Appendix A

Concrete Properties of Test Beams

BETONZUSAMMENSETZUNG — B1

Betonsorte : 1633736Z

Werk : neuland beton

1. ANFORDERUNGEN

Expositionsklasse(n) : **XC4XD1XS1XF2XA1** **WU**
Festigkeitskl. / Konsist. : **C 30/37 / F 3**
Besond. Eigenschaften : **ZTV-Ing. XC4; XD1; XS1; XF2; XA1**

Eignung : **ZTV- Ing. Widerlager, Stützen; (Sprühnebel)**

w/z-Wert: **0,49**

Art der Verwendung : **Stahlbeton**
Sieblinienummer : **NL20A5**
Sieblinienbereich / K-Wert : **AB 16 / 4,01**
Festigkeitsentwicklung : **mittel**
Überwachungsklasse : **2**
Festigkeitsnachweis nach : **28 Tagen**
Pumpfähigkeit : **J**
Feuchtigkeitsklasse : **WA**

2. AUSGANGSSTOFFE UND ZUSAMMENSETZUNG

Ausgangsstoffe	Bezeichnung	Anteil %	Stoffraum dm³	Dichte kg/m³	Menge kg trocken	Oberfl.feucht. %	Oberfl.feucht. l	Menge kg f.
Zement	CEM III/A 42,5N		123	3,00	**370**			
Zusatzstoff								
Zusatzmittel	1BV N9 MC - Bauchemie	0,80	2,57	1,15	**2,96**			
Wasser			182	1,00	**182**			
Restwasser								
Porenraum			15					
Summen			323		**555**			
Restraum für Gesteinskörnung			677					
FGK 0/2	EI-O-EI-OF	42,0	284	2,63	**748**	4,0	30	778
GGGK 2/8	EI	20,0	135	2,72	**368**	1,0	4	372
GGGK 8/16	EI	38,0	257	2,72	**700**	0,5	4	704
Summen		100	677		**1816**		38	1854

3. KENNWERTE

Gesamtwasser .... **182** Liter
Zugabewasser .... **144** Liter

Mehlkorngehalt .... **374** kg
Mehlkorn +Feinstsand .. **417** kg

Gesteinsk.menge trocken .... **1816** kg
Eigenfeuchte .... **38** kg
Gesteinsk.menge feucht .... **1854** kg
Mörtelgehalt .... **597** dm³/m³
Frischbetonrohdichte .... **2371** kg/m³

XF3;ZTV-Ing. Widerlager; Stützen; Pfeiler (Sprühnebel)

Hamburg, den 04.03.2009

Betonlabor Süderelbe
Abt. der Neuland Beton
Prüfstelle E. U. W.

Prüfstellenleiter

A1. Compressive strength

3 cubic samples 150 mm preserved in water conditions were tested after 28 days (06/04/2009)

Sample	Dimension (mm)			Weight	Density	Force	$f_{c,cube}$
	a	B	h	(kg)	(kg/m³)	(kN)	(MPa)
1	151,8	150,1	150,1	8,161	2.386	1.392	61,1
2	151,2	150,1	150,0	8,158	2.396	1.450	63,9
3	151,5	150,0	150,0	8,129	2.385	1.442	63,5
Mean value					2.389		62,8

Table A.1–Tests of cubic samples for compressive strength after 28 days

$f_{c,cube}$ is the mean value of compressive strength of cubic samples tested in the laboratory. The characteristic compressive strength of cylinder at 28 days f_{ck} is determined as follows:

$$f_{ck} = \frac{0,75}{0,95} f_{c,cubic} - 4MPa$$

where : 0,75/0,95: conversion factors from cubic sample to cylindrical sample.

4 MPa : conversion value from mean value to characteristic value in laboratory.

3 cubic samples 150 mm preserved in normal conditions as the test beams was tested after 52 days (30/04/2009)

Sample	Dimension (mm)			Weight	Density	Force	$f_{c,cube}$
	a	*b*	*h*	(kg)	(kg/m³)	(kN)	(MPa)
1	150,9	150,0	150,1	8,015	2.359	1.466	64,8
2	151,2	149,9	149,9	8,008	2.357	1.500	66,2
3	151,8	150,0	149,9	8,122	2.380	1.528	67,1
Mean value					2.365		66,0

Table A.2– Tests of cubic samples for compressive strength after 52 days

3 cubic samples 150 mm preserved in normal conditions as the test beams was tested after 101 days (18/06/2009)

Sample	Dimension (mm)			Weight	Density	Force	$f_{c,cube}$
	a	*b*	*h*	(kg)	(kg/m³)	(kN)	(MPa)
1	152,2	150,0	150,0	8,039	2.347	1.669	73,1
2	152,1	150,0	150,0	8,024	2.345	1.637	71,8
3	151,3	149,9	150,0	8,001	2.352	1.699	74,9
Mean value					2.348		73,3

Table A.3– Tests of cubic samples for compressive strength after 101 days

A2. Modulus of elasticity and compressive strength

4 Cylinder samples ϕ150/300 mm preserved in normal conditions as the test beams were tested after 52 days (30/04/2009).

Sample	Dimension (mm)		Weight	Density	σ_o	σ_u	ε_o	ε_u	E_c	Force	$f_{c,cyl}$
	ϕ	*h*	(kg)	(kg/m³)	(MPa)	(MPa)	mm/m	mm/m	(MPa)	(kN)	(MPa) (dry)
1	150,0	299,0	12,46	2.358	-	-	-	-	-	958	54,2
2	149,9	300,0	12,490	2.359	17,8	0,5	0,574	0,033	32.071	957	54,2
3	150,0	299,3	12,478	2.359	17,8	0,5	0,592	0,035	31.098	953	53,9
4	150,0	300,0	12,521	2.362	17,8	0,5	0,603	0,039	30.712	946	53,5
Mean value				2.360					31.294		54,0

Table A.4– Tests of cylinder samples for modulus of elasticity
and compressive strength after 52 days

A3. Tensile strength

3 cylinder samples ϕ150/300mm preserved in normal conditions as the test beams were tested after 101 days (18/06/2009).

Sample	Dimension (mm)		Weight (kg)	Density (kg/m³)	Force (kN)	$f_{ct,sp}$ (MPa)
	Ø	*h*				(dry)
1	150,0	299,8	12,447	2.349	253,2	3,58
2	150,0	299,9	12,462	2.351	244,6	3,46
3	150,0	299,8	12,405	2.341	264,2	3,74
Mean value				2.350	254,0	3,60

Table A.5– Tests of cylinder samples for tensile strength after 101 days

Appendix B

Test Results

TEST SAMPLE: 1L1

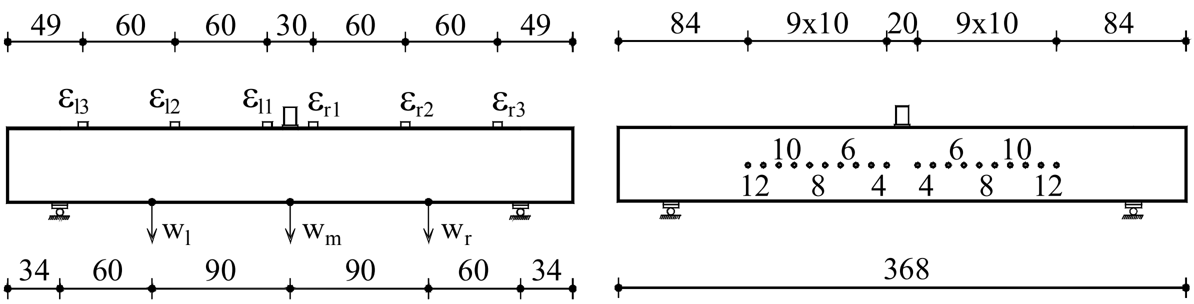


Figure B.1L1.1- The detailed arrangement of the data acquisition system

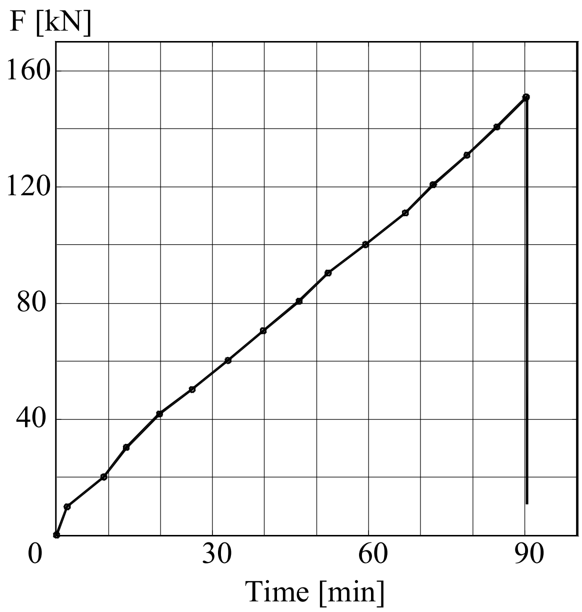


Figure B.1L1.2- The Time – Load graph

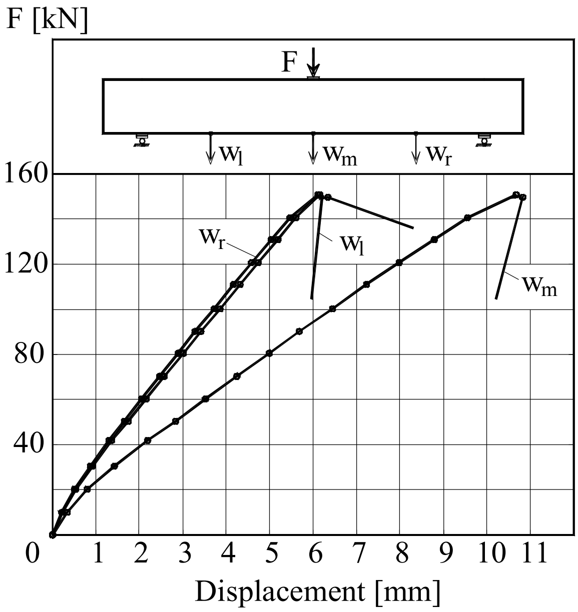


Figure B.1L1.3–The Load – Displacement graph

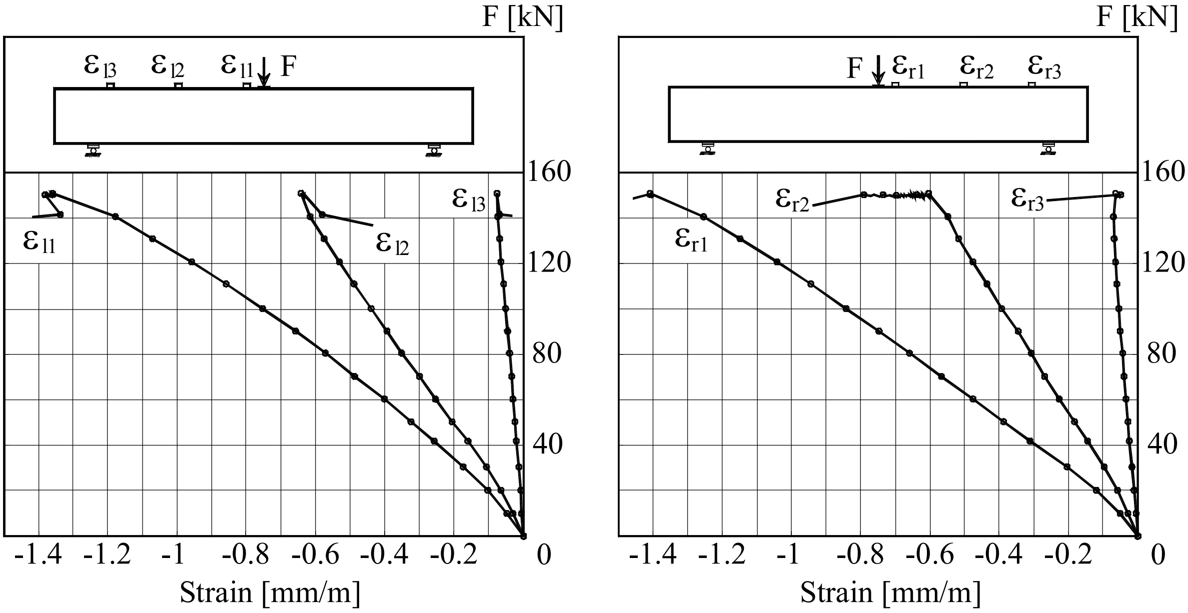


Figure B.1L1.4– The Load – Strains graph at top surface of beam

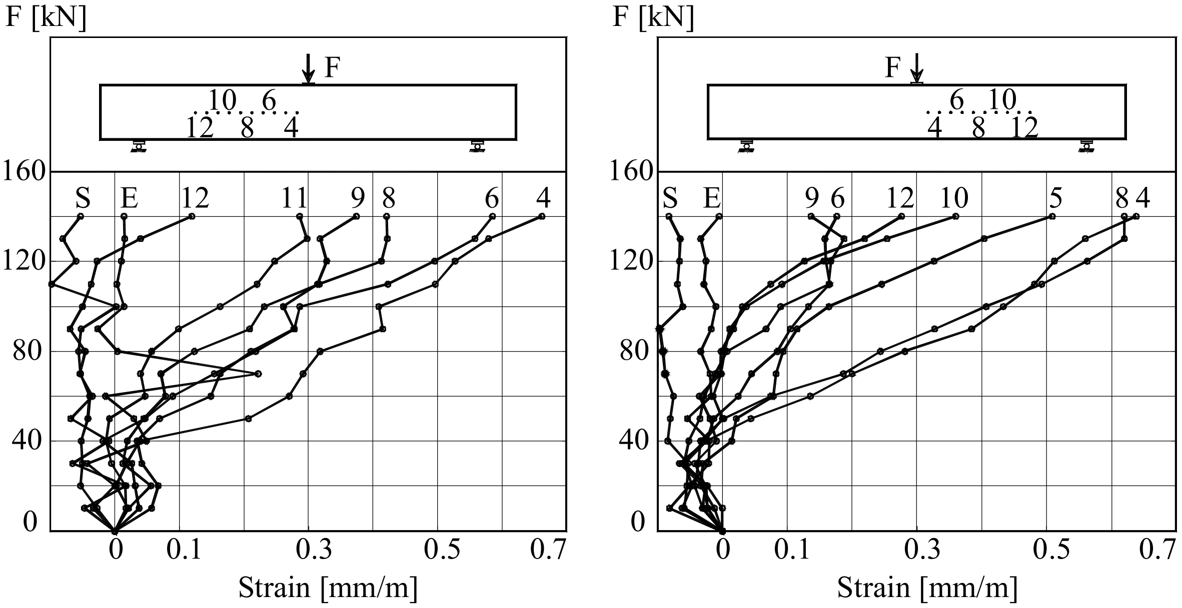


Figure B.1L1.5– The Load – Strains graph at mid-depth of beam

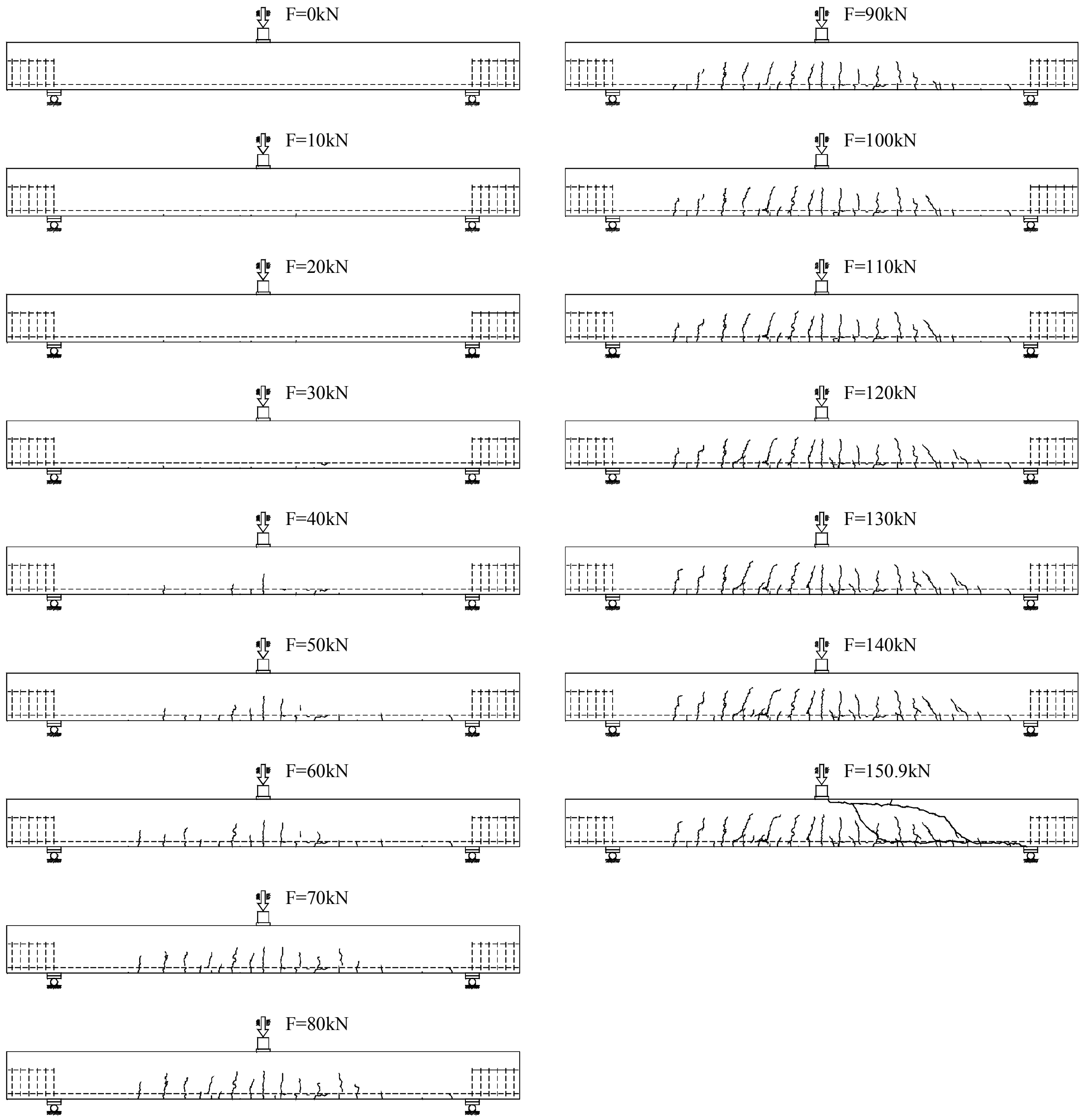


Figure B.1L1.6– Crack propagation of beam 1L1 after each load step.

TEST SAMPLE: 1L2

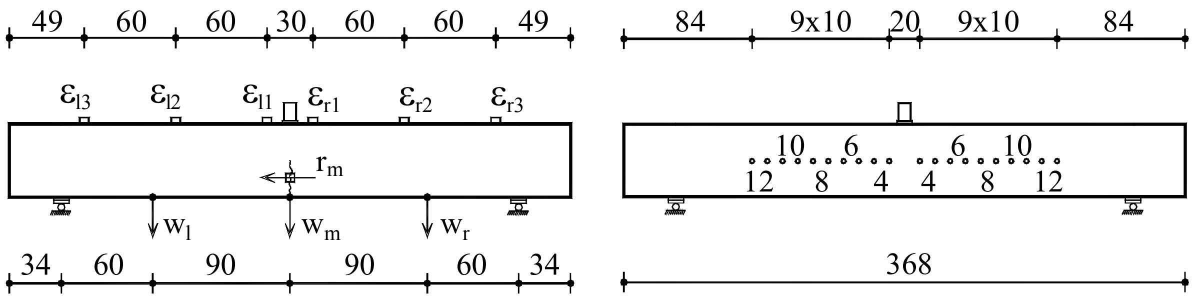


Figure B.1L2.1– The detailed arrangement of the data acquisition system

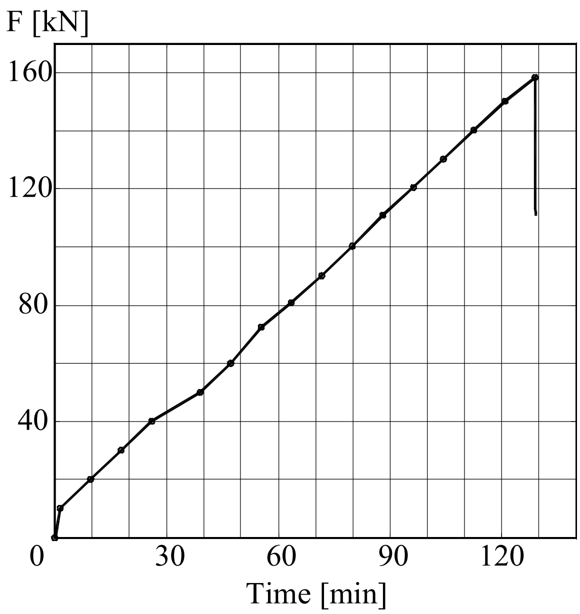


Figure B.1L2.2– The Time – Load graph

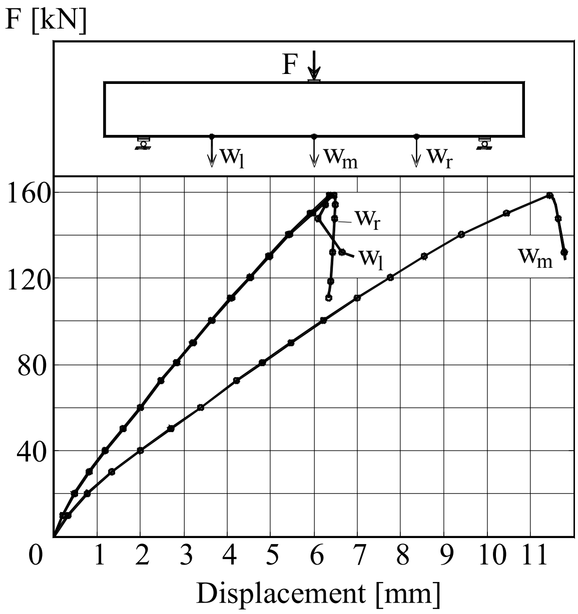


Figure B.1L2.3– The Load – Displacement graph

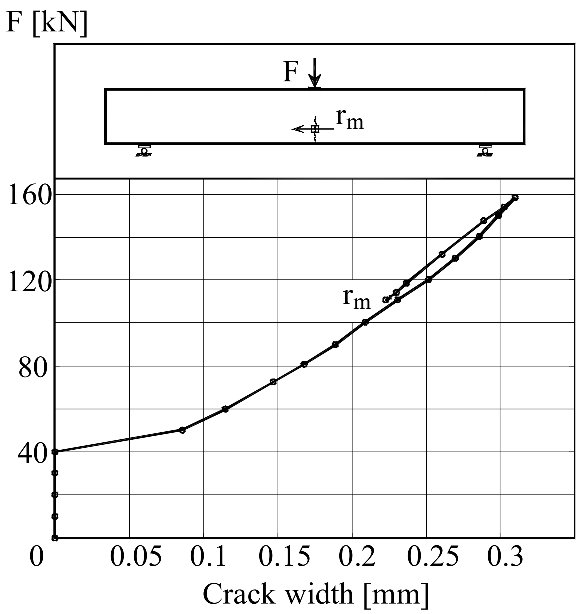


Figure B.1L2.4– The load – crack width graph

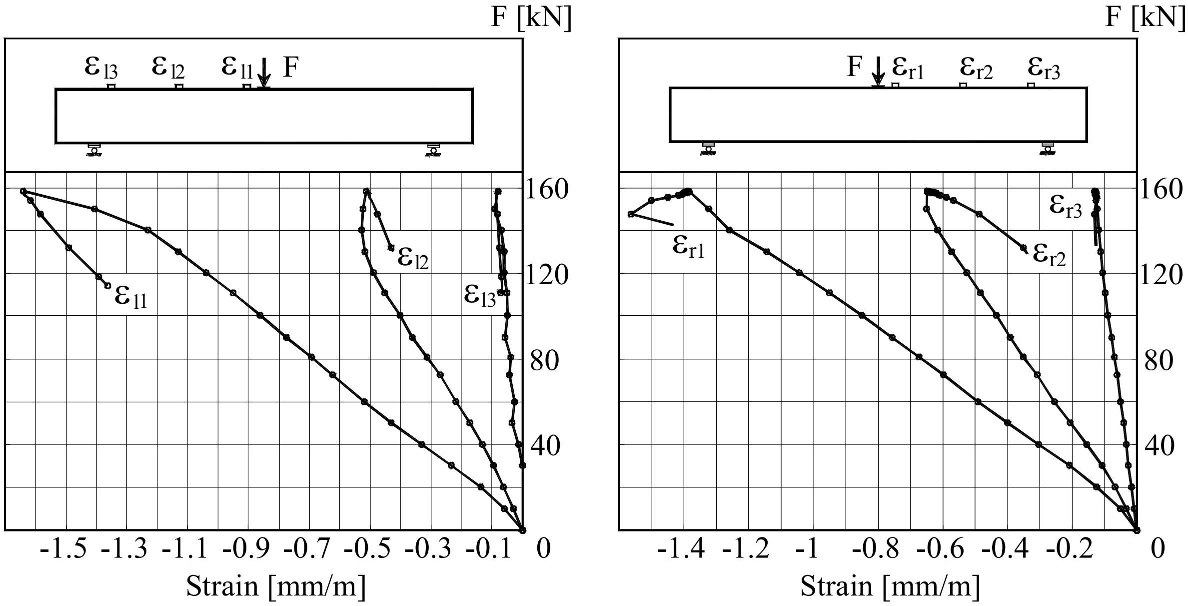


Figure B.1L2.5– The Load –Strains graph at top surface of beam

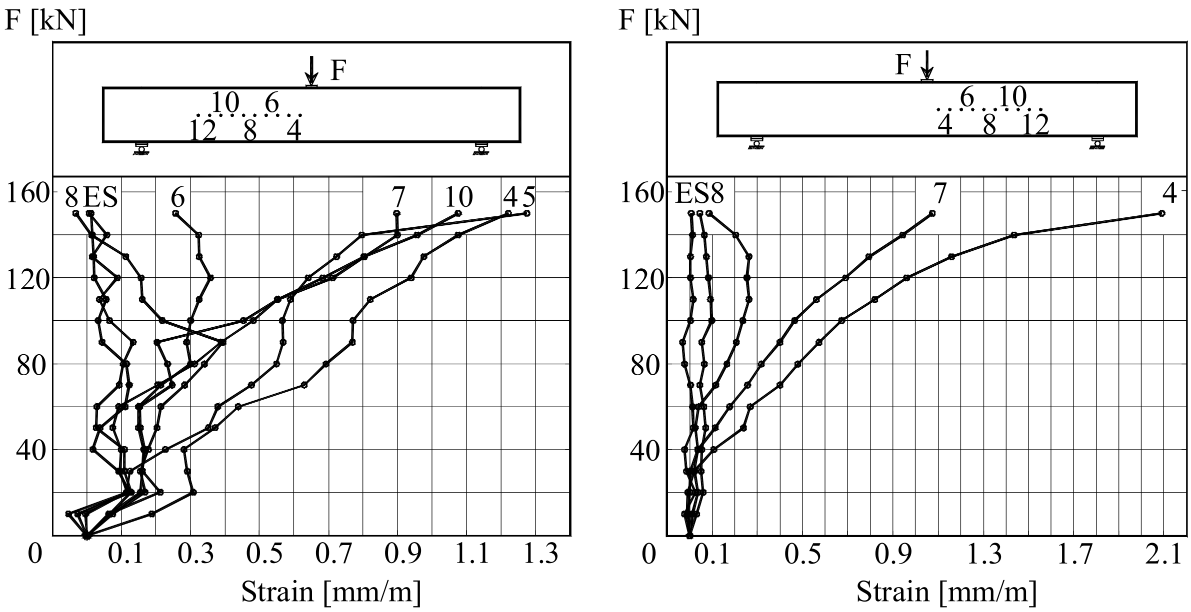


Figure B.1L2.6– The Load –Strains graph at mid-depth of beam

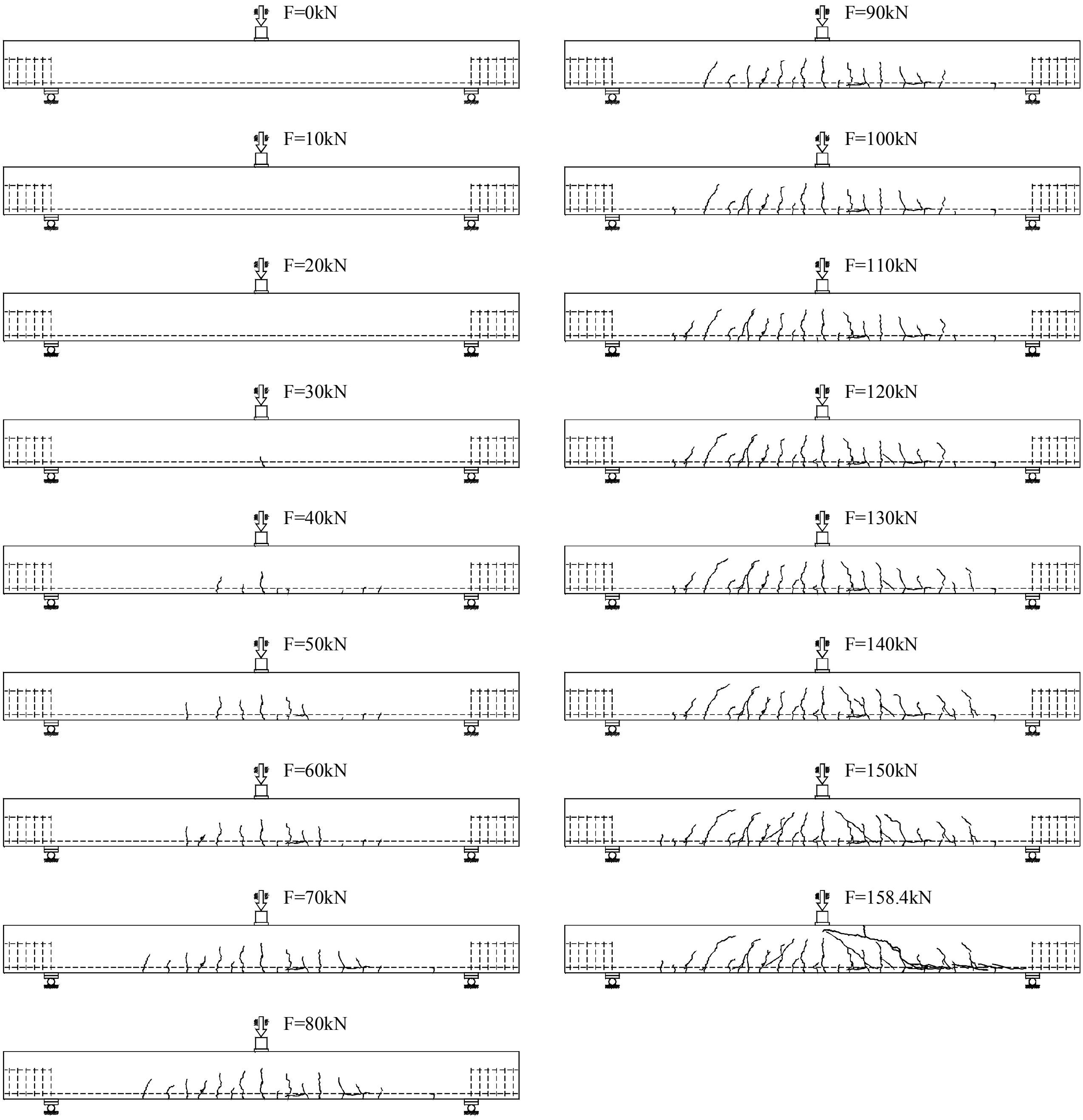


Figure B.1L2.7– Crack propagation of beam 1L2 after each load step.

