Time
	kN	kN	26	27	28	29	8	9	min
0	0.0	0.0	0.000	0.000	0.000	0.000	0.0000	0.0000	0
1	0.0	103.0	0.017	0.012	0.013	0.020			2
2	0.0	205.0	0.020	0.023	0.049	0.056			3
3	0.0	306.0	0.024	0.035	0.098	0.101			4
4	0.0	404.0	0.031	0.043	0.136	0.141			4
5	0.0	505.0	0.035	0.051	0.175	0.180	-0.0069	0.0067	5
6	6.6	508.0	0.039	0.070	0.187	0.192	0.0000	0.0000	10
7	10.4	508.0	0.038	0.068	0.191	0.196	-0.0028	0.0092	11
8	15.0	507.0	0.038	0.069	0.195	0.199	0.0000	0.0000	13
9	18.0	509.0	0.041	0.070	0.195	0.201	-0.0003	0.0133	13
10	18.0	606.0	0.048	0.077	0.226	0.227			15
11	18.4	692.0	0.056	0.085	0.257	0.260			16
12	18.2	804.0	0.070	0.095	0.296	0.299			16
13	18.0	904.0	0.077	0.103	0.332	0.337			17
14	17.6	1002.0	0.082	0.112	0.371	0.376	-0.0058	0.0203	17
15	14.2	999.0	0.084	0.113	0.381	0.387			19
16	9.8	999.0	0.085	0.114	0.381	0.387			21
17	6.0	998.0	0.084	0.112	0.382	0.388			22
18	0.2	998.0	0.084	0.112	0.382	0.387	-0.0100	0.0144	22
19	6.8	997.0	0.086	0.112	0.385	0.392			24
20	11.0	997.0	0.088	0.112	0.386	0.393			24
21	14.2	997.0	0.088	0.112	0.388	0.395			25
22	18.4	997.0	0.088	0.113	0.389	0.397	-0.0058	0.0203	26
23	0.2	998.0	0.091	0.115	0.392	0.398	-0.0114	0.0147	29
24	18.2	997.0	0.092	0.117	0.377	0.404			32
25	0.4	997.0	0.092	0.116	0.377	0.403			33
26	18.0	996.0	0.094	0.120	0.379	0.406			34
27	0.2	996.0	0.091	0.120	0.381	0.404			35
28	18.2	995.0	0.094	0.121	0.379	0.405			36
29	0.2	996.0	0.092	0.119	0.378	0.404	-0.0114	0.0147	37
30	18.2	996.0	0.096	0.120	0.378	0.409	-0.0053	0.0203	39
31	20.2	997.0	0.095	0.122	0.379	0.410	0.0000	0.0000	41
32	30.2	1197.0	0.092	0.095	0.507	0.521	0.0689	0.0567	43
33	40.4	1411.0	0.086	0.088	0.624	0.626	0.1069	0.0792	50
34	50.4	1595.0	0.085	0.091	0.736	0.739	0.1553	0.1347	54
35	60.4	1810.0	0.112	0.112	0.843	0.846	0.1864	0.1819	63
36	70.2	2004.0	0.122	0.129	0.955	0.944	0.2347	0.2236	70
37	80.2	2204.0	0.134	0.141	1.069	1.055	0.2844	0.2789	78
38	90.2	2403.0	0.155	0.151	1.185	1.168	0.2997	0.3594	84
39	100.0	2611.0	0.174	0.166	1.315	1.291	0.5414	0.4872	92
40	110.0	2804.0	0.190	0.186	1.433	1.410	0.7594	0.7278	98

Table 3. Continued.

Step	$2P_2$ kN	ΣP_1 kN	Displacement mm 26	27	28	29	Angle degree 8	9	Time min
41	120.6	3016.0	0.216	0.215	1.567	1.551	0.9886	0.9467	106
42	120.8	3209.0	0.243	0.248	1.677	1.666	1.0164	0.9689	113
43	120.2	3384.0	0.275	0.280	1.804	1.790	1.0217	0.9750	118
43	120.4	3380.0	0.277	0.282	1.807	1.790			118
43	120.6	3391.0	0.277	0.281	1.818	1.798			119
43	120.8	3406.0	0.278	0.281	1.826	1.808			119
44	120.8	3584.0	0.310	0.310	1.955	1.936	1.0200	0.9794	124
44	120.8	3603.0	0.313	0.315	1.968	1.951			124
44	120.6	3619.0	0.314	0.321	2.027	2.015			126
45	121.2	3809.0	0.309	0.346	2.239	2.278	1.0311	1.0058	132
45	120.8	3855.0	0.315	0.371	2.422	2.494	1.0339	1.0108	141
46	121.2	3994.0	0.347	0.415	2.539	2.627	1.0400	1.0178	148
46	121.2	4006.0	0.346	0.413	2.561	2.649			148
46.5	120.6	4110.0	0.417	0.500	2.833	2.940	1.0406	1.0094	161
47	121.2	4203.0	0.455	0.546	2.908	3.027	1.0469	1.0181	167
47	120.6	4177.0	0.488	0.593	2.958	3.101			171
47.5	119.6	4307.0	0.493	0.602	2.971	3.121	1.0431	1.0125	172
48	121.2	4411.0	0.589	0.707	3.162	3.338	1.0569	1.0197	180
48.5	121.2	4500.0	0.617	0.742	3.228	3.411	1.0594	1.0194	186
-	0.0	2.0	0.127	0.187	1.036	1.102			191
48.5	121.4	4503.0	0.617	0.742	3.228	3.411	1.0594	1.0194	277
49	120.8	4605.0	0.667	0.817	3.339	3.547	1.0594	1.0194	280
49.5	121.8	4710.0	0.718	0.894	3.450	3.681	1.0600	1.0219	282
50	120.8	4838.0	0.808	1.010	3.646	3.887	1.0719	1.0244	288
50.5	121.0	4938.0	0.883	1.156	3.850	4.124	1.0700	1.0253	294

MEASURED DISPLACEMENTS AND ANGLES, TEST N2

Table 1. Loads and displacements measured by transducers 10 – 17.

