

Appendix C

Test Results & Shear Strength of Codes

Shear Strength V(kN)

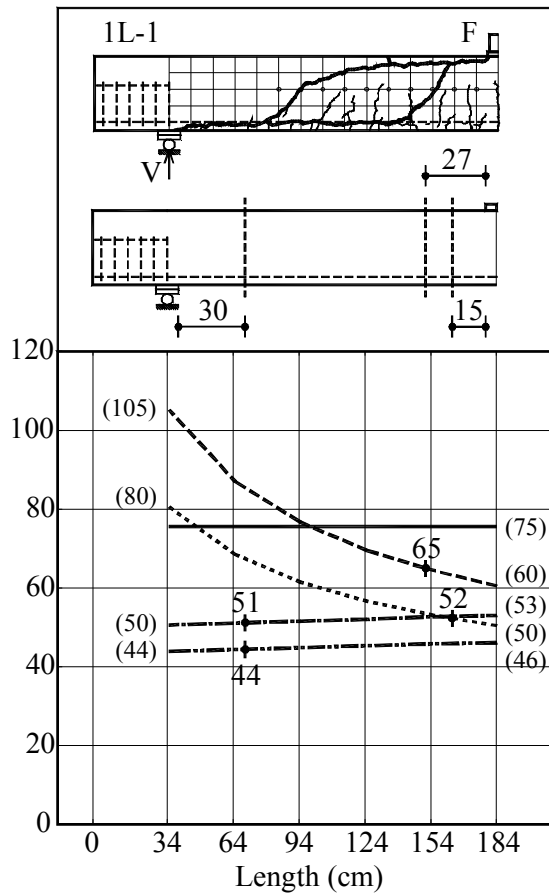


Figure C.1L1.1– Shear strength of test 1L-1

Shear Strength V(kN)