TEST SAMPLE: 2L1

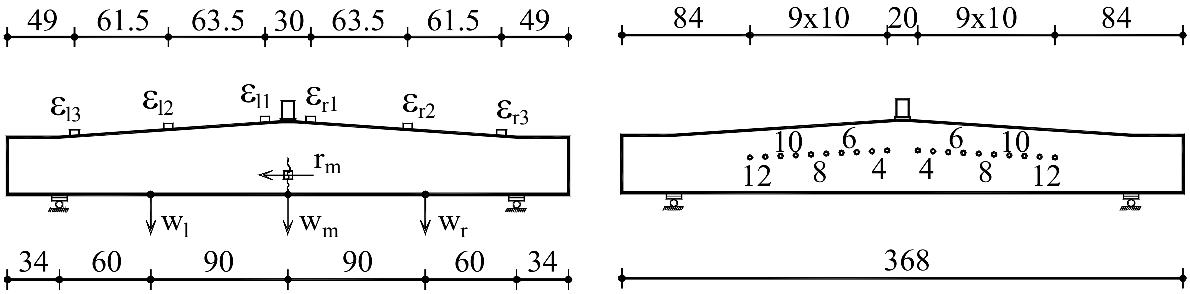


Figure B.2L1.1– The detailed arrangement of the data acquisition system

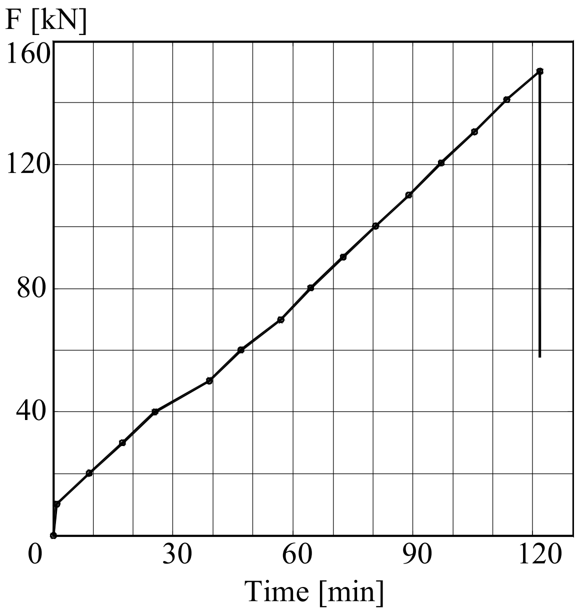


Figure B.2L1.2– The Time – Load graph

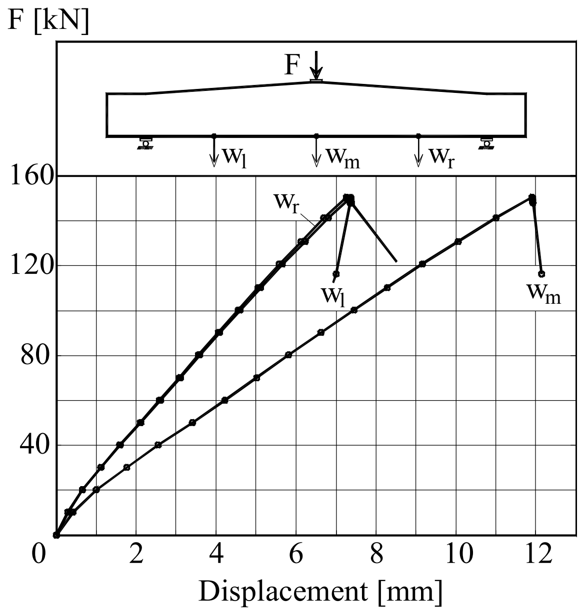


Figure B.2L1.3–The Load – Displacement graph

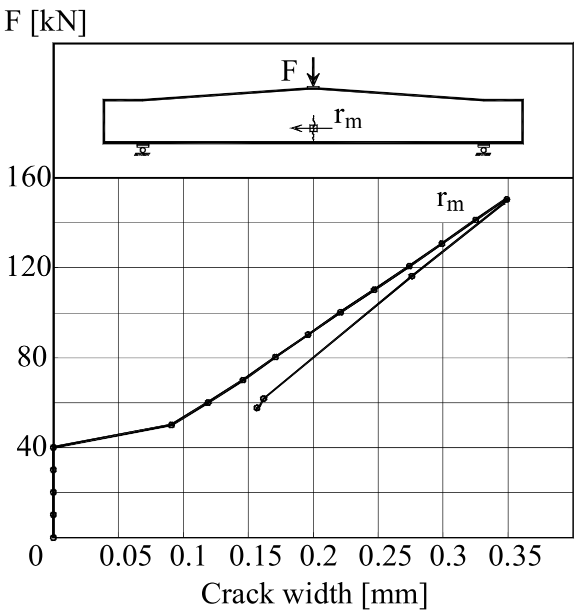


Figure B.2L1.4– The load – crack width graph

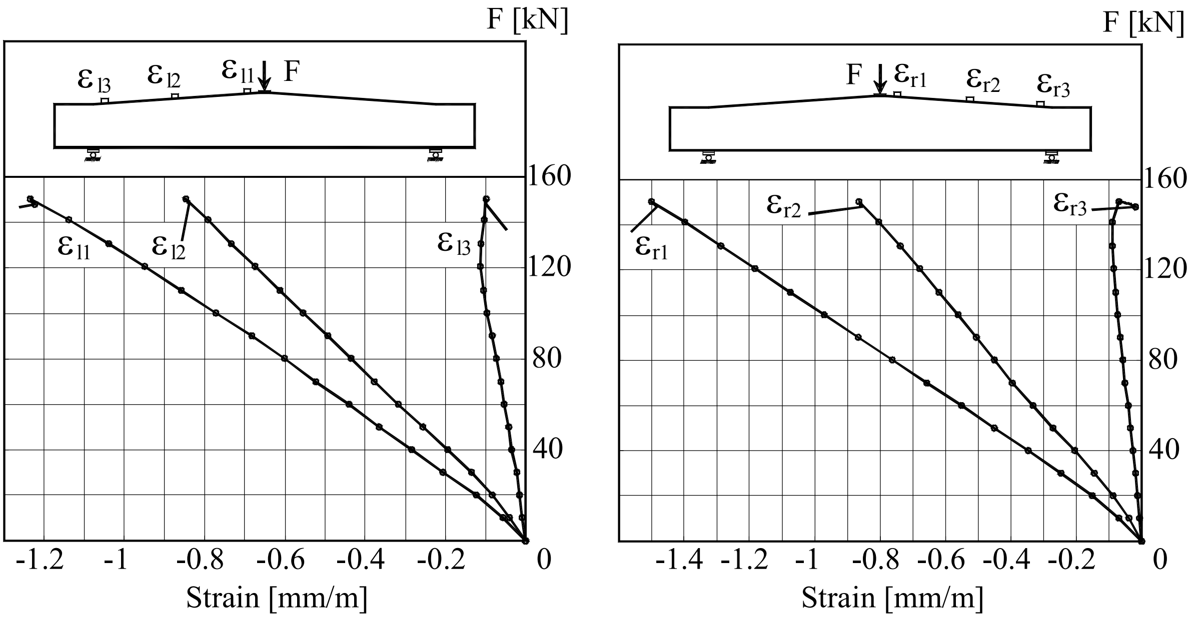


Figure B.2L1.5– The Load –Strains graph at top surface of beam

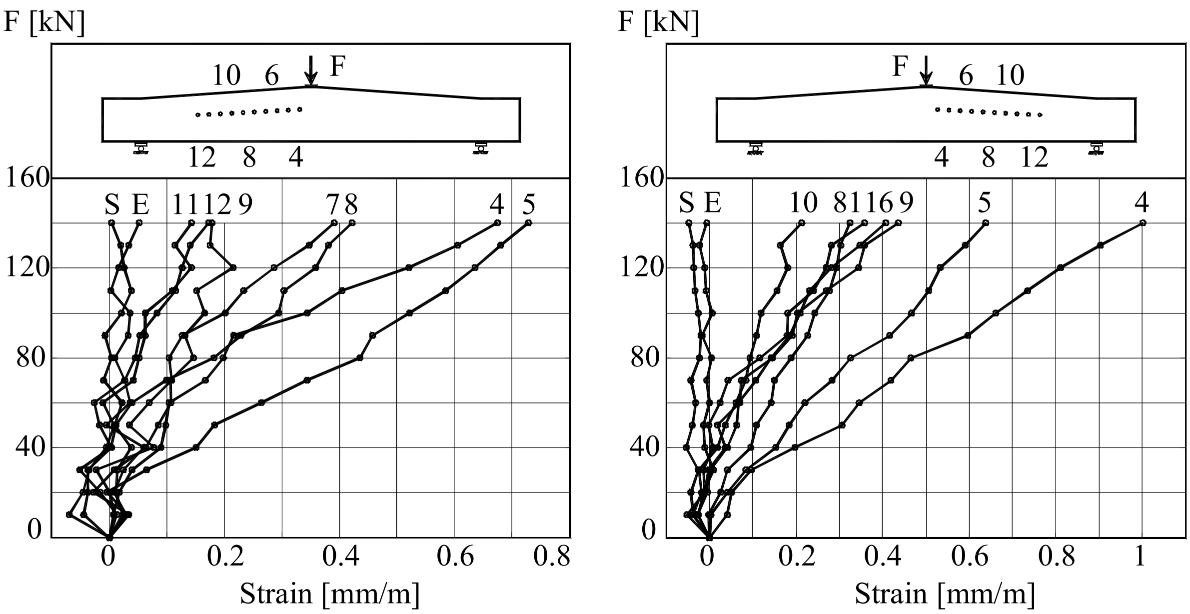


Figure B.2L1.6– The Load –Strains graph at mid-depth of beam

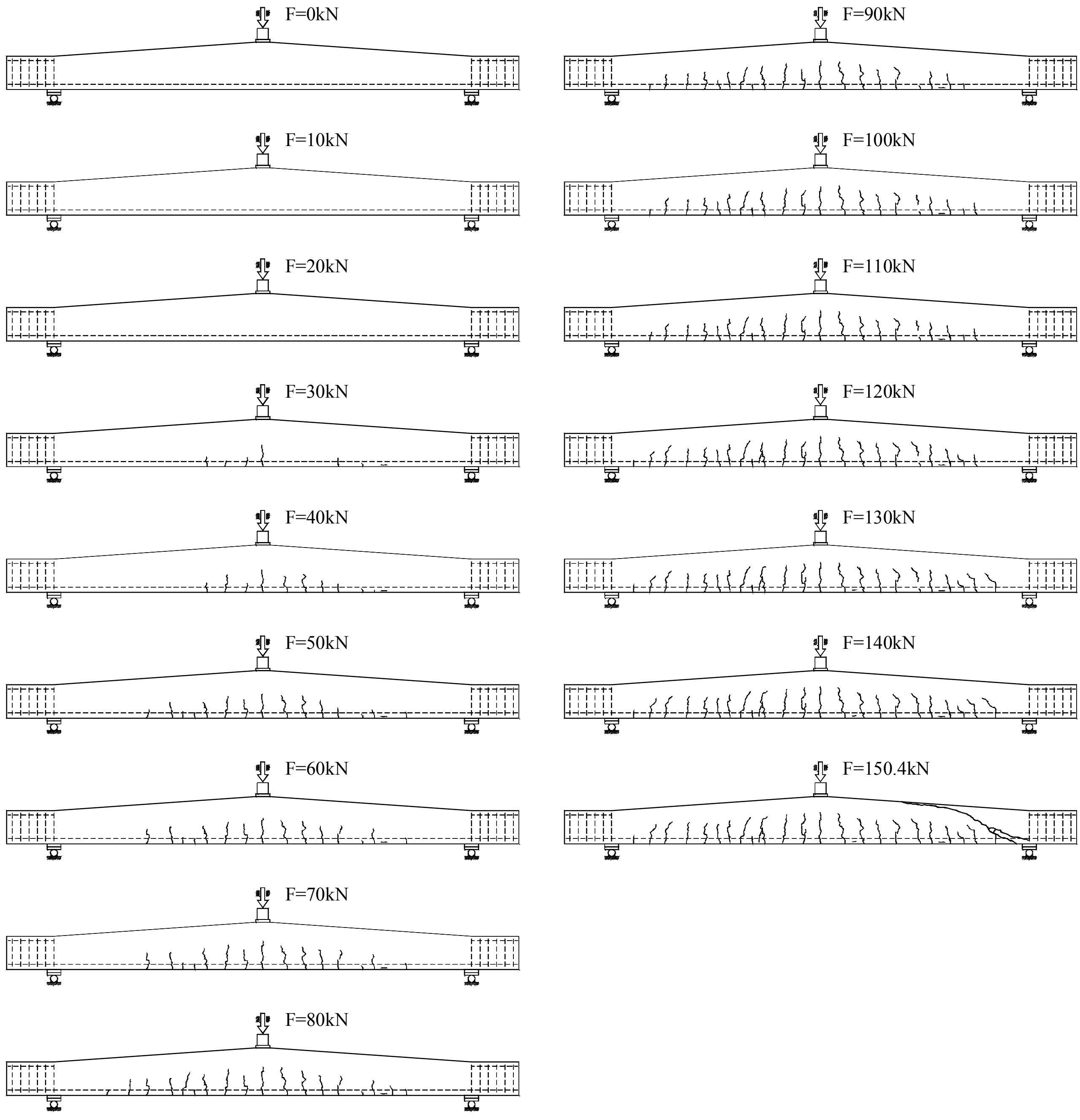


Figure B.2L1.7– Crack propagation of beam 2L1 after each load step.

TEST SAMPLE: 2L2

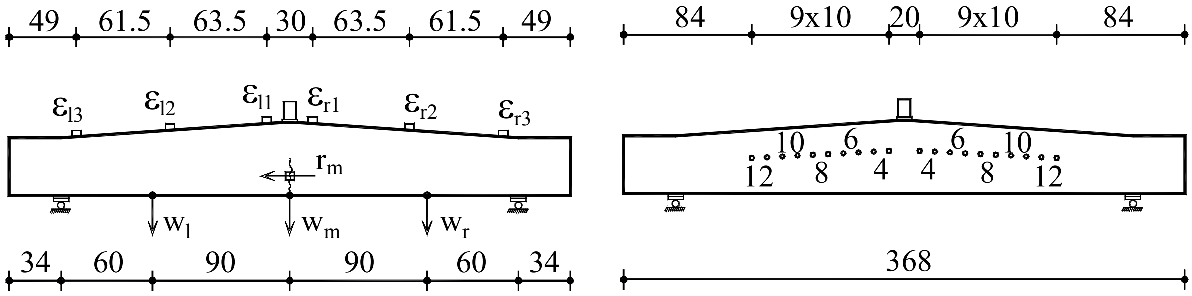


Figure B.2L2.1– The detailed arrangement of the data acquisition system

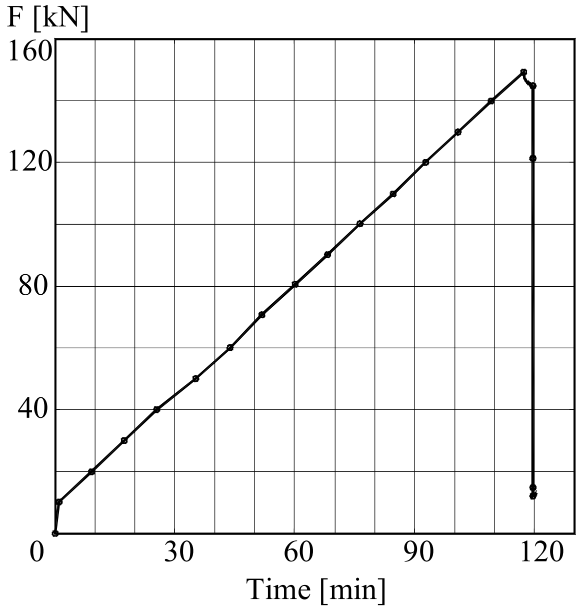


Figure B.2L2.2–The Time – Load graph

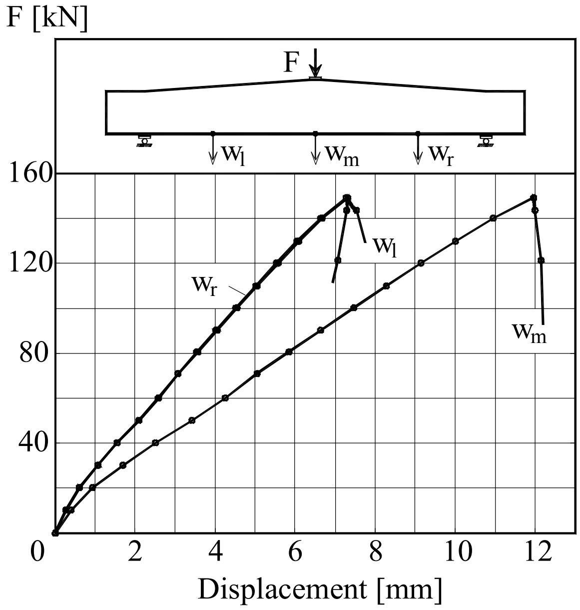


Figure B.2L2.3–The Load – Displacement graph

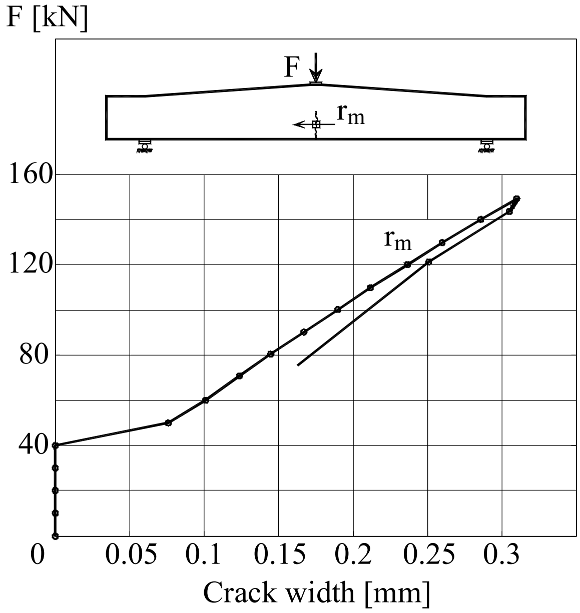


Figure B.2L2.4–-The load – crack width graph

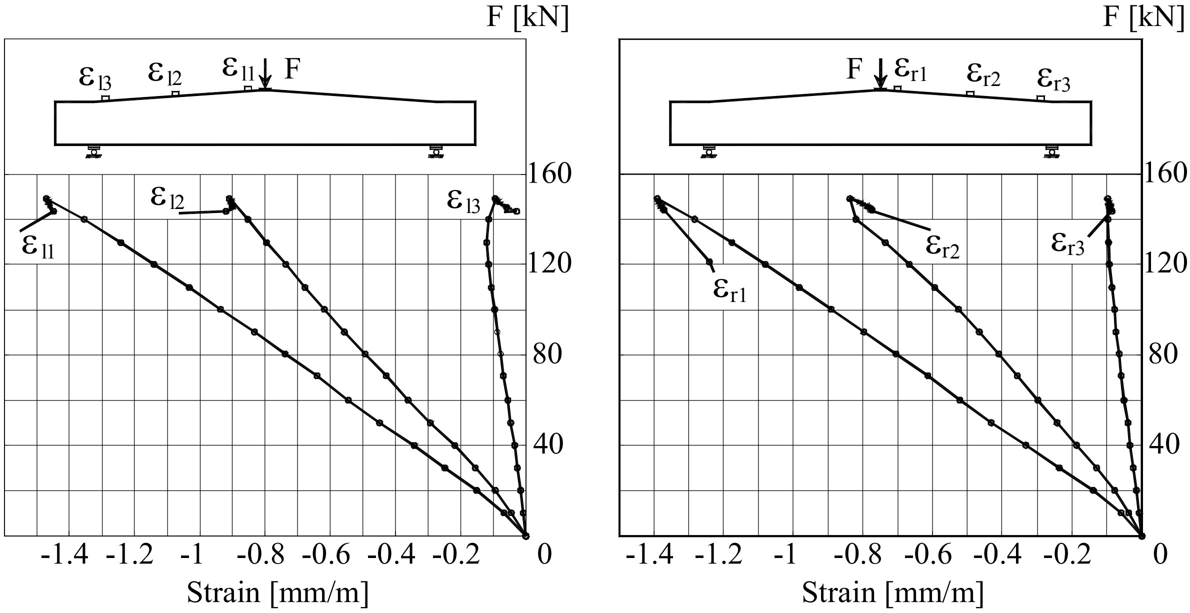


Figure B. 2L2.5– The Load –Strains graph at top surface of beam

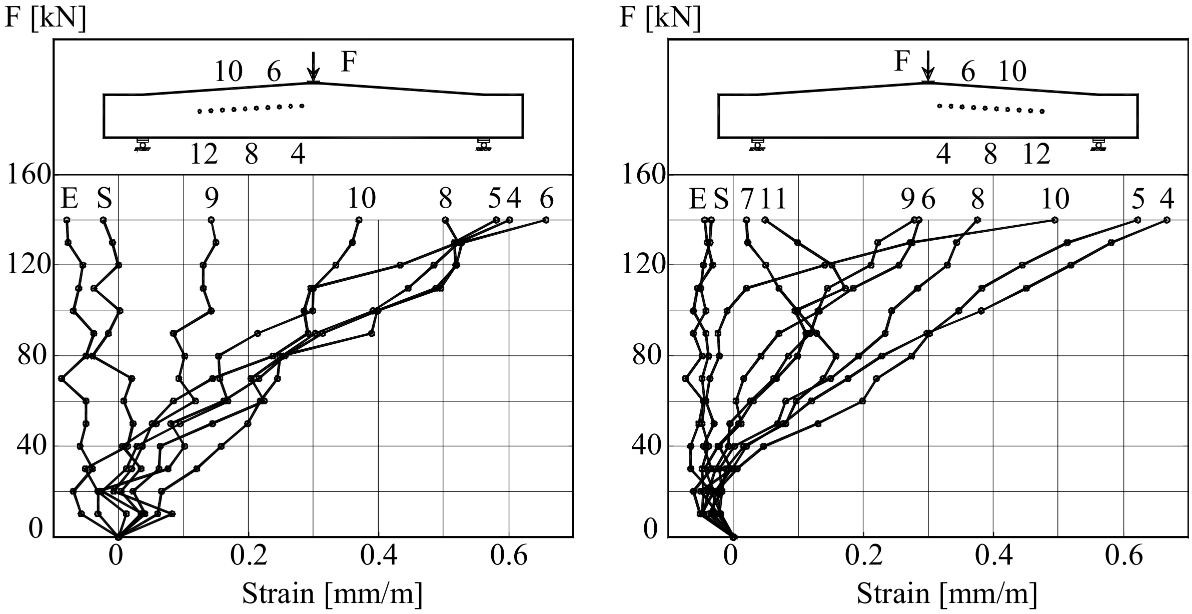


Figure B.2L2.6– The Load –Strains graph at mid-depth of beam

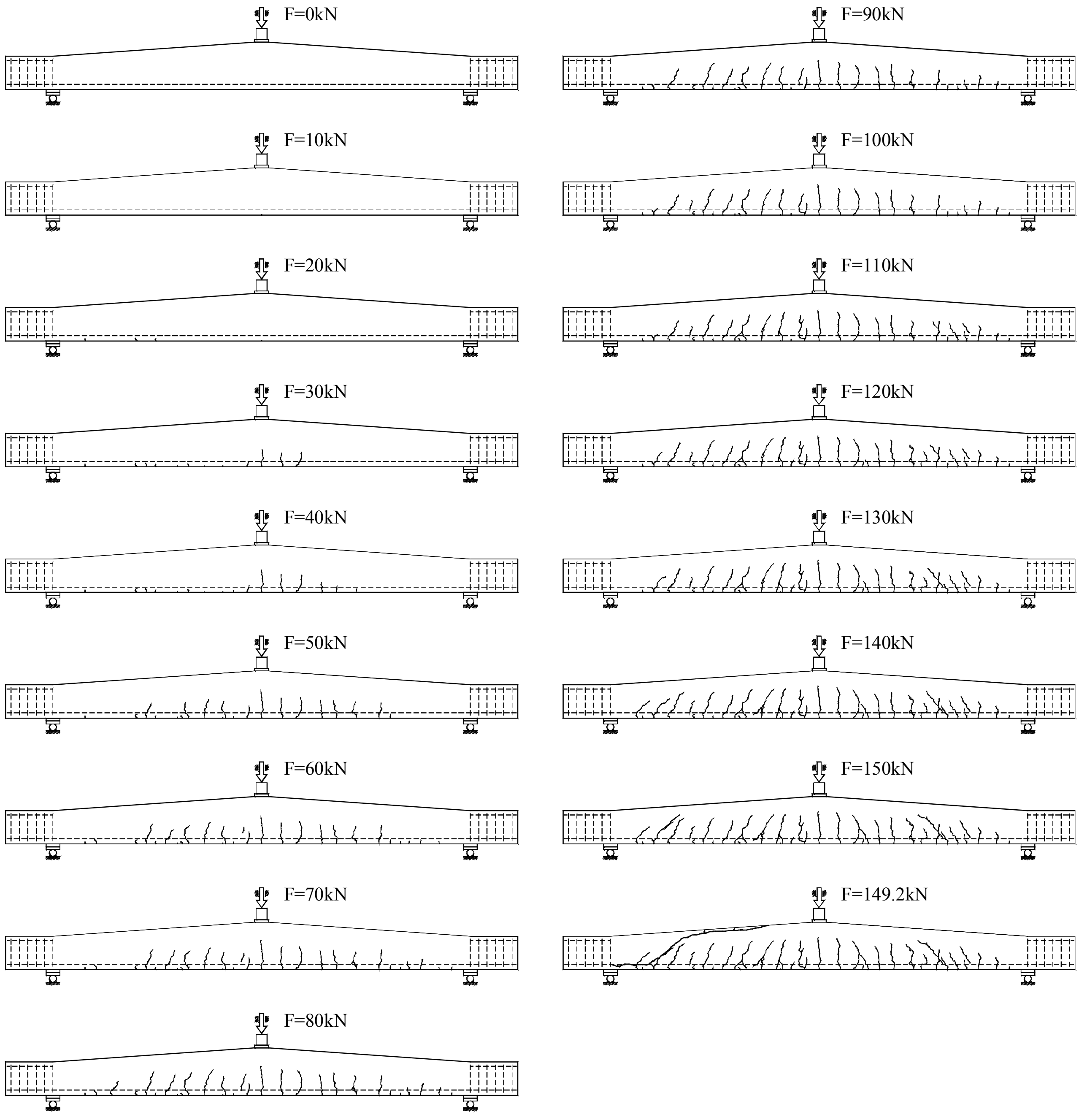


Figure B.2L2.7– Crack propagation of beam 2L2 after each load step.