Step	$2P_2$ kN	ΣP_1 kN	Displacement mm 10	11	12	13	14	15	16	17
0	0.0	0.0	0.000	0.000	0.00	0.00	0.000	0.000	0.000	0.000
3	0.0	318.0	0.001	0.000	-0.15	-0.17	0.020	0.000	0.032	0.020
5	0.0	503.0	0.004	0.000	-0.19	-0.22	0.028	0.018	0.053	0.042
7	10.8	505.0	0.009	0.000	0.26	0.28	0.046	0.039	0.059	0.049
9	19.0	505.0	0.014	0.000	0.68	0.75	0.062	0.059	0.065	0.053
10	18.0	605.0	0.015	0.000	0.75	0.78	0.077	0.076	0.077	0.066
12	18.0	810.0	0.019	0.000	0.74	0.82	0.102	0.101	0.100	0.089
14	18.2	1007.0	0.020	0.000	1.60	1.77	0.214	0.232	0.117	0.115
16	10.2	1000.0	0.020	0.000	1.21	1.28	0.200	0.213	0.116	0.117
18	0.6	999.0	0.017	0.000	0.34	0.32	0.139	0.135	0.116	0.109
20	10.8	997.0	0.021	-0.001	1.09	1.19	0.184	0.201	0.118	0.115
22	18.6	997.0	0.021	0.000	1.84	1.99	0.240	0.265	0.121	0.123
23	0.4	994.0	0.024	0.015	0.34	0.32	0.140	0.136	0.117	0.112
24	19.0	996.0	0.025	0.015	1.93	2.11	0.251	0.287	0.124	0.128
25	0.4	997.0	0.023	0.017	0.30	0.30	0.137	0.137	0.116	0.114
26	18.8	997.0	0.023	0.016	1.94	2.16	0.255	0.288	0.127	0.130
27	0.4	995.0	0.022	0.017	0.31	0.34	0.139	0.137	0.117	0.115
28	18.8	995.0	0.024	0.018	1.99	2.14	0.257	0.292	0.125	0.131
29	0.4	995.0	0.021	0.017	0.30	0.30	0.138	0.138	0.117	0.115
30	18.4	994.0	0.023	0.018	1.94	2.13	0.255	0.291	0.126	0.131
31	20.6	993.0	0.026	0.023	2.18	2.40	0.277	0.316	0.127	0.135
33	40.4	1407.0	0.044	0.104	5.30	5.69	0.643	0.733	0.218	0.250
35	61.0	1813.0	0.067	0.147	9.04	9.53	1.132	1.268	0.437	0.475
36	70.6	2020.0	0.072	0.177	11.07	11.57	1.400	1.553	0.550	0.592
37	80.4	2207.0	0.080	0.223	13.42	13.92	1.711	1.878	0.671	0.711
38	90.2	2406.0	0.079	0.261	17.30	17.76	2.171	2.349	0.842	0.874
39	100.6	2601.0	0.062	0.324	25.29	25.83	3.090	3.261	1.164	1.167
40	110.6	2823.0	-0.008	0.416	36.41	37.15	4.384	4.535	1.613	1.564
41	120.4	3014.0	-0.046	0.508	48.28	49.14	5.747	5.894	2.070	1.981
43	120.8	3410.0	-0.056	0.532	50.78	51.63	6.029	6.254	2.229	2.130
45	120.8	3809.0	-0.058	0.545	51.43	52.29	6.175	6.422	2.338	2.246
46	121.4	4010.0	-0.054	0.544	51.81	52.67	6.275	6.518	2.413	2.313
47	121.4	4219.0	-0.063	0.547	52.27	53.13	6.396	6.643	2.513	2.410
48	120.0	4405.0	-0.075	0.559	52.12	53.03	6.540	6.763	2.684	2.554
-	109.0	287.0	-0.437	0.827	55.38	55.96	18.140	18.948	15.317	12.422

Table 2. Displacements measured by transducers 18 – 25.

Step	$2P_2$ kN	ΣP_1 kN	Displacement mm 18	19	20	21	22	23	24	25
0	0.0	0.0	0.000	0.000	0.000	0.000	0.00	0.00	0.000	0.000
3	0.0	318.0	0.073	0.065	0.089	0.078	0.24	0.18	0.004	0.002
5	0.0	503.0	0.111	0.107	0.133	0.125	0.35	0.26	0.008	0.000
7	10.8	505.0	0.117	0.115	0.155	0.144	0.83	0.63	0.009	0.011
9	19.0	505.0	0.122	0.121	0.173	0.165	1.22	0.98	0.015	0.030
10	18.0	605.0	0.147	0.151	0.204	0.203	1.32	1.06	0.018	0.033
12	18.0	810.0	0.190	0.201	0.261	0.260	1.48	1.25	0.019	0.036
14	18.2	1007.0	0.268	0.289	0.392	0.397	2.01	1.76	0.030	0.035
16	10.2	1000.0	0.269	0.287	0.382	0.388	1.65	1.41	0.032	0.035
18	0.6	999.0	0.249	0.263	0.335	0.344	1.06	0.84	0.033	0.034
20	10.8	997.0	0.262	0.282	0.372	0.378	1.62	1.37	0.033	0.034
22	18.6	997.0	0.279	0.304	0.412	0.419	2.10	1.87	0.034	0.036
23	0.4	994.0	0.250	0.266	0.340	0.348	1.04	0.83	0.034	0.037
24	19.0	996.0	0.287	0.313	0.422	0.430	2.17	1.92	0.035	0.037
25	0.4	997.0	0.252	0.270	0.341	0.353	1.02	0.83	0.034	0.037
26	18.8	997.0	0.287	0.313	0.424	0.433	2.17	1.91	0.035	0.038
27	0.4	995.0	0.252	0.270	0.343	0.354	1.02	0.82	0.037	0.037
28	18.8	995.0	0.289	0.316	0.427	0.436	2.18	1.95	0.037	0.043
29	0.4	995.0	0.252	0.271	0.342	0.357	1.02	0.82	0.035	0.039
30	18.4	994.0	0.289	0.315	0.428	0.435	2.15	1.90	0.037	0.040
31	20.6	993.0	0.296	0.323	0.445	0.453	2.33	2.09	0.038	0.057
33	40.4	1407.0	0.486	0.530	0.788	0.811	4.58	4.51	0.040	0.098
35	61.0	1813.0	0.671	0.759	1.370	1.418	9.02	8.90	0.077	0.208
36	70.6	2020.0	0.790	0.896	1.623	1.699	11.12	10.96	0.100	0.241
37	80.4	2207.0	0.922	1.046	1.918	2.006	13.35	13.16	0.116	0.275
38	90.2	2406.0	1.091	1.232	2.328	2.432	16.74	16.51	0.145	0.315
39	100.6	2601.0	1.476	1.585	3.280	3.306	24.61	24.34	0.176	0.388
40	110.6	2823.0	1.950	2.033	4.566	4.530	35.56	35.20	0.176	0.499
41	120.4	3014.0	2.559	2.583	6.041	5.969	48.23	47.89	0.168	0.616
43	120.8	3410.0	2.782	2.913	6.523	6.505	51.31	51.02	0.162	0.654
45	120.8	3809.0	3.082	3.277	6.915	6.942	52.64	52.39	0.161	0.670
46	121.4	4010.0	3.264	3.455	7.143	7.162	53.45	53.19	0.161	0.671
47	121.4	4219.0	3.428	3.626	7.357	7.389	54.24	53.98	0.159	0.699
48	120.0	4405.0	3.538	3.797	7.505	7.572	54.49	54.25	0.150	0.709
-	109.0	287.0	3.352	3.678	7.222	7.353	52.84	52.46	0.168	0.788

Table 3. Displacements measured by transducers 26 – 29, angles measured by clinometers 8 – 9 and time from the beginning of the test.