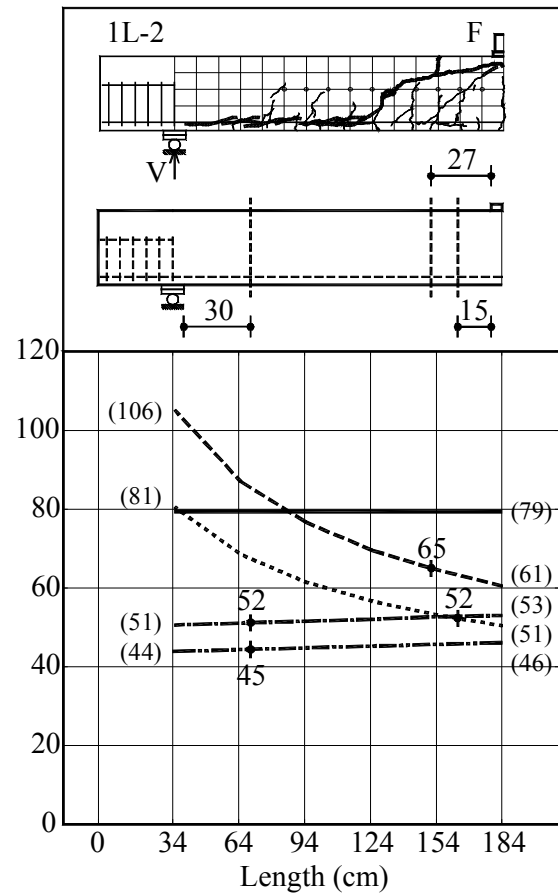


Figure C.1L2.1– Shear strength of test 1L-2

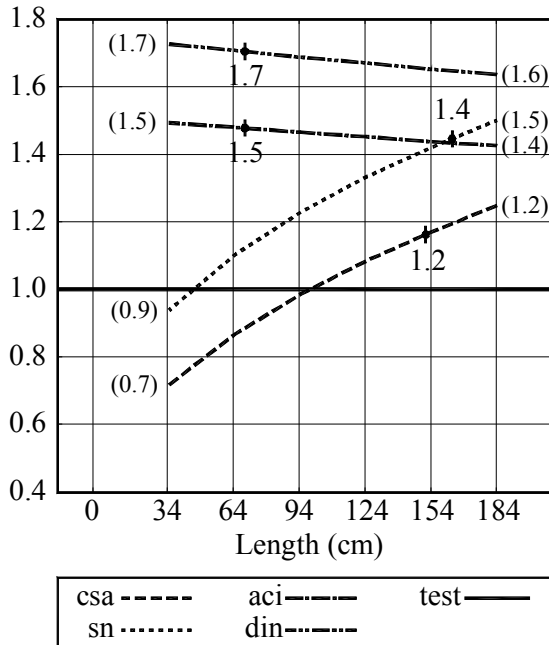
 V_{test}/V_{design} 

Figure C.1L1.2– Safety level of test 1L-1

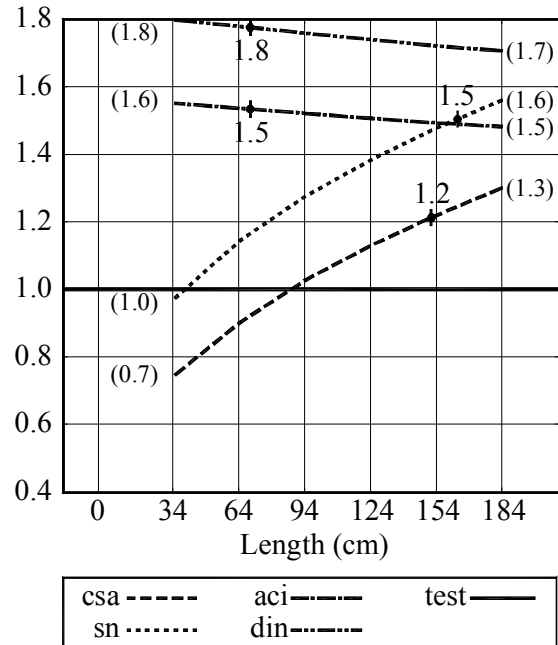
 V_{test}/V_{design} 

Figure C.1L2.2– Safety level of test 1L-2

Shear Strength V(kN)-without Vccd

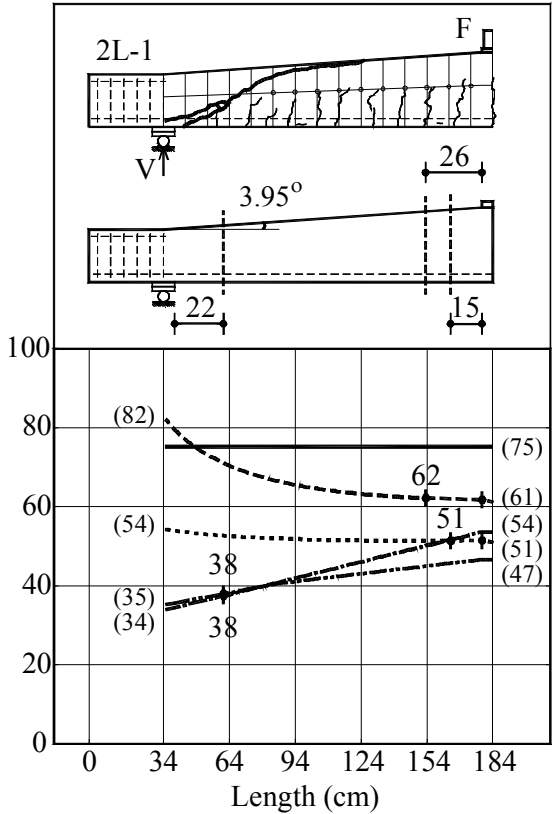


Figure C.2L1.1– Shear strength of test 2L-1

Shear Strength V(kN)-with Vccd

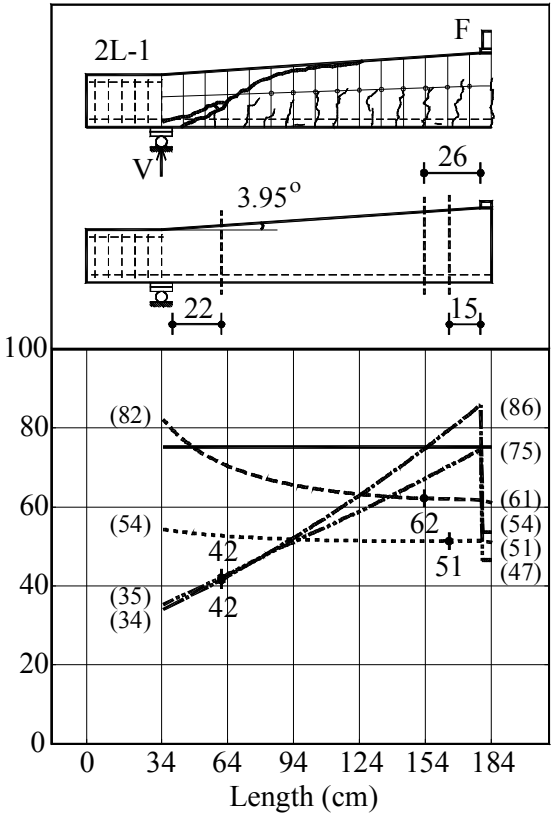


Figure C.2L1.2– Shear strength of test 2L-1

V_{test}/V_{design} -without Vccd

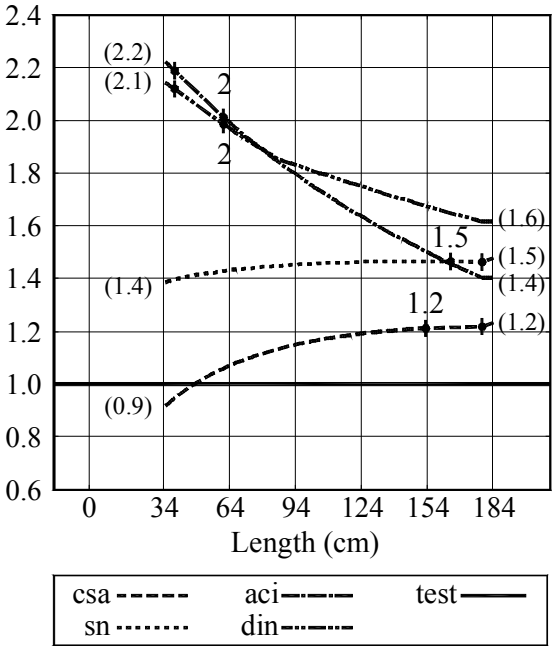


Figure C.2L1.3– Safety level of test 2L-1

V_{test}/V_{design} -with Vccd

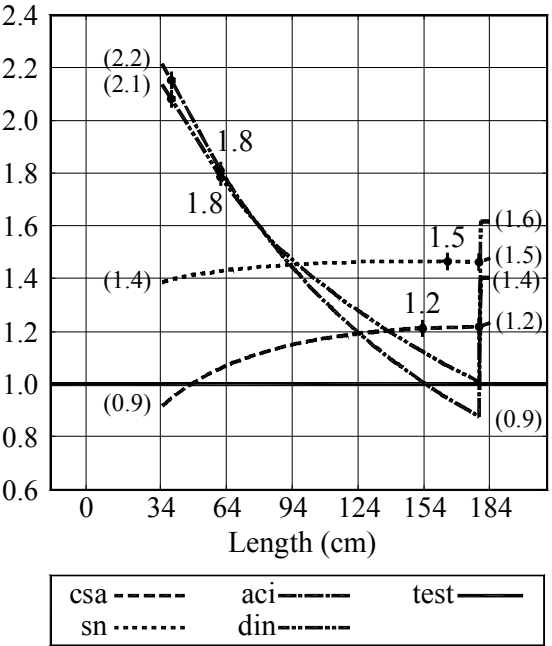


Figure C.2L1.4– Safety level of test 2L-1

Shear Strength V(kN)-without V_{cd}

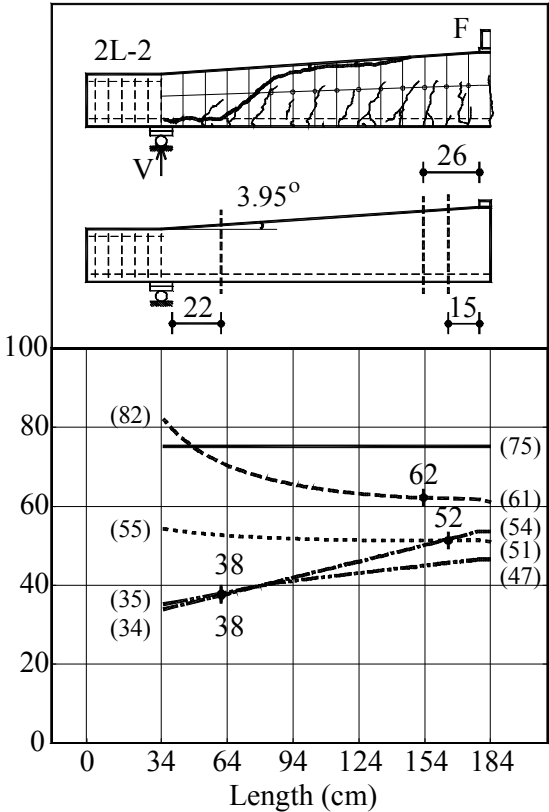


Figure C.2L2.1– Shear strength of test 2L–2

Shear Strength V(kN)-with V_{cd}

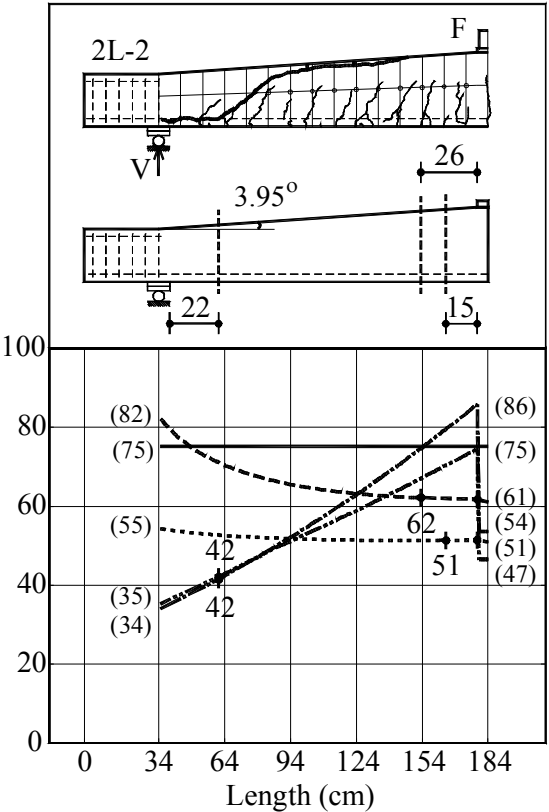


Figure C.2L2.2– Shear strength of test 2L–2

V_{test}/V_{design}-without V_{cd}

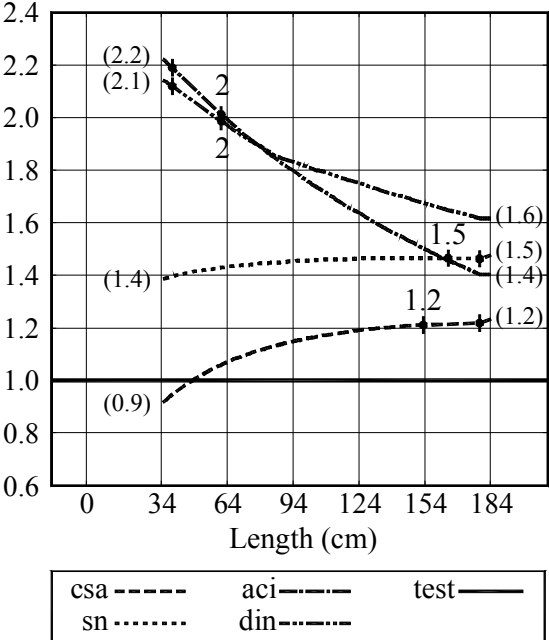


Figure C.2L2.3– Safety level of test 2L–2

V_{test}/V_{design}-with V_{cd}

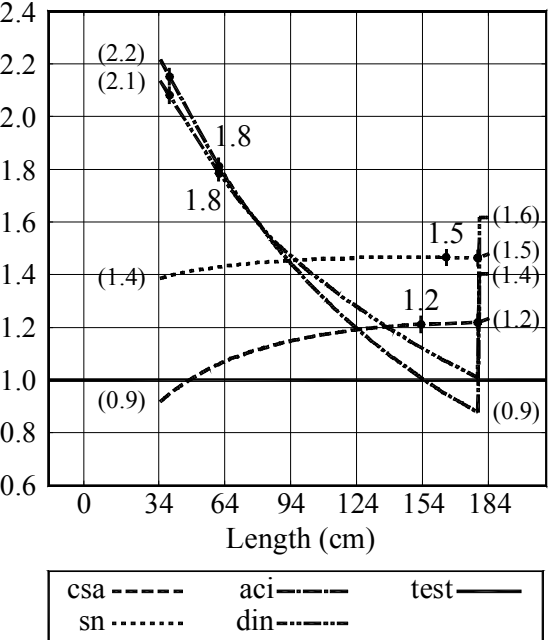


Figure C.2L2.4– Safety level of test 2L–2

Shear Strength V(kN)-without V_{ccd}

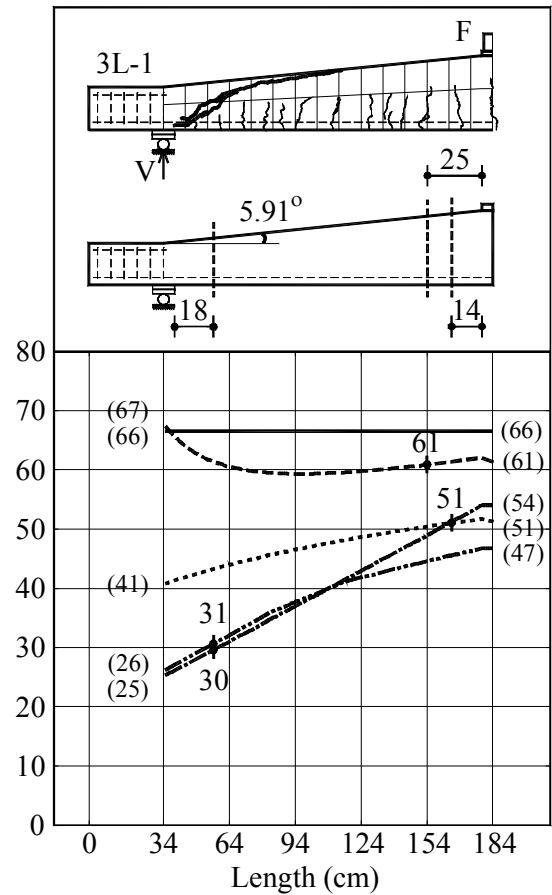


Figure C.3L1.1– Shear strength of test 3L-1

Shear Strength V(kN)-with V_{ccd}

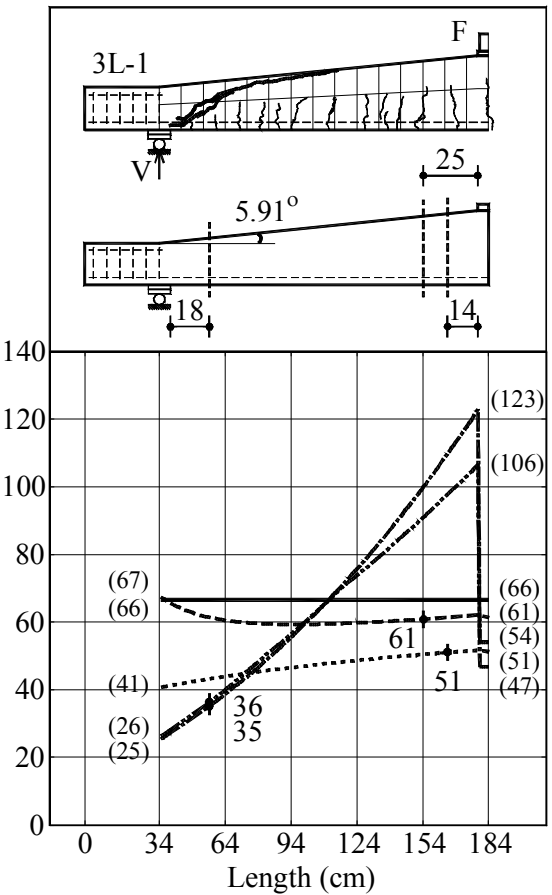


Figure C.3L1.2– Shear strength of test 3L-1

V_{test}/V_{design}-without V_{ccd}

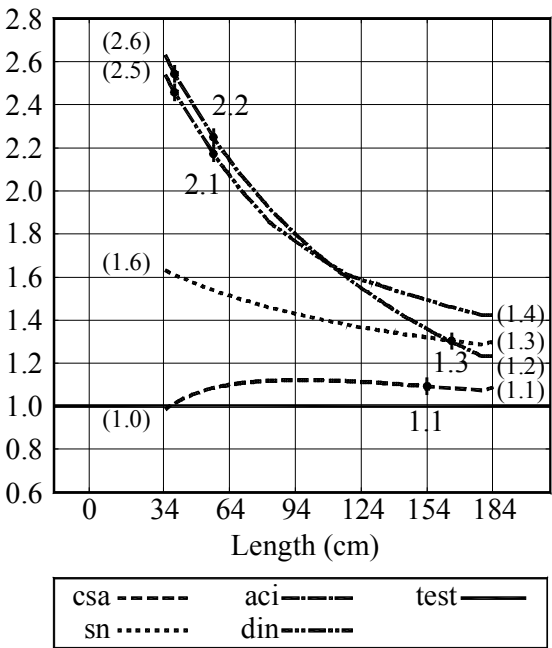


Figure C.3L1.3– Safety level of test 3L-1

V_{test}/V_{design}-with V_{ccd}

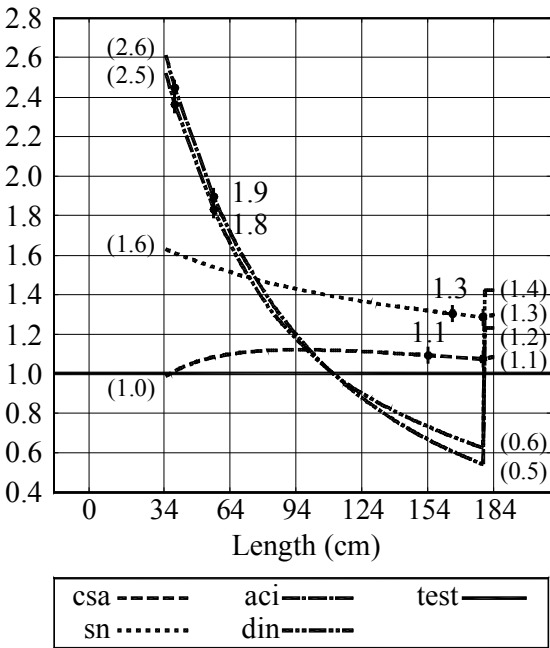


Figure C.3L1.4– Safety level of test 3L-1

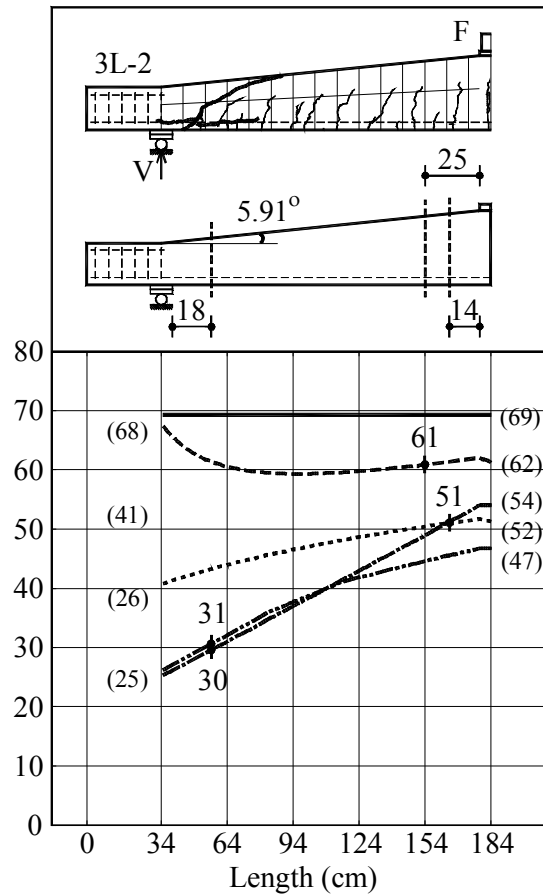
Shear Strength V(kN)-without V_ccd

Figure C.3L2.1– Shear strength of test 3L-2

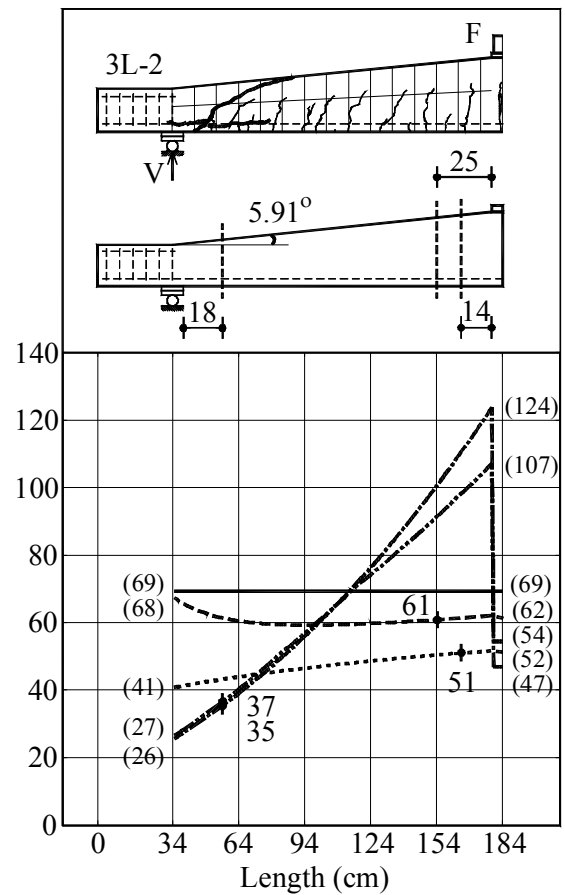
Shear Strength V(kN)-with V_ccd

Figure C.3L2.2– Shear strength of test 3L-2

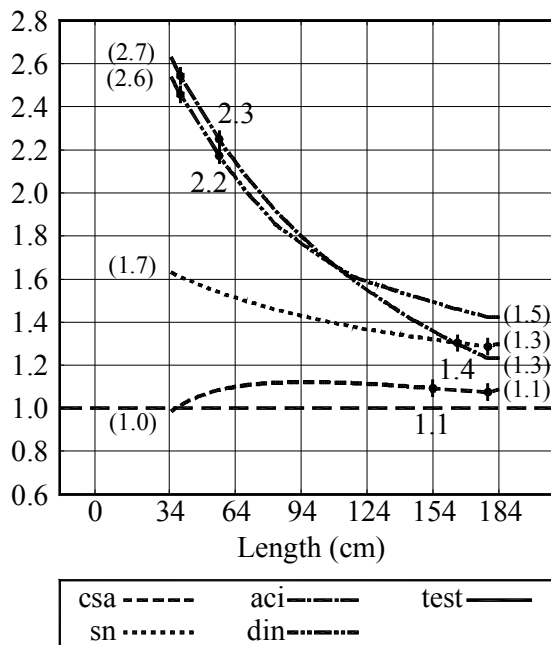
 V_{test}/V_{design} -without V_ccd

Figure C.3L2.3– Safety level of test 3L-2

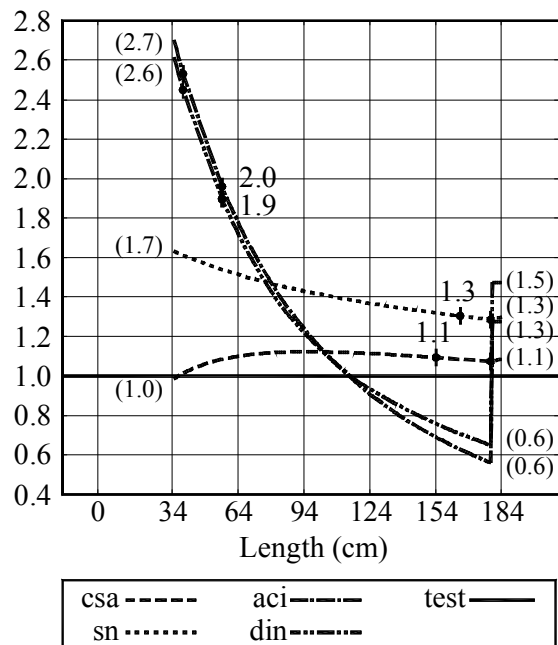
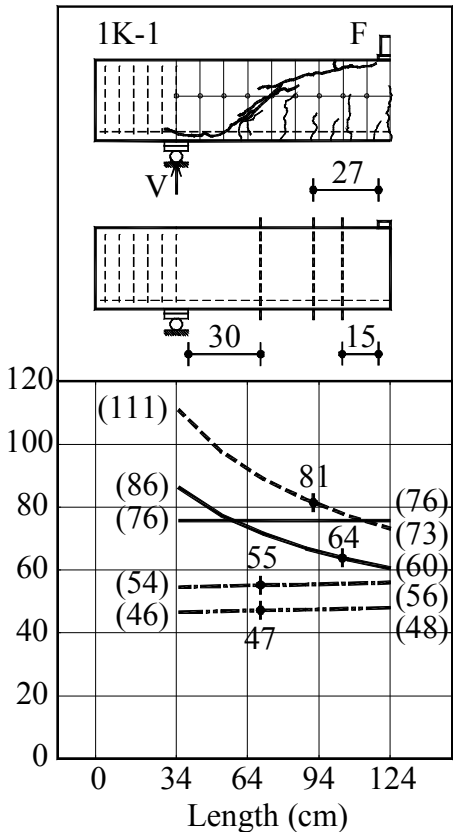
 V_{test}/V_{design} -with V_ccd

Figure C.3L2.4– Safety level of test 3L-2

Shear Strength V(kN)



Shear Strength V(kN)

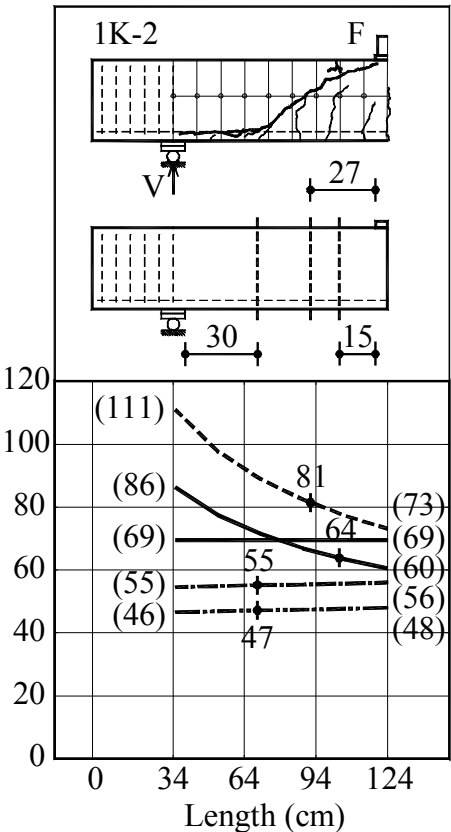


Figure C.1K1.1– Shear strength of test 1K–1 Figure C.1K2.1– Shear strength of test 1K–2

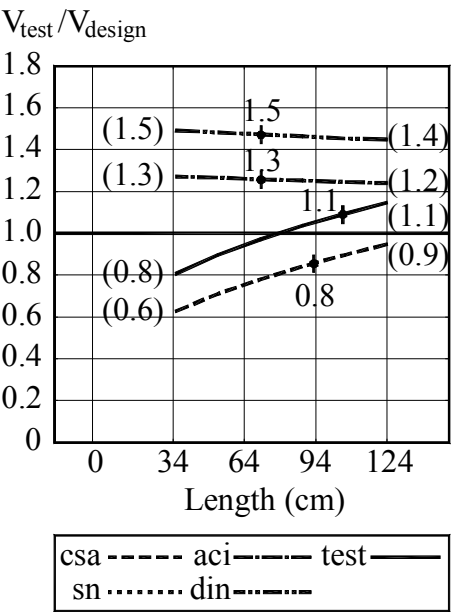
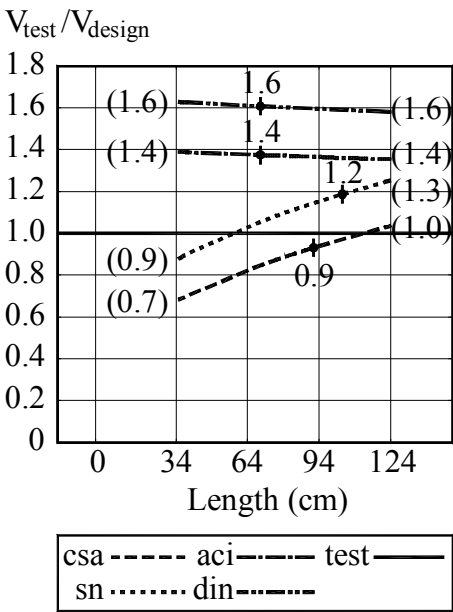


Figure C.1K1.2– Safety level of test 1K–1 Figure C.1K2.2– Safety level of test 1K–2