TEST SAMPLE: 3L1

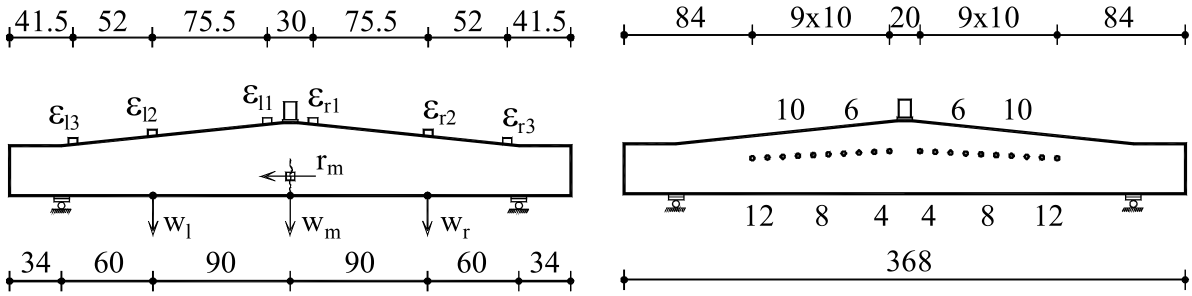


Figure B.3L1.1– The detailed arrangement of the data acquisition system

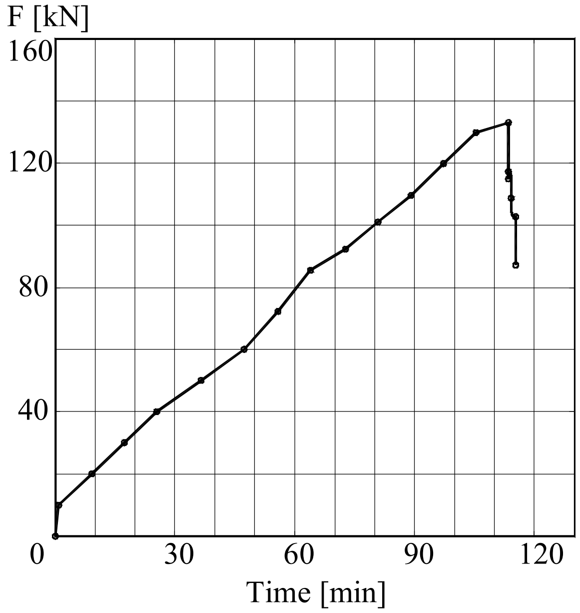


Figure B.3L1.2– The Time – Load graph

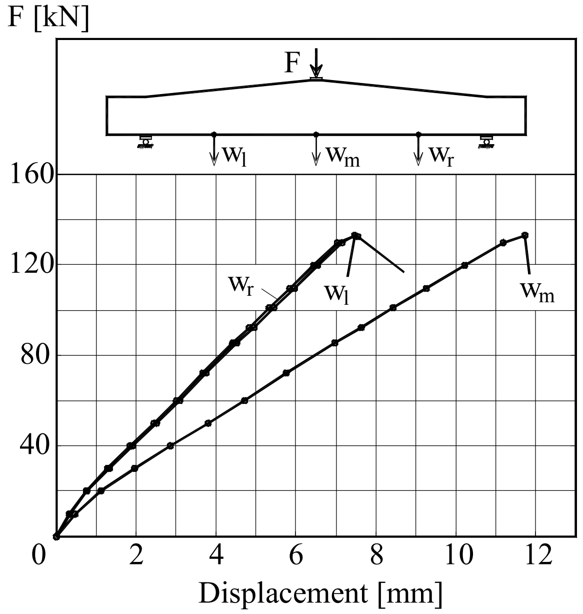


Figure B.3L1.3–The Load – Displacement graph

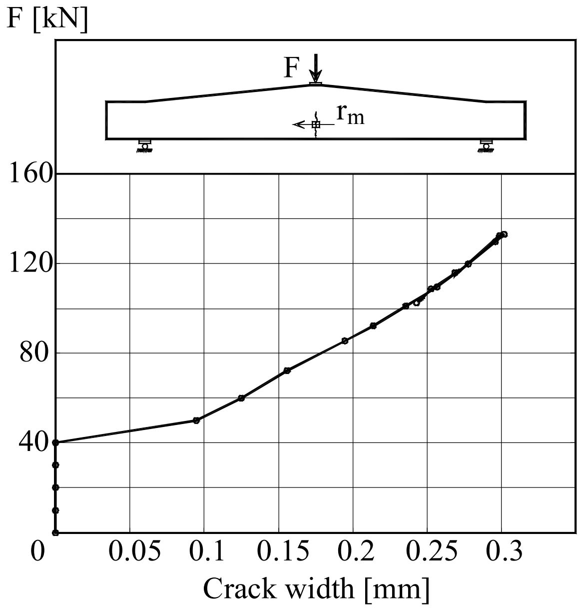


Figure B.3L1.4–The load – crack width graph

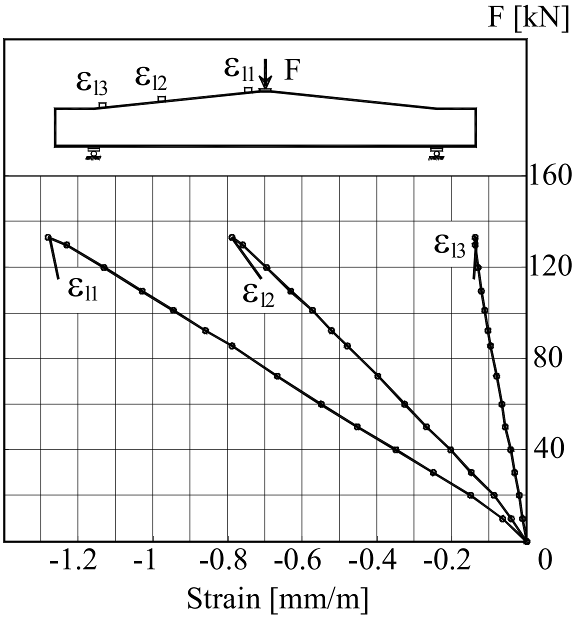


Figure B.3L1.5– The Load –Strains graph at top surface of beam

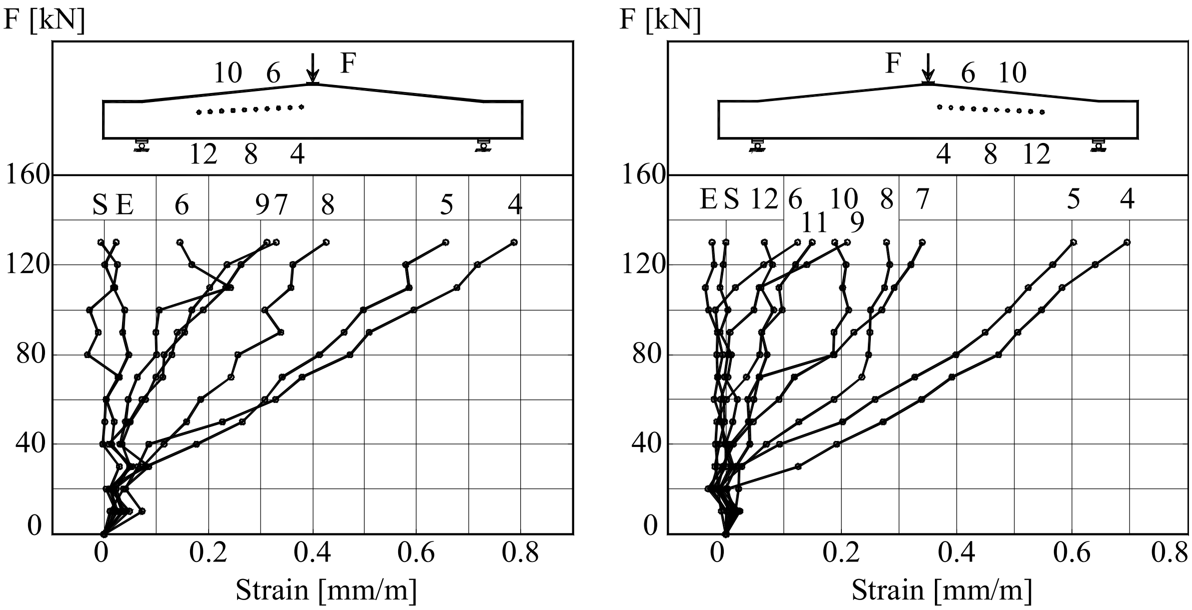


Figure B.3L1.6– The Load –Strains graph at mid-depth of beam

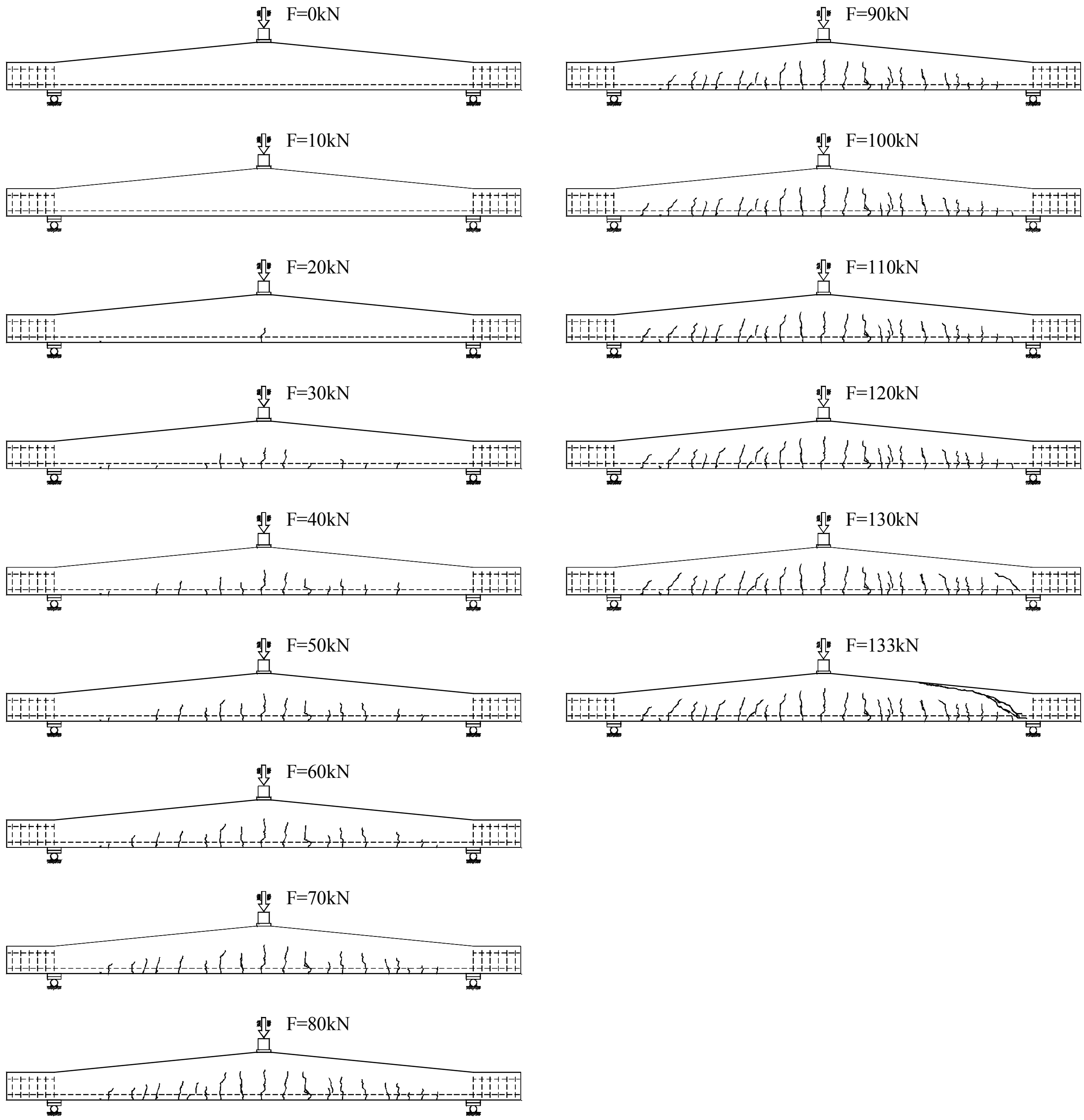


Figure B.3L1.7– Crack propagation of beam 3L1 after each load step.

TEST SAMPLE: 3L2

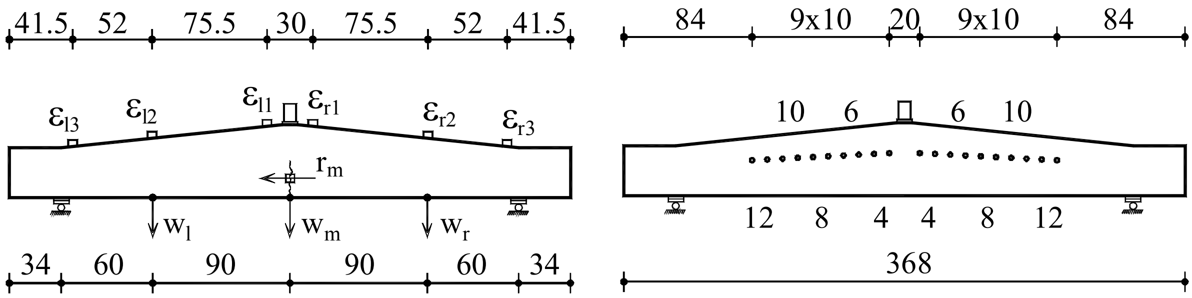


Figure B.3L2.1- The detailed arrangement of the data acquisition system

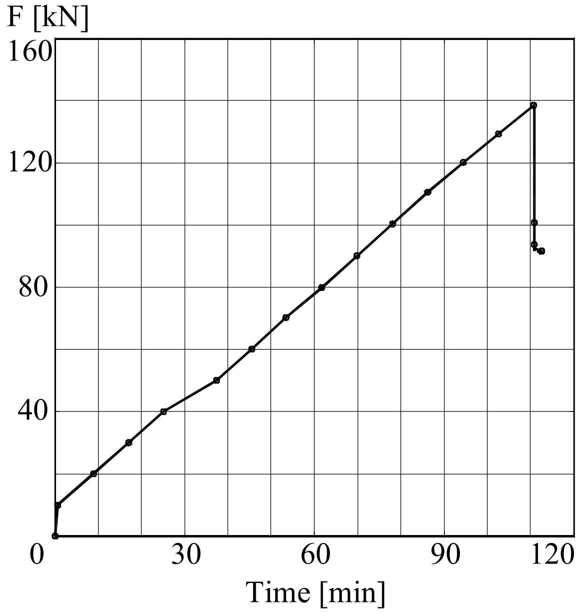


Figure B.3L2.2-The Time – Load graph

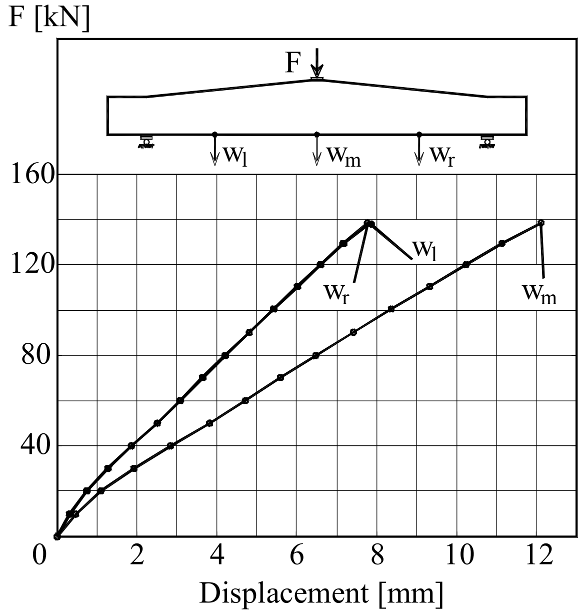


Figure B.3L2.3-The Load – Displacement graph

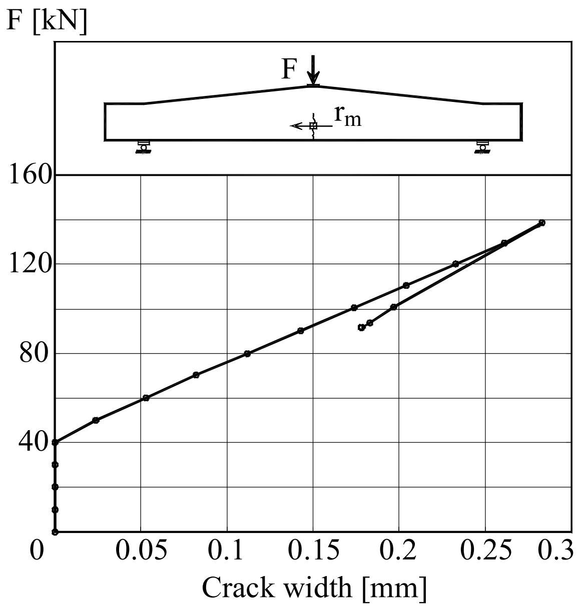


Figure B.3L2.4-The load – crack width graph

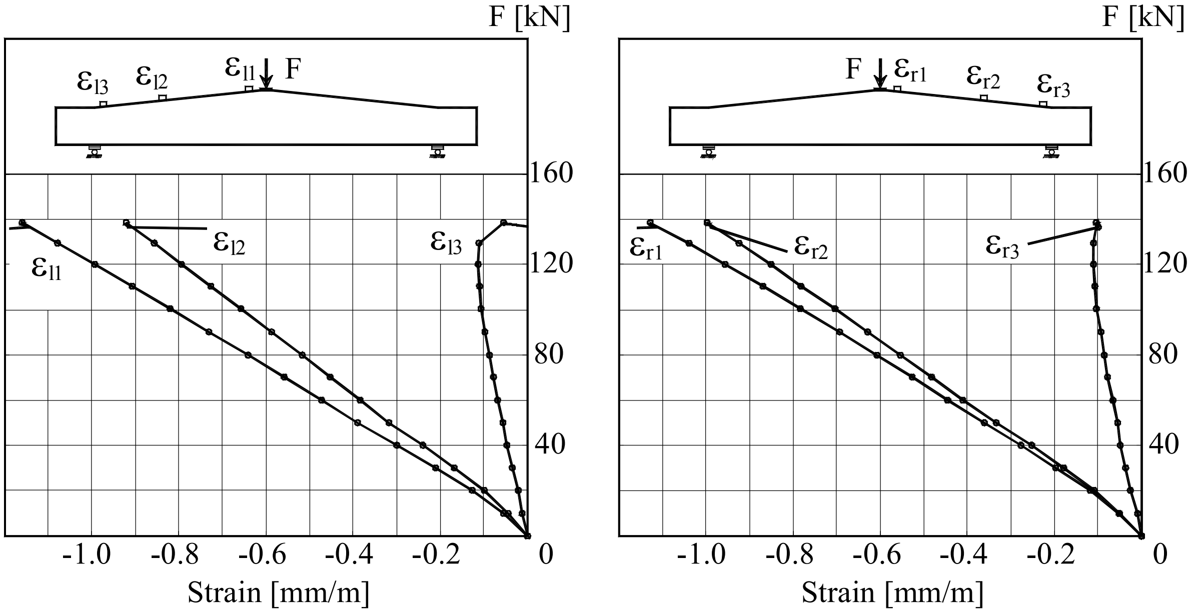


Figure B.3L2.5-The Load –Strains graph at top surface of beam

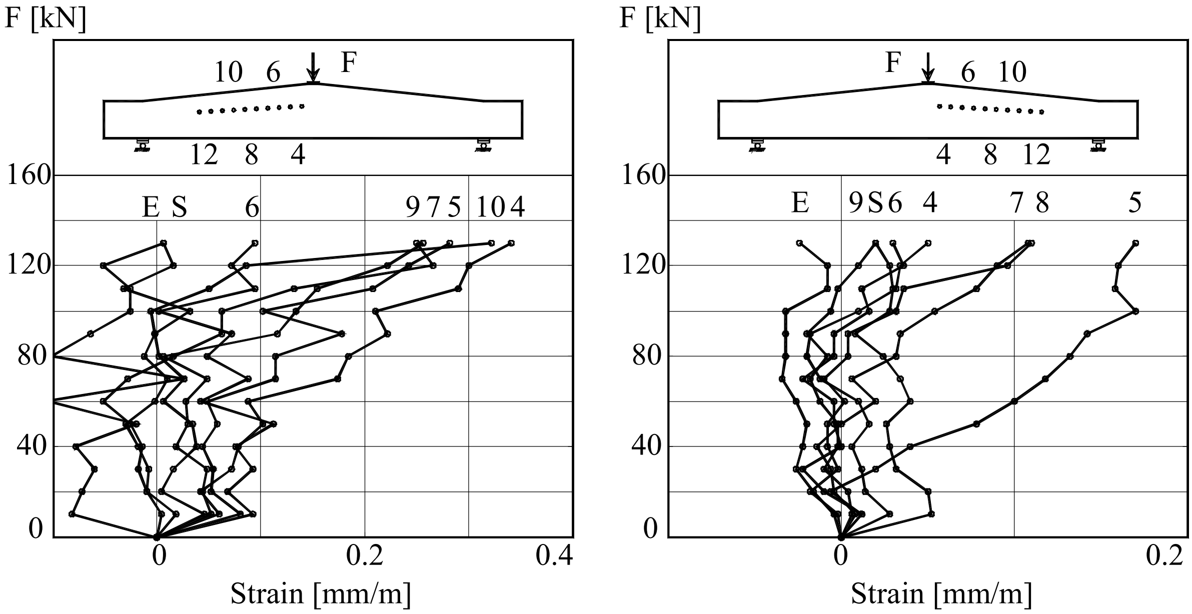


Figure B.3L2.6- The Load –Strains graph at mid-depth of beam

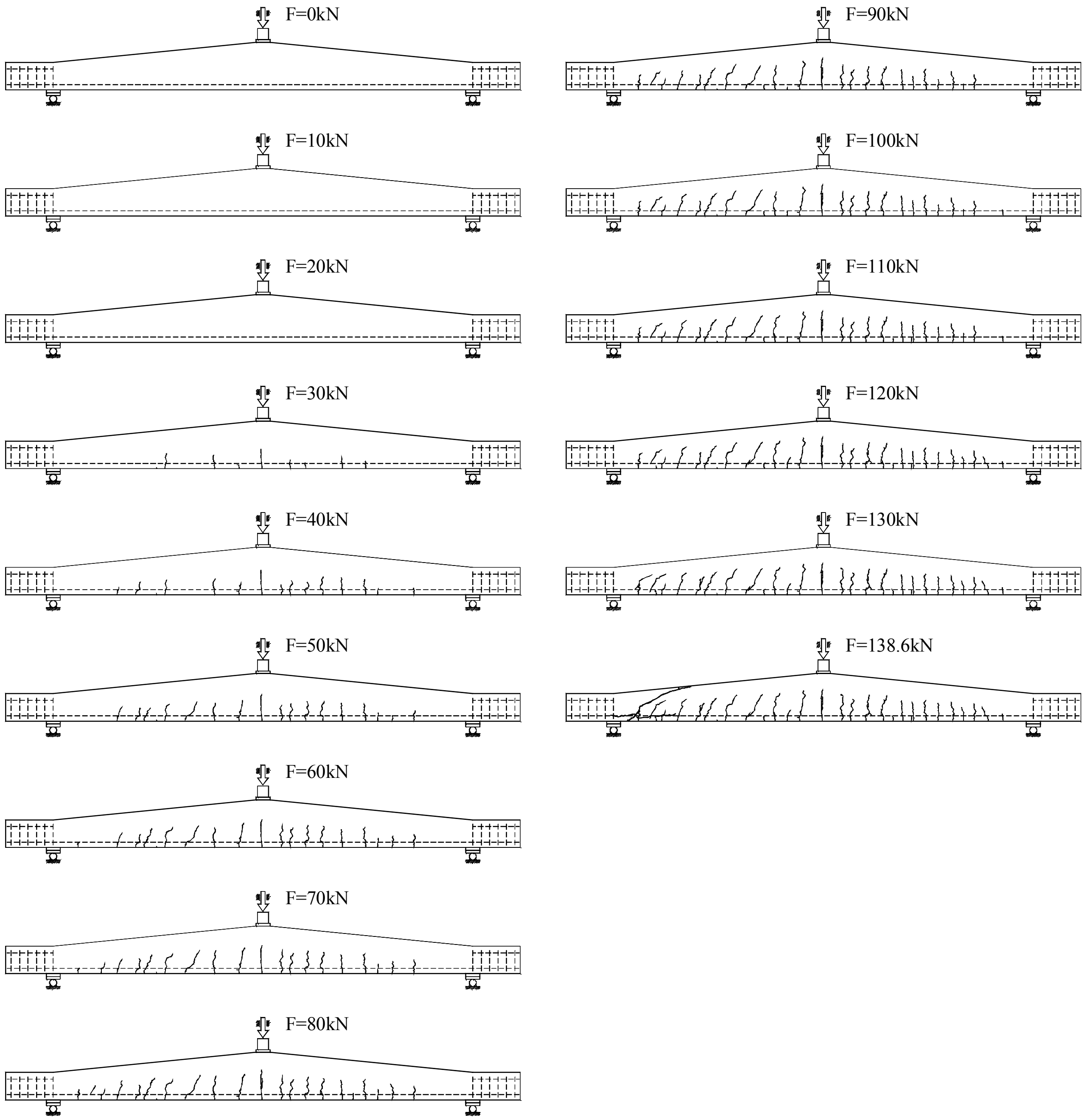


Figure B.3L2.7- Crack propagation of beam 3L2 after each load step.