Step	$2P_2$	ΣP_1	Displacement mm				Angle degree		Time
	kN	kN	26	27	28	29	8	9	min
0	0.0	0.0	0.000	0.000	0.000	0.000	0.0000	0.0000	0
3	0.0	318.0	0.027	0.006	0.161	0.152			3
5	0.0	503.0	0.043	0.026	0.235	0.231	-0.0064	0.0078	4
7	10.8	505.0	0.048	0.031	0.249	0.246	-0.0047	0.0097	7
9	19.0	505.0	0.049	0.033	0.256	0.252	0.0028	0.0128	9
10	18.0	605.0	0.057	0.044	0.293	0.292			11
12	18.0	810.0	0.081	0.071	0.371	0.375			12
14	18.2	1007.0	0.102	0.091	0.472	0.476	0.0297	0.0325	13
16	10.2	1000.0	0.109	0.099	0.483	0.487			17
18	0.6	999.0	0.113	0.105	0.479	0.472	0.0031	0.0211	18
20	10.8	997.0	0.123	0.111	0.480	0.485			22
22	18.6	997.0	0.121	0.108	0.495	0.496	0.0325	0.0333	22
23	0.4	994.0	0.116	0.108	0.488	0.479	0.0036	0.0211	26
24	19.0	996.0	0.124	0.111	0.505	0.506			30
25	0.4	997.0	0.120	0.111	0.492	0.485			31
26	18.8	997.0	0.122	0.110	0.506	0.508			32
27	0.4	995.0	0.121	0.111	0.493	0.487			33
28	18.8	995.0	0.122	0.110	0.506	0.509			34
29	0.4	995.0	0.122	0.113	0.493	0.488	0.0042	0.0214	35
30	18.4	994.0	0.123	0.112	0.508	0.511	0.0353	0.0103	38
31	20.6	993.0	0.124	0.108	0.513	0.516			40
33	40.4	1407.0	0.143	0.117	0.712	0.729	0.1139	0.0800	43
35	61.0	1813.0	0.173	0.194	0.925	0.943	0.1928	0.1758	48
36	70.6	2020.0	0.215	0.240	1.032	1.052	0.2361	0.2197	53
37	80.4	2207.0	0.260	0.279	1.151	1.161	0.2892	0.2692	58
38	90.2	2406.0	0.288	0.311	1.264	1.261	0.3764	0.3425	62
39	100.6	2601.0	0.315	0.353	1.429	1.396	0.5583	0.5189	68
40	110.6	2823.0	0.356	0.512	1.602	1.543	0.7564	0.6922	75
41	120.4	3014.0	0.403	0.543	1.766	1.680	0.9650	0.9431	80
43	120.8	3410.0	0.470	0.647	2.002	1.926	1.0086	0.9844	87
45	120.8	3809.0	0.592	0.765	2.366	2.263	1.0169	1.0000	91
46	121.4	4010.0	0.696	0.838	2.604	2.454	1.0236	1.0117	95
47	121.4	4219.0	0.852	0.964	2.850	2.661	1.0264	1.0186	99
48	120.0	4405.0	1.133	1.076	3.363	2.929			104
-	109.0	287.0	11.430	9.651	13.795	11.426			104

PHOTOGRAPHS, TEST BES1

Fig. 1. Steel plate under hollow core slab.

Fig. 2. Joint reinforcement and plastic pipes being pushed to their final position .

Fig. 3. Steel plates to support the upper wall element.

Fig. 4. Loading arrangements seen from west.

Fig. 5. Inductive transducers for measuring vertical displacements.

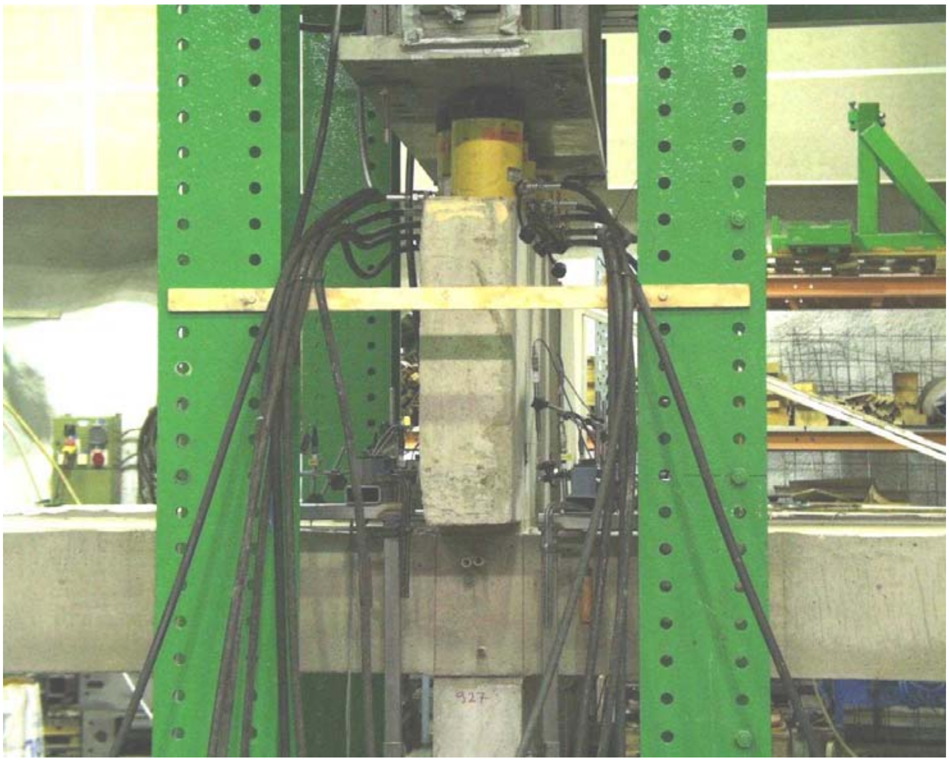


Fig. 6. Loading arrangements seen from north.

Fig. 7. Cracks at step 38 seen from north.

Fig. 8. Cracks at step 38 seen from north.

Fig. 9. Transverse crack on the top of the western slab at step 38.

Fig. 10. Transverse crack on the top of the eastern slab at step 38.

Fig. 11. Cracking pattern after failure seen from north.

Fig. 12. Cracking pattern in the upper wall element after failure see4n from west.

Fig. 13. Cracking pattern in the upper wall element after failure seen from west. Note also the failure of the cantilevered end which took place after step 44.

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Fig. 14. 2nd phase grout after removal of the upper wall element.

Fig. 15. Lower wall element after removal of slabs seen from north.

Fig. 16. Lower wall element after removal of slabs seen from east.

Fig. 17. Lower wall element after removal of slab seen from west.

Fig. 18. Uncracked joint concrete on top of the upper wall element seen from north.

Fig. 19. Uncracked joint concrete on top of the upper wall element seen from south.

Fig. 20. End of western slab.

Fig. 21. End of western slab.

Fig. 22. End of eastern slab.

Fig. 23. End of eastern slab.