Shear Strength V(kN)-without V_{ccd}

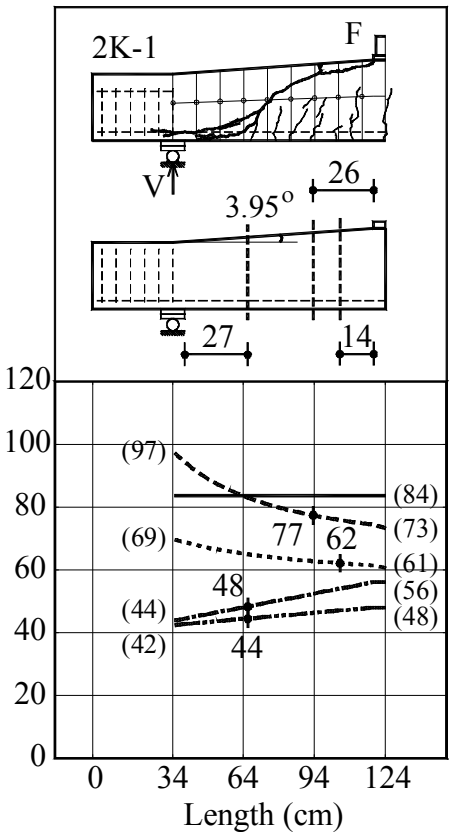


Figure C.2K1.1– Shear strength of test 2K-1

Shear Strength V(kN)-with V_{ccd}

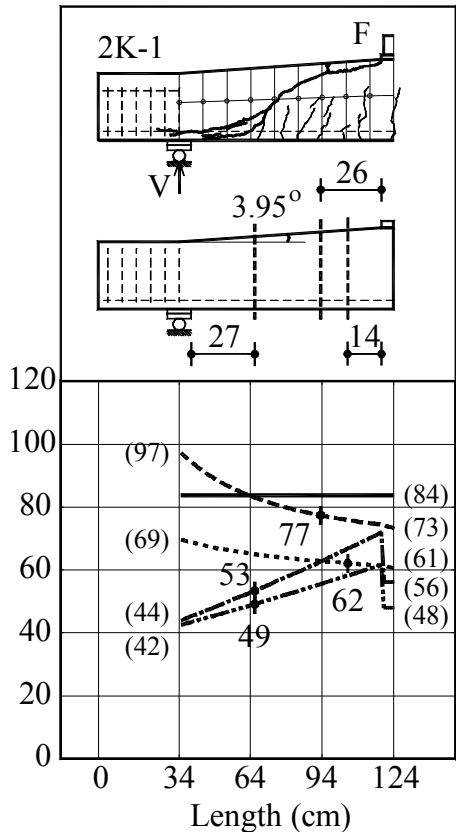


Figure C.2K1.2– Shear strength of test 2K-1

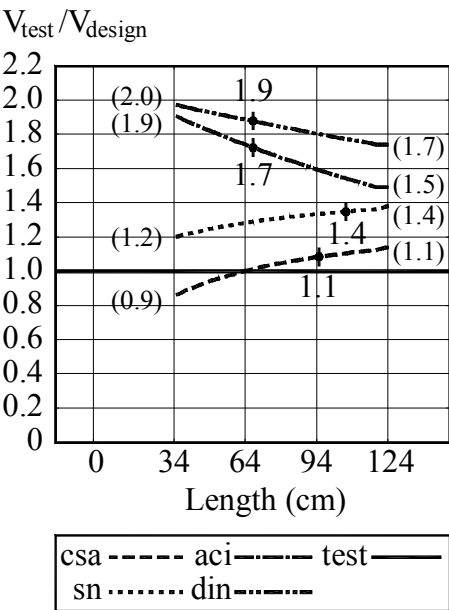


Figure C.2K1.3– Safety level of test 2K-1

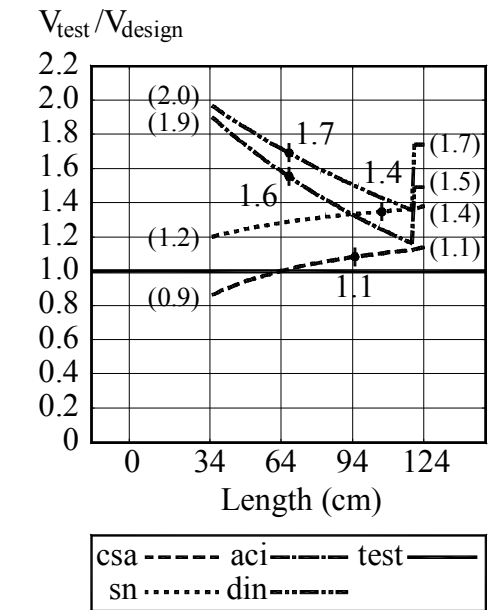


Figure C.2K1.4– Safety level of test 2K-1

Shear Strength V(kN)-without V_{ccd}

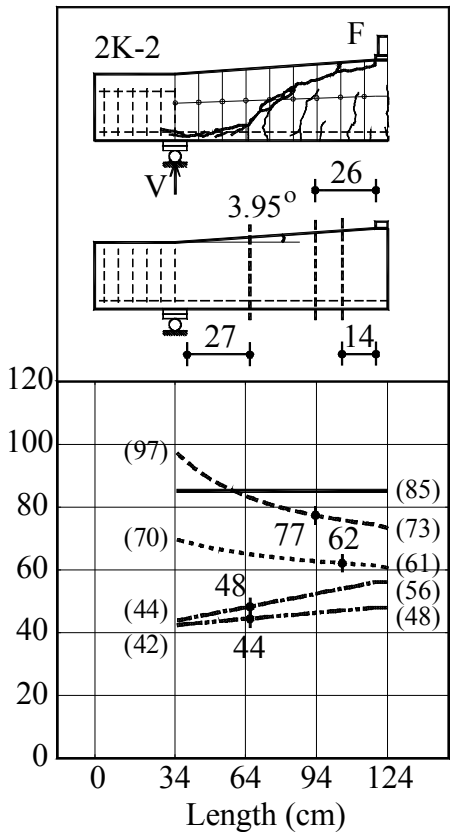


Figure C.2K2.1– Shear strength of test 2K–2

Shear Strength V(kN)-with V_{ccd}

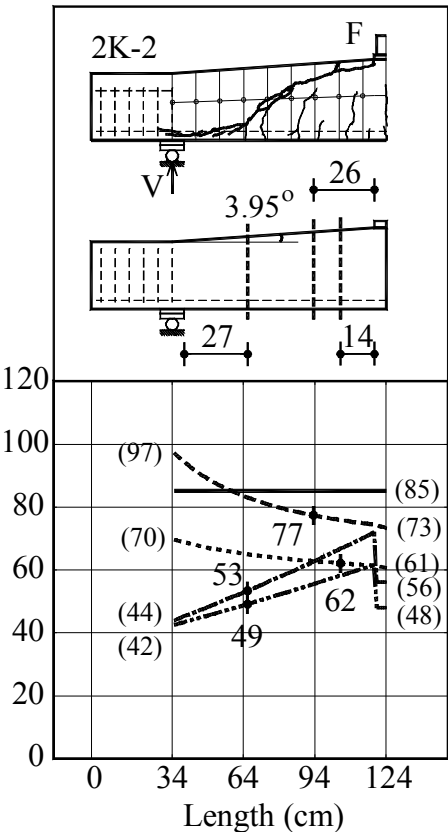


Figure C.2K2.2– Shear strength of test 2K–2

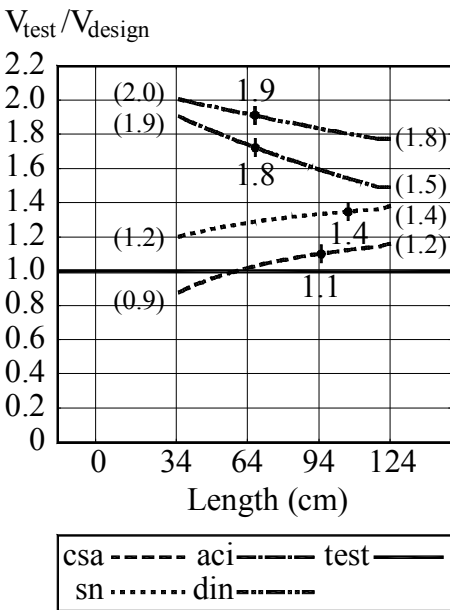


Figure C.2K2.3– Safety level of test 2K–2

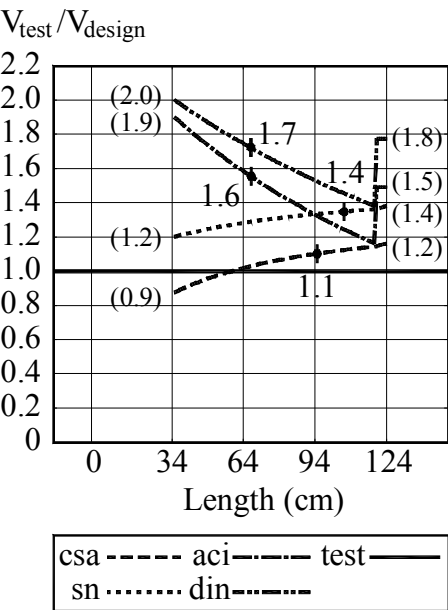
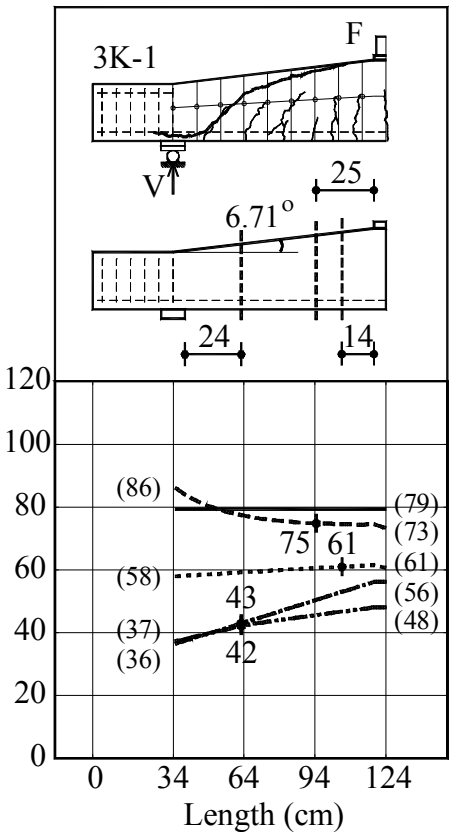


Figure C.2K2.4– Safety level of test 2K–2

Shear Strength V(kN)-without V_{ccd}



Shear Strength V(kN)-with V_{ccd}

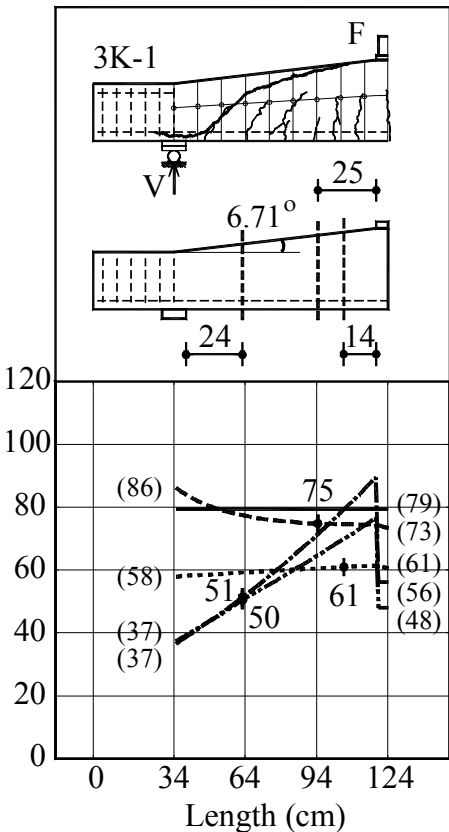


Figure C.3K1.1– Shear strength of test 3K–1 Figure C.3K1.2– Shear strength of test 3K–1

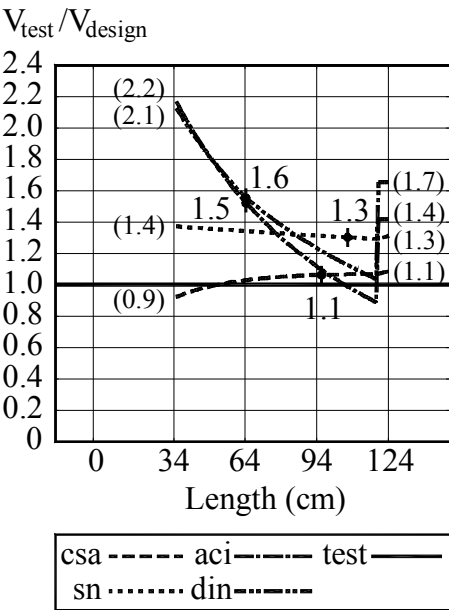
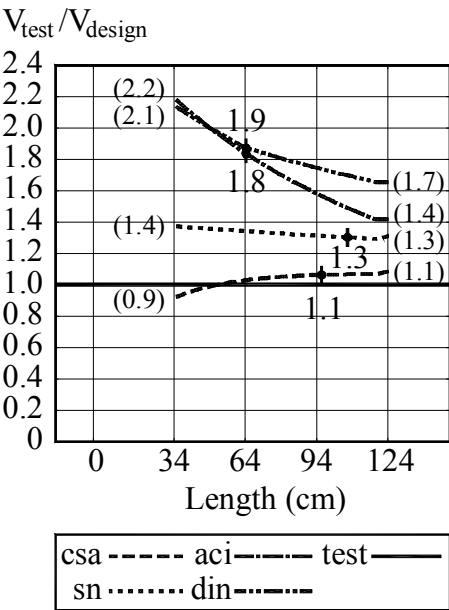
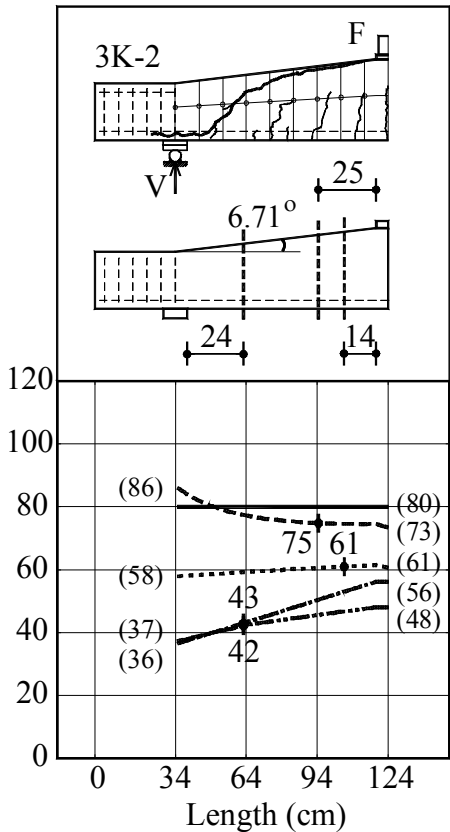


Figure C.3K1.3– Safety level of test 3K–1 Figure C.3K1.4– Safety level of test 3K–1

Shear Strength V(kN)-without Vccd



Shear Strength V(kN)-with Vccd

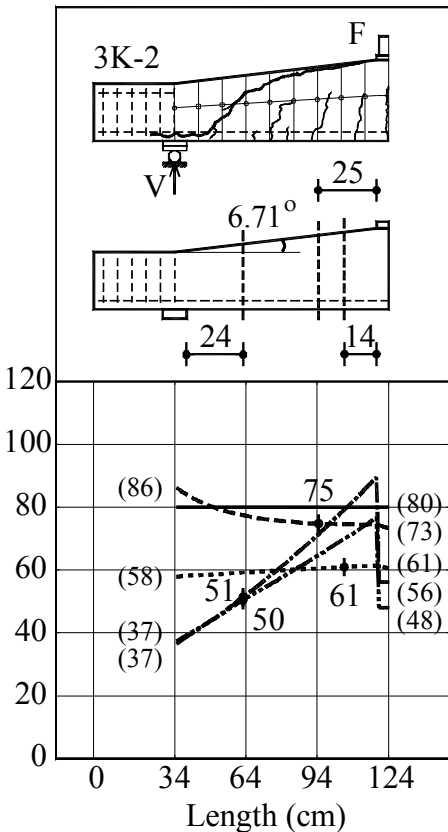


Figure C.3K2.1– Shear strength of test 3K-2

Figure C.3K2.2– Shear strength of test 3K-2

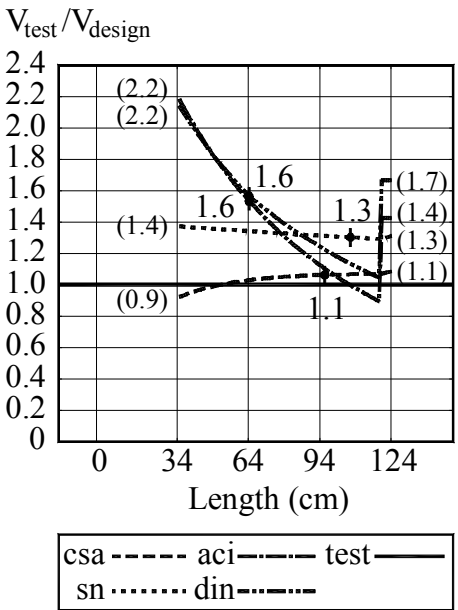
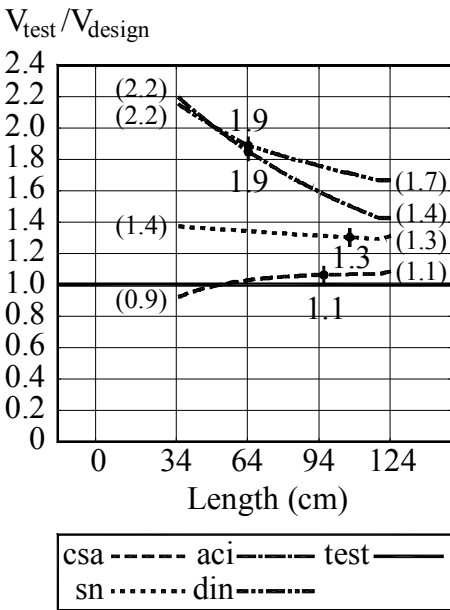


Figure C.3K2.3– Safety level of test 3K-2

Figure C.3K2.4– Safety level of test 3K-2

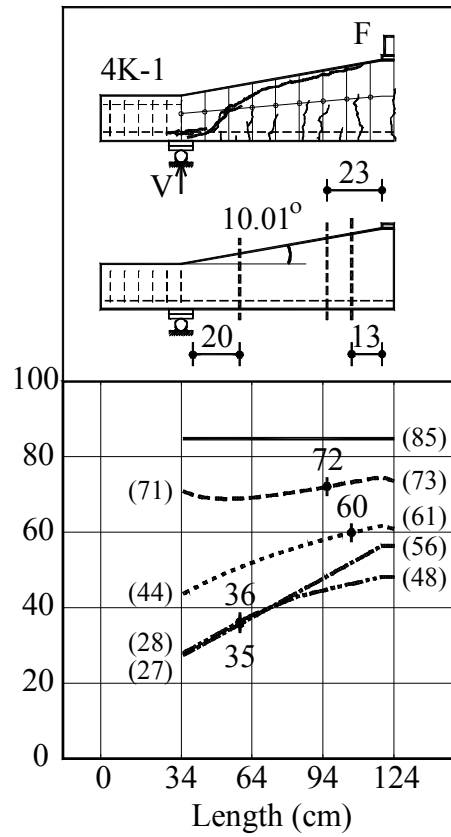
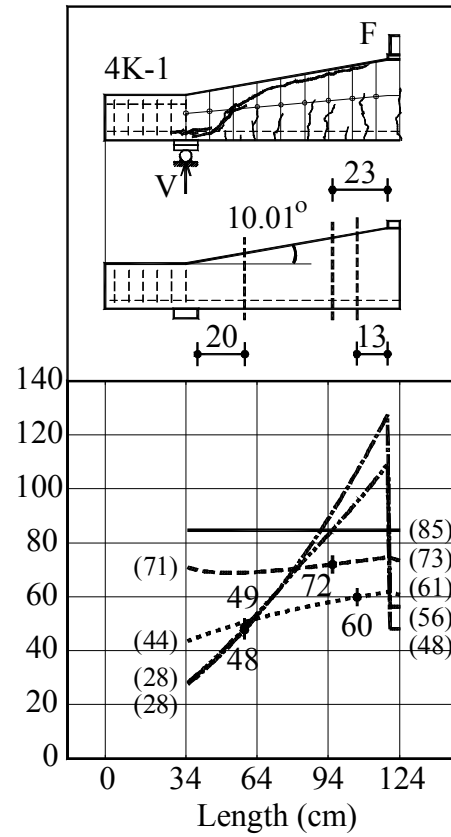
Shear Strength V(kN)-without V_{ccd}

Shear Strength V(kN)-with V_{ccd}


Figure C.4K1.1– Shear strength of test 4K–1

Figure C.4K1.2– Shear strength of test 4K–1

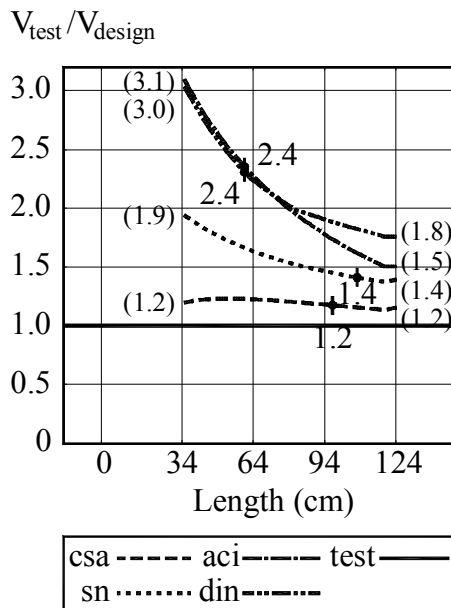


Figure C.4K1.3– Safety level of test 4K–1

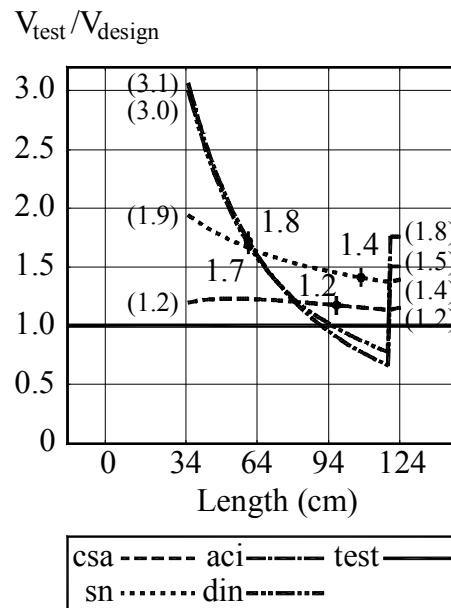
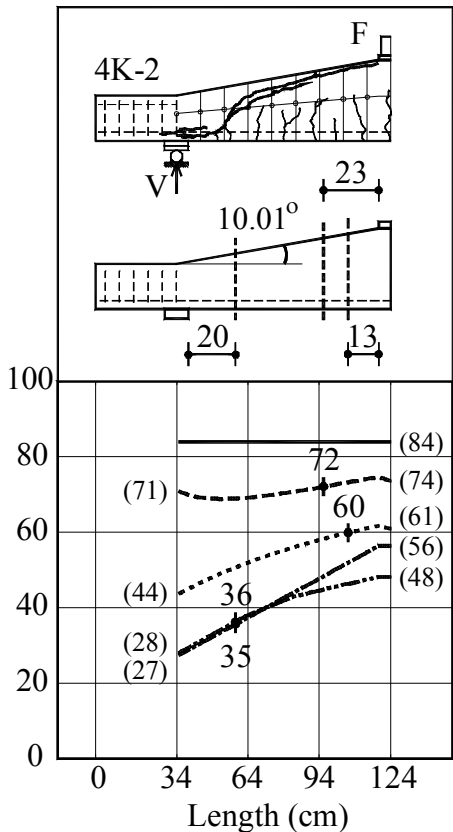


Figure C.4K1.4– Safety level of test 4K–1

Shear Strength V(kN)-without V_{ccd}



Shear Strength V(kN)-with V_{ccd}

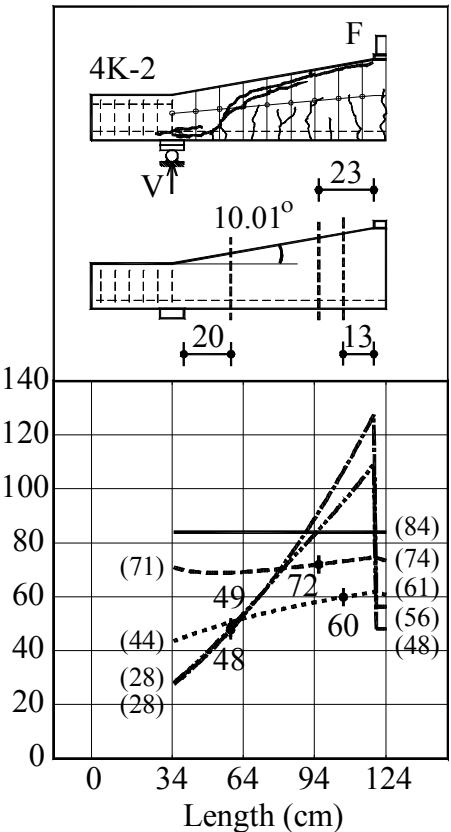


Figure C.4K2.1– Shear strength of test 4K-2 Figure C.4K2.2– Shear strength of test 4K-2