TEST SAMPLE: 4L1

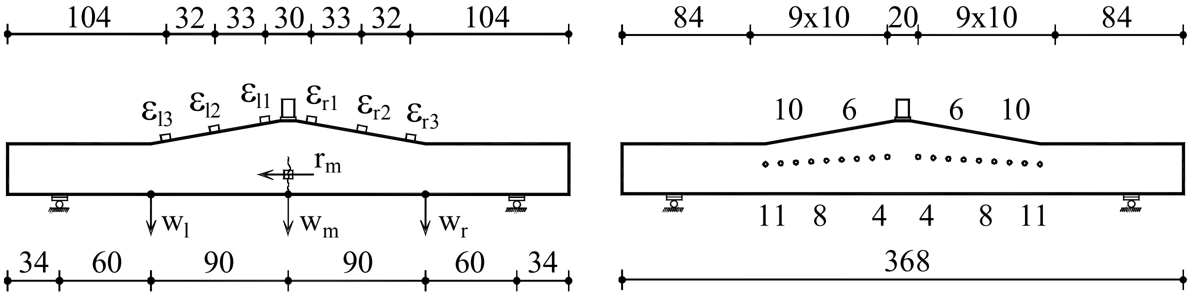


Figure B.4L1.1- The detailed arrangement of the data acquisition system

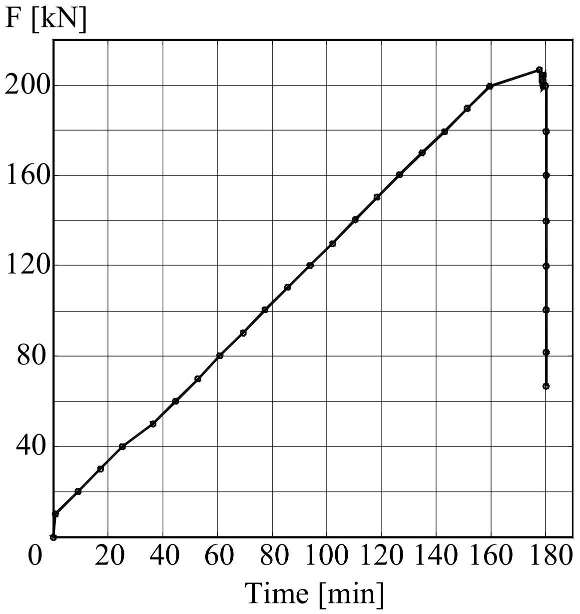


Figure B.4L1.2-The Time – Load graph

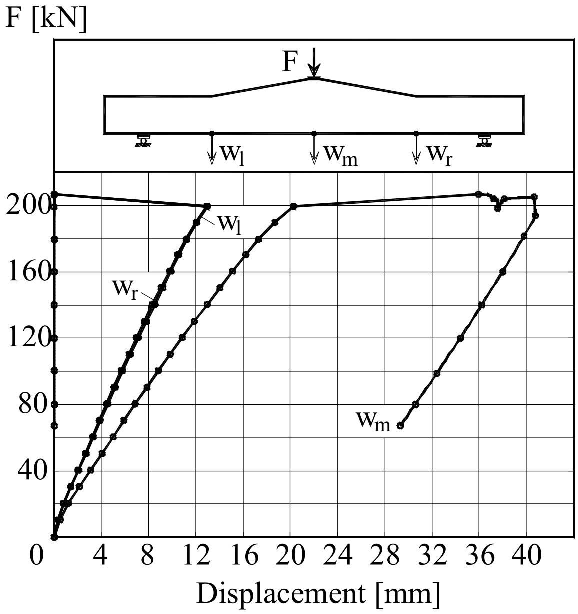


Figure B.4L1.3-The Load – Displacement graph

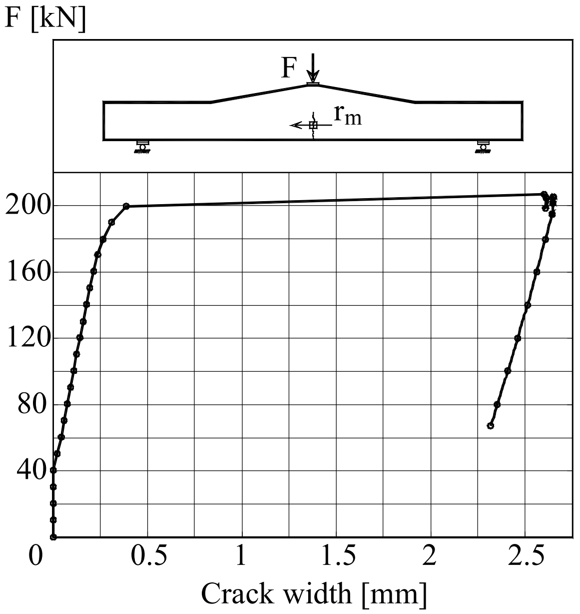


Figure B.4L1.4-The load – crack width graph

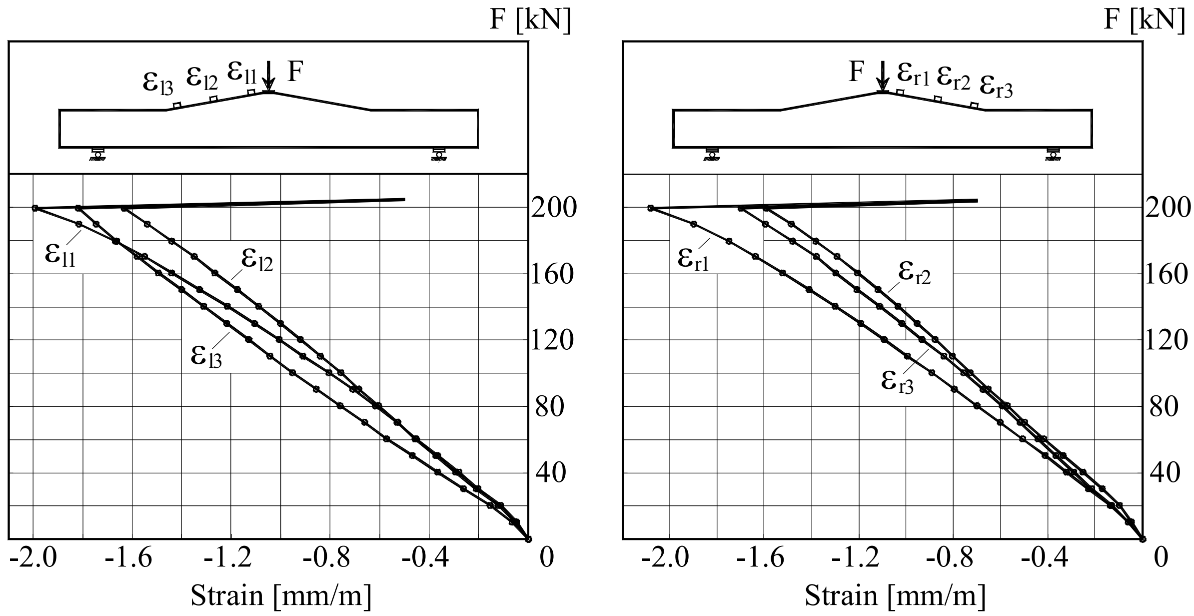


Figure B.4L1.5-The Load –Strains graph at top surface of beam

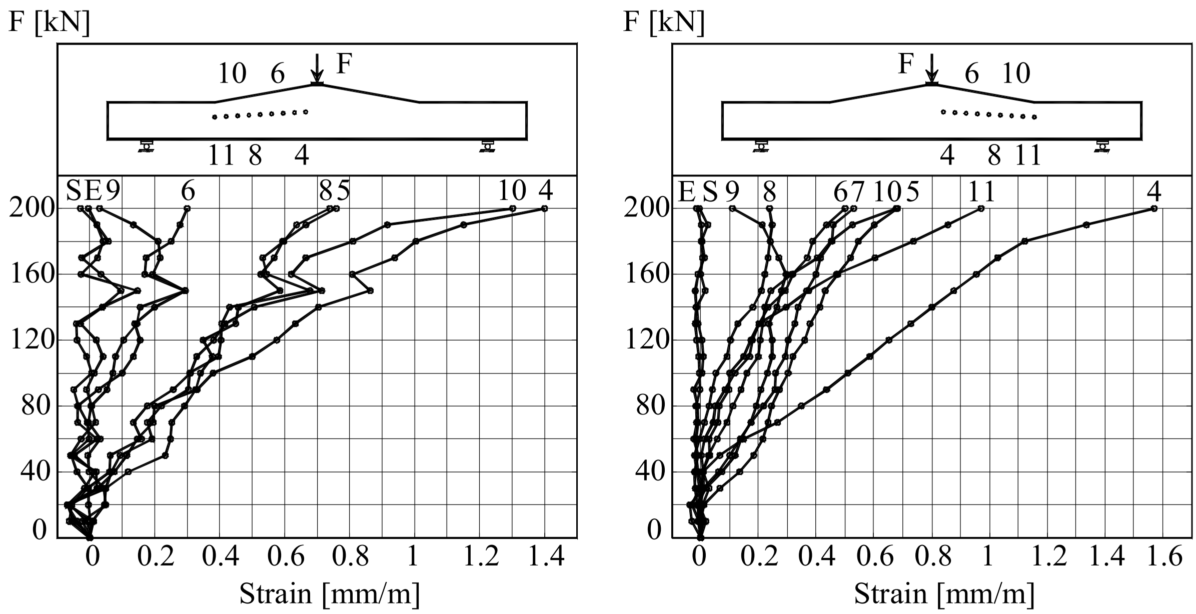


Figure B.4L1.6- The Load –Strains graph at mid-depth of beam

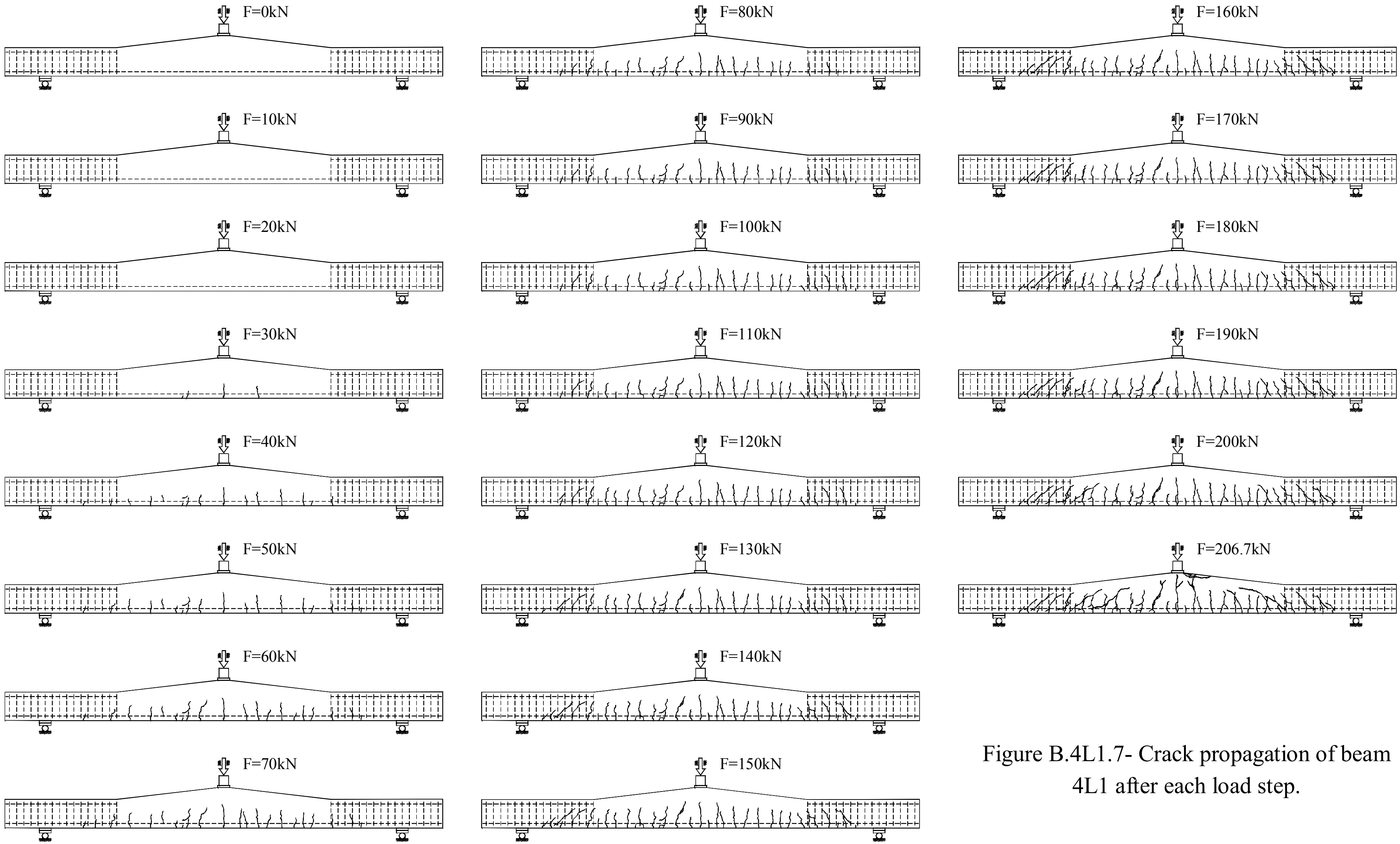


Figure B.4L1.7- Crack propagation of beam 4L1 after each load step.

TEST SAMPLE: 4L2

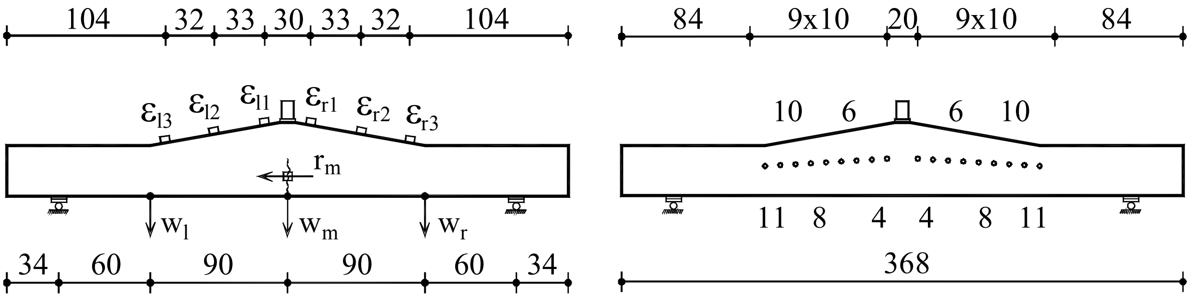


Figure B.4L2.1- The detailed arrangement of the data acquisition system

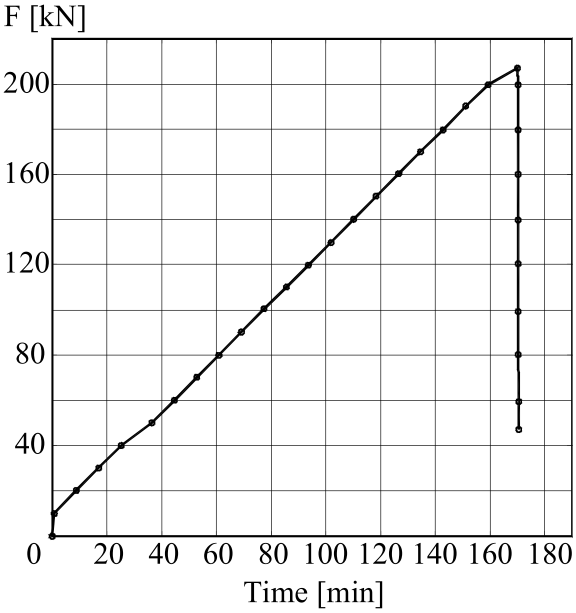


Figure B.4L2.2-The Time – Load graph

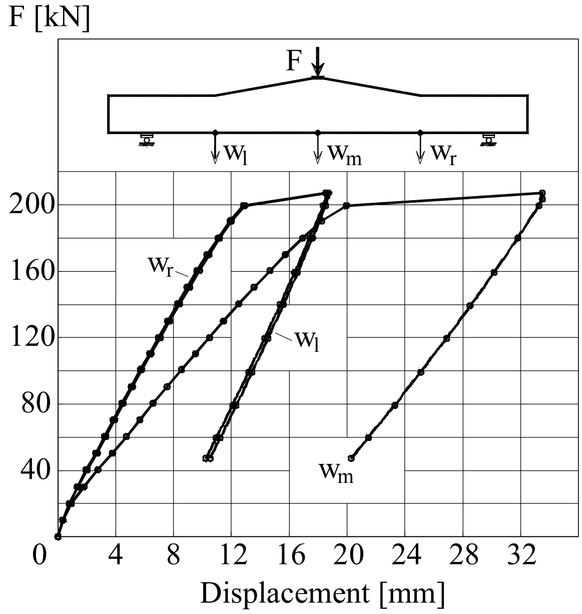


Figure B.4L2.3-The Load – Displacement graph

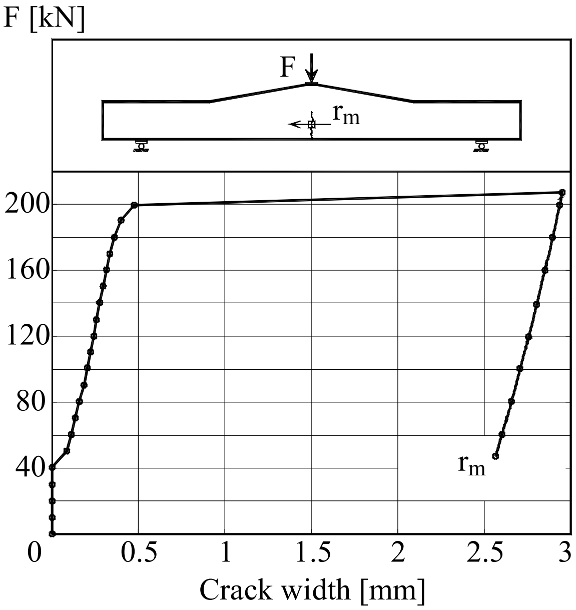


Figure B.4L2.4-The load – crack width graph

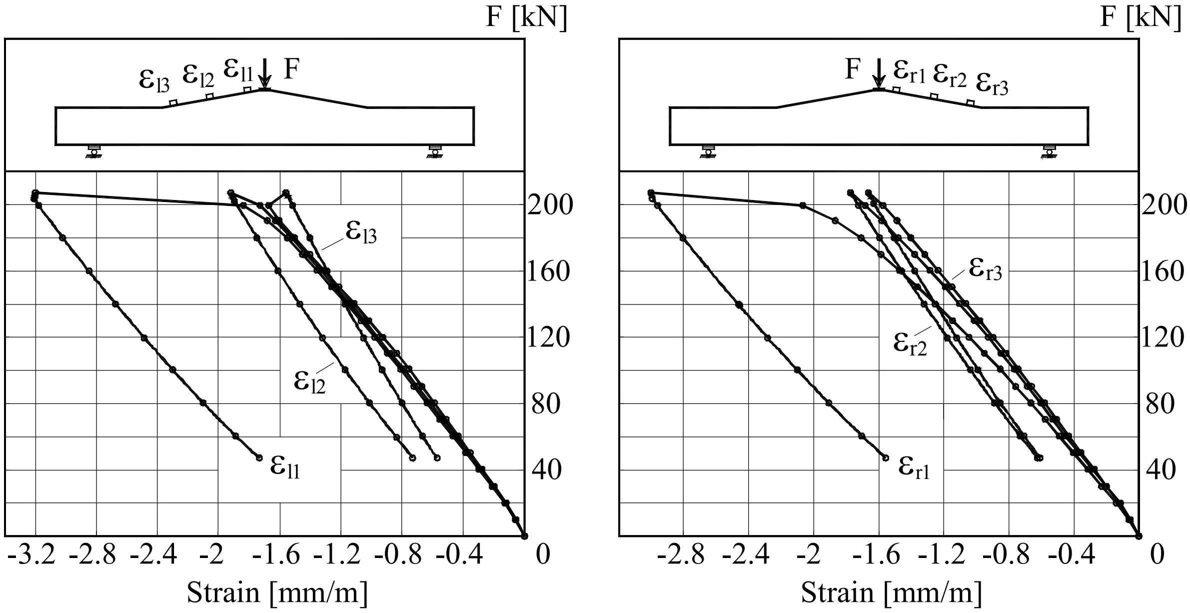


Figure B.4L2.5-The Load –Strains graph at top surface of beam

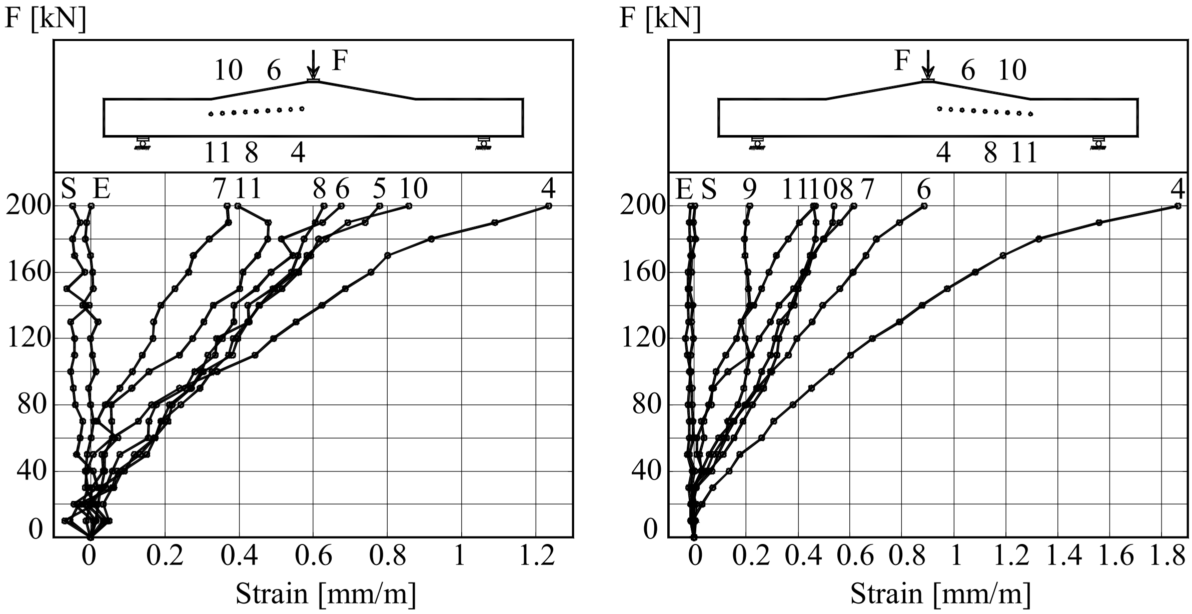


Figure B.4L2.6- The Load –Strains graph at mid-depth of beam

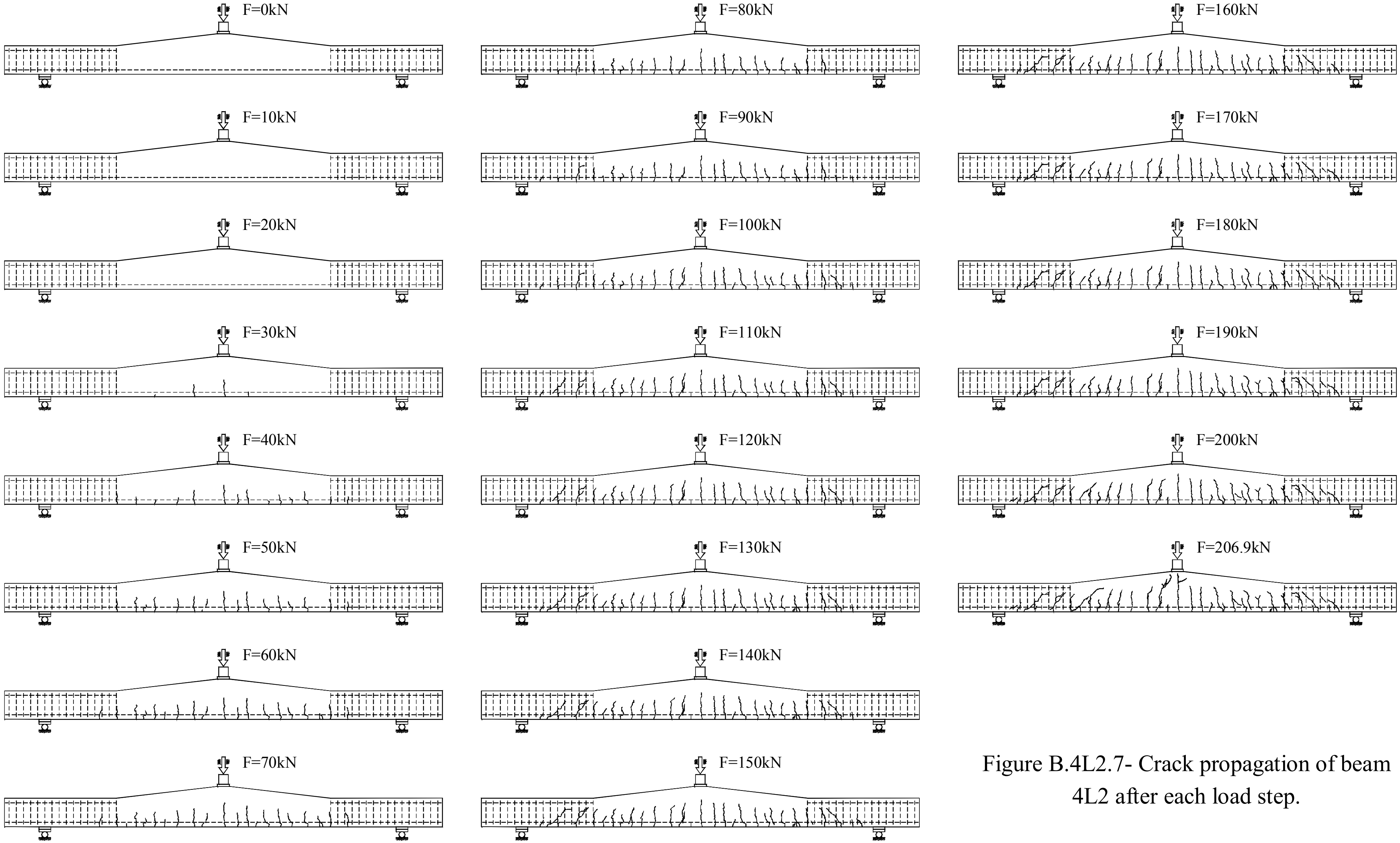


Figure B.4L2.7- Crack propagation of beam 4L2 after each load step.

TEST SAMPLE: 5L1

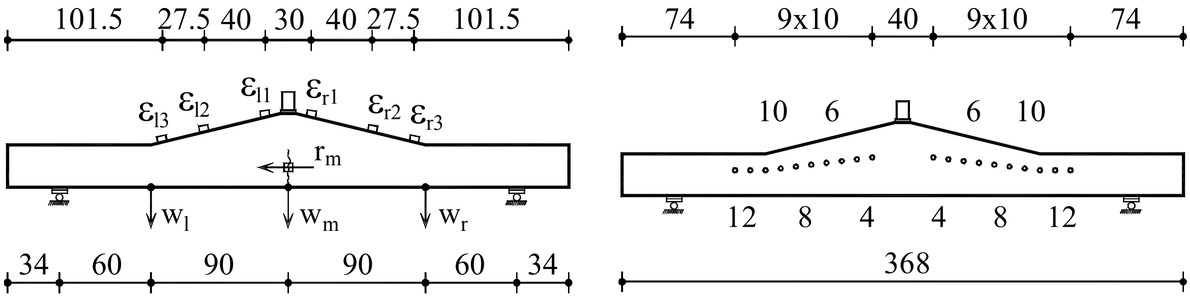


Figure B.5L1.1- The detailed arrangement of the data acquisition system

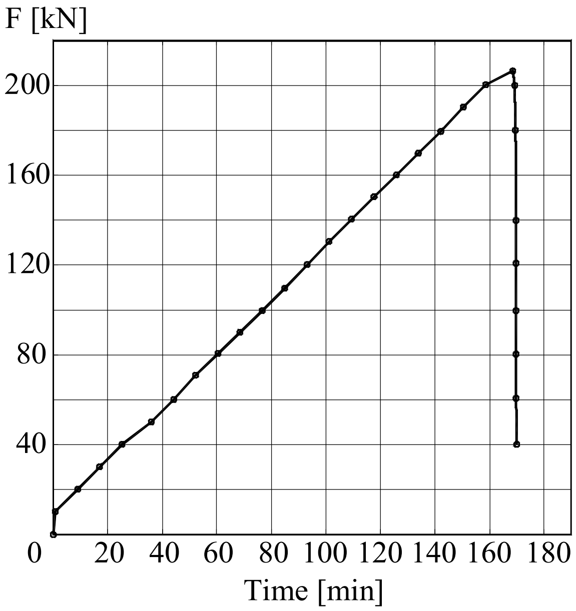


Figure B.5L1.2-The Time – Load graph

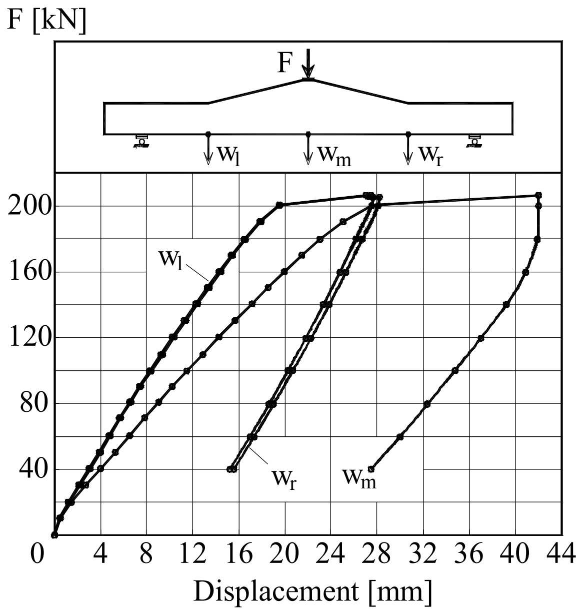


Figure B.5L1.3-The Load – Displacement graph

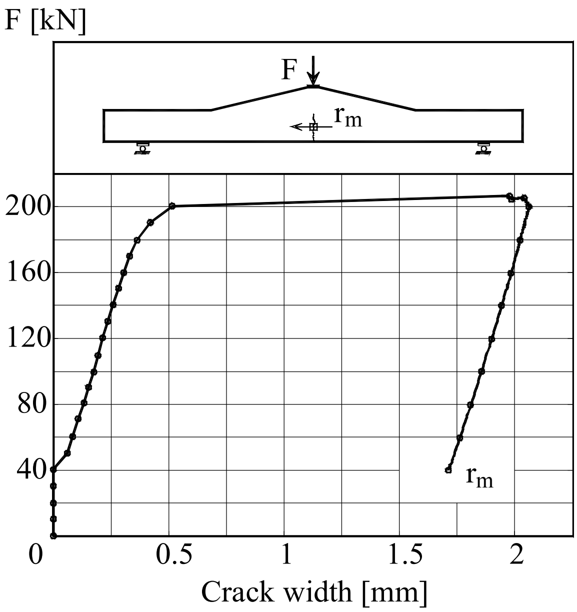


Figure B.5L1.4-The load – crack width graph

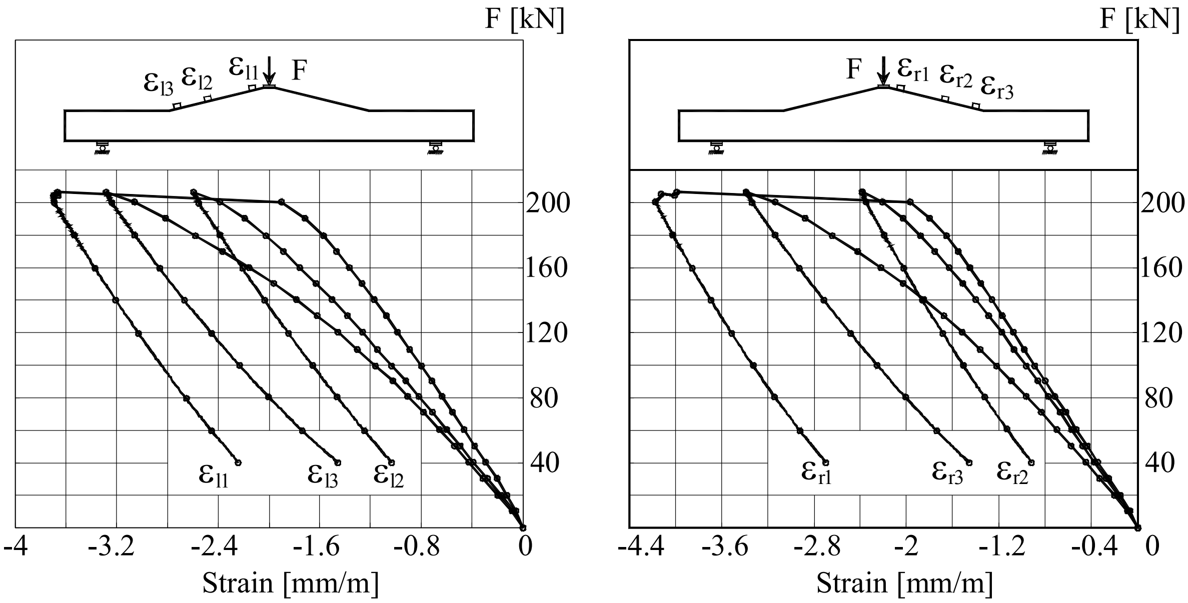


Figure B.5L1.5-The Load –Strains graph at top surface of beam

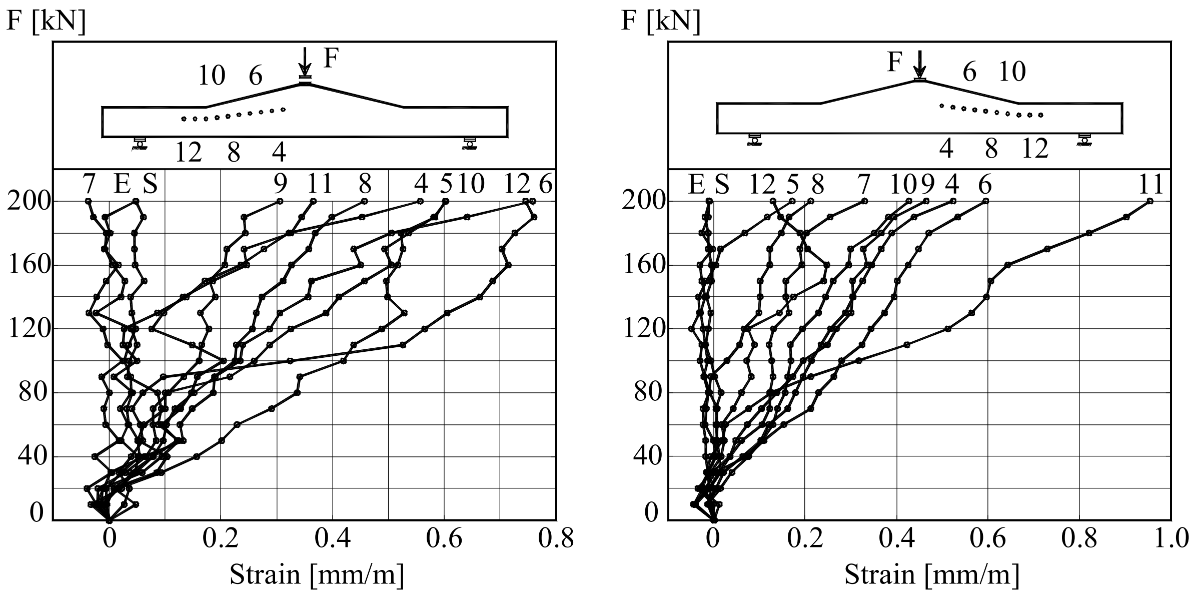


Figure B.5L1.6- The Load –Strains graph at mid-depth of beam

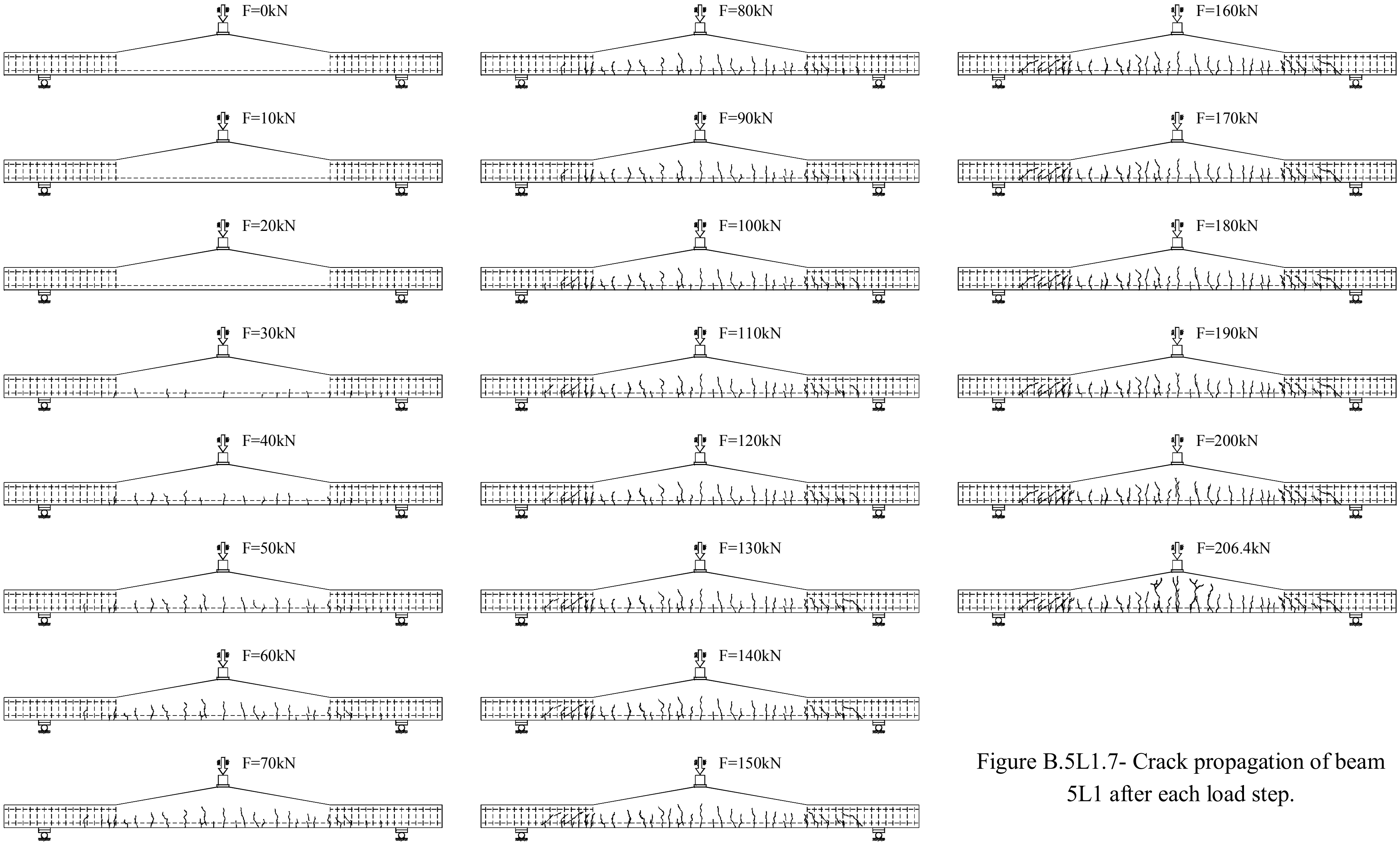


Figure B.5L1.7- Crack propagation of beam 5L1 after each load step.