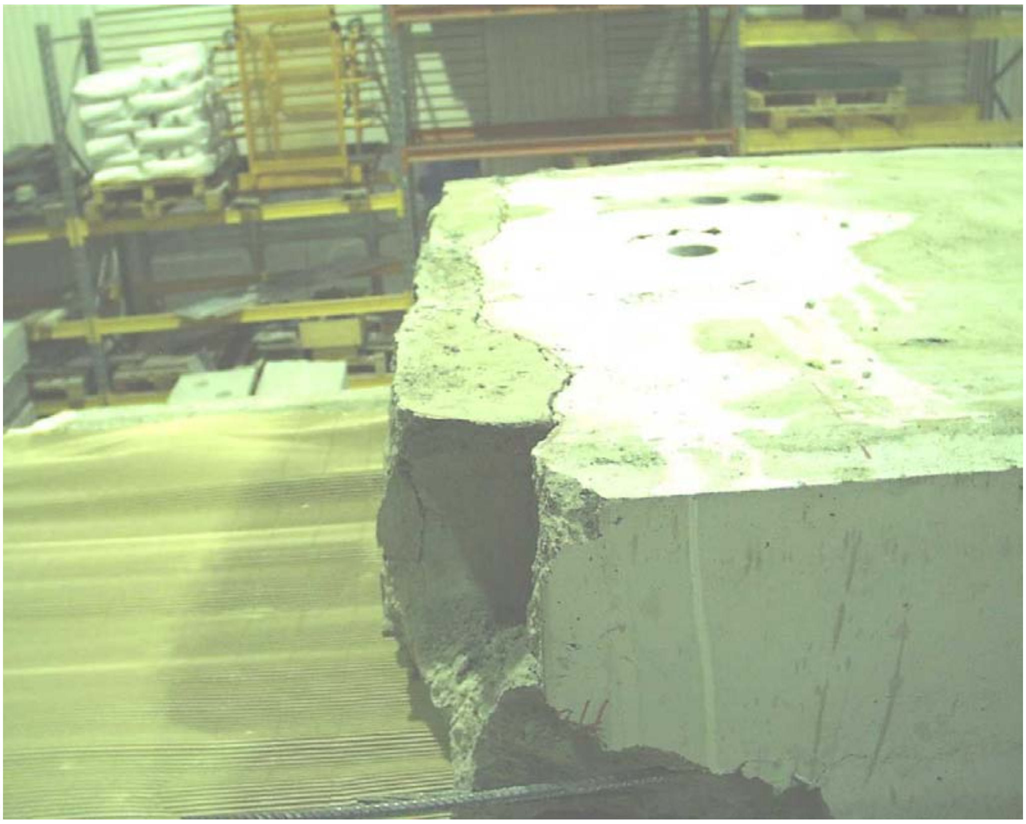

Fig. 24. End of eastern slab.

PHOTOGRAPHS, TEST N1

Fig. 1. Steel plate between neoprene strip and slab. Note the curvature of the strip close to the plate.

Fig. 2. Joint before concreting.

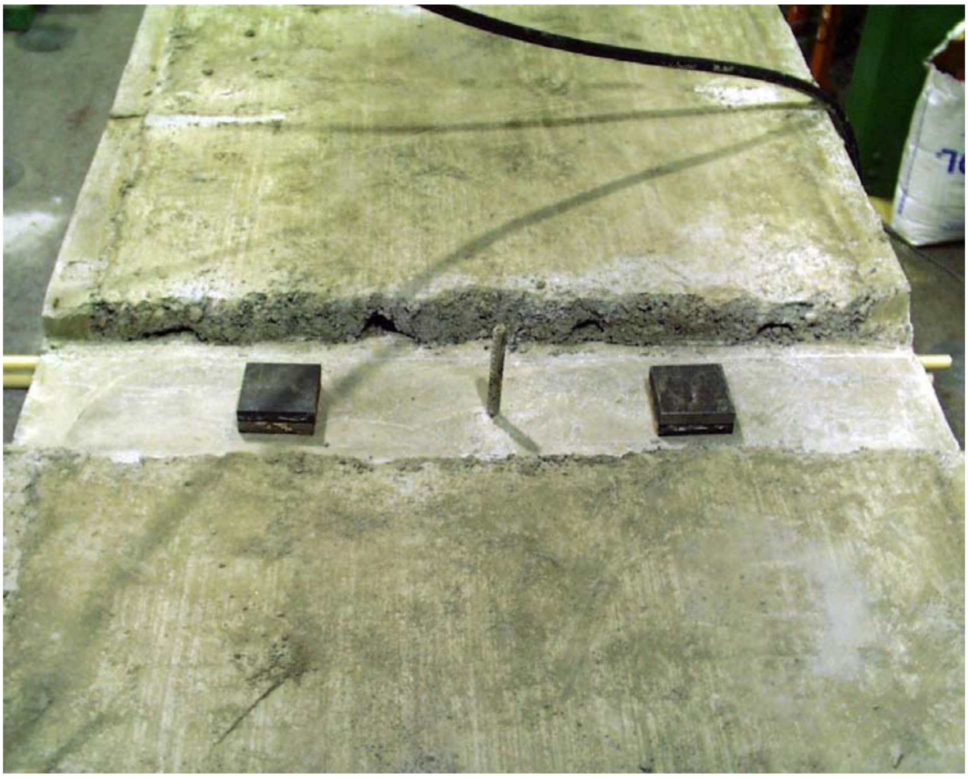

Fig. 3. Joint before installation of the upper wall element.

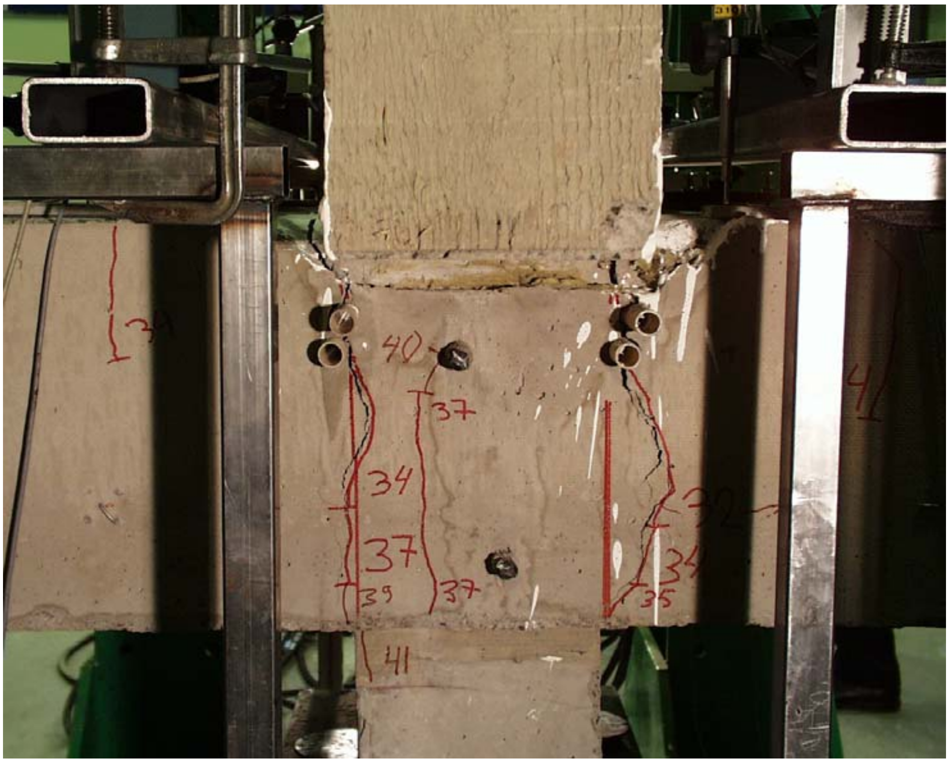

Fig.4. Cracking pattern at step 41 seen from south.