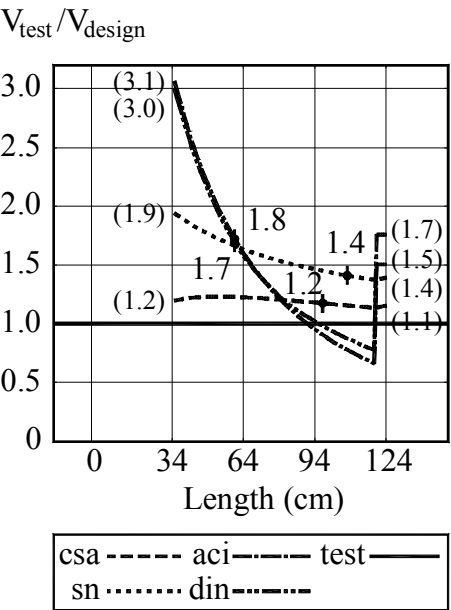
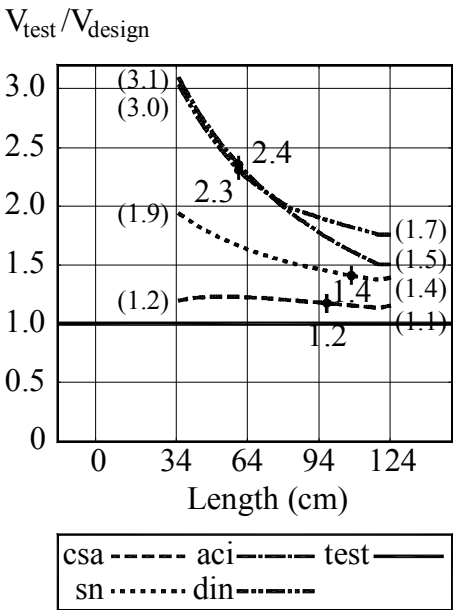


Figure C.4K2.3– Safety level of test 4K-2 Figure C.4K2.4– Safety level of test 4K-2

Appendix D

Test Results & Shear Strength of 13 Models

Shear Strength V(kN)

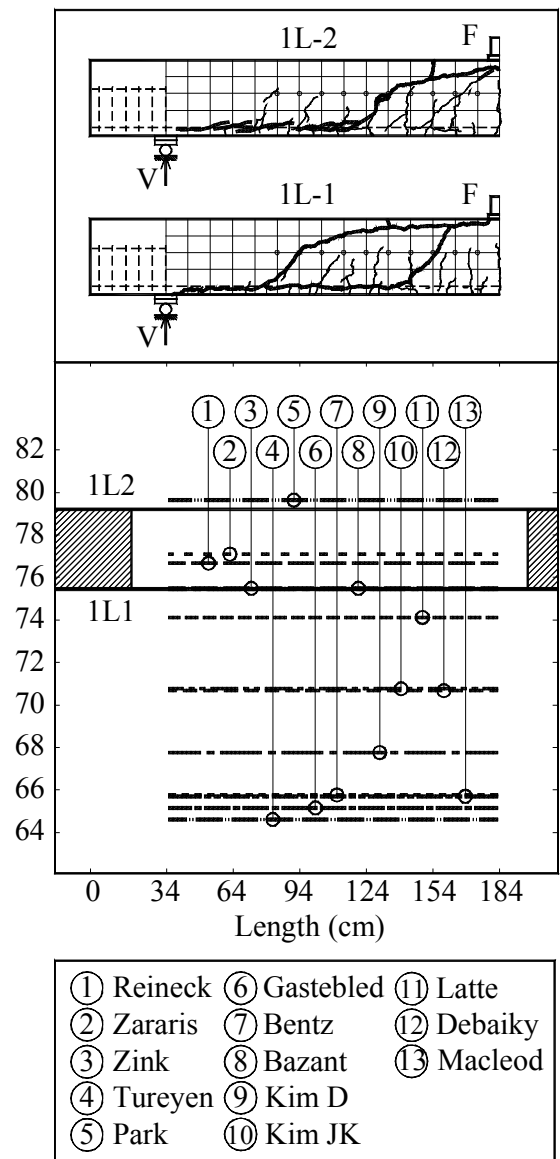


Figure D.1L.1– Shear strength comparison of test 1L

Shear Strength V(kN)

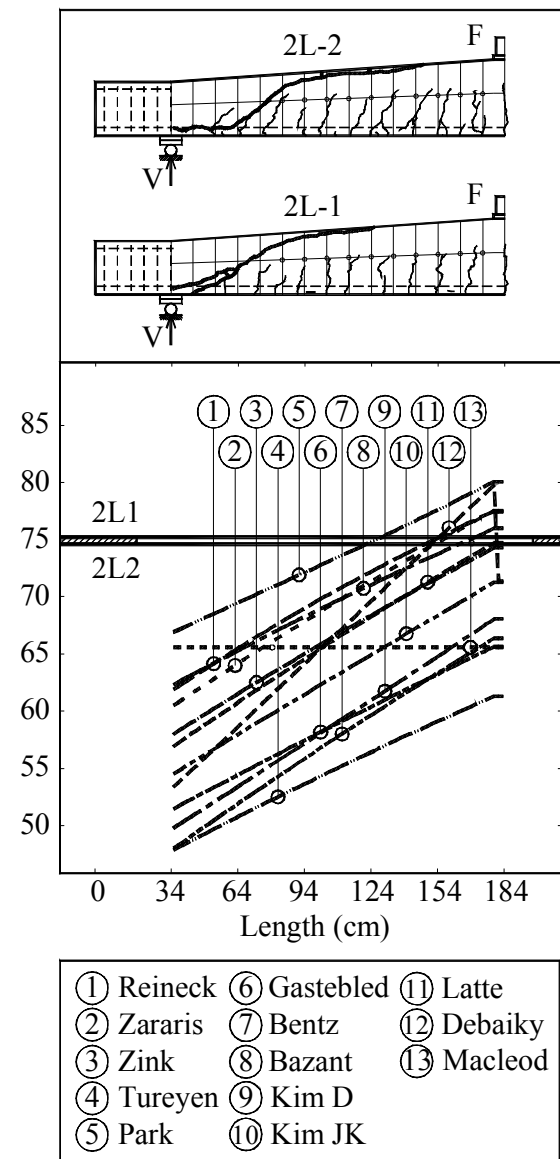


Figure D.2L.1– Shear strength comparison of test 2L

Note:

The results were calculated with average value of concrete strength.

Shear Strength V(kN)

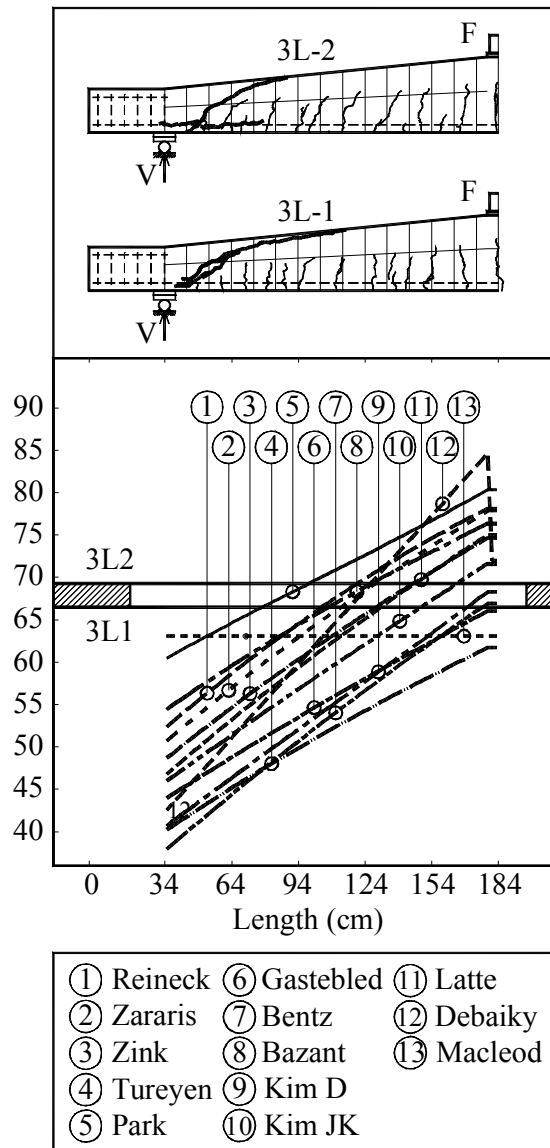


Figure D.3L.1– Shear strength comparison
of test 3L

Note:

The results were calculated with average value of concrete strength.

Shear Strength V(kN)

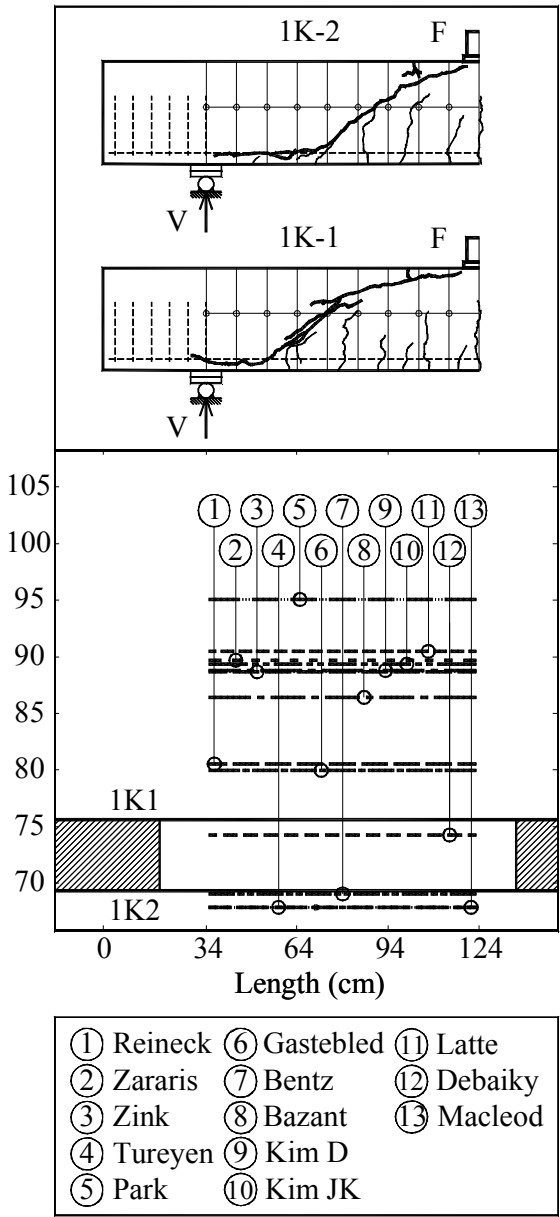


Figure D.1K.1– Shear strength comparison of test 1K

Shear Strength V(kN)

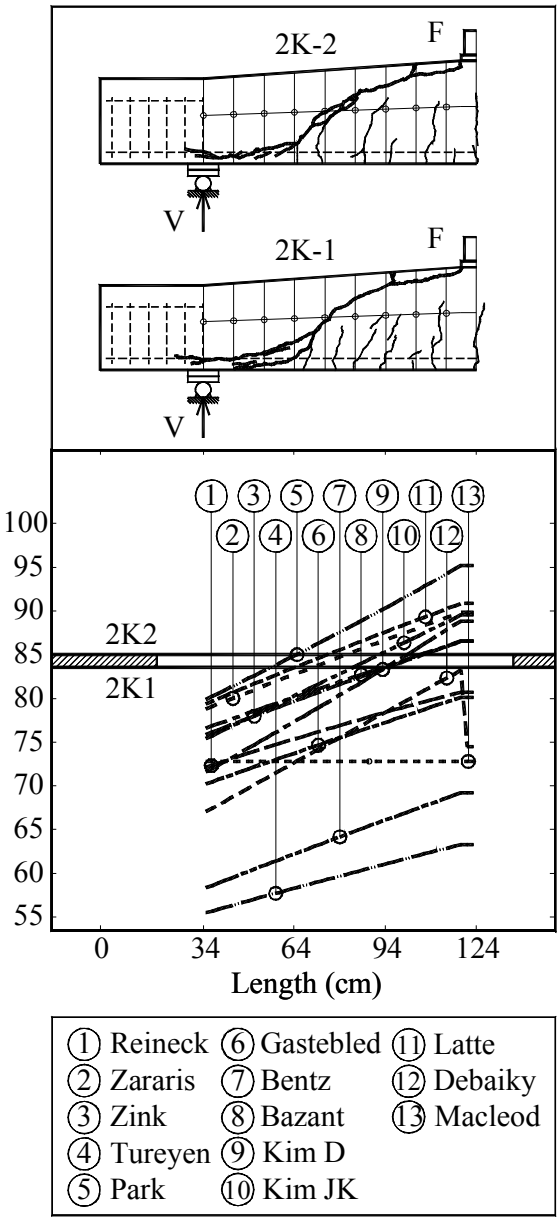


Figure D.2K.1– Shear strength comparison of test 2K

Note:

The results were calculated with average value of concrete strength.

Shear Strength V(kN)

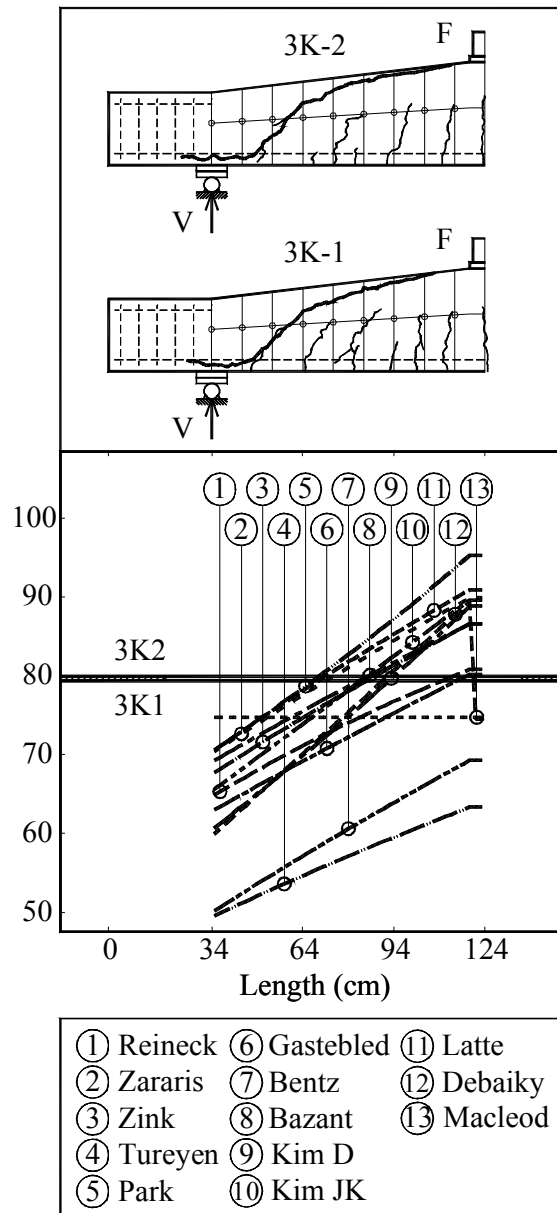


Figure D.3K.1– Shear strength comparison of test 3K

Shear Strength V(kN)

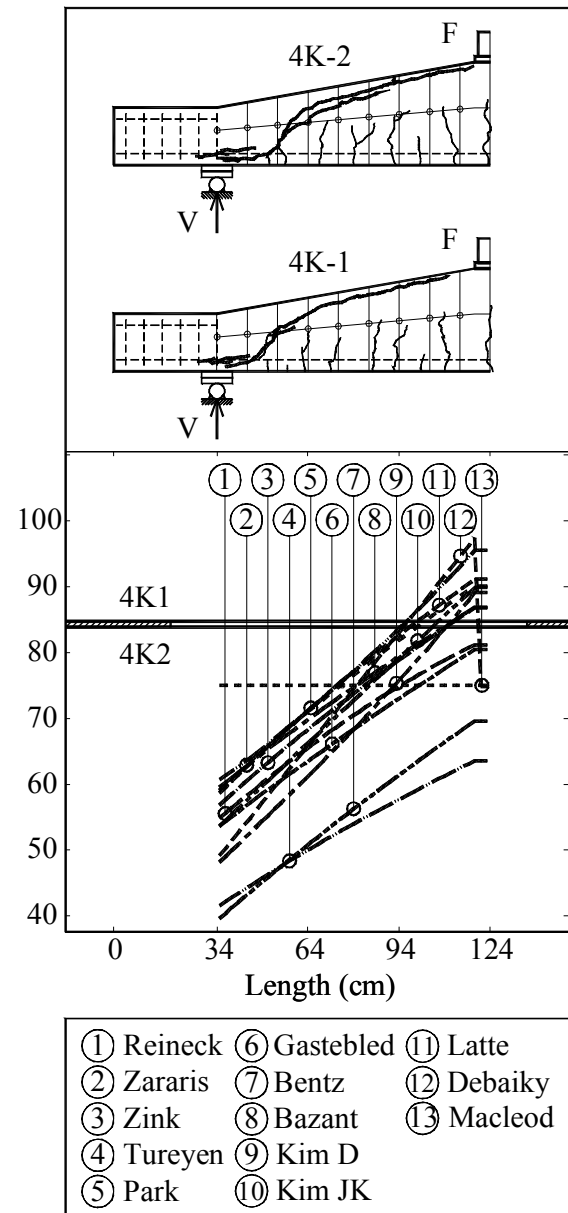


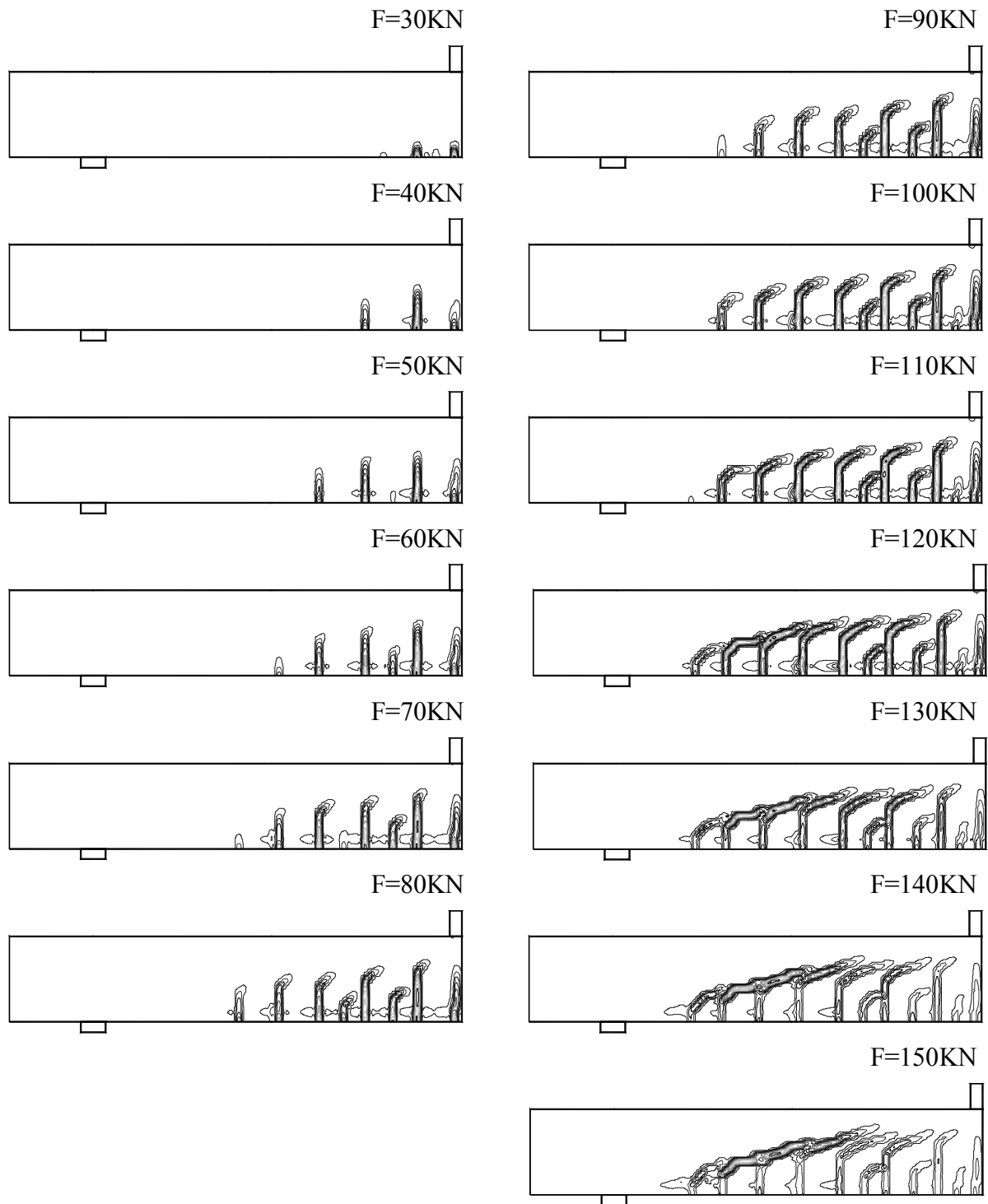
Figure D.4K.1– Shear strength comparison of test 4K

Note:

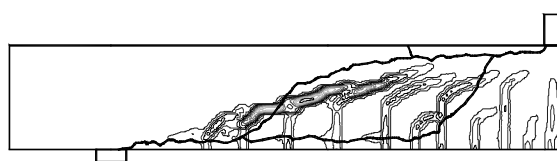
The results were calculated with average value of concrete strength.