TEST SAMPLE: 5L2

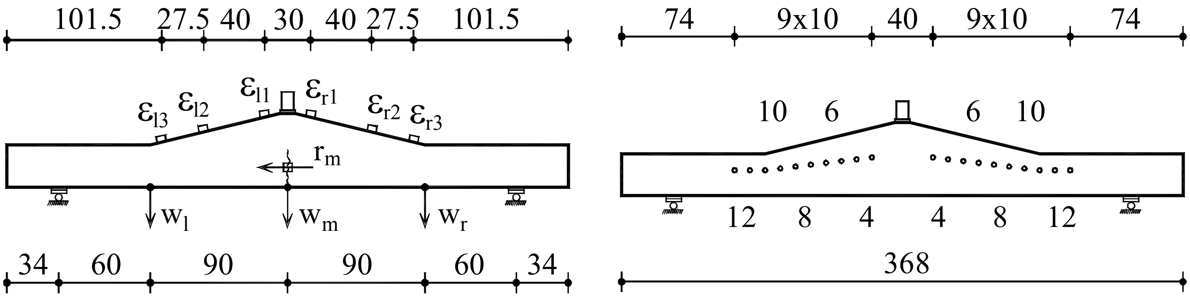


Figure B.5L2.1- The detailed arrangement of the data acquisition system

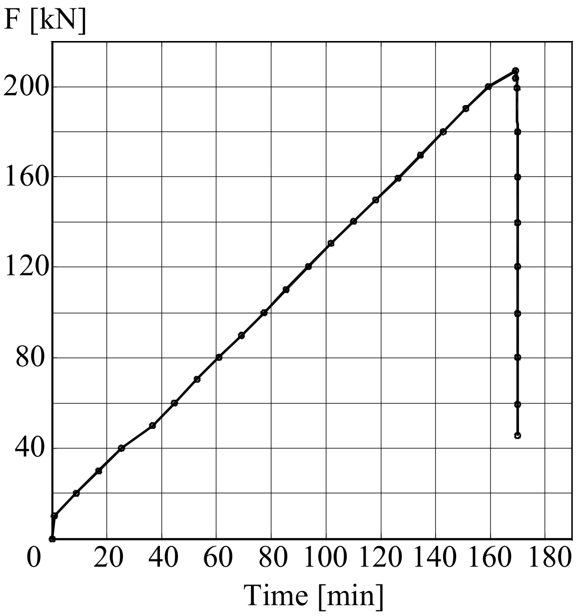


Figure B.5L2.2-The Time – Load graph

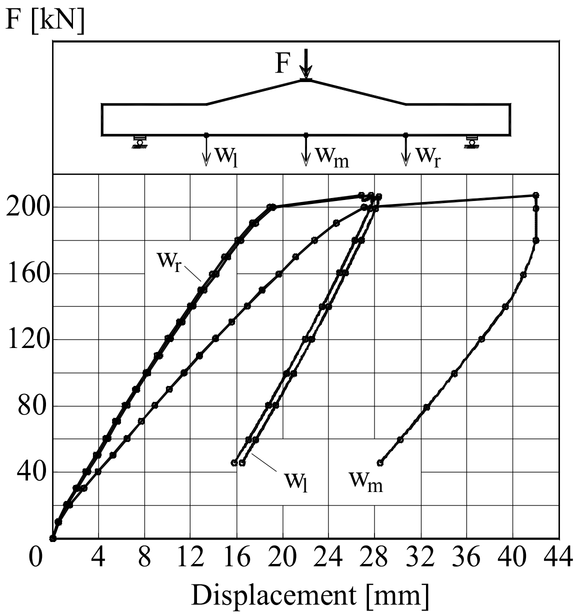


Figure B.5L2.3-The Load – Displacement graph

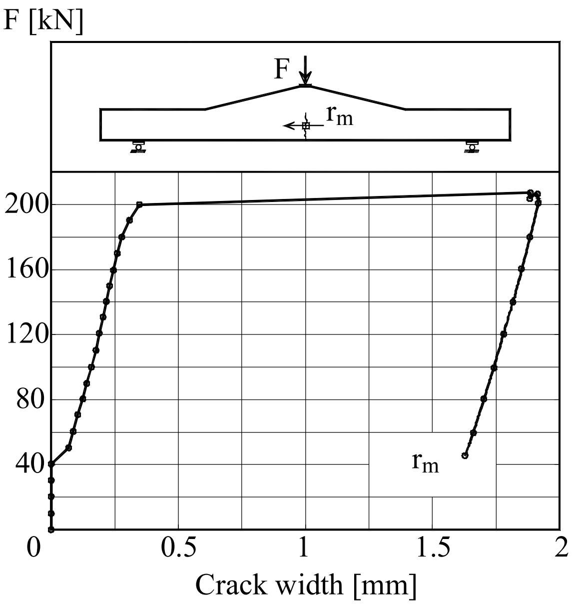


Figure B.5L2.4-The load – crack width graph

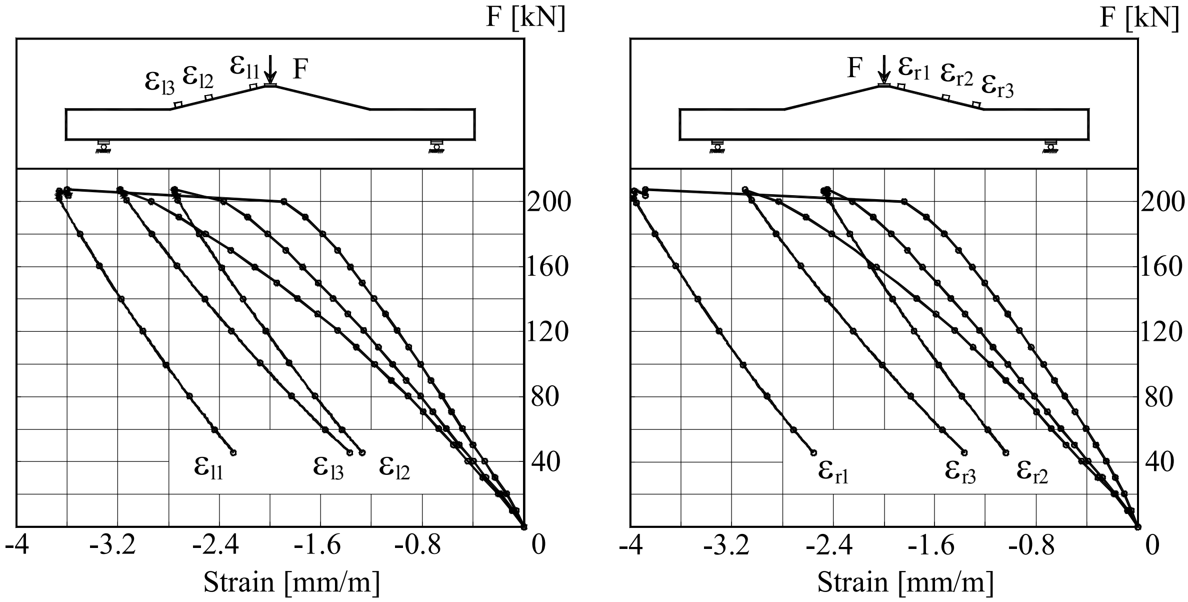


Figure B.5L2.5-The Load –Strains graph at top surface of beam

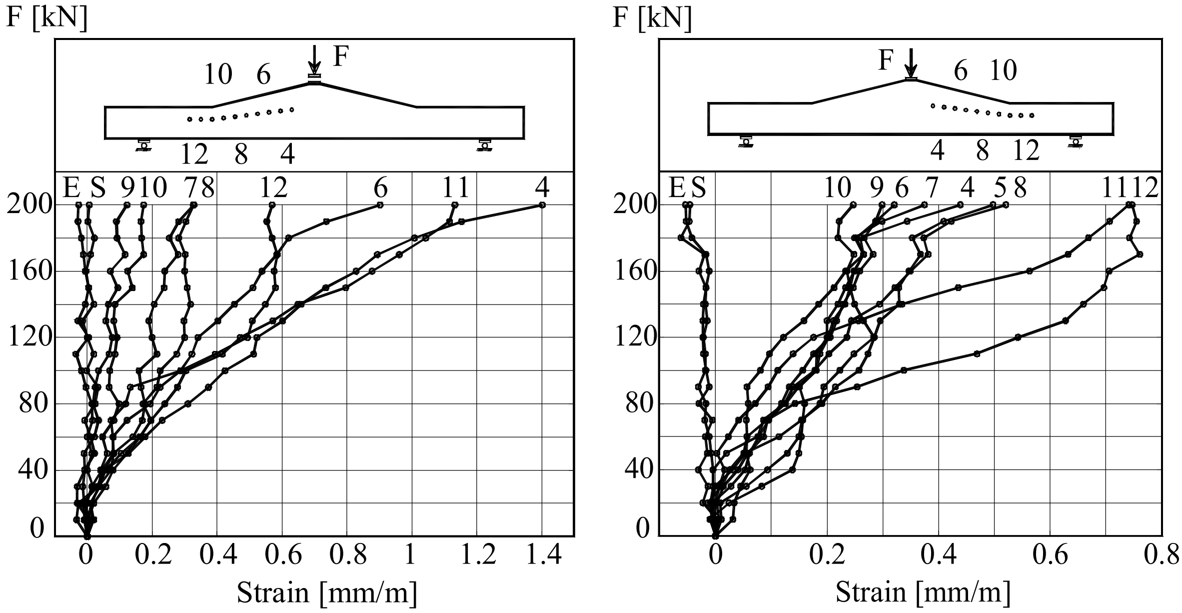


Figure B.5L2.6- The Load –Strains graph at mid-depth of beam

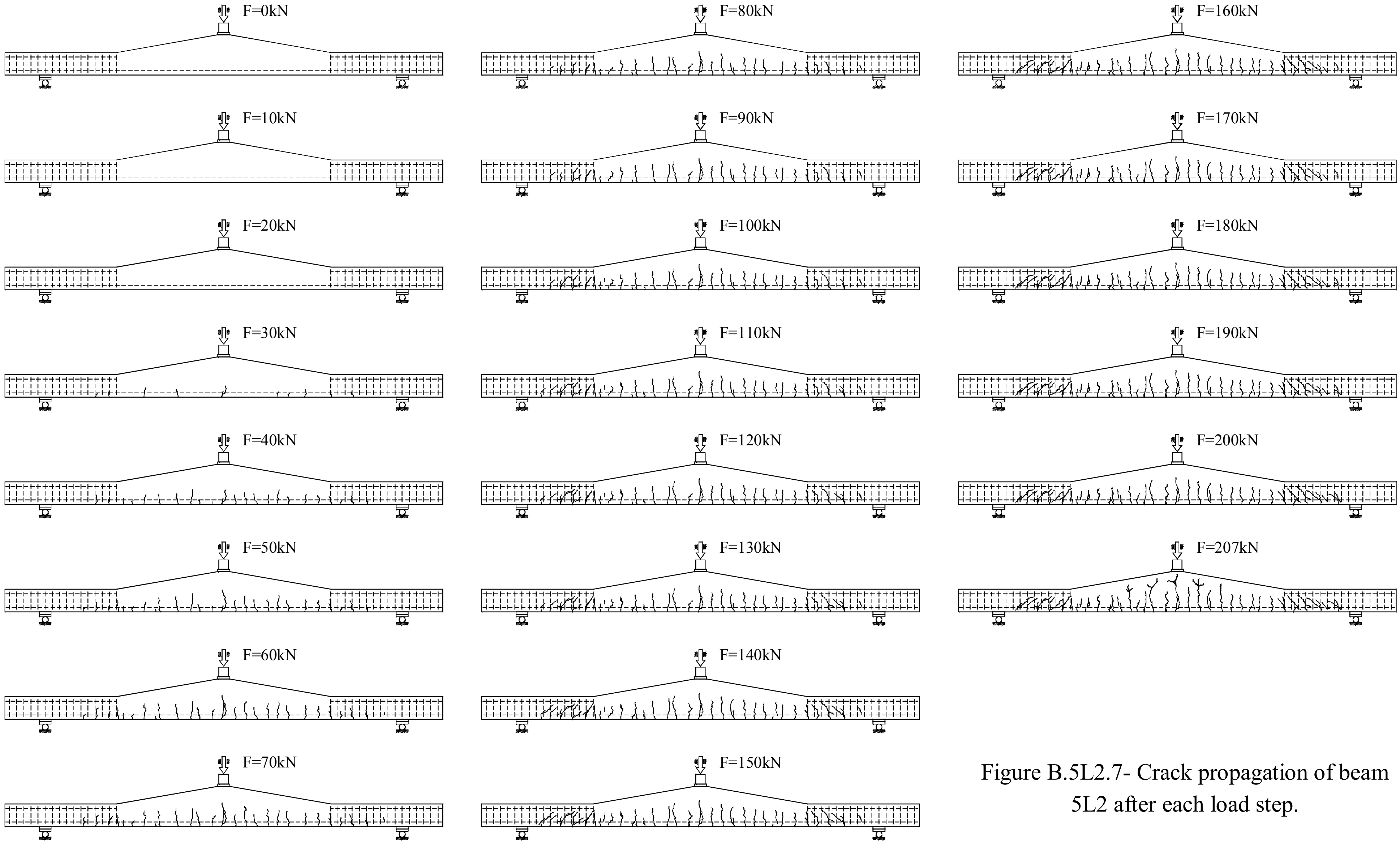


Figure B.5L2.7- Crack propagation of beam 5L2 after each load step.

TEST SAMPLE: 1K1

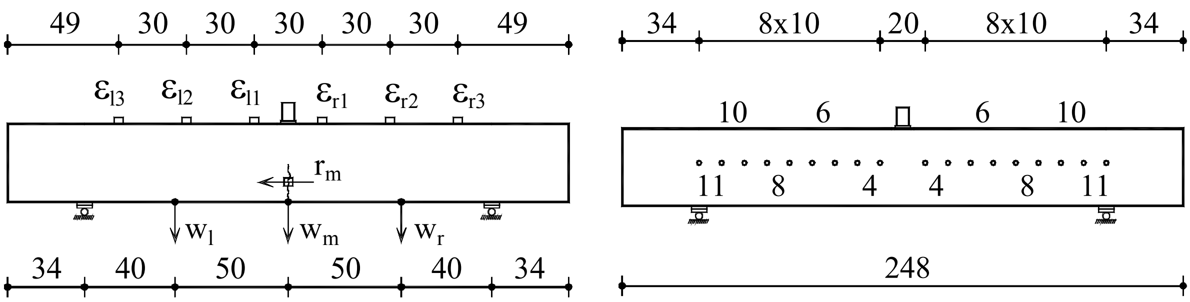


Figure B.1K1.1- The detailed arrangement of the data acquisition system

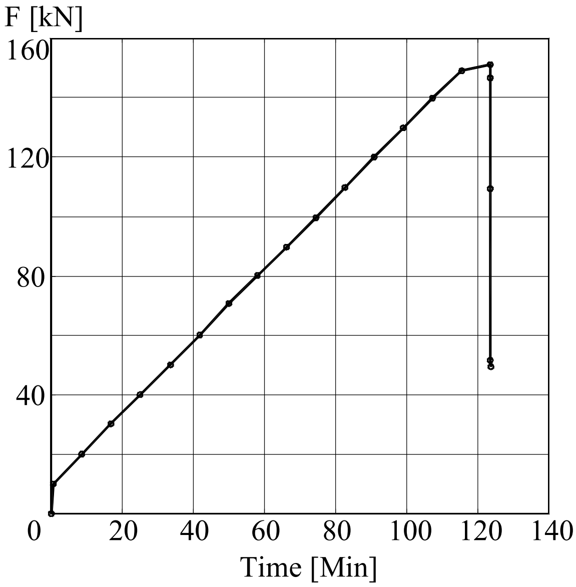


Figure B.1K1.2-The Time – Load graph

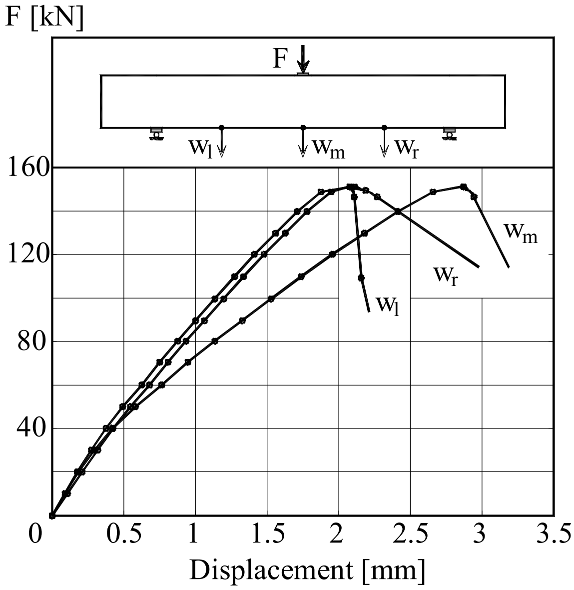


Figure B.1K1.3-The Load – Displacement graph

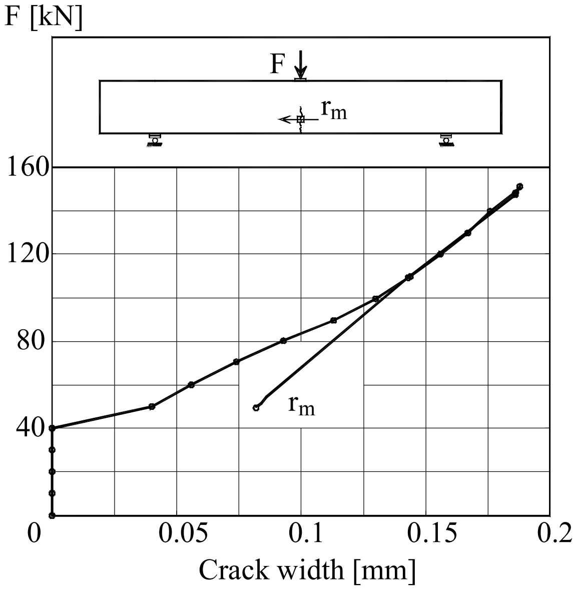


Figure B.1K1.4-The load – crack width graph

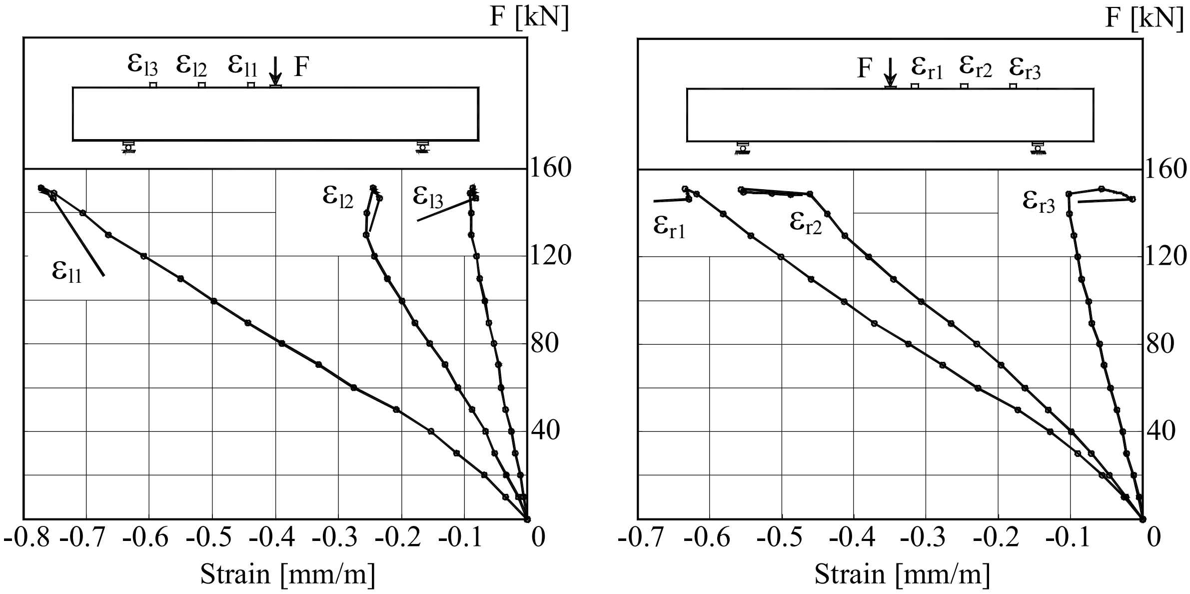


Figure B.1K1.5-The Load –Strains graph at top surface of beam

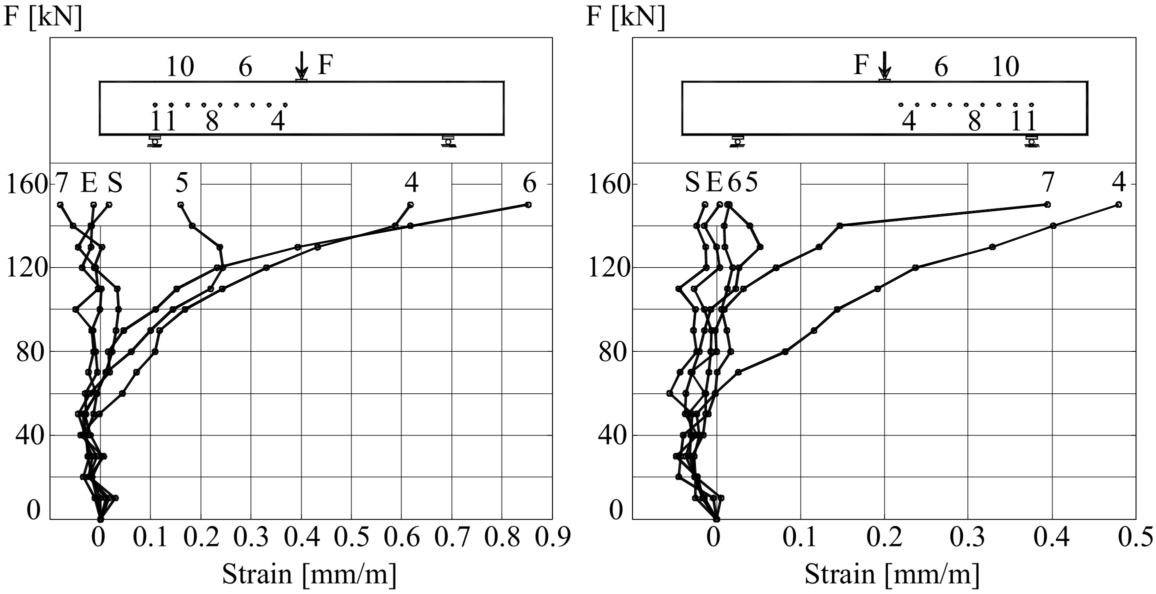


Figure B.1K1.6- The Load –Strains graph at mid-depth of beam

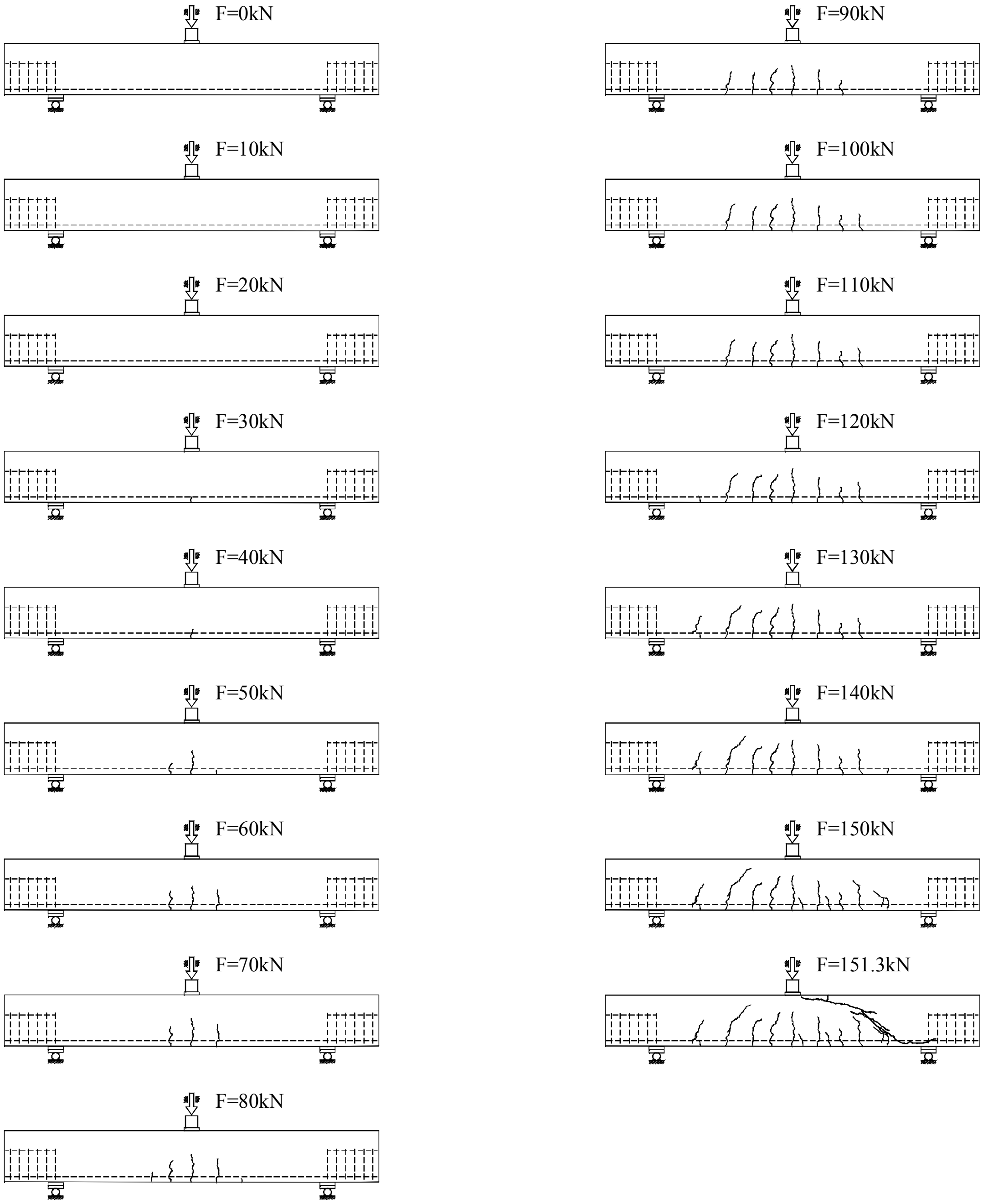


Figure B.1K1.7- Crack propagation of beam 1K1 after each load step.