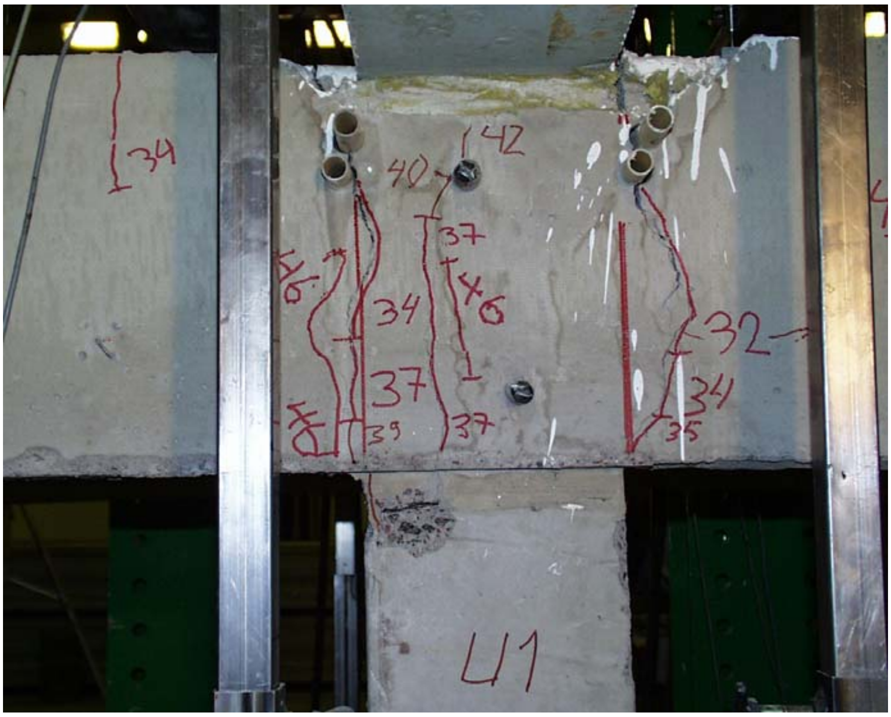

Fig. 5. Cracking pattern at step 46 seen from south.

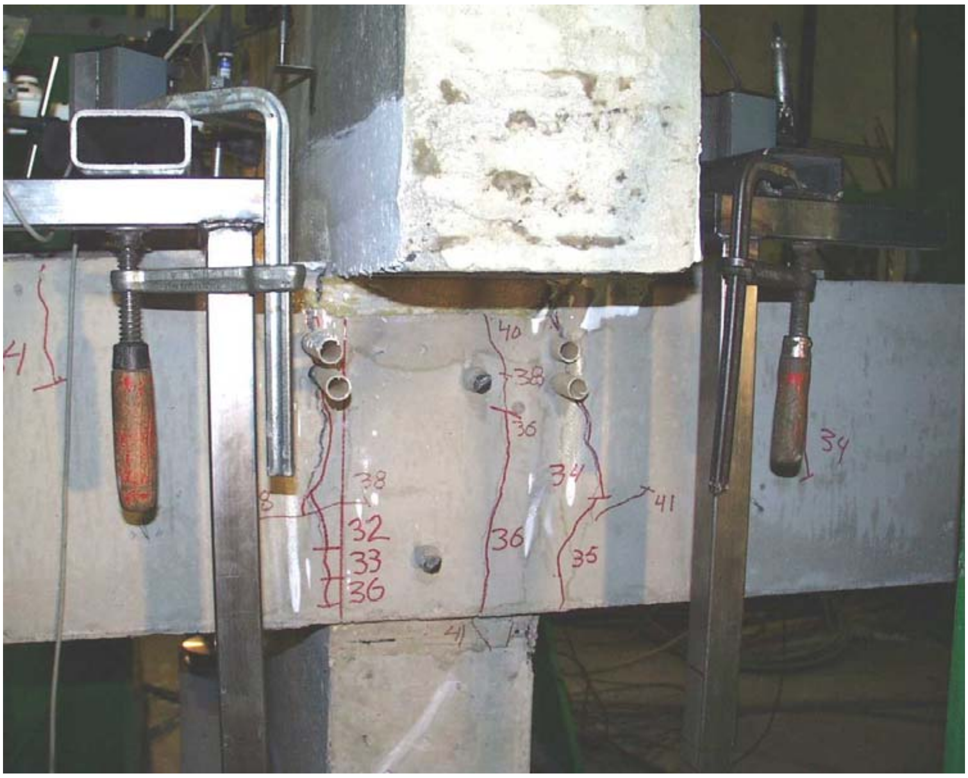

Fig. 6. Cracking pattern at step 41 seen from north.

Fig. 7. Peeling of the concrete below and above the neoprene strip before failure seen from west.

Fig. 8. Deformation of the eastern slab before failure.

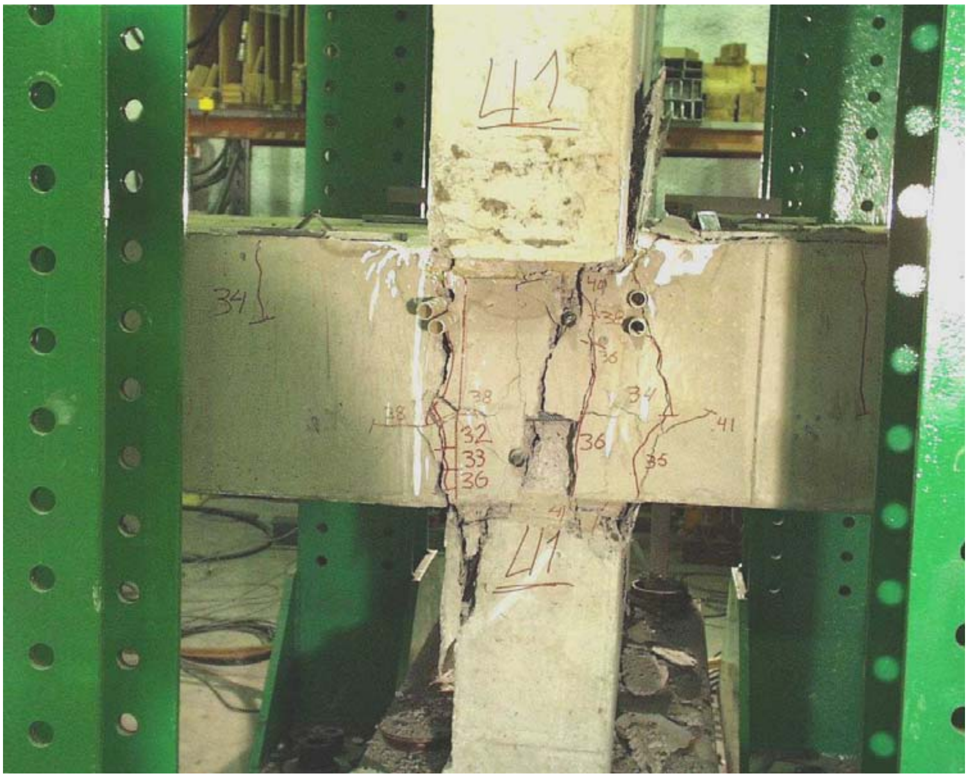

Fig. 9. Cracking pattern after failure seen from north.