Appendix E
**Crack Propagation of 18 Test Beams from
Non-FEM Analysis**

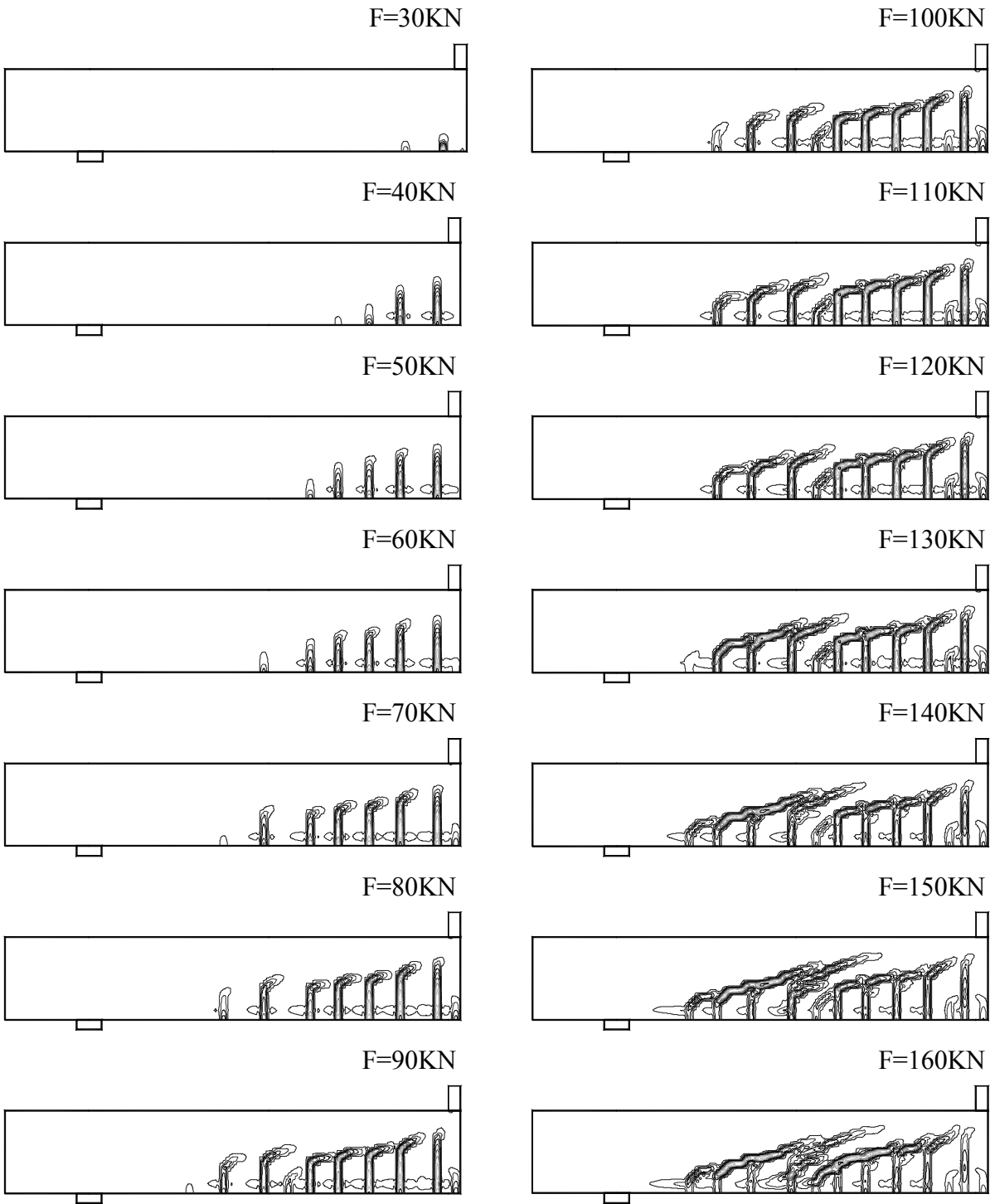
TEST 1L1



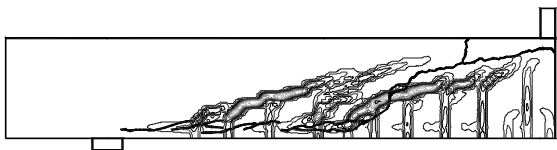
Crack pattern from Test and Abaqus



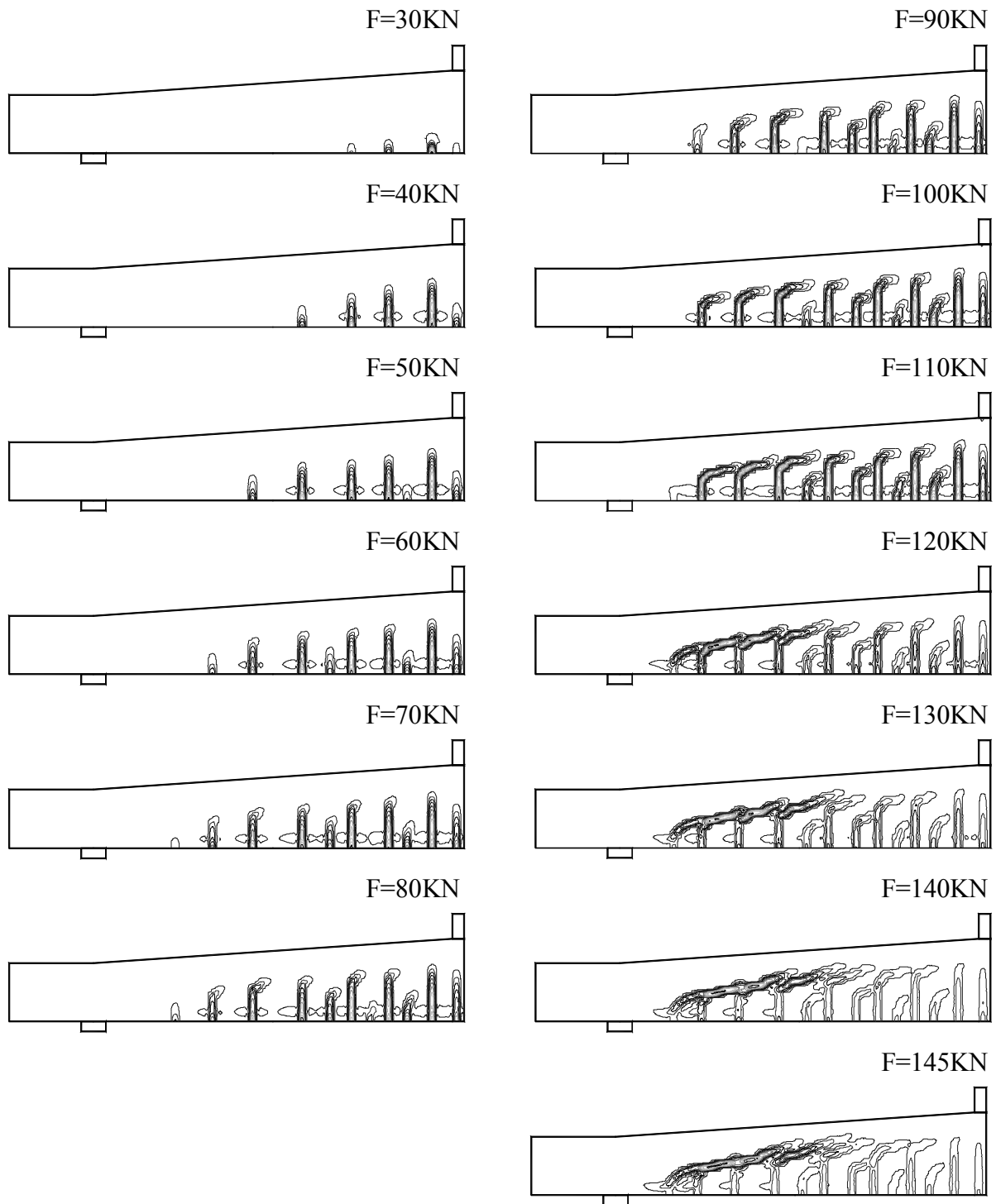
TEST 1L2



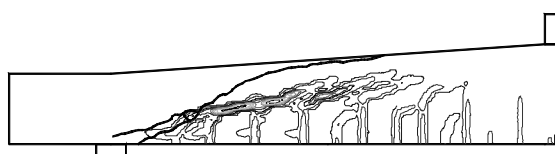
Crack pattern from Test and Abaqus



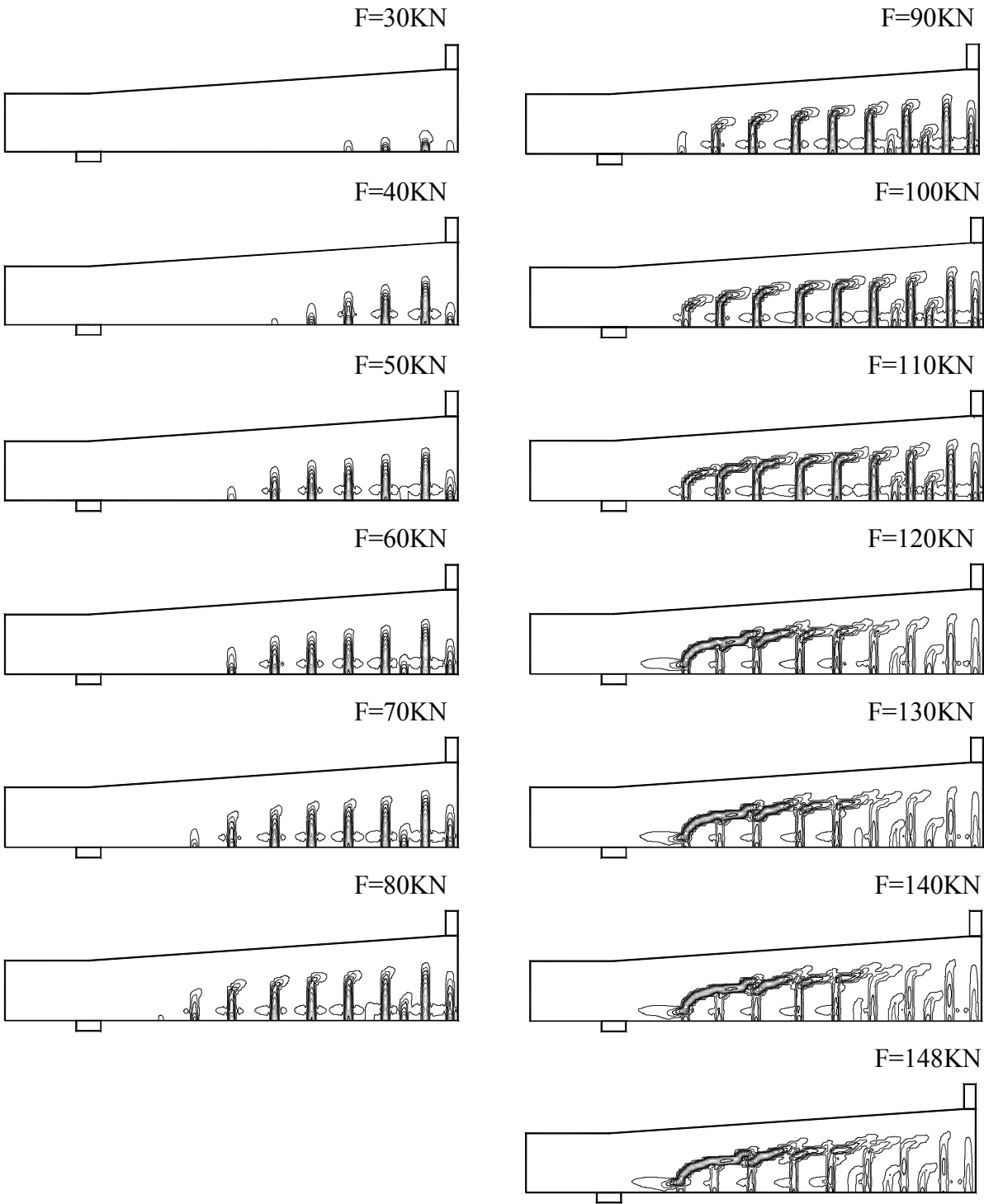
TEST 2L1



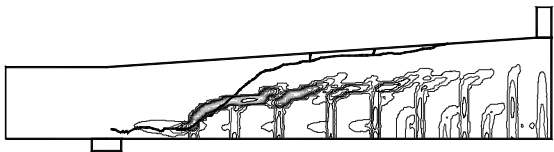
Crack pattern from Test and Abaqus



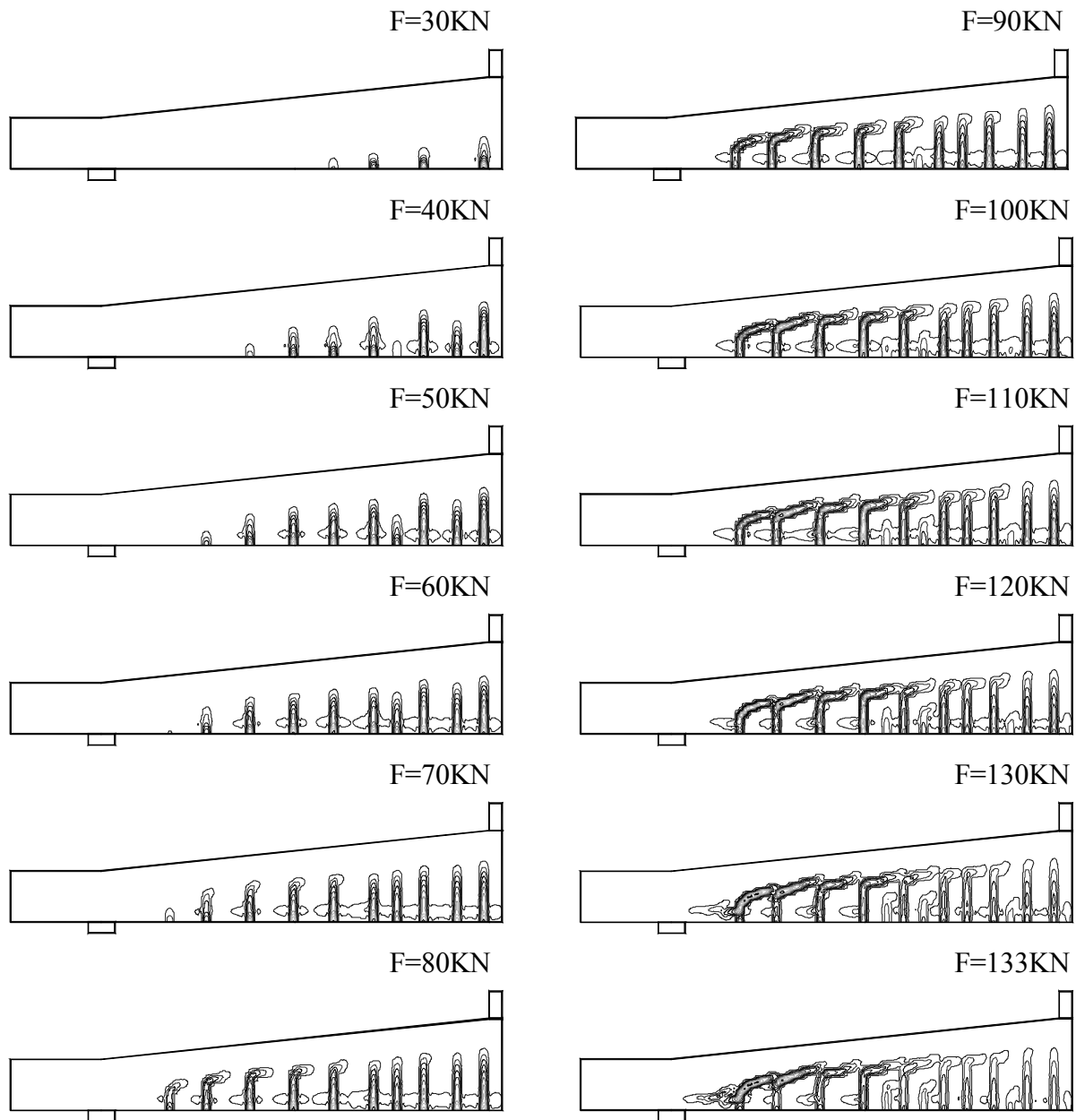
TEST 2L2



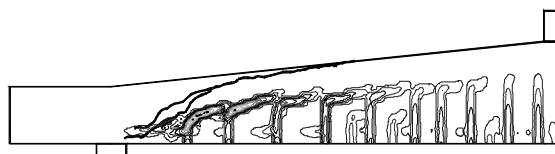
Crack pattern from Test and Abaqus



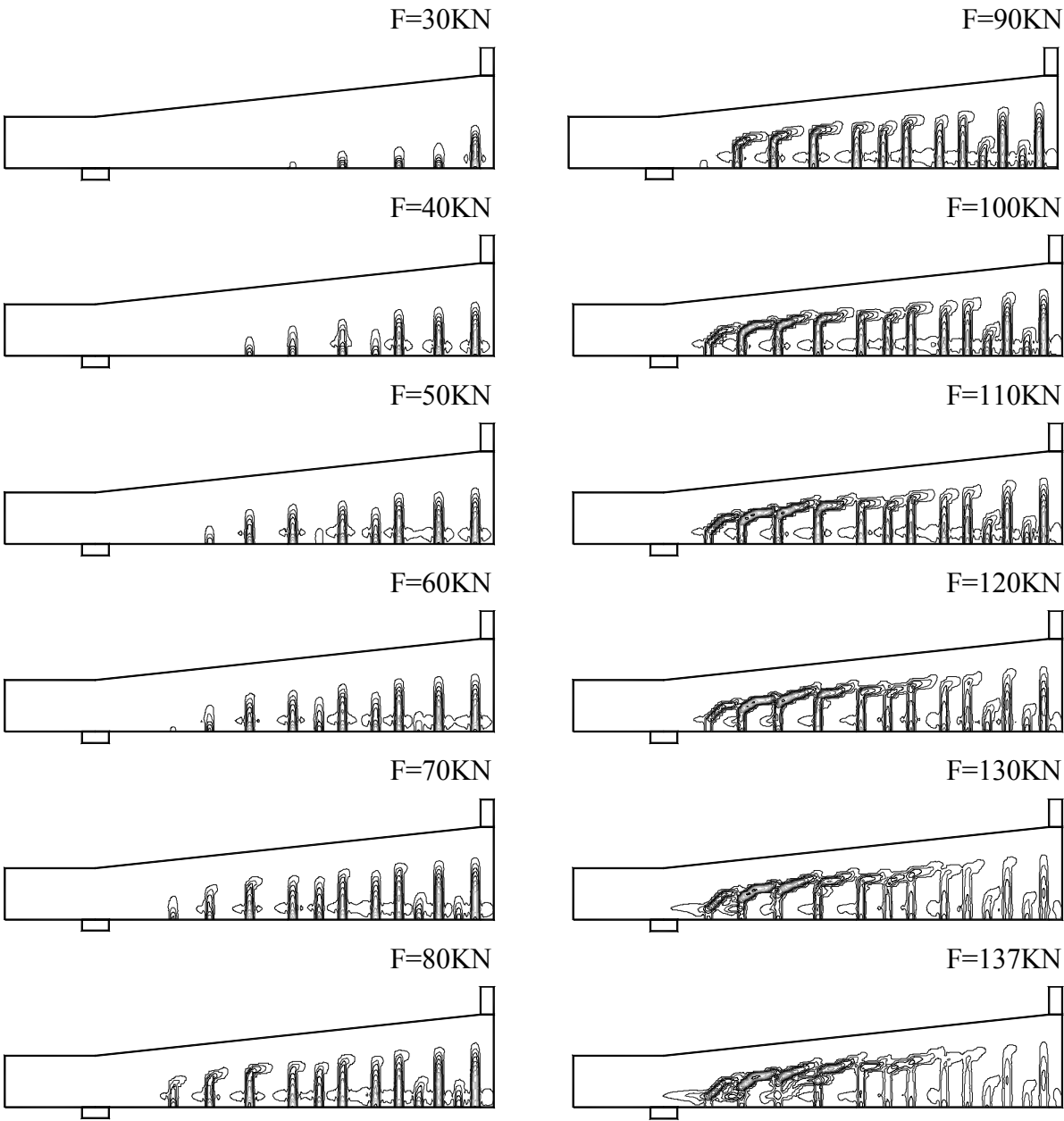
TEST 3L1



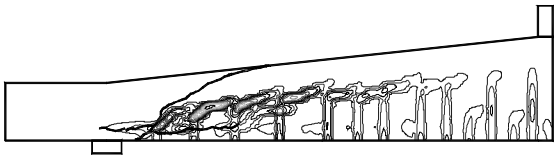
Crack pattern from Test and Abaqus