TEST SAMPLE: 1K2

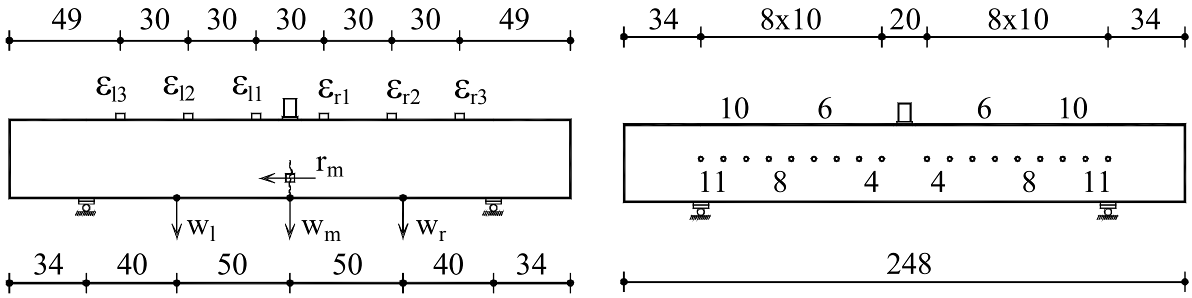
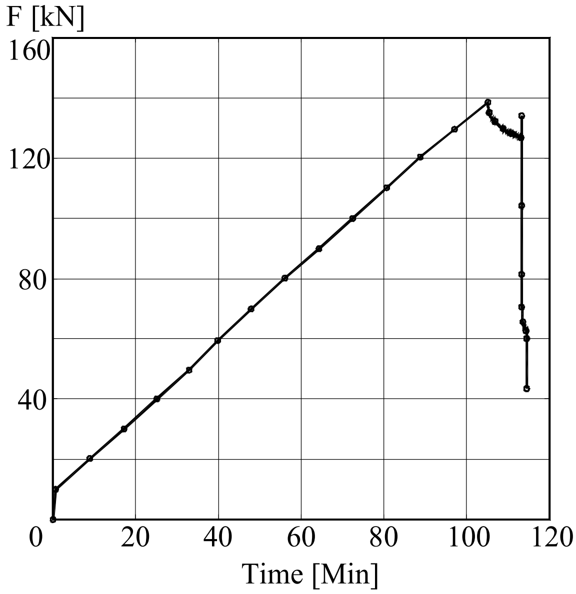


Figure B.1K2.1- The detailed arrangement of the data acquisition system



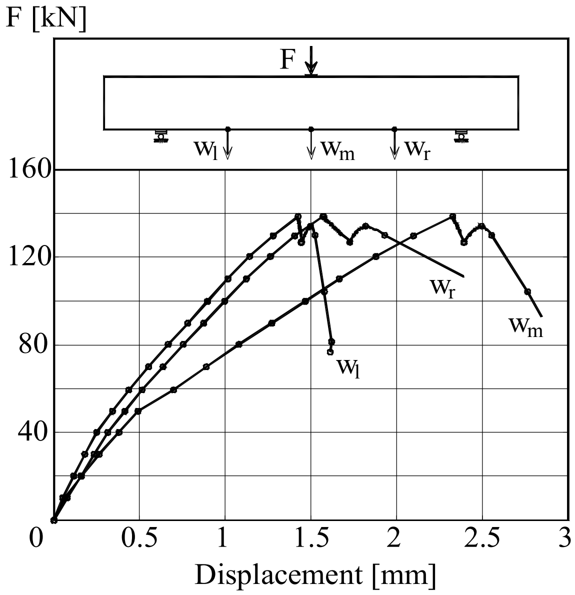


Figure B.1K2.2-The Time – Load graph

Figure B.1K2.3-The Load – Displacement graph

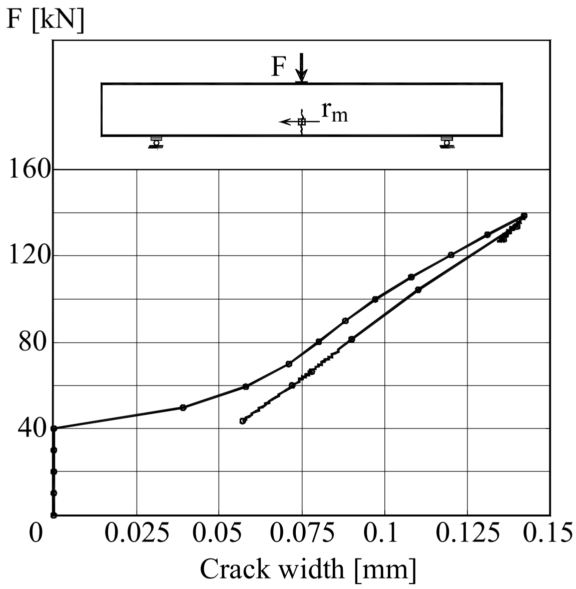


Figure B.1K2.4-The load – crack width graph

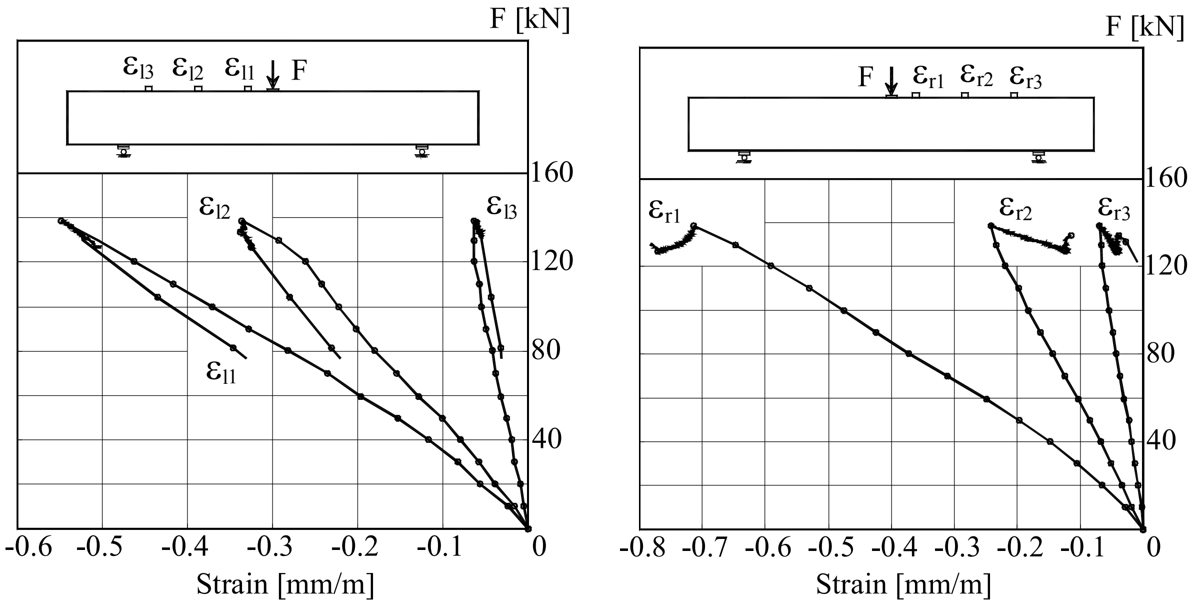


Figure B.1K2.5-The Load –Strains graph at top surface of beam

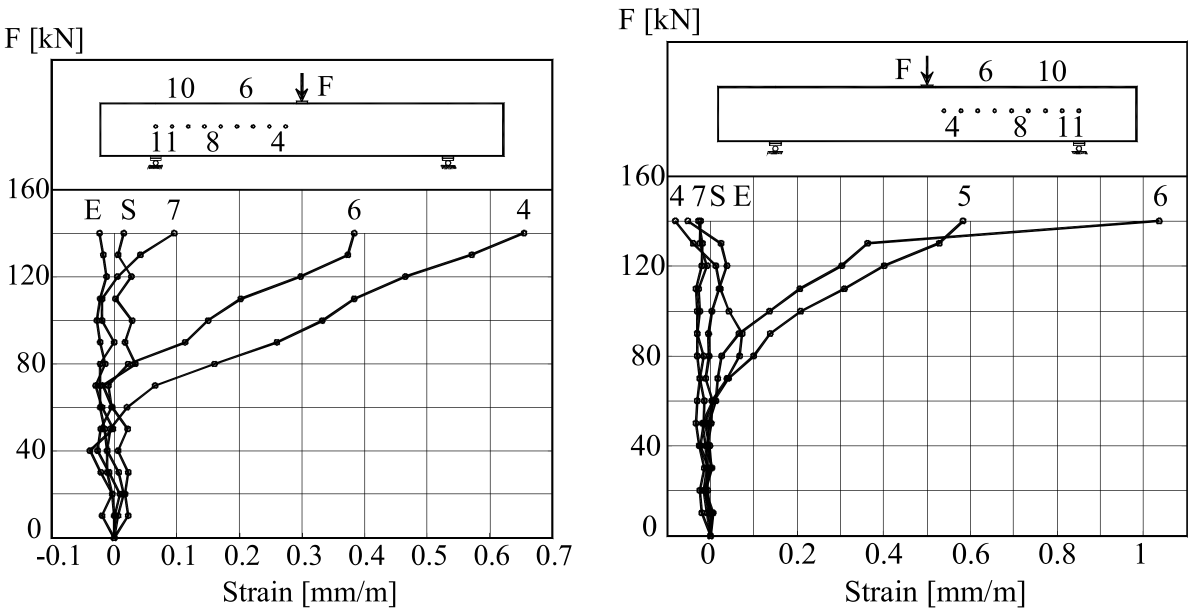


Figure B.1K2.6- The Load –Strains graph at mid-depth of beam

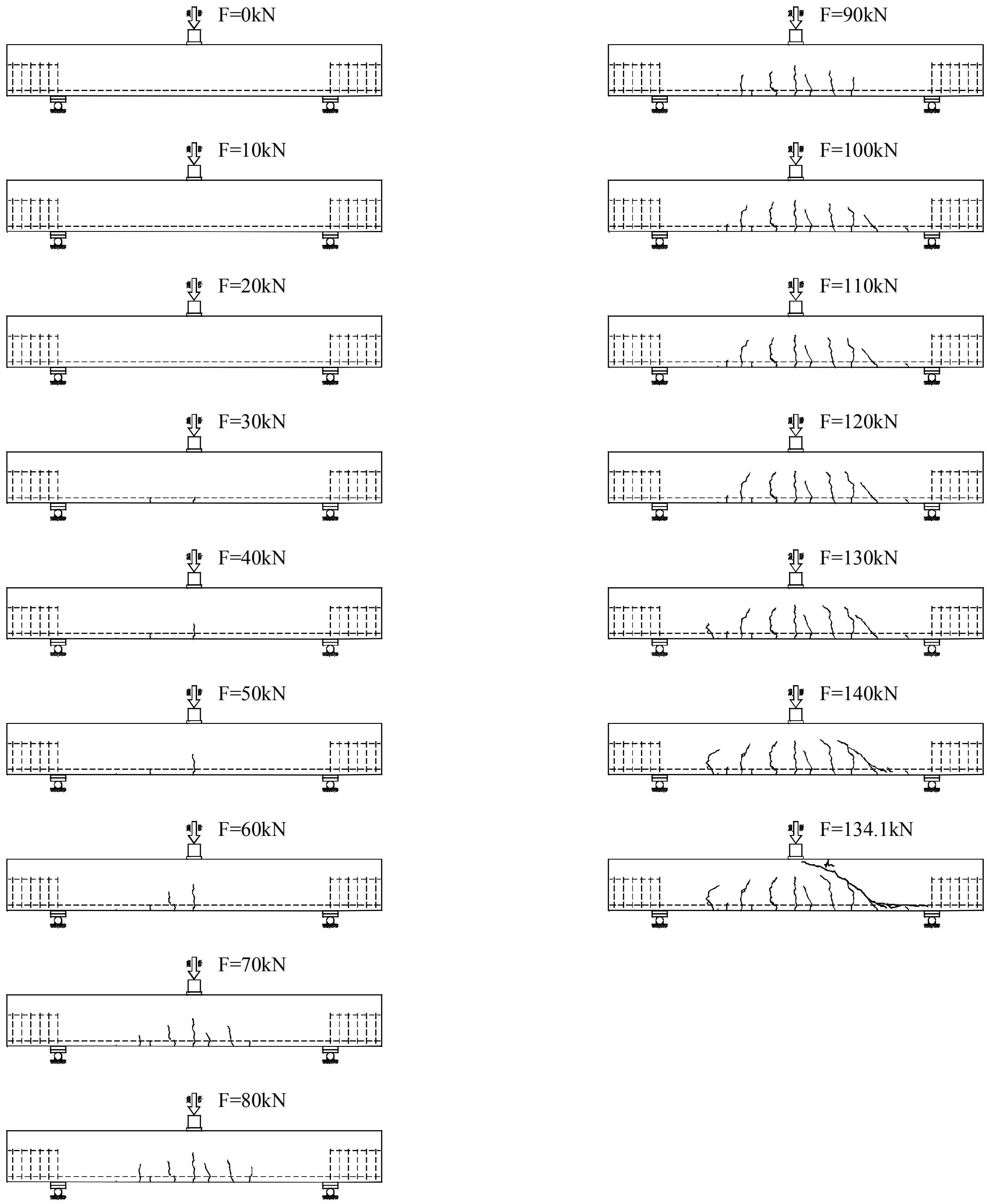


Figure B.1K2.7- Crack propagation of beam 1K2 after each load step.

TEST SAMPLE: 2K1

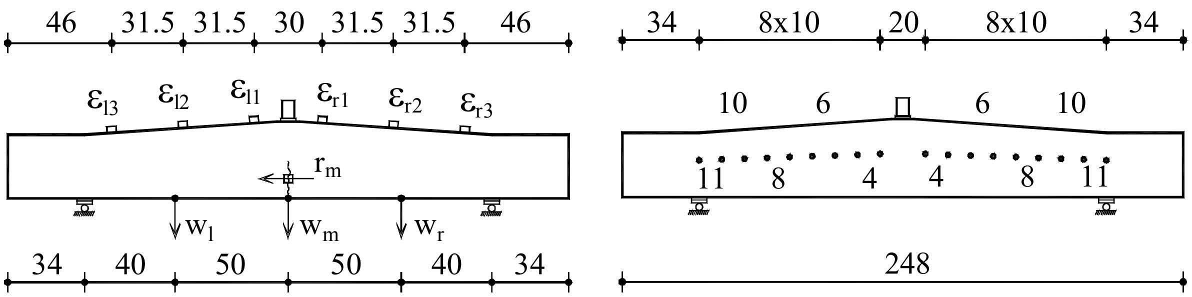


Figure B.2K1.1- The detailed arrangement of the data acquisition system

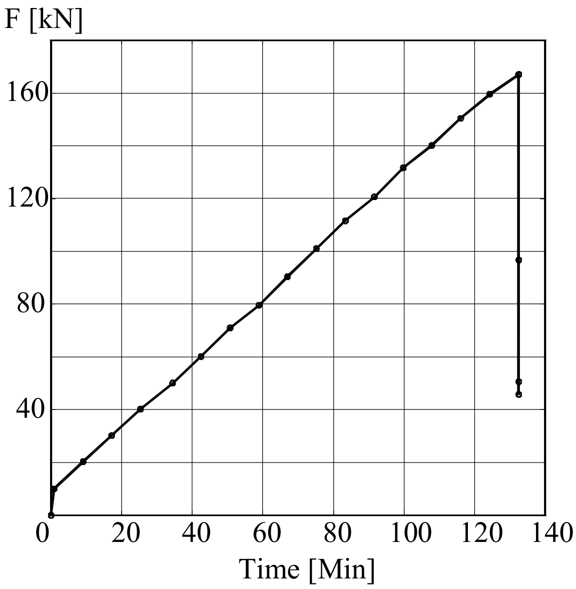


Figure B.2K1.2-The Time – Load graph

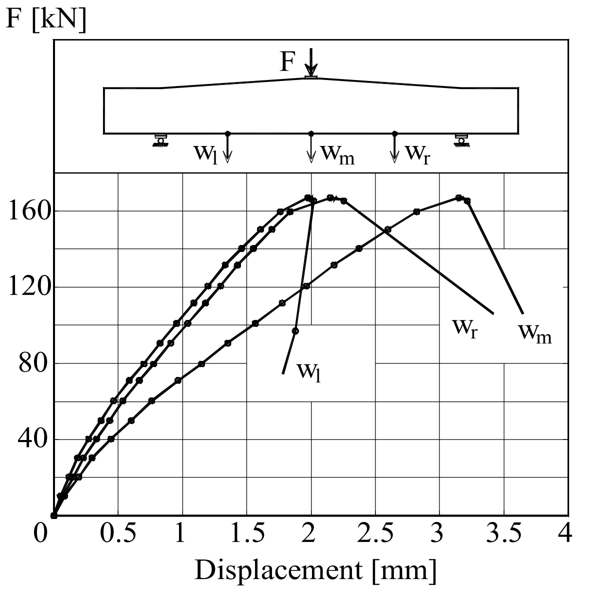


Figure B.2K1.3-The Load – Displacement graph

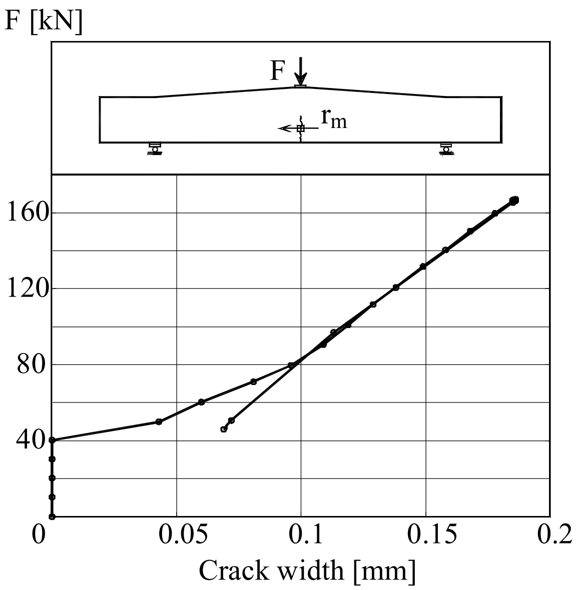


Figure B.2K1.4-The load – crack width graph

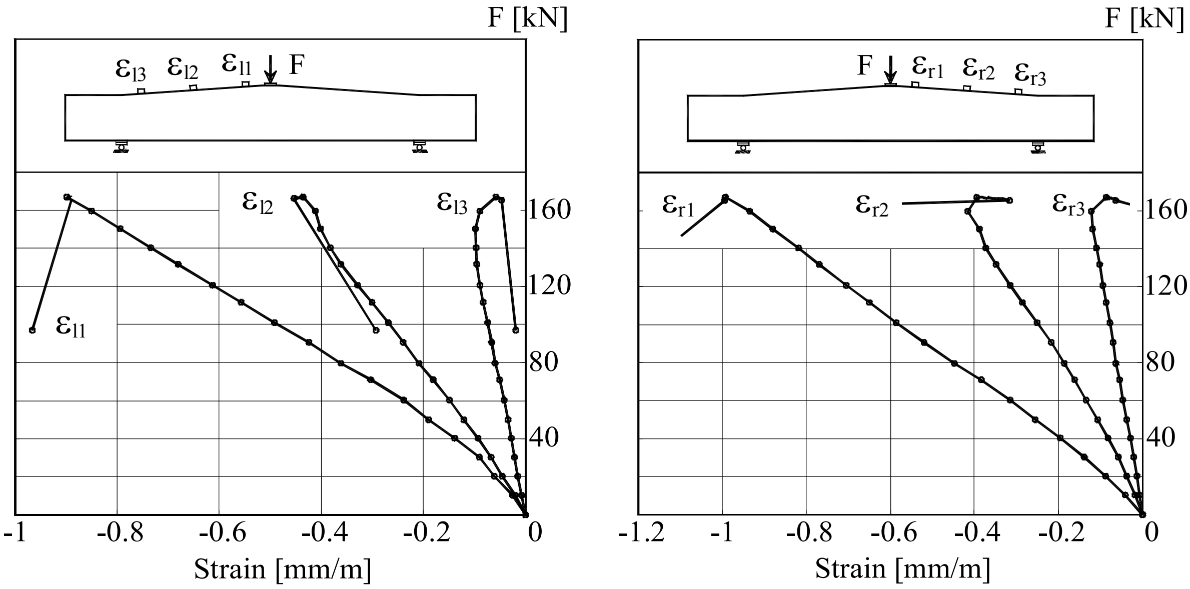


Figure B.2K1.5-The Load –Strains graph at top surface of beam

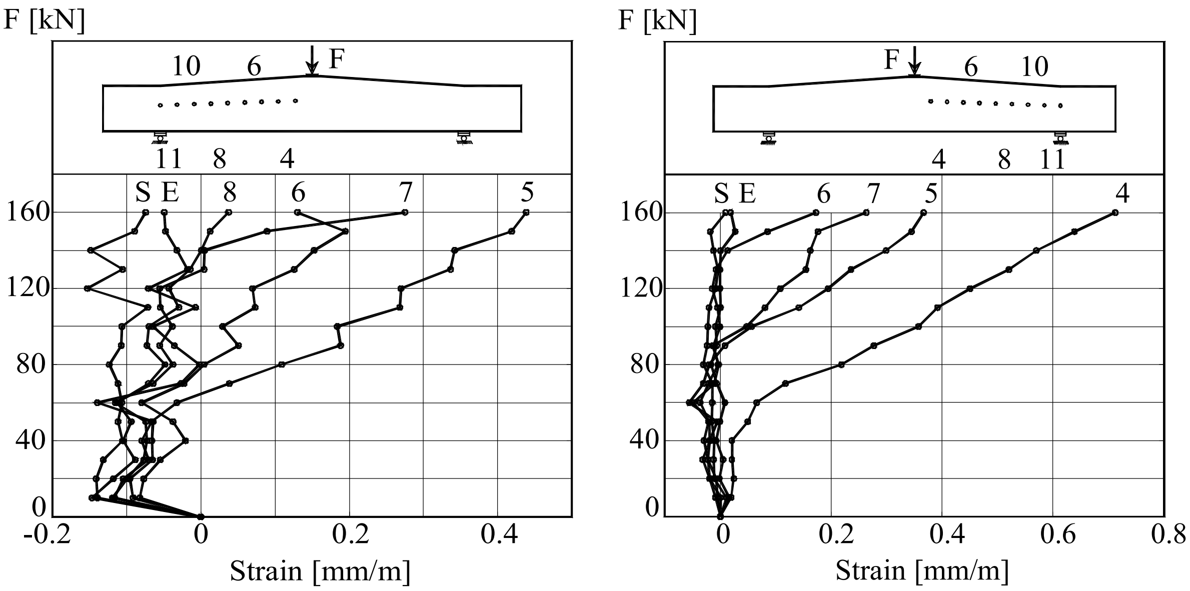


Figure B.2K1.6- The Load –Strains graph at mid-depth of beam

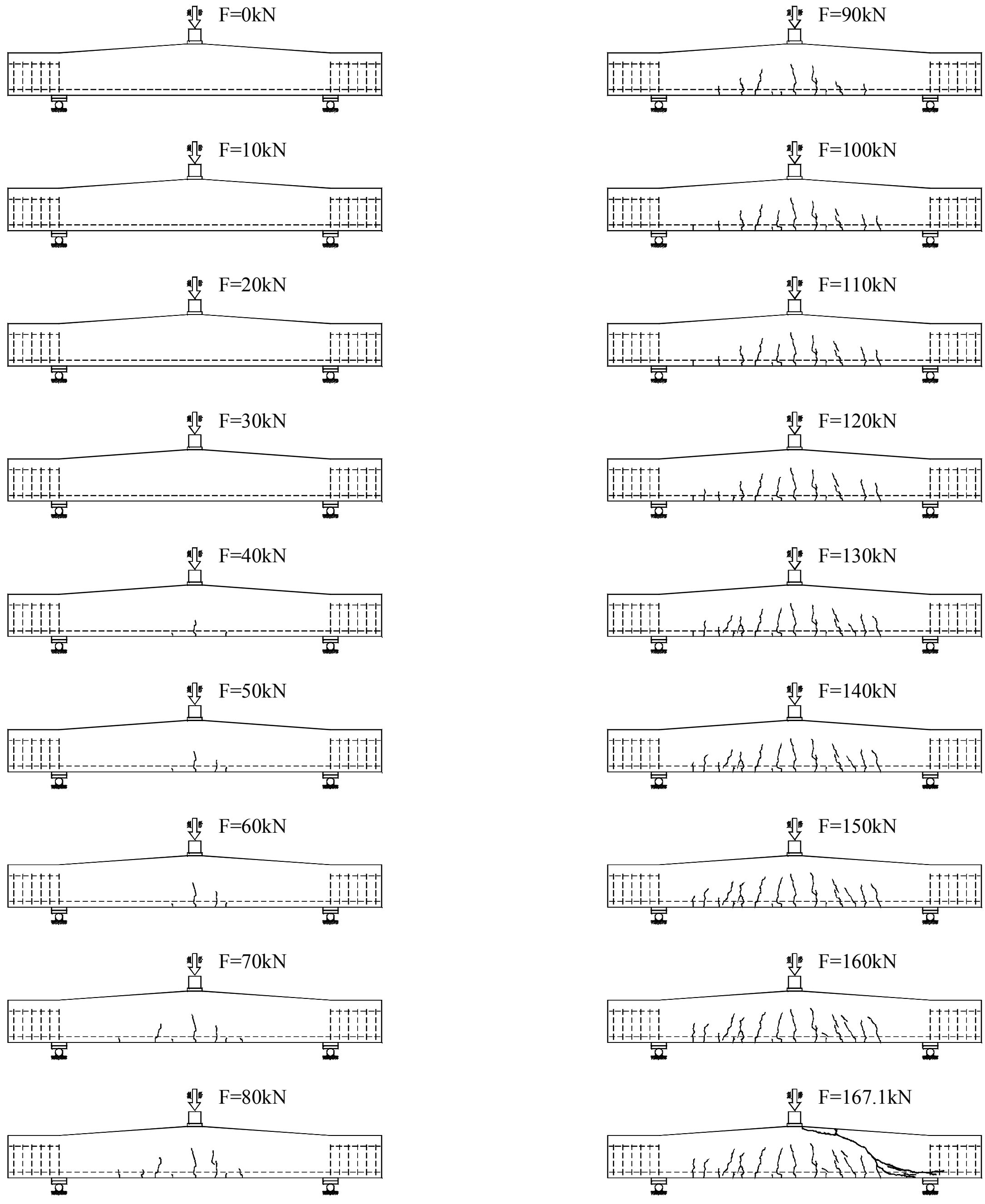


Figure B.2K1.7- Crack propagation of beam 2K1 after each load step.

TEST SAMPLE: 2K2

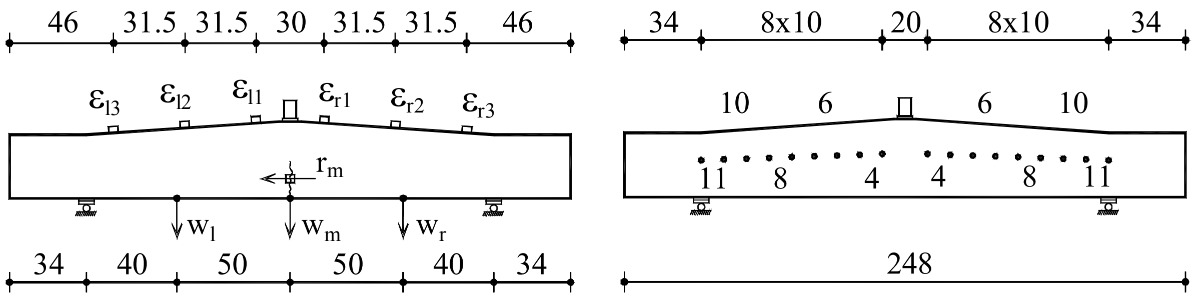
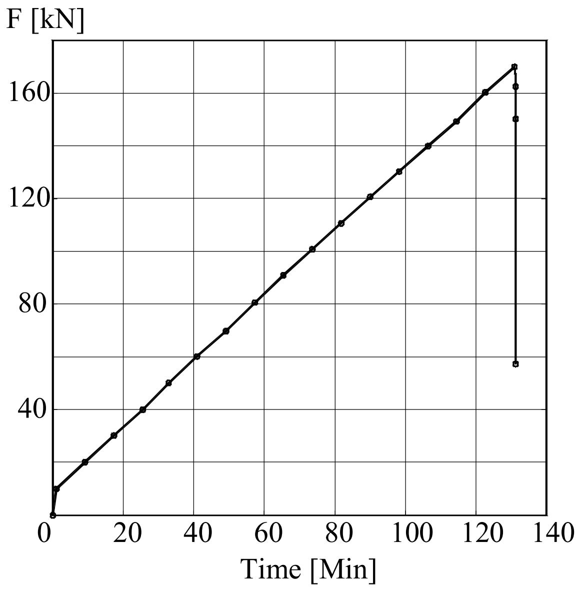