Fig. 10. Cracking pattern after failure seen from south.

Fig. 11. Upper wall element after failure seen from west.

Fig. 12. Upper wall element after failure seen from west.

Fig. 13. Lower wall element after failure seen from west.

Fig. 14. Lower wall element after failure seen from east.

Fig.15. Uncracked eastern face of the upper wall element after failure.

Fig. 16. Top surface of the joint after removal of the upper wall element.

Fig. 17. Top surface of the joint after removal of the upper wall element. Note the air pores.

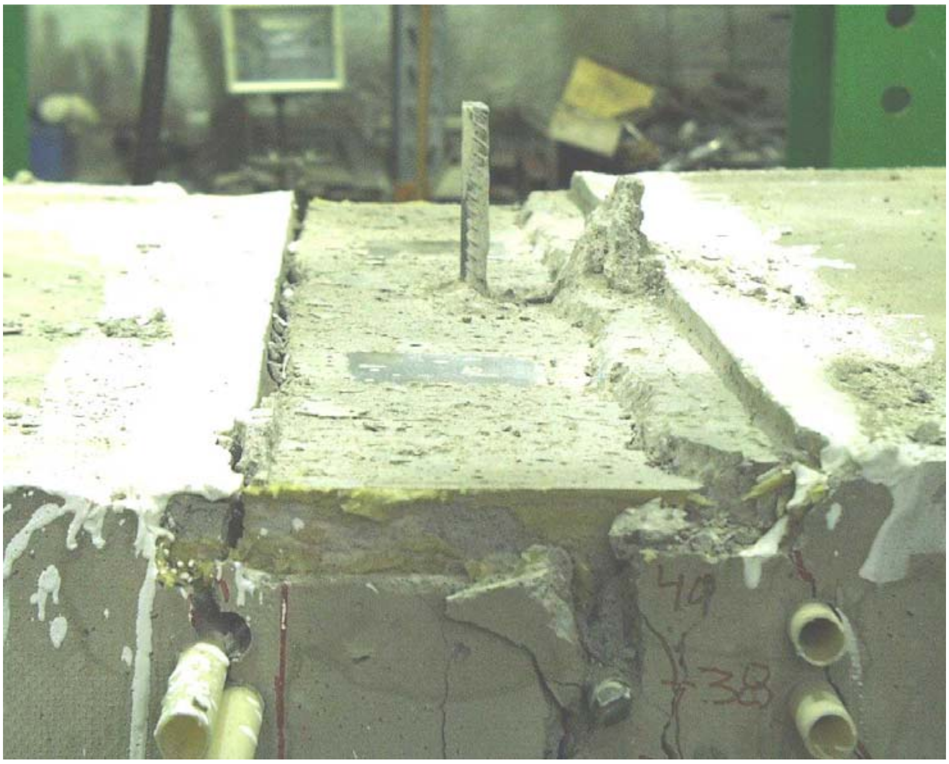

Fig. 18. Top surface of the joint after removal of the upper wall element seen from north.

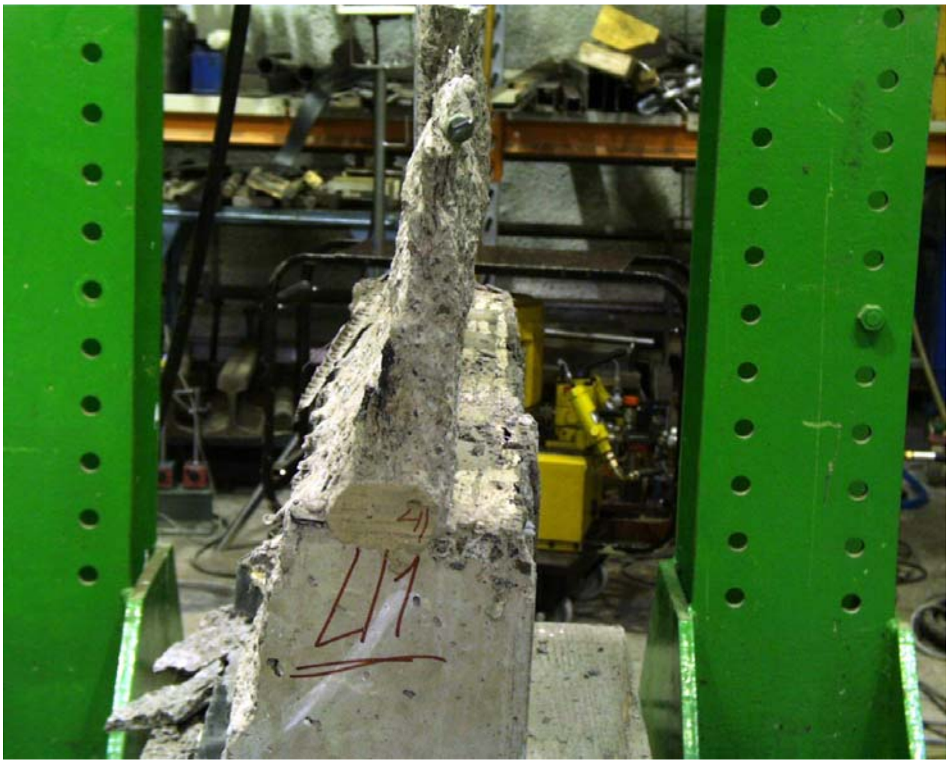

Fig. 19. Lower wall element after removal of slabs seen from north.

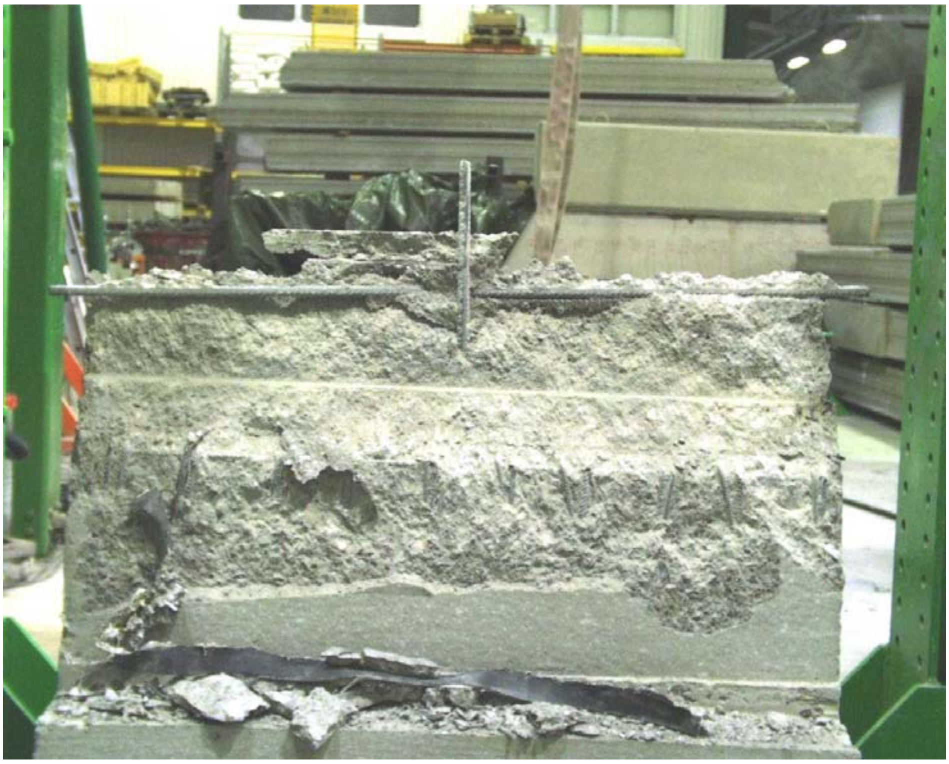

Fig. 20. Lower wall element after removal of slabs seen from east.