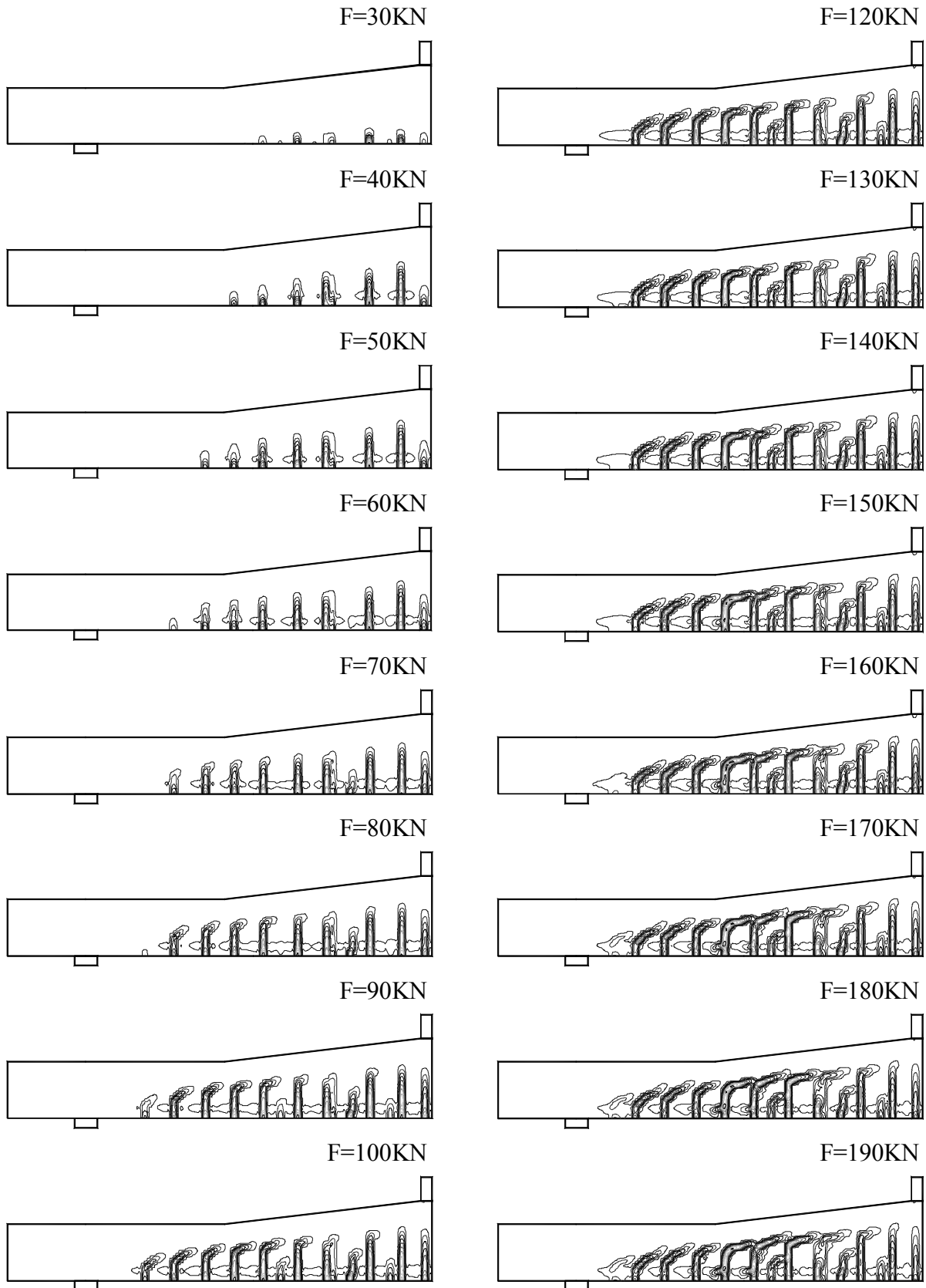
TEST 3L2

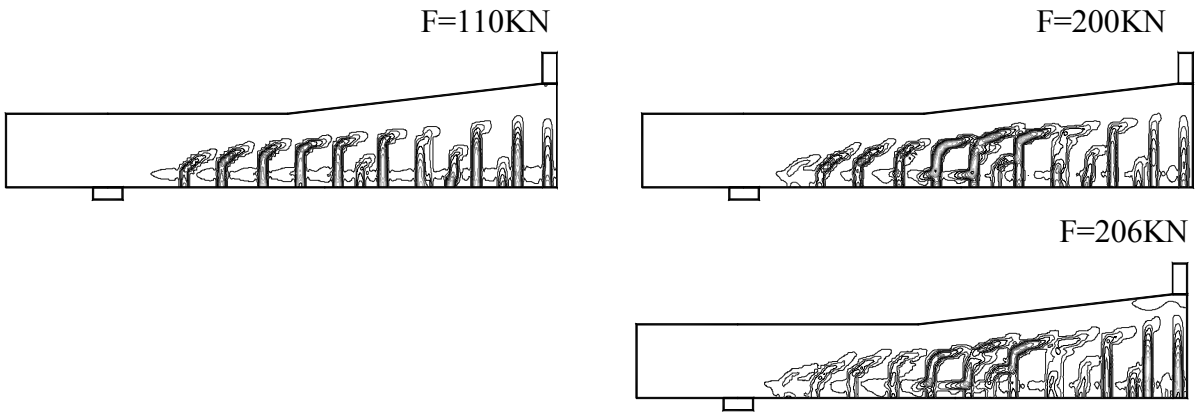


Crack pattern from Test and Abaqus

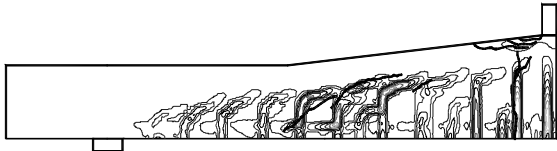


TEST 4L1

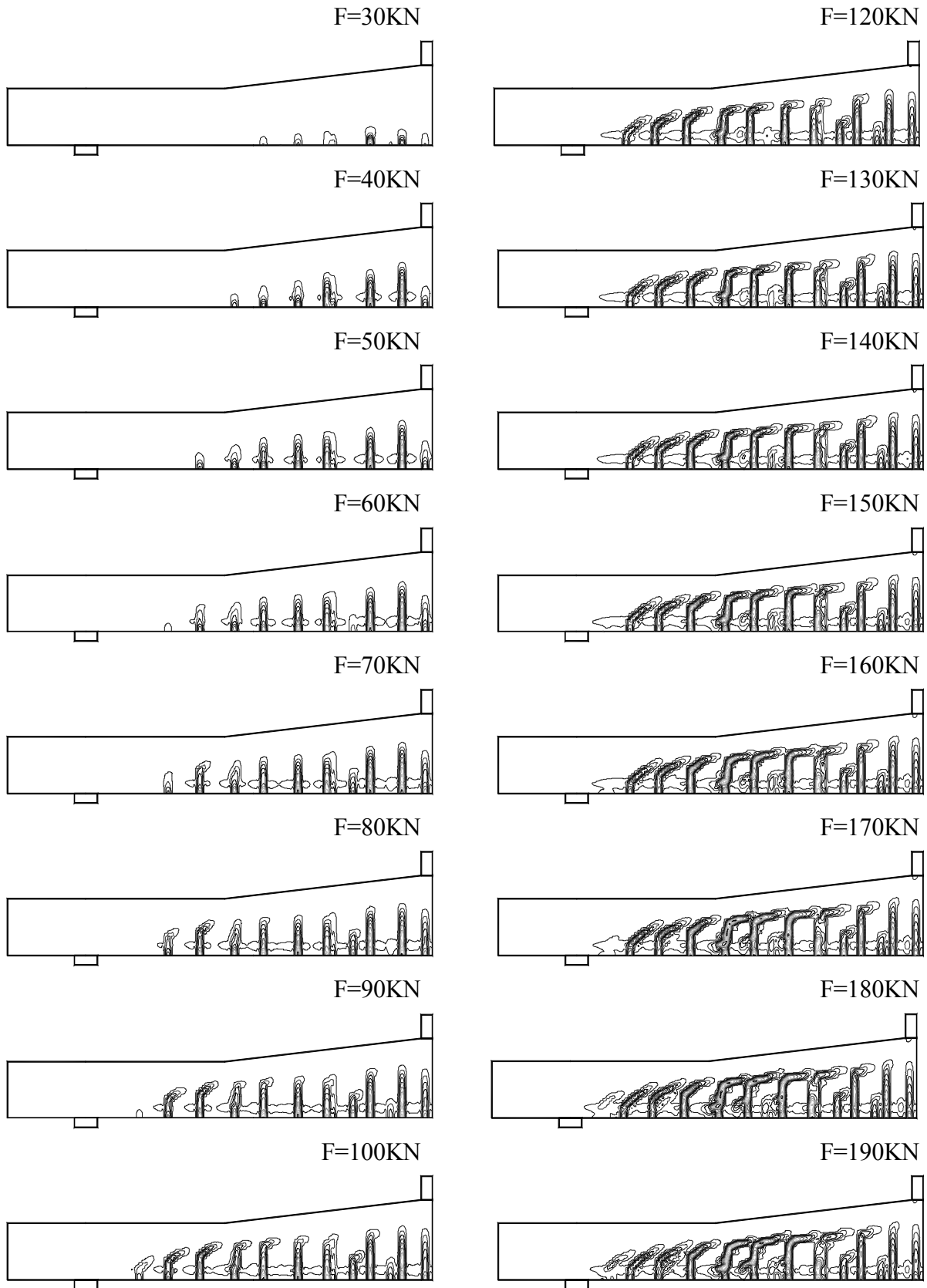


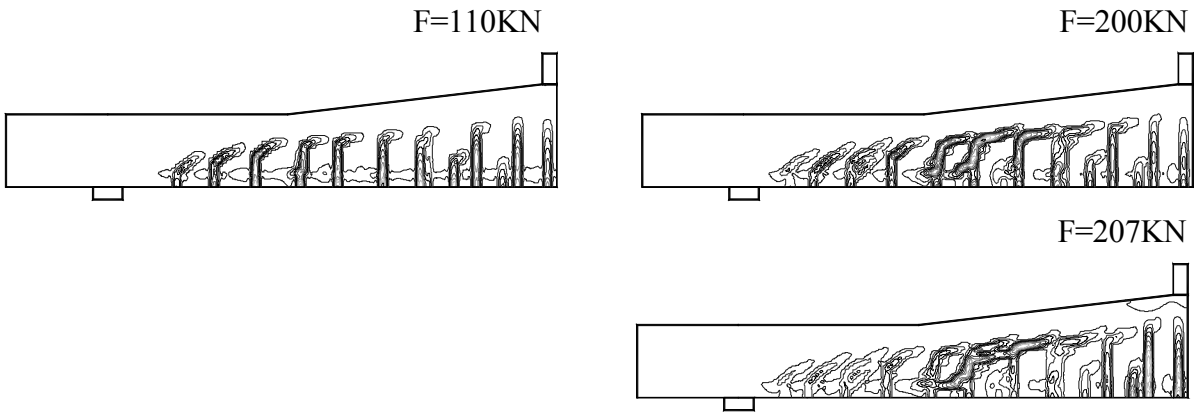


Crack pattern from Test and Abaqus

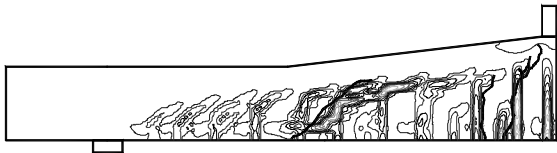


TEST 4L2

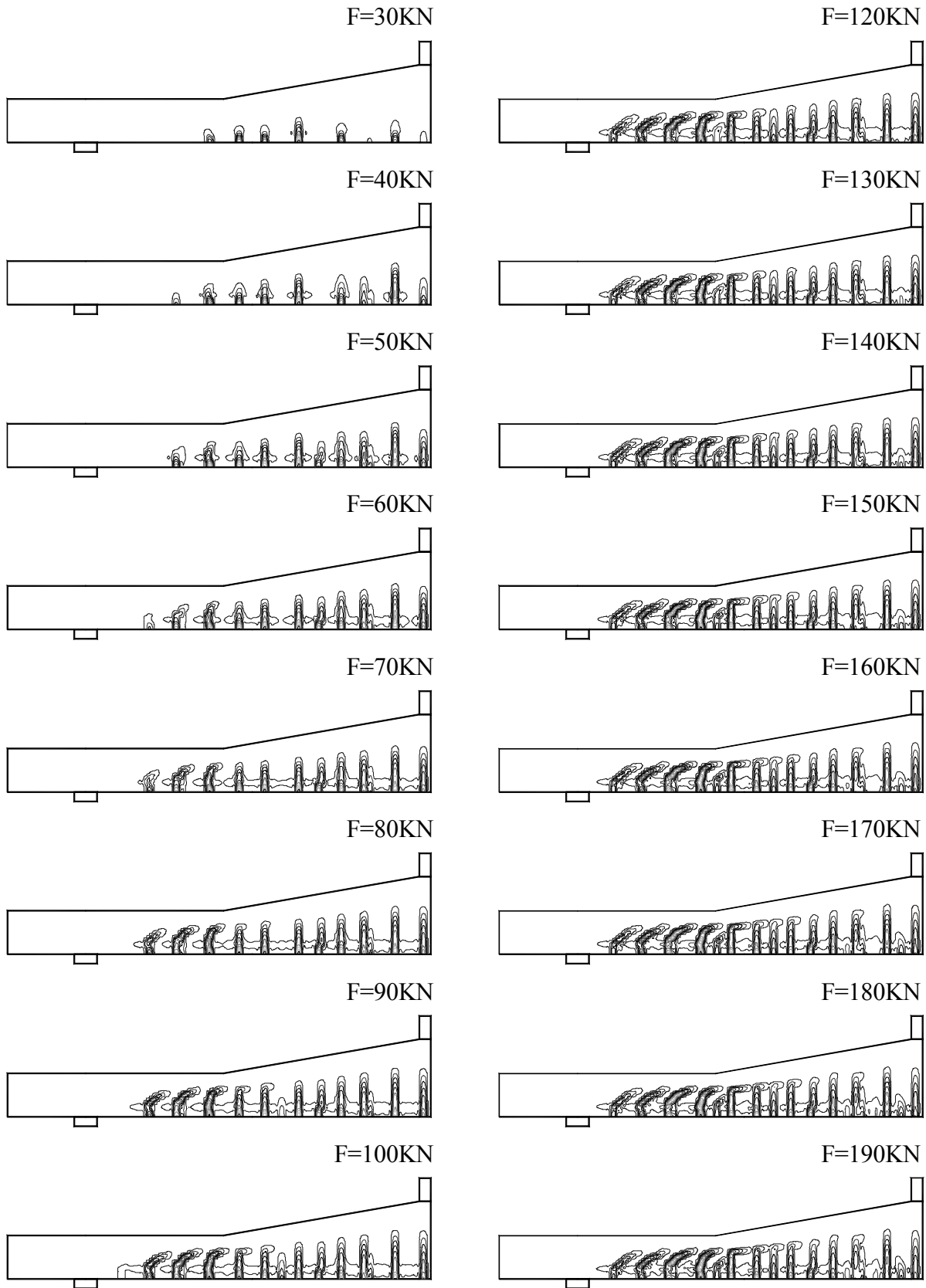


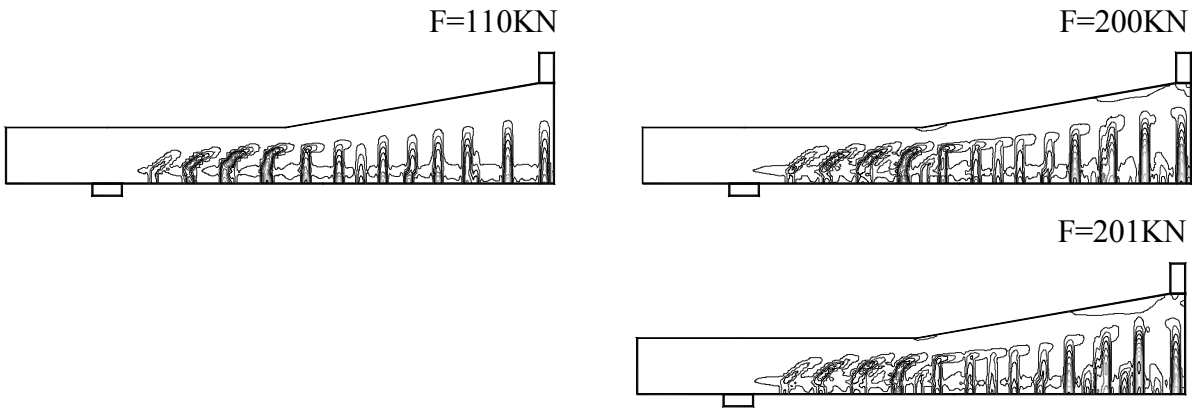


Crack pattern from Test and Abaqus

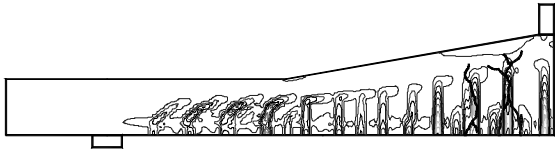


TEST 5L1

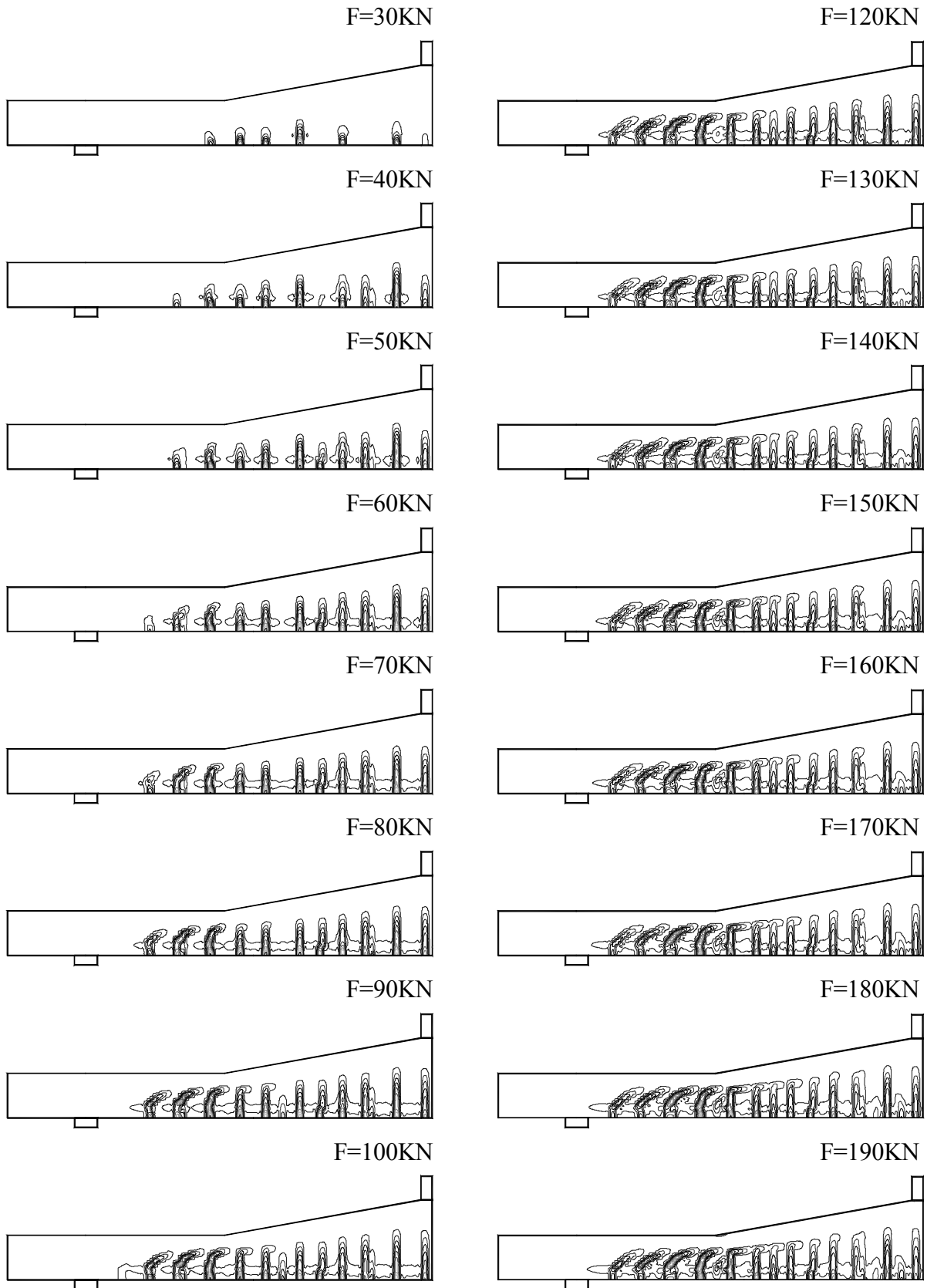


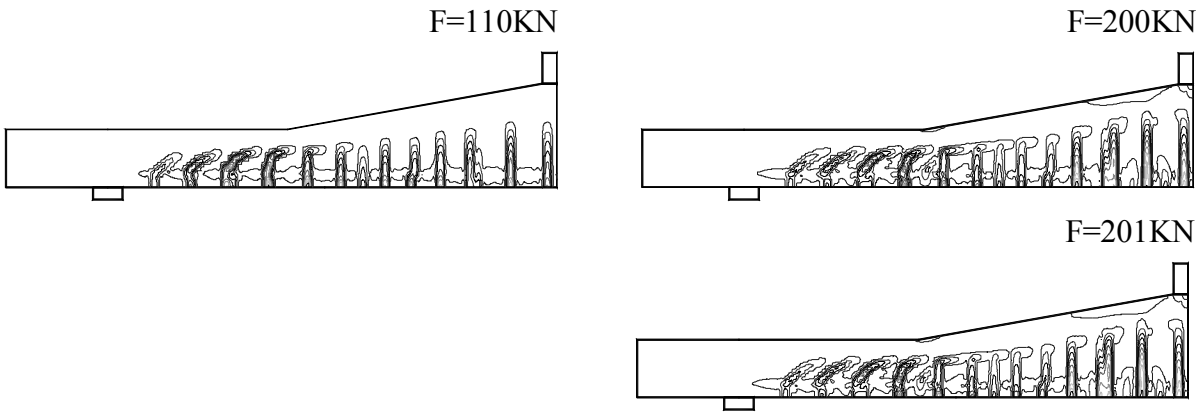


Crack pattern from Test and Abaqus

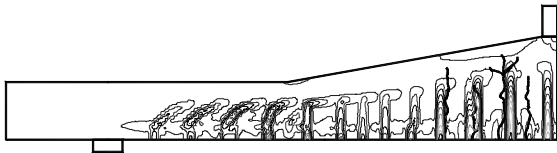