Figure B.2K2.1- The detailed arrangement of the data acquisition system



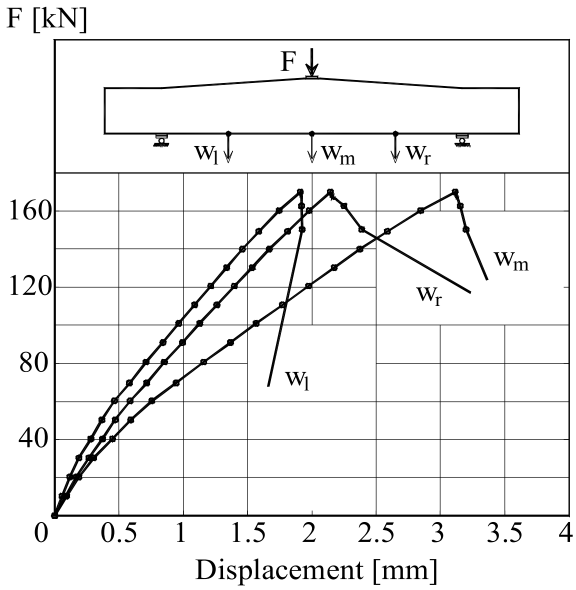


Figure B.2K2.2-The Time – Load graph

Figure B.2K2.3-The Load – Displacement graph

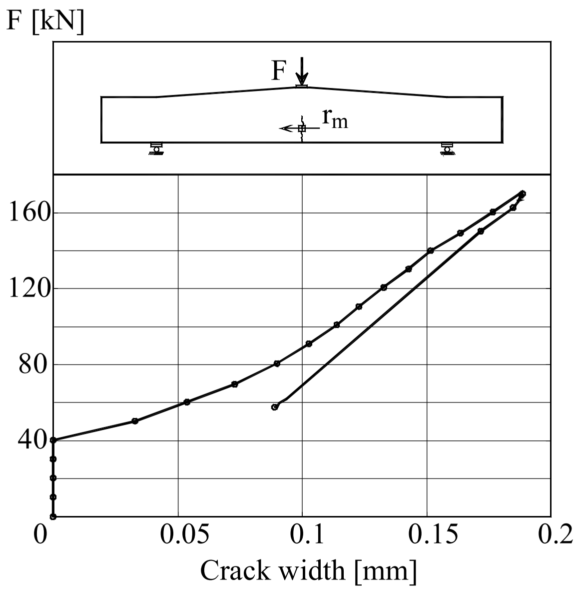


Figure B.2K2.4-The load – crack width graph

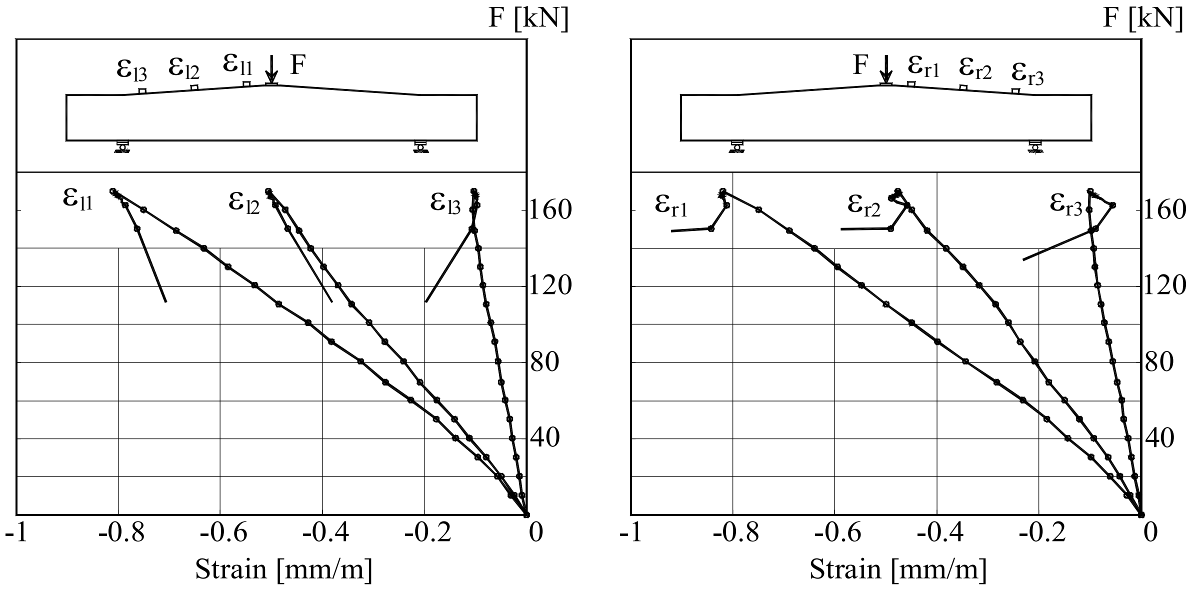


Figure B.2K2.5-The Load –Strains graph at top surface of beam

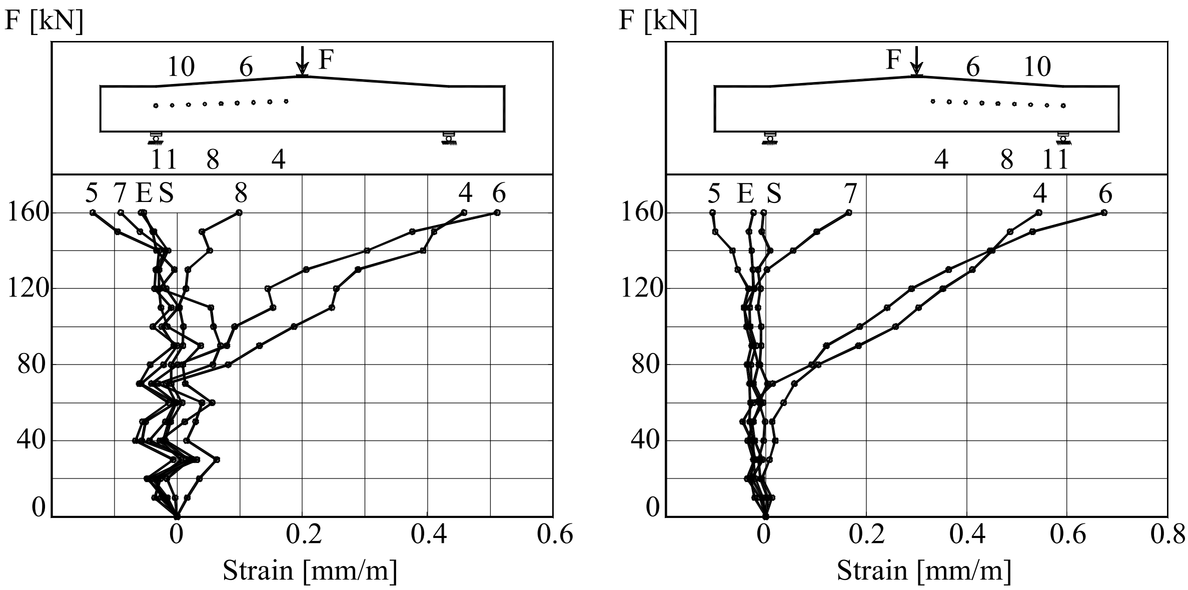


Figure B.2K2.6- The Load –Strains graph at mid-depth of beam

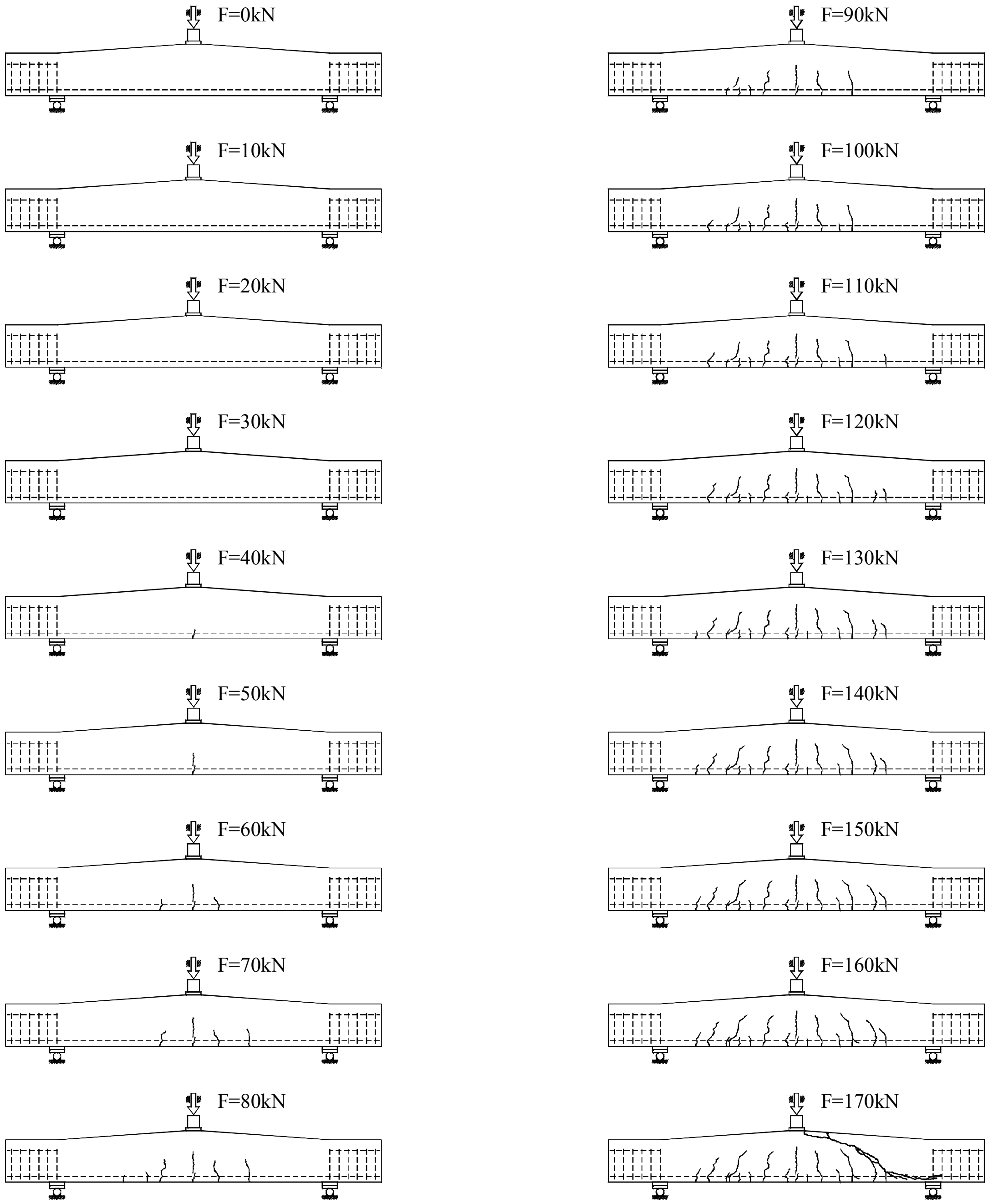


Figure B.2K2.7- Crack propagation of beam 2K2 after each load step.

TEST SAMPLE: 3K1

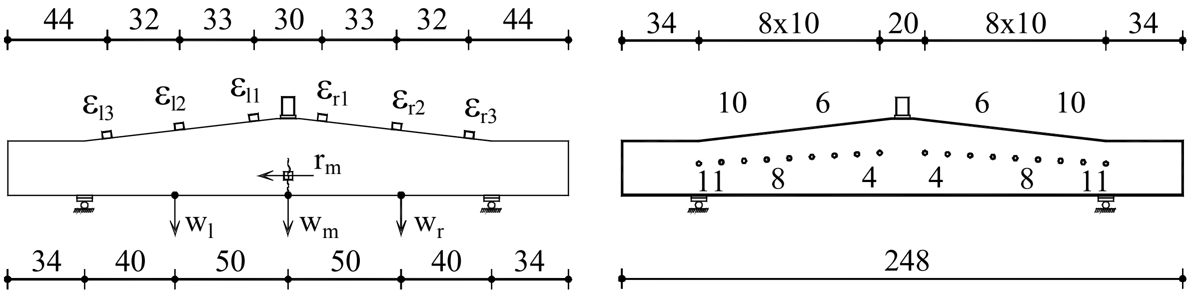


Figure B.3K1.1- The detailed arrangement of the data acquisition system

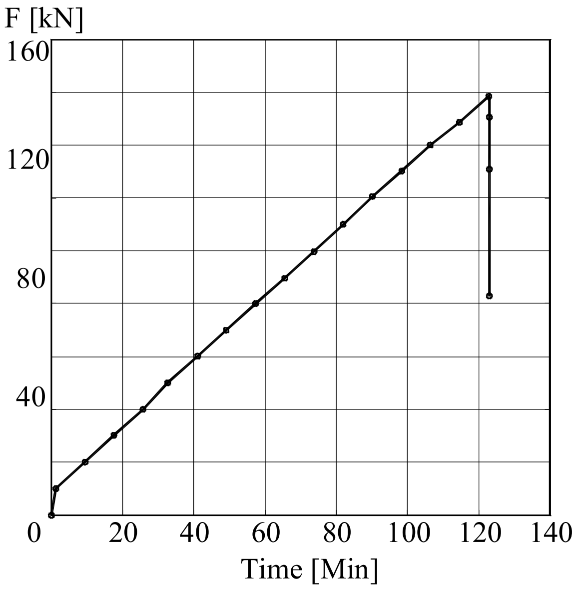


Figure B.3K1.2-The Time – Load graph

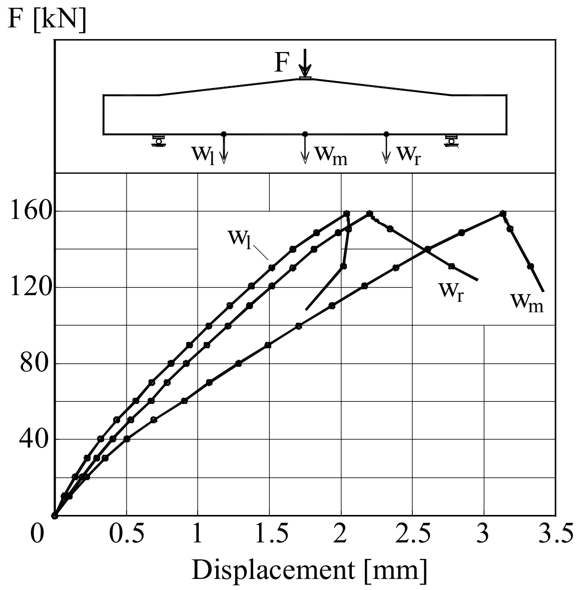


Figure B.3K1.3-The Load – Displacement graph

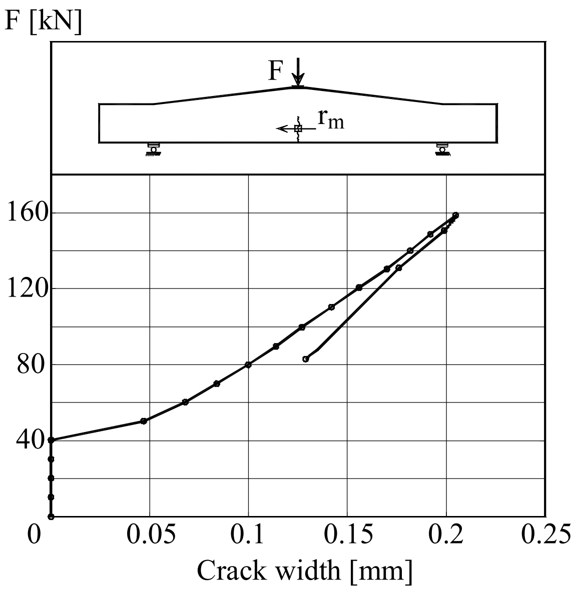


Figure B.3K1.4-The load – crack width graph

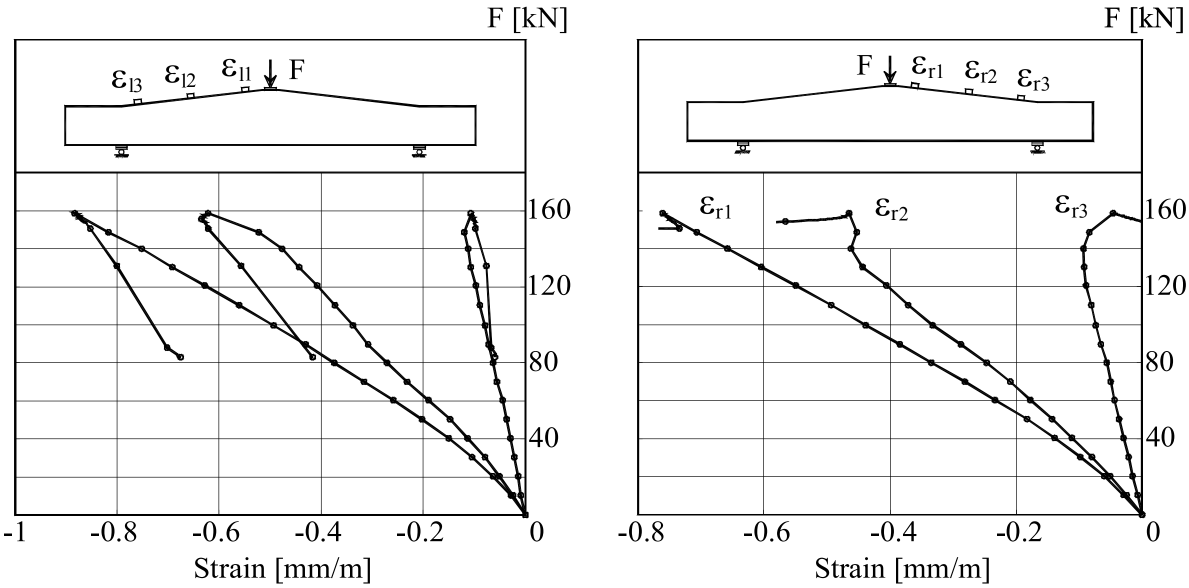


Figure B.3K1.5-The Load –Strains graph at top surface of beam

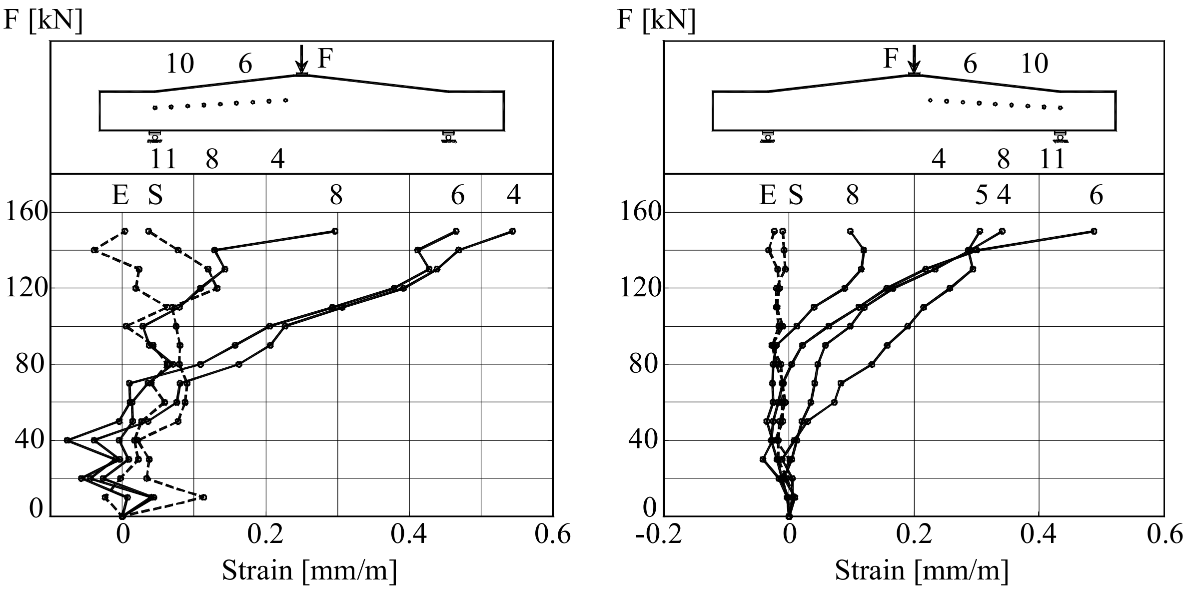


Figure B.3K1.6- The Load –Strains graph at mid-depth of beam

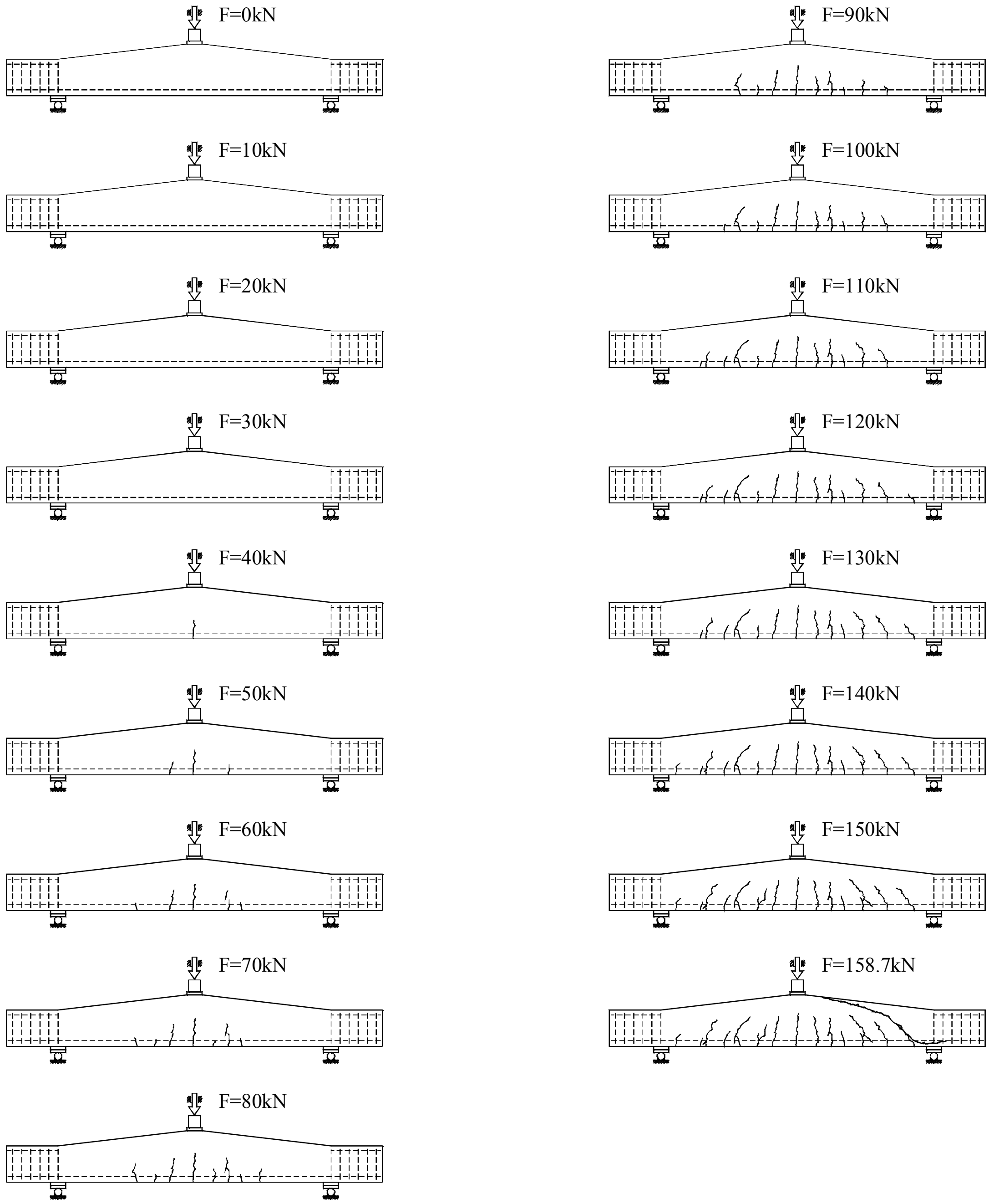


Figure B.3K1.7- Crack propagation of beam 3K1 after each load step.

TEST SAMPLE: 3K2

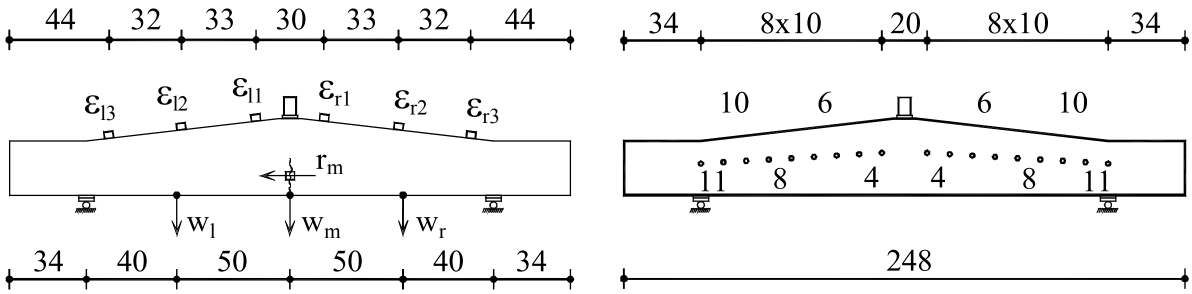
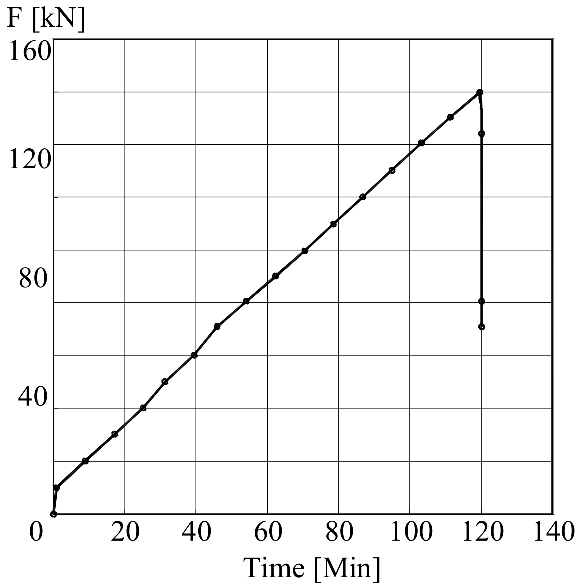


Figure B.3K2.1- The detailed arrangement of the data acquisition system



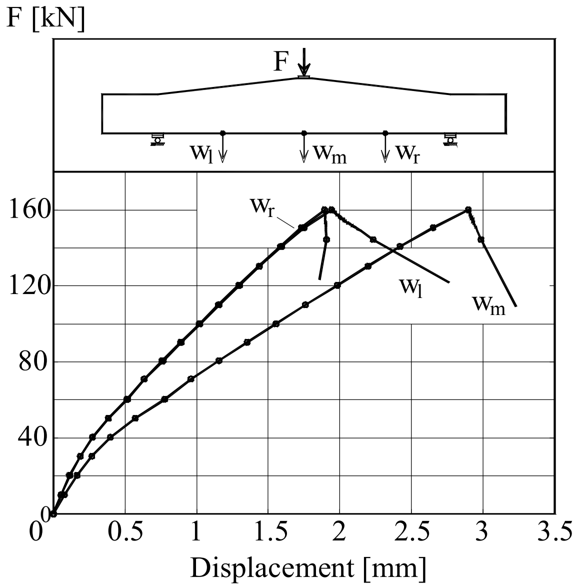


Figure B.3K2.2-The Time – Load graph

Figure B.3K2.3-The Load – Displacement graph

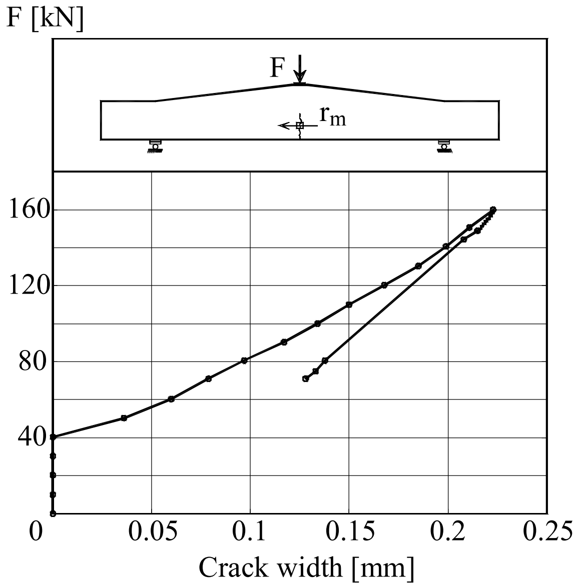


Figure B.3K2.4-The load – crack width graph

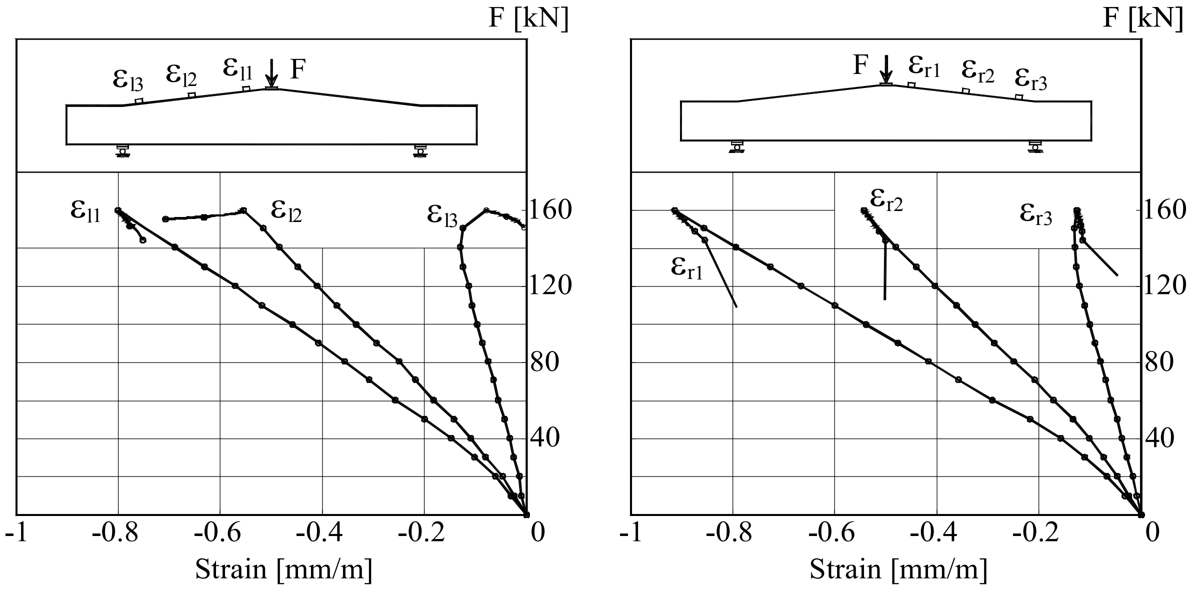


Figure B.3K2.5-The Load –Strains graph at top surface of beam

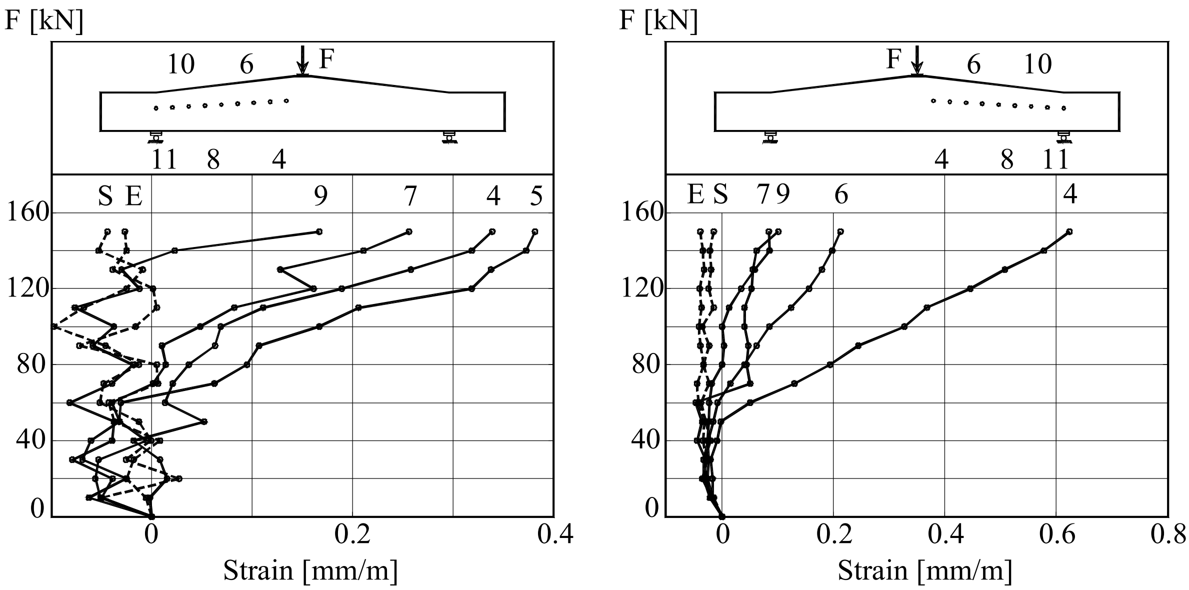


Figure B.3K2.6- The Load –Strains graph at mid-depth of beam

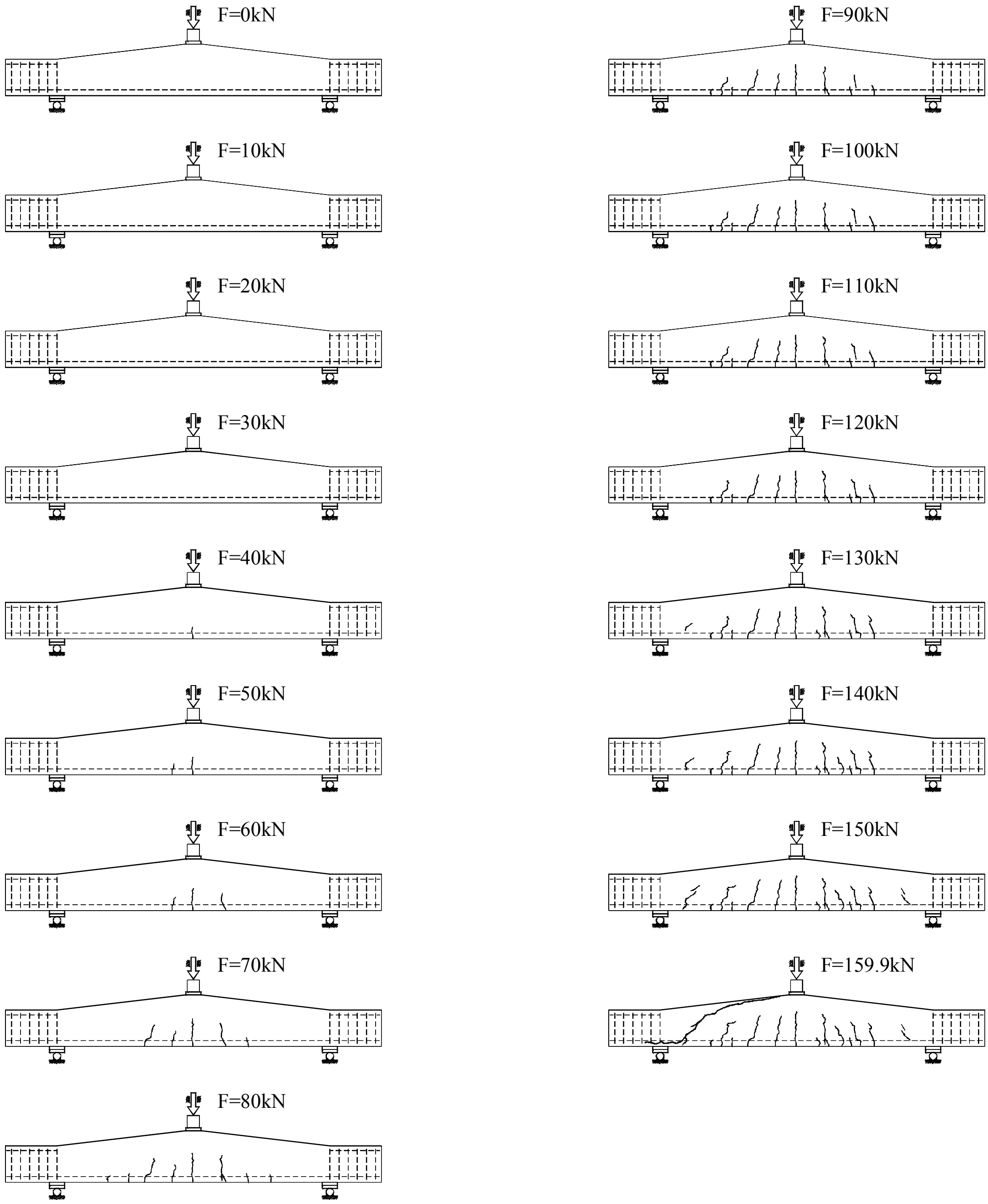


Figure B.3K2.7- Crack propagation of beam 3K2 after each load step.