Fig. 21. A monolithic block (joint concrete) which was broken when falling down from the top of the lower wall element, seen from east.

Fig. 22. Removing a concrete block from end of western slab.

Fig. 23. End of western slab.

Fig. 24. End of western slab.

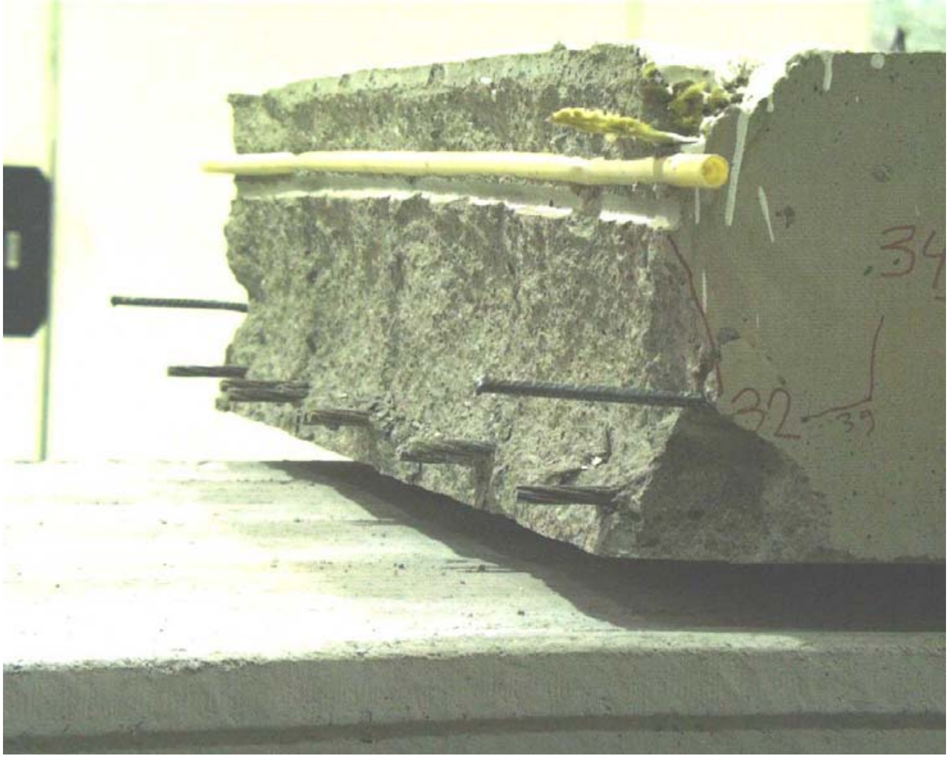

Fig. 25. End of eastern slab.

PHOTOGRAPHS, TEST N2

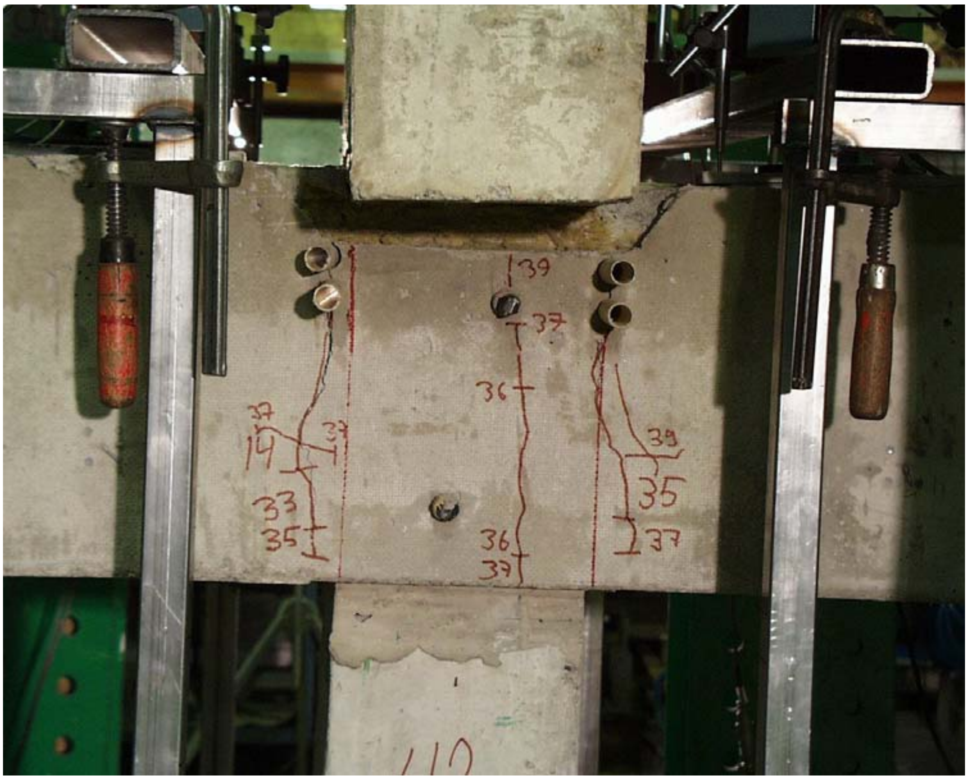

Fig. 1. Cracking pattern at step 39 seen from north.