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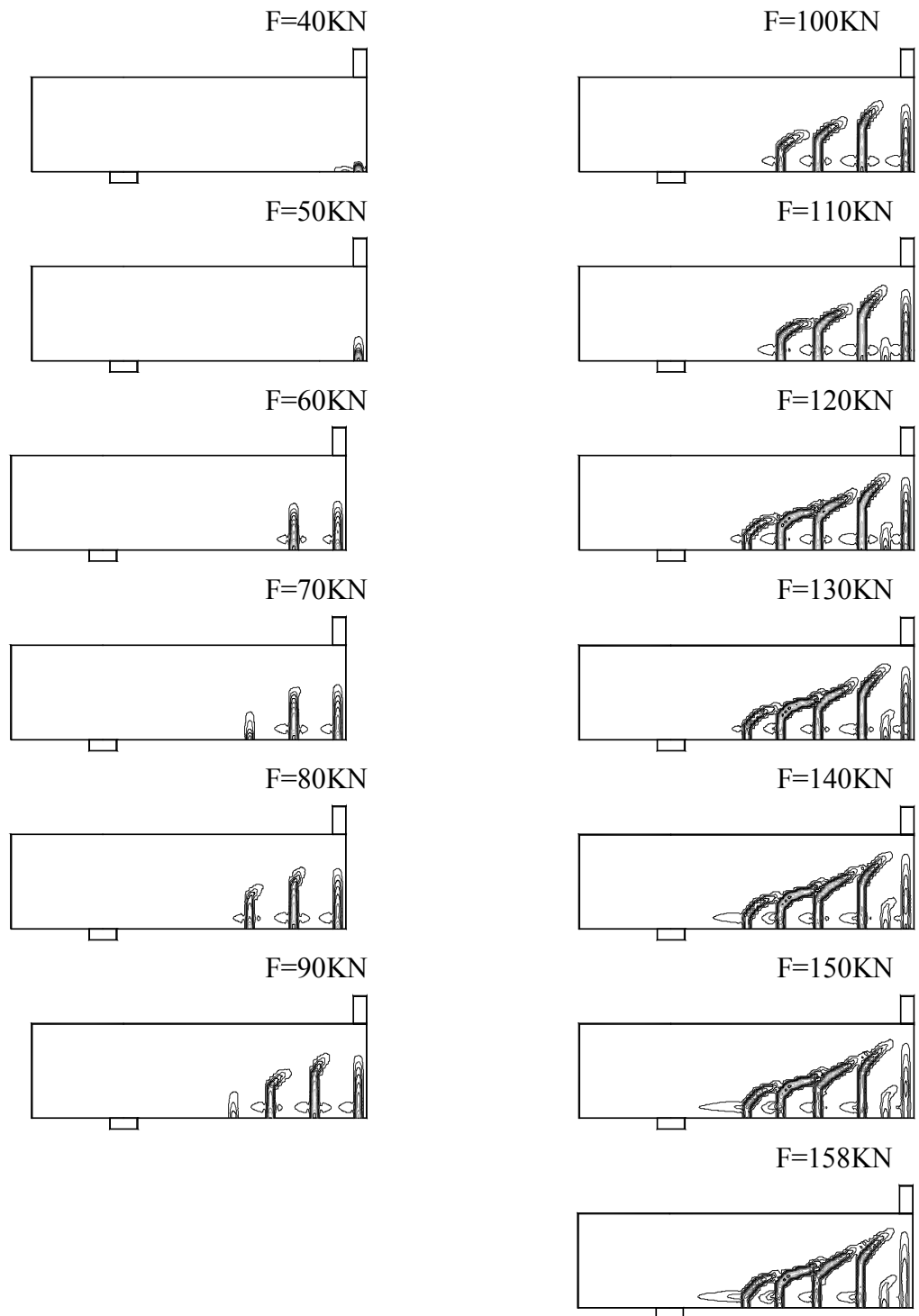




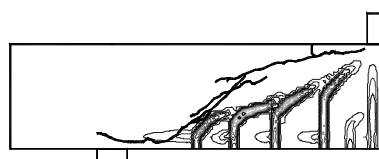
Crack pattern from Test and Abaqus



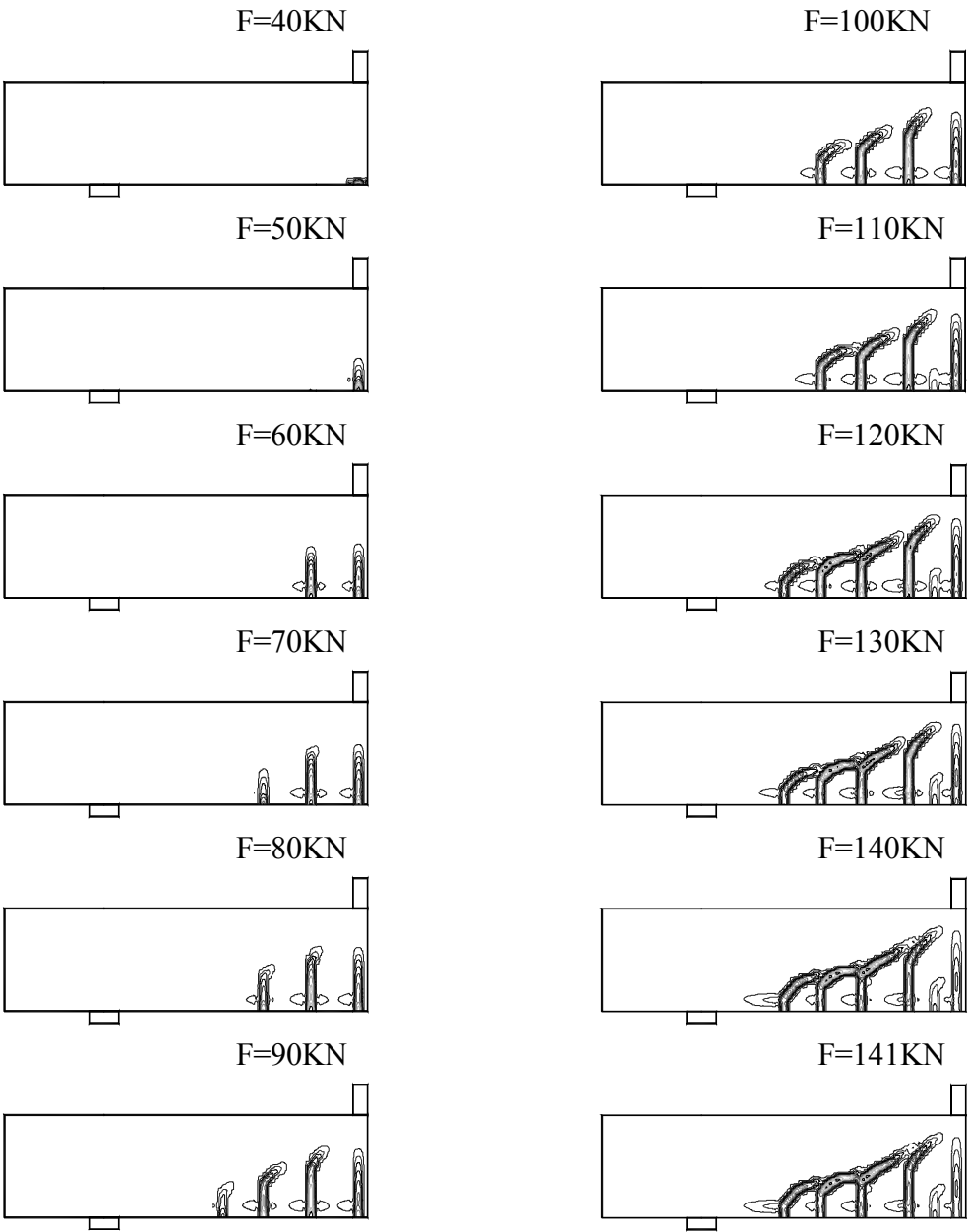
TEST 1K1



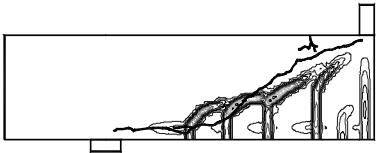
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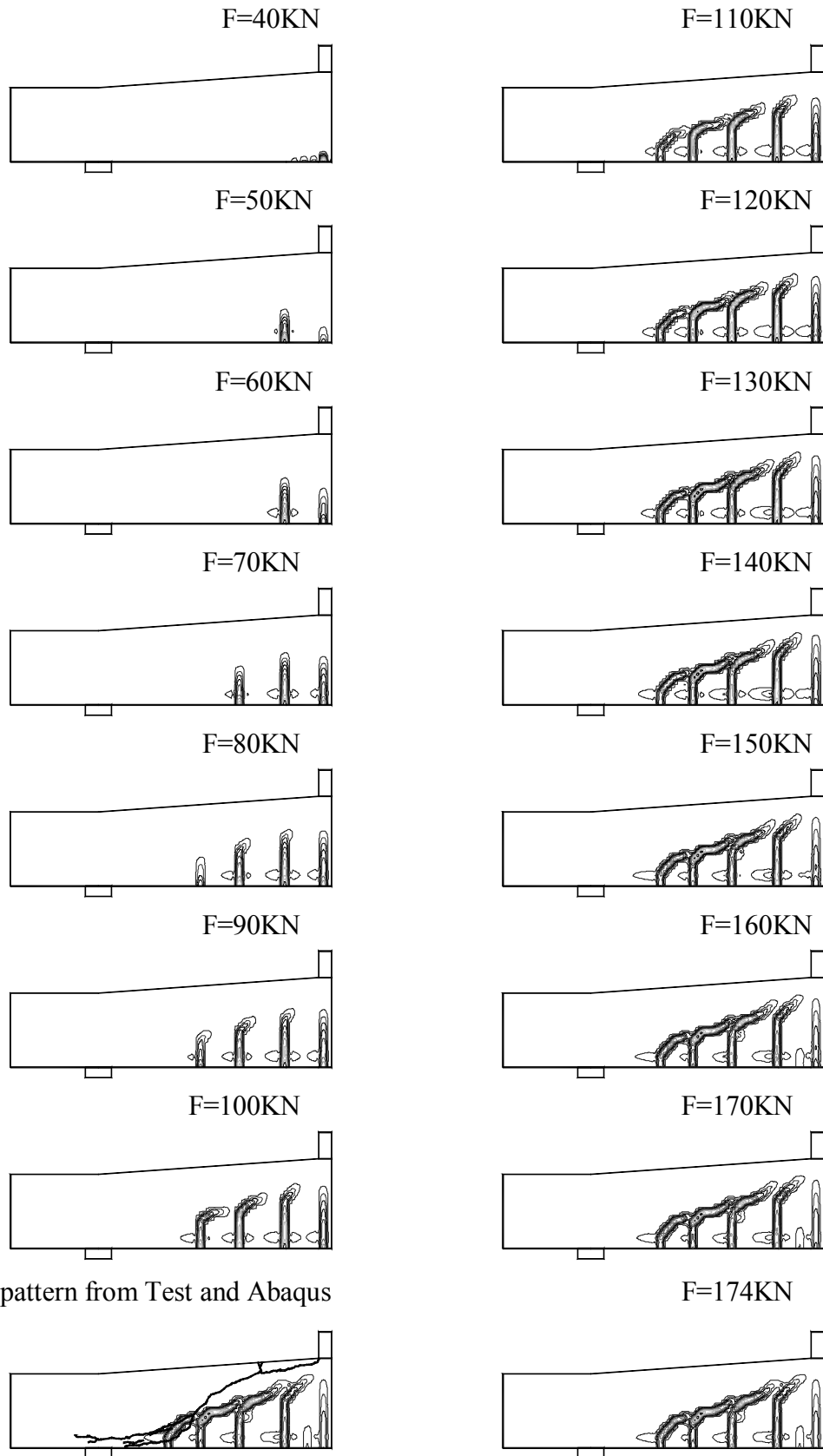
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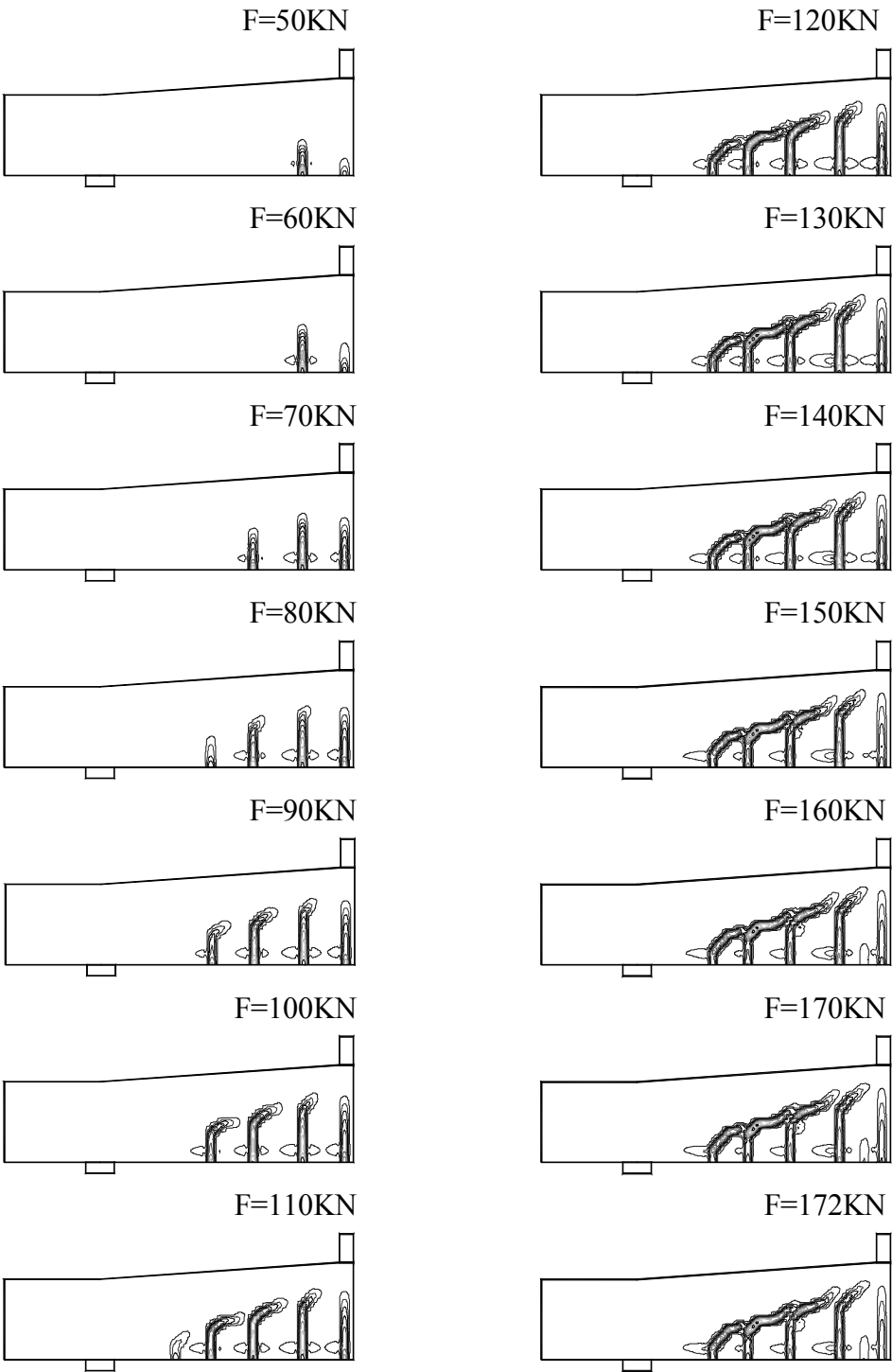
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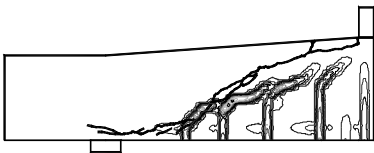
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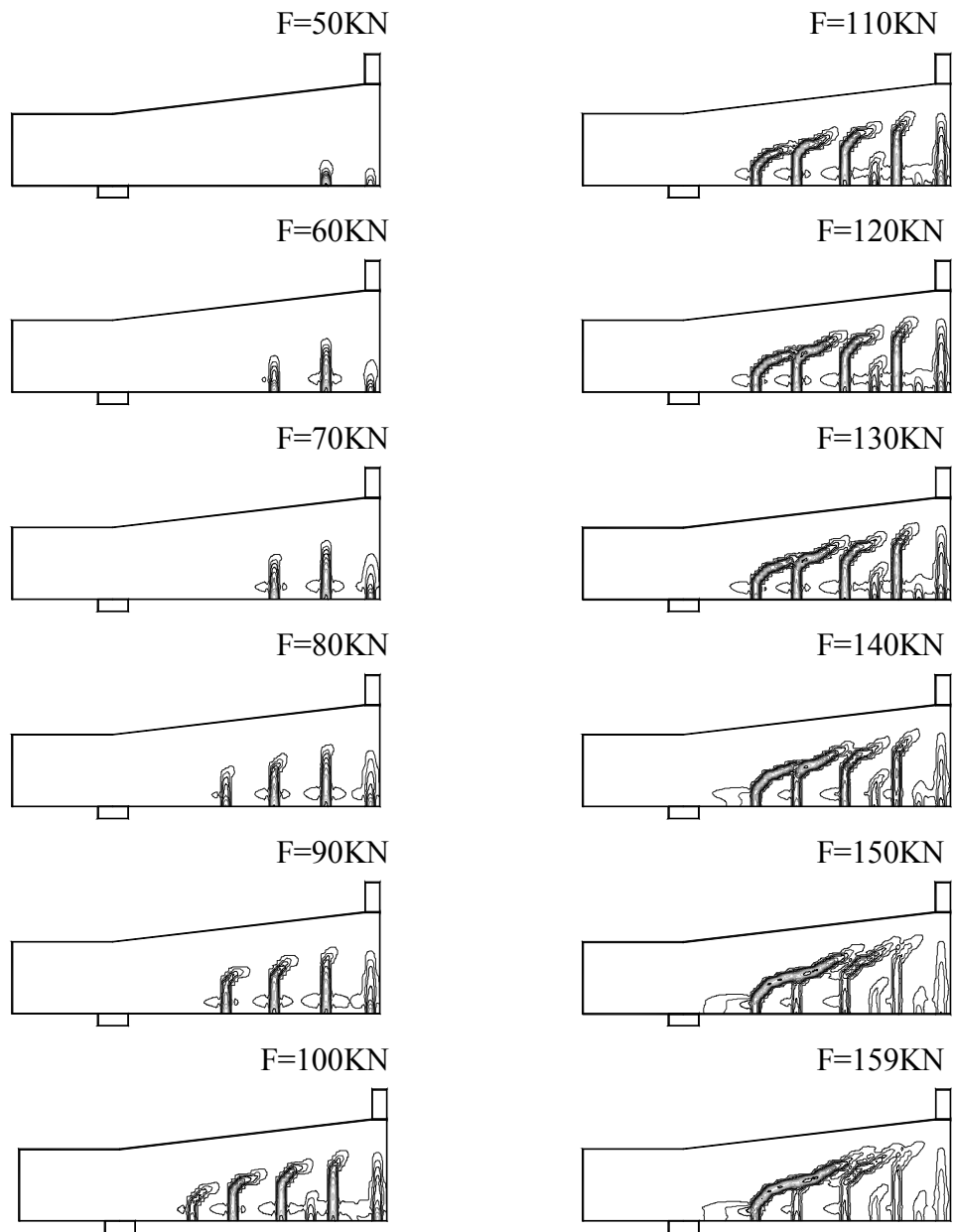
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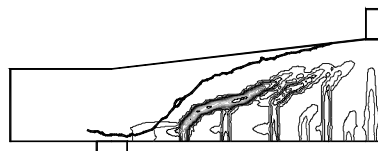
Crack pattern from Test and Abaqus