TEST SAMPLE: 4K1

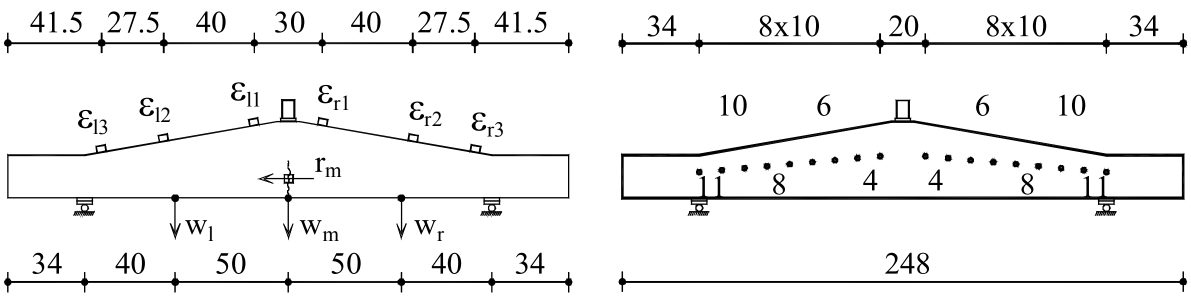


Figure B.4K1.1- The detailed arrangement of the data acquisition system

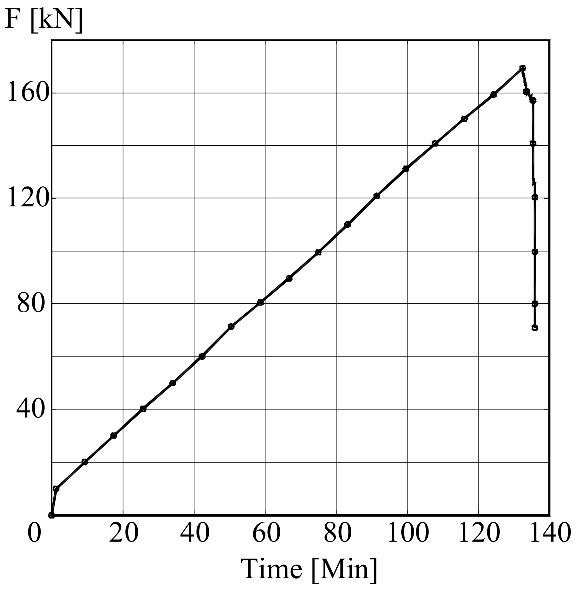


Figure B.4K1.2-The Time – Load graph

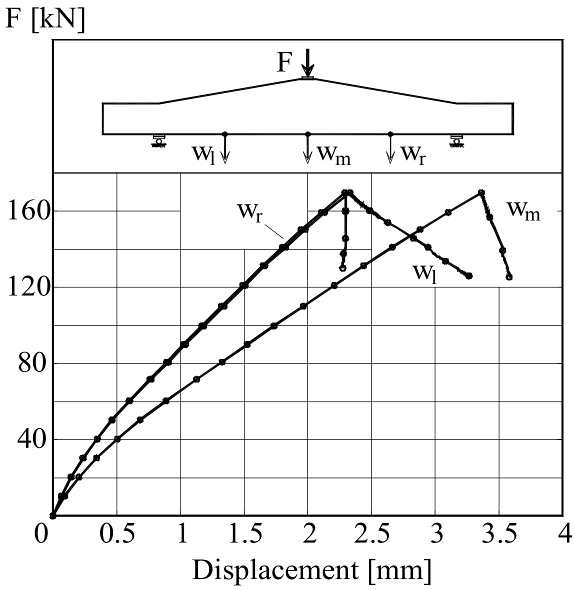


Figure B.4K1.3-The Load – Displacement graph

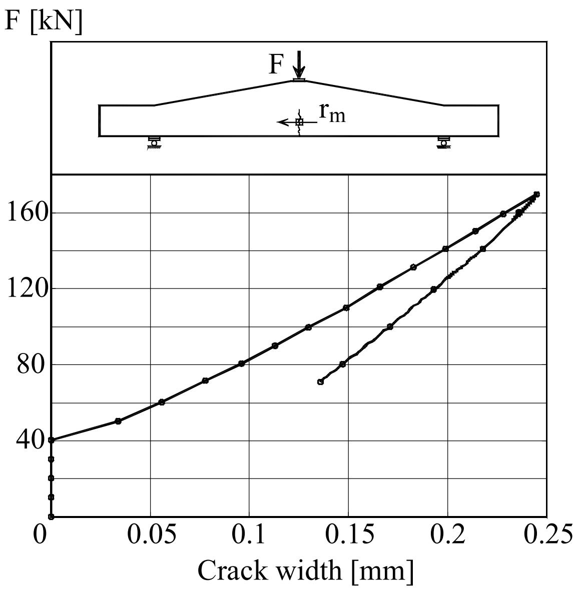


Figure B.4K1.4-The load – crack width graph

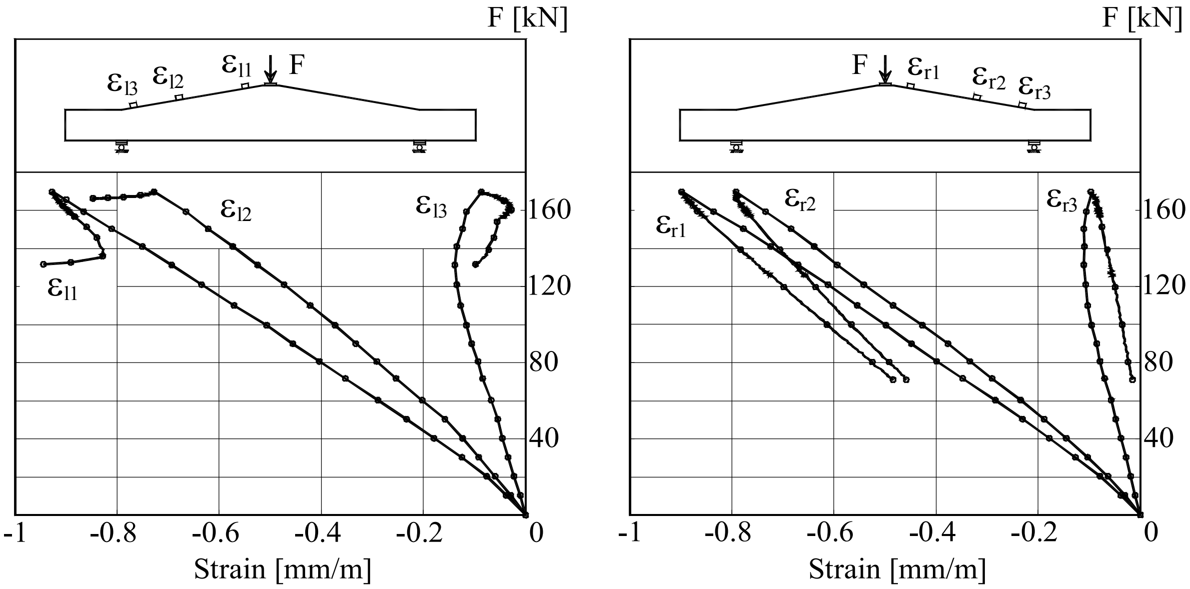


Figure B.4K1.5-The Load –Strains graph at top surface of beam

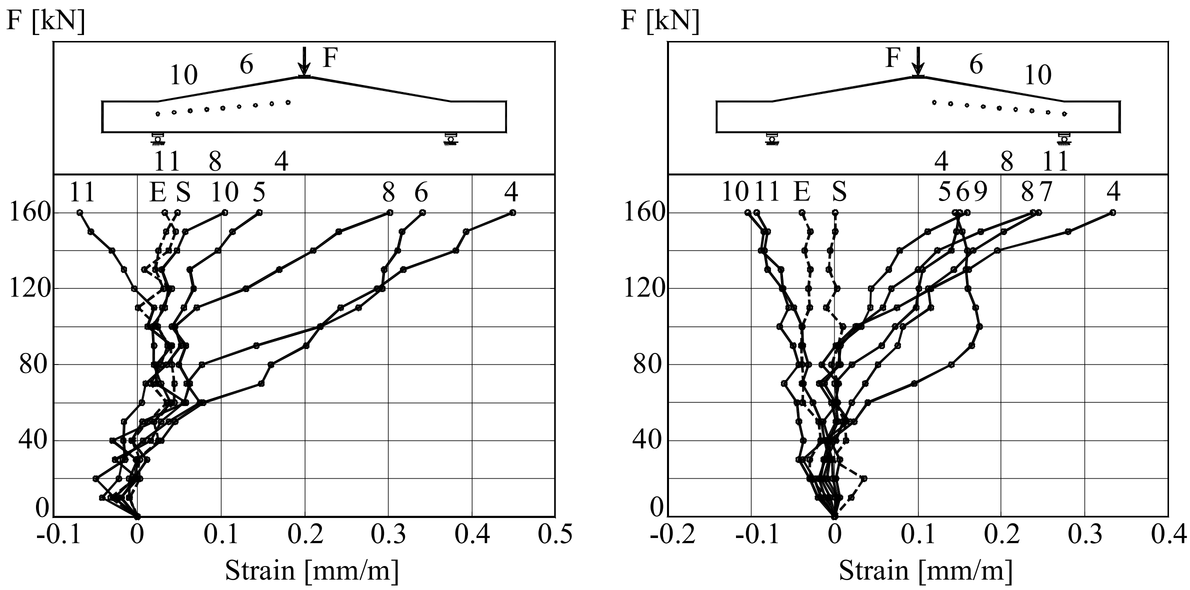


Figure B.4K1.6- The Load –Strains graph at mid-depth of beam

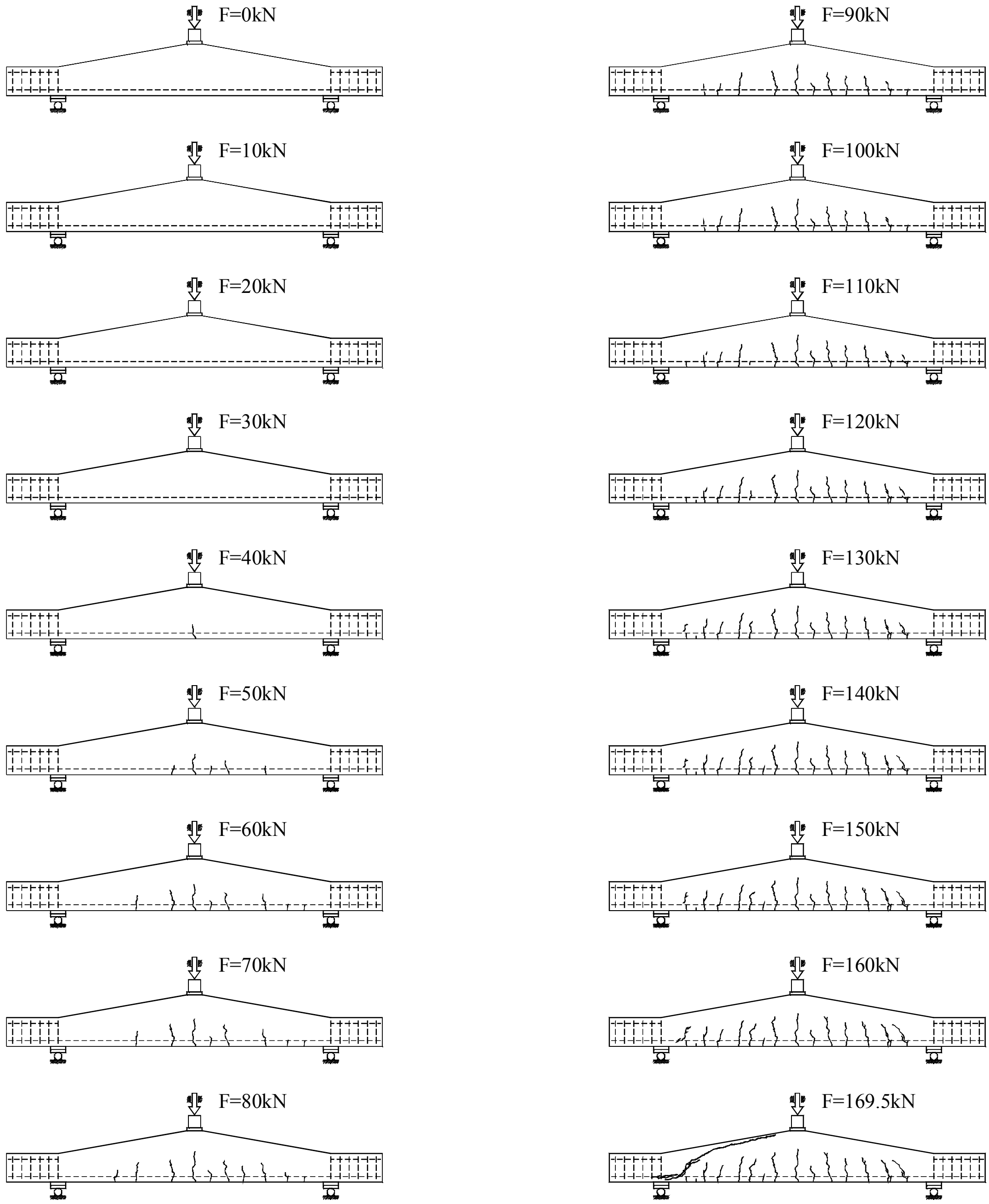


Figure B.4K1.7- Crack propagation of beam 4K1 after each load step.

TEST SAMPLE: 4K2

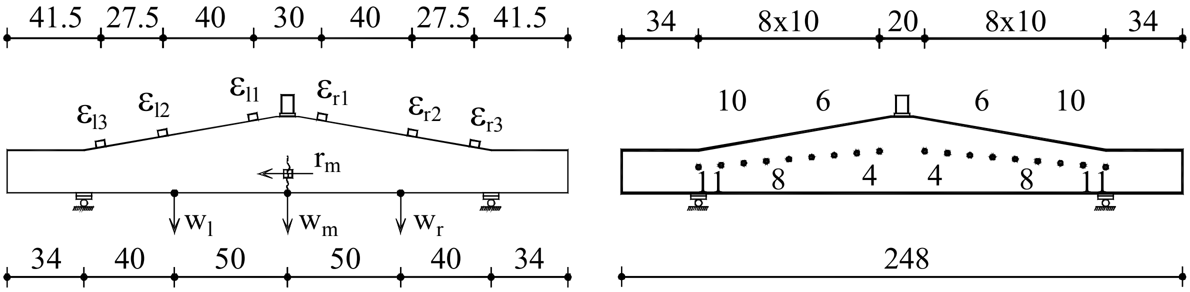


Figure B.4K2.1- The detailed arrangement of the data acquisition system

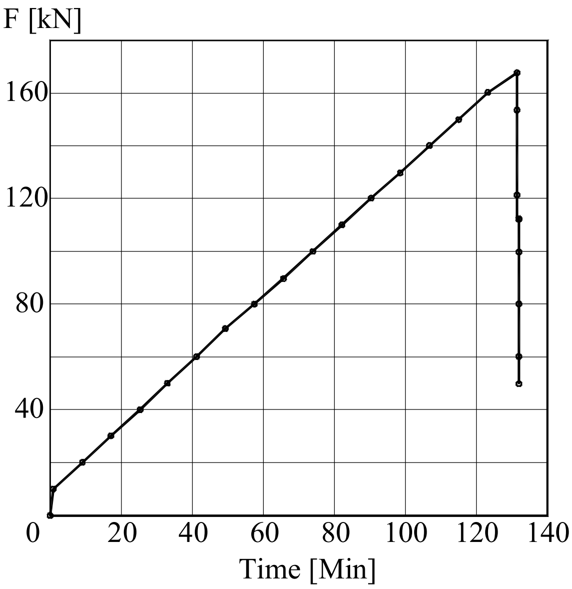


Figure B.4K2.2-The Time – Load graph

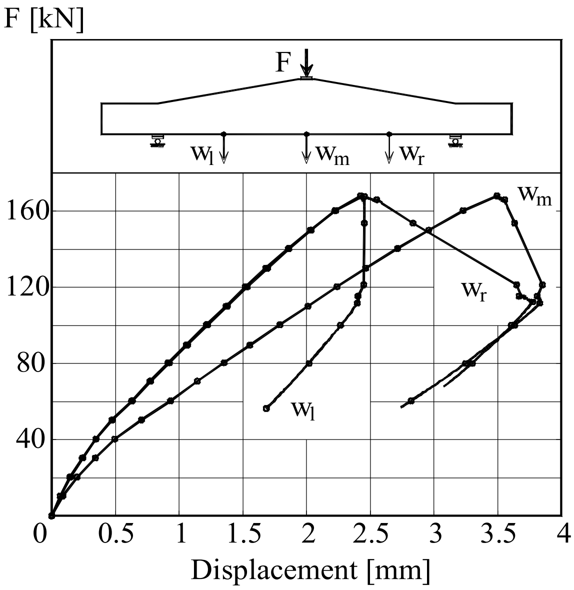


Figure B.4K2.3-The Load – Displacement graph

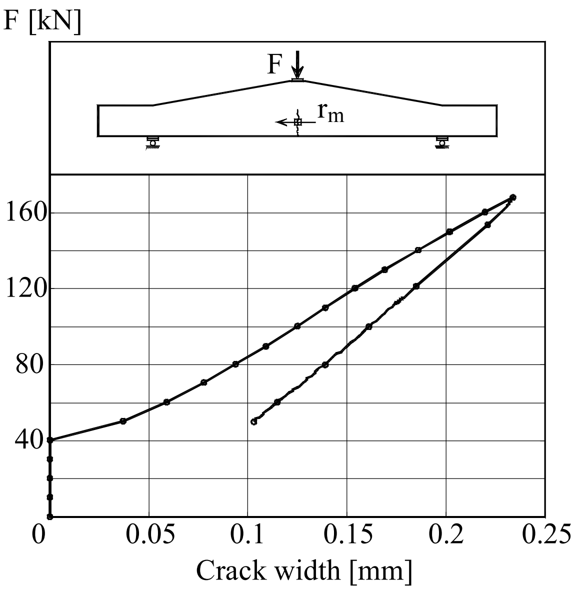


Figure B.4K2.4-The load – crack width graph

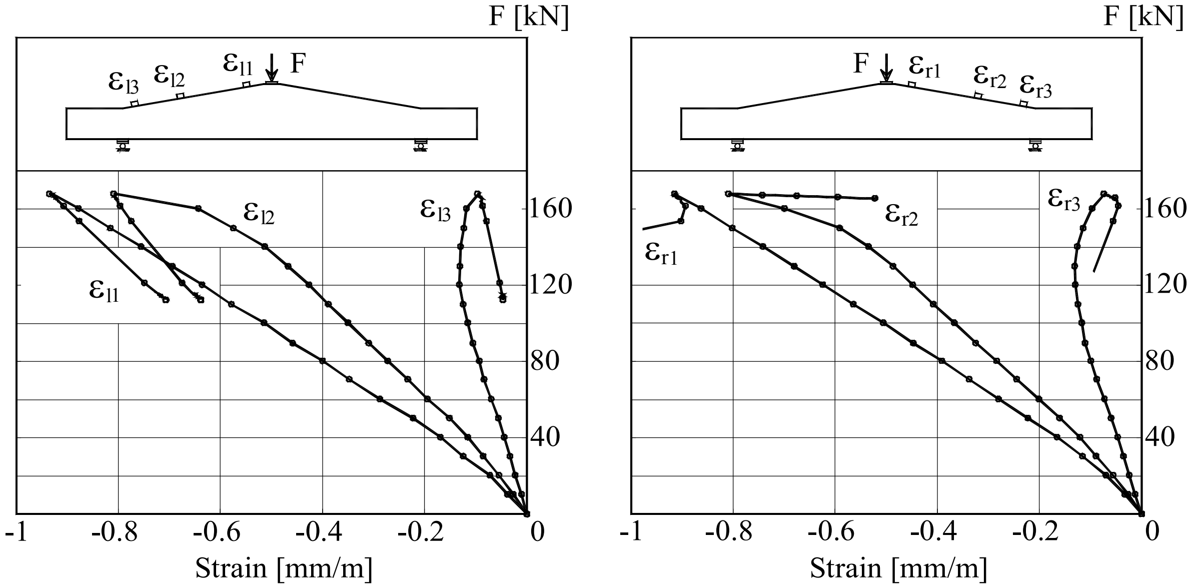


Figure B.4K2.5-The Load –Strains graph at top surface of beam

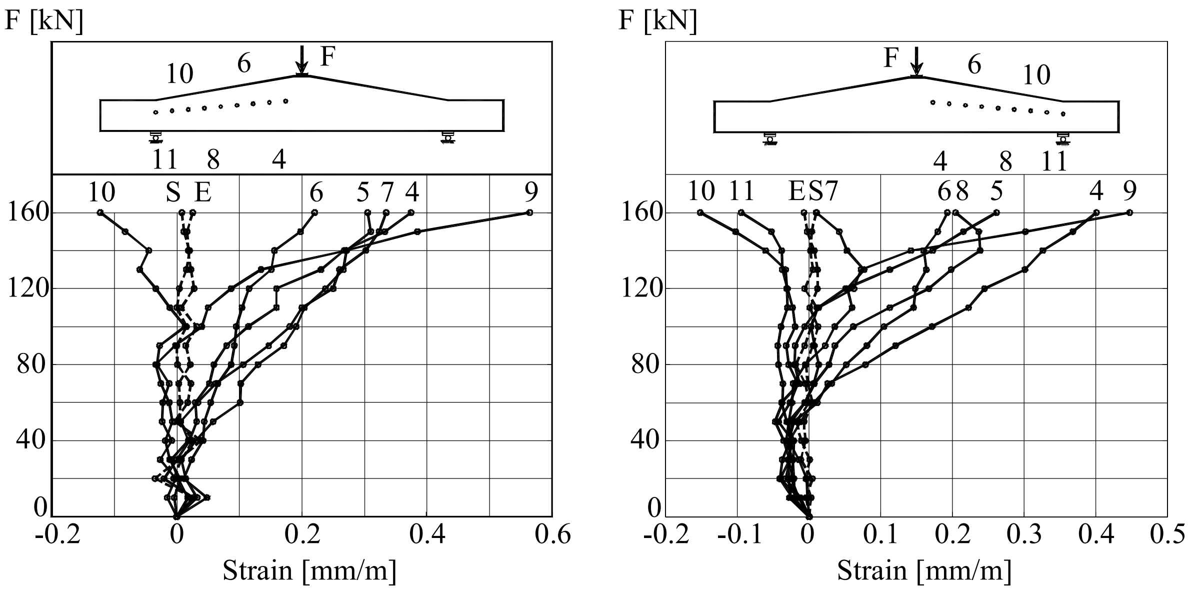


Figure B.4K2.6- The Load –Strains graph at mid-depth of beam

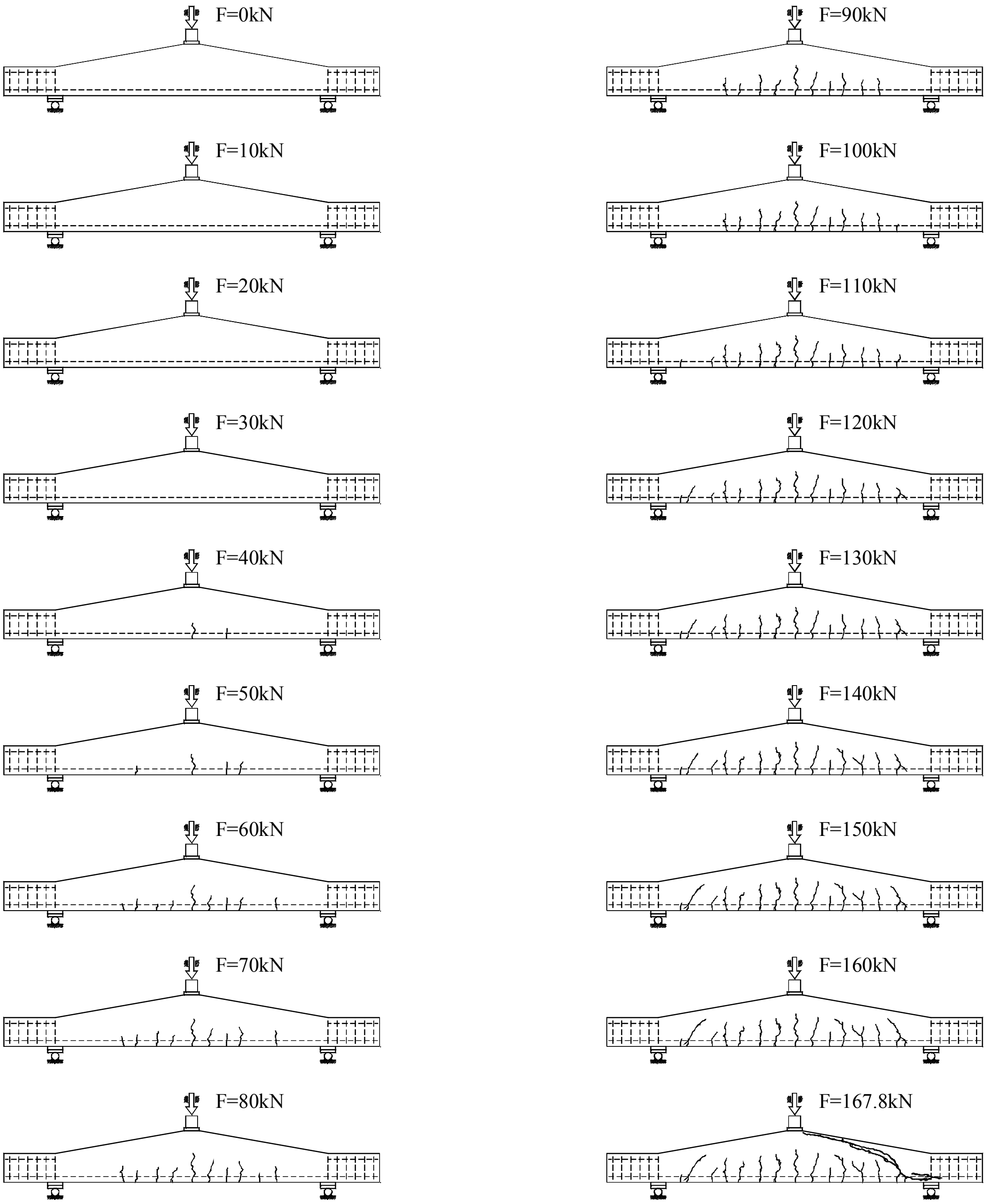


Figure B.4K2.7- Crack propagation of beam 4K2 after each load step.