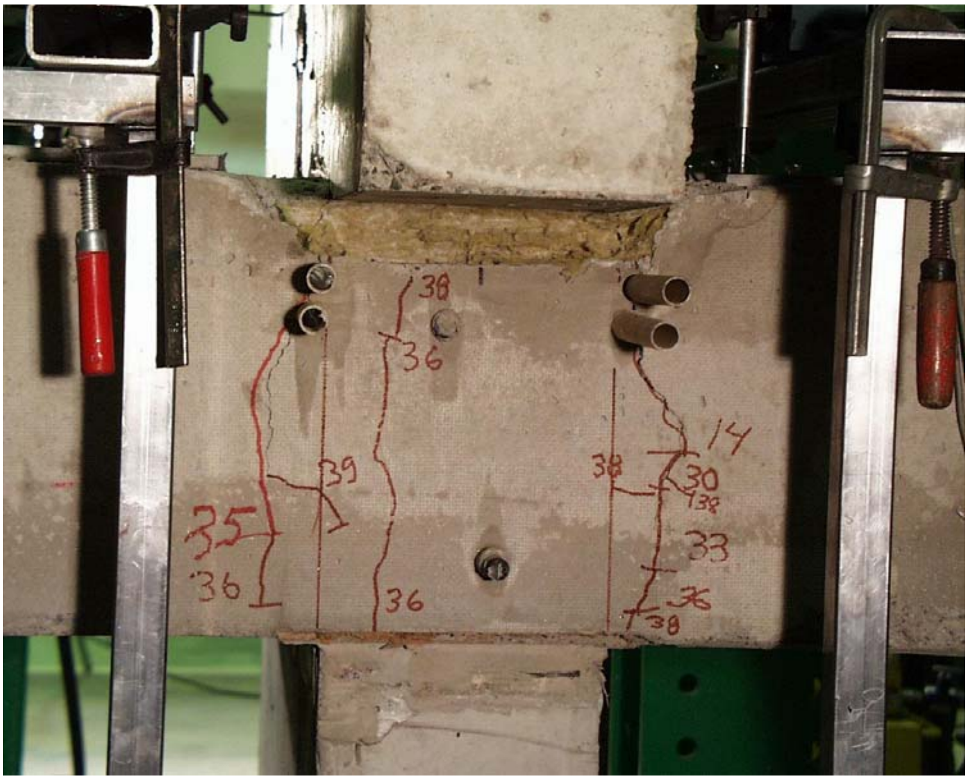

Fig. 2. Cracking pattern at step 39 seen from south.

Fig. 3. Cracking pattern at failure seen from north.

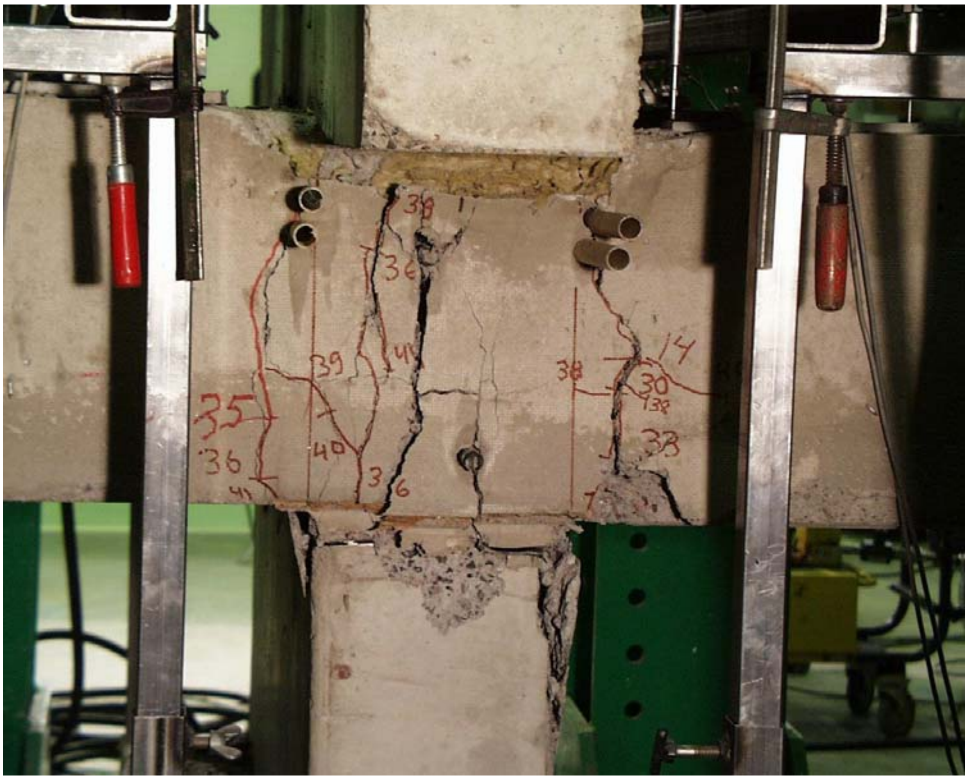

Fig. 4. Cracking pattern at failure seen from south.

Fig. 5. Location of flexural cracks in western slab.

Fig. 6. Location of flexural cracks in eastern slab.

Fig. 7. Peeling of concrete in lower wall element seen from east.

Fig. 8. Peeling of concrete in lower wall element seen from west.

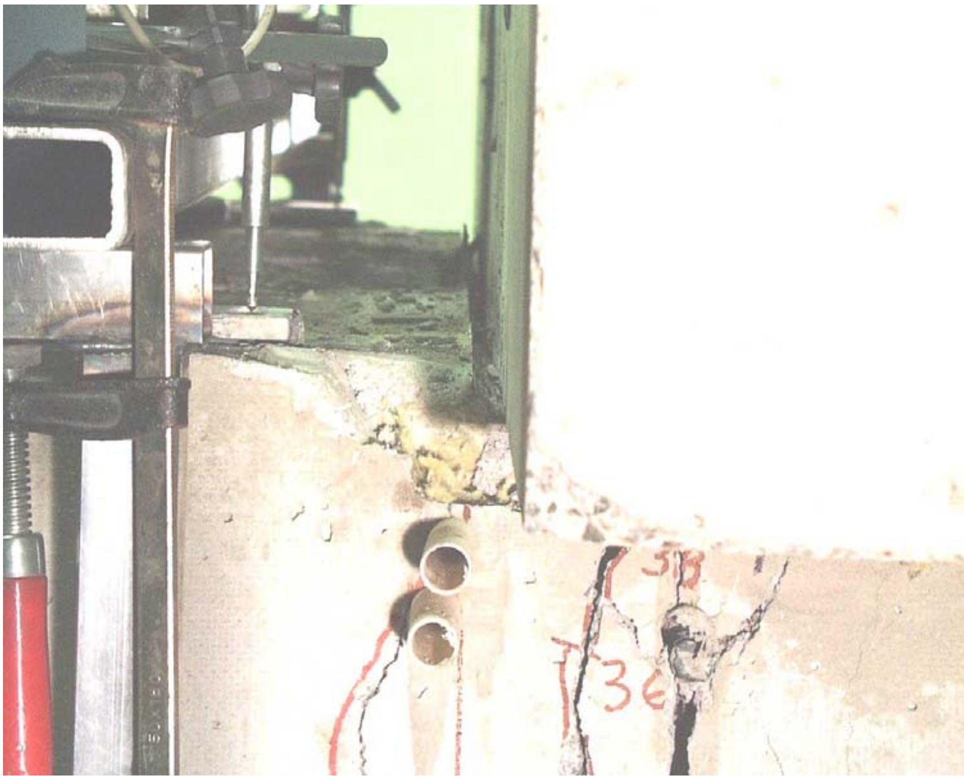

Fig. 9. Cracking in upper wall element after failure seen from north.

Fig. 10. No visible cracking in upper wall element after failure, seen from east.

Fig. 11. Cracking pattern in upper wall element. Western face on the left.

Fig. 12. Joint after removal of the upper wall element seen from west.

Fig. 13. Removal of the failed slab seen from north.

Fig. 14. Lower wall element seen from east.

Fig. 15. End of western slab.

Fig. 16. Lower wall element seen from north.

Fig. 17. Lower wall element seen from west.

Fig. 18. Lower wall element seen from east.

Fig. 19. End of eastern slab.

Fig. 20. End of eastern slab.

Fig. 21. End of eastern slab.

Fig. 22. End of western slab.