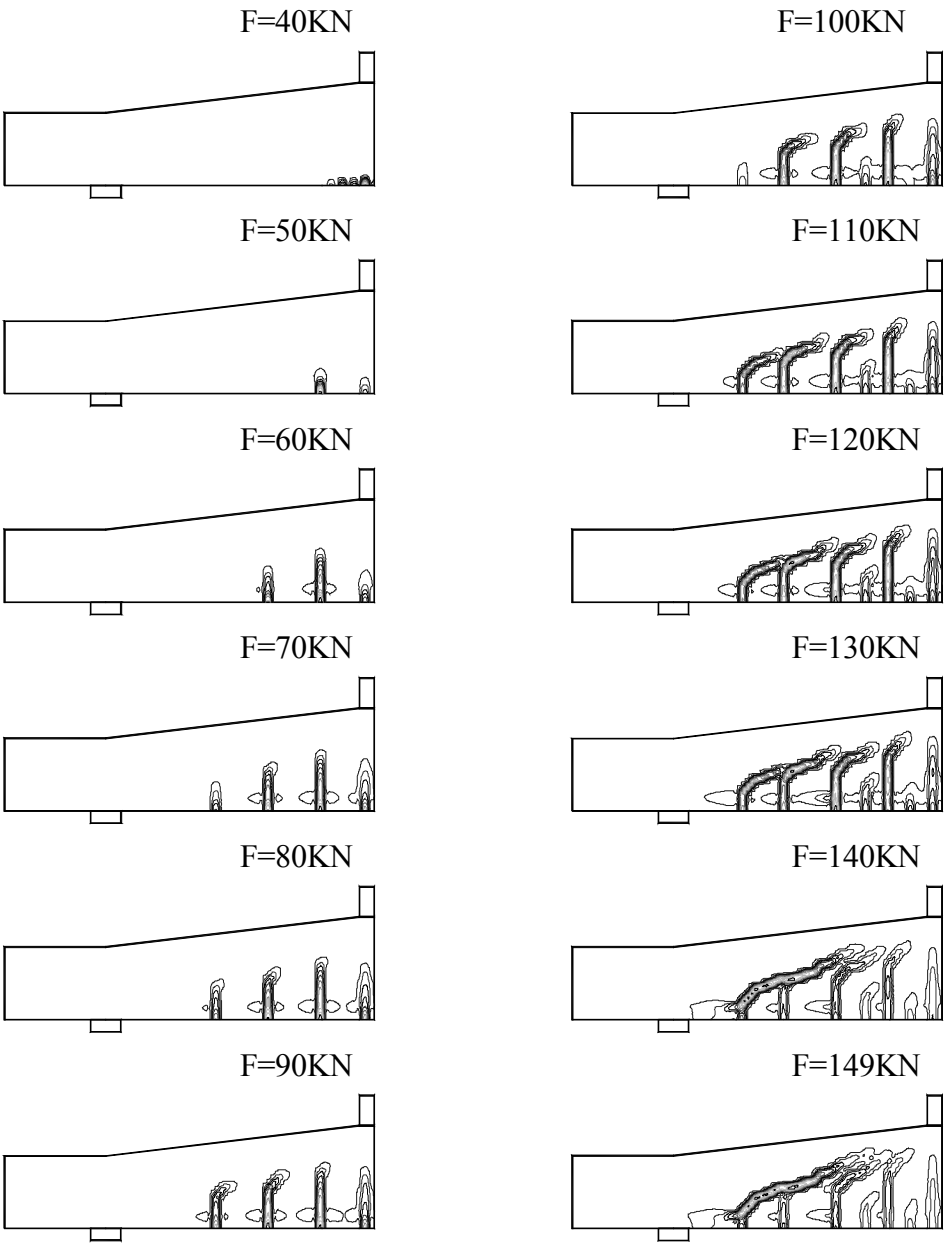
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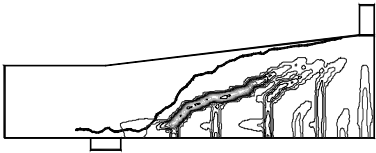
Crack pattern from Test and Abaqus



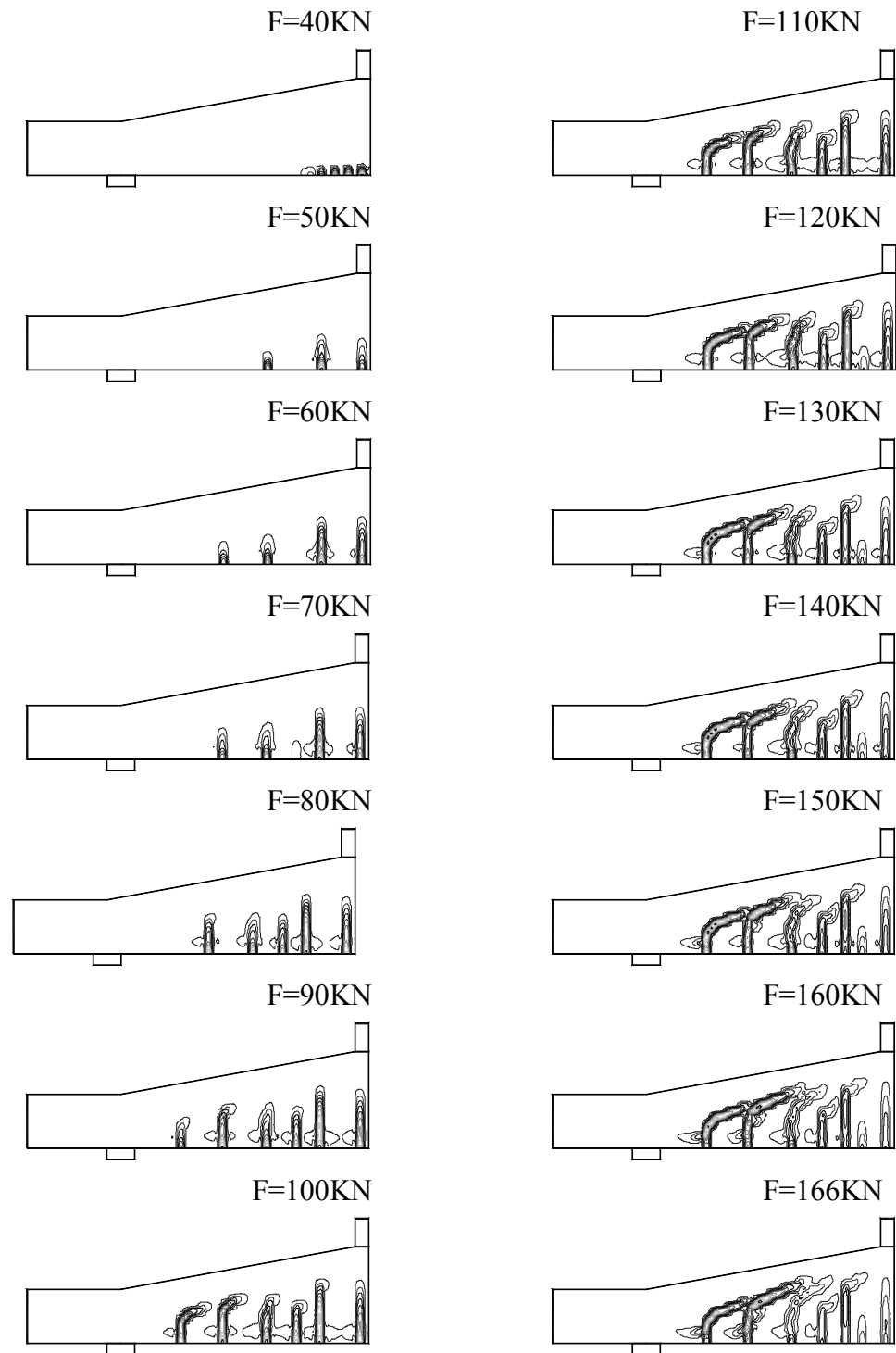
TEST 3K2



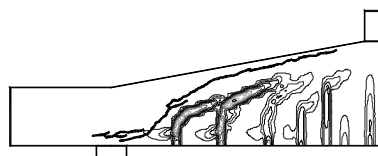
Crack pattern from Test and Abaqus



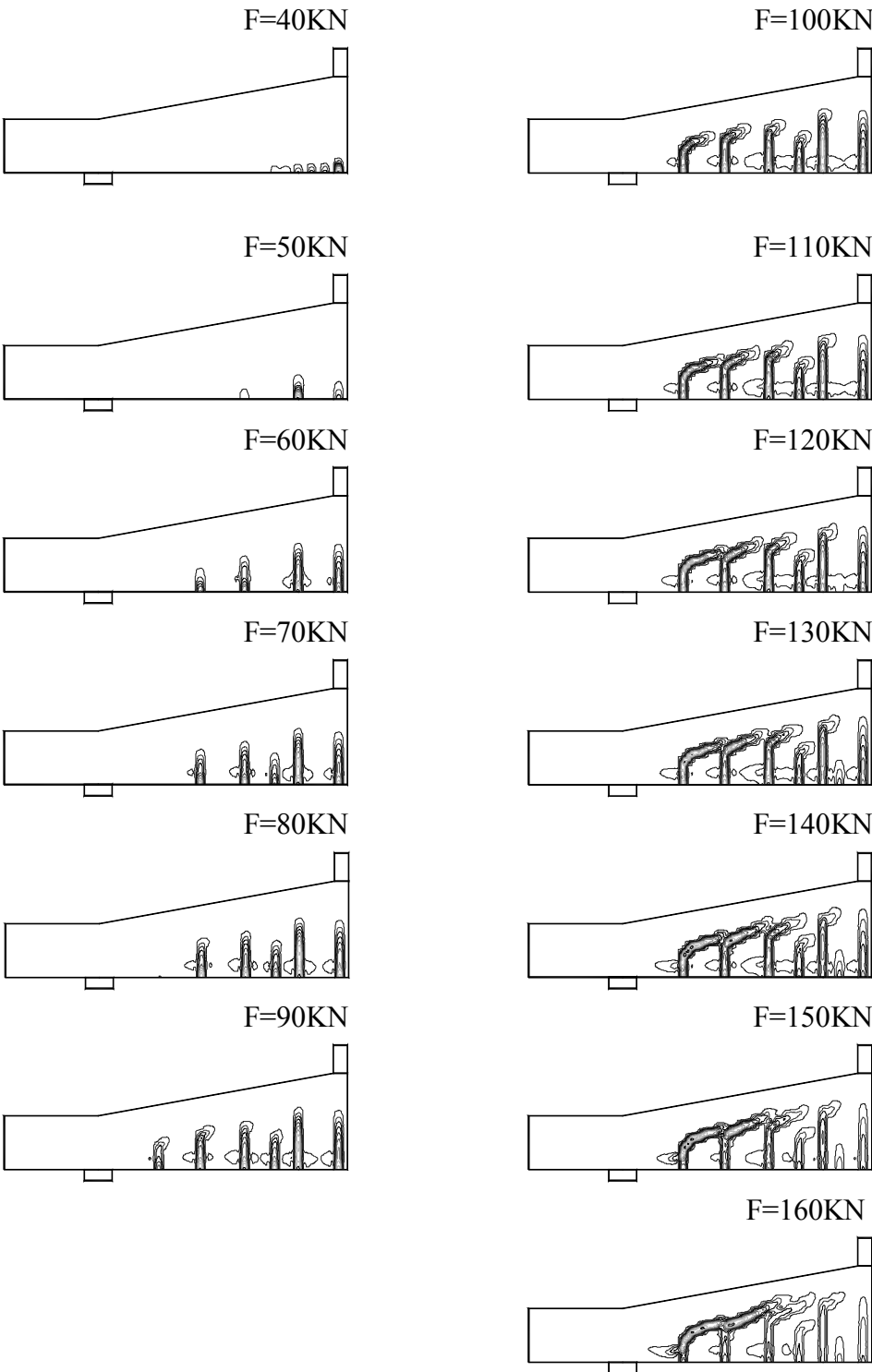
TEST 4K1



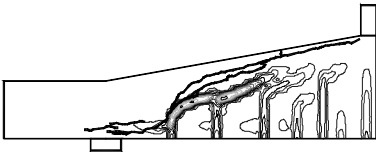
Crack pattern from Test and Abaqus



TEST 4K2



Crack pattern from Test and Abaqus



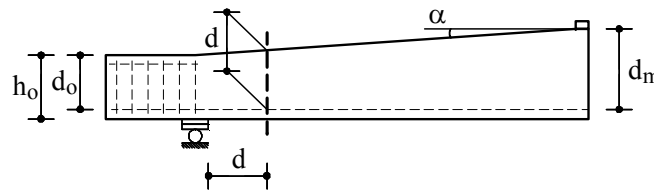
Appendix F
Shear Database of 14 Test Beams

Table F.1. Shear database of 4 straight beams failed in shear

No.	Author and Notes	Year	Beam Name	b_w (mm)	b (mm)	h (mm)	d (mm)	$a:M/V$ (mm)	Load Type	a/d	Bear (mm)	ρ_l (%)	f'_c (MPa)	a_g (mm)	f_{yd} (MPa)	Rep. Mode	V_u (kN)
1850	Rombach & Vu	2009	1L1	200	200	340	300	1500	P	5,00	340	1,57	49,71	16	550	S	75,5
1851		2009	1L2	200	200	340	300	1500	P	5,00	340	1,57	50,84	16	550	S	79,0
1852		2009	1K1	200	200	340	300	900	P	3,00	340	1,57	55,43	16	550	S	75,5
1853		2009	1K2	200	200	340	300	900	P	3,00	340	1,57	55,55	16	550	S	69,5

Table F.2. Shear database of 10 haunched beams failed in shear

No.	Author and Notes	Year	Beam Name	b_w (mm)	b (mm)	h_0 (mm)	d_0 (mm)	d (mm)	d_m (mm)	α (o)	Load Type	a/d_m Ratio	ρ_l (%)	f'_c (Mpa)	a_g (mm)	f_{yd} (Mpa)	V_u (kN)
1	Rombach & Vu	2009	2L1	200	200	240	200	223	340	3,95	P	5,00	2,11	51,05	16	550	75,00
2		2009	2L2	200	200	240	200	223	340	3,95	P	5,00	2,11	51,59	16	550	74,50
3		2009	3L1	200	200	190	150	178	340	5,91	P	5,00	2,65	51,81	16	550	66,50
4		2009	3L2	200	200	190	150	178	340	5,91	P	5,00	2,65	52,58	16	550	69,50
5		2009	2K1	200	200	281	241	267	340	3,95	P	3,00	1,76	55,78	16	550	83,50
6		2009	2K2	200	200	281	241	267	340	3,95	P	3,00	1,76	55,82	16	550	85,00
7		2009	3K1	200	200	240	200	238	340	6,71	P	3,00	1,98	55,86	16	550	79,50
8		2009	3K2	200	200	240	200	238	340	6,71	P	3,00	1,98	55,91	16	550	80,00
9		2009	4K1	200	200	190	150	198	340	10,01	P	3,00	2,38	56,38	16	550	85,00
10		2009	4K2	200	200	190	150	198	340	10,01	P	3,00	2,38	56,42	16	550	84,00



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Notation

a	distance from position of load application to support (length of shear span)
α	inclined angle of haunched beams or inclined angle of principal compressive stress
a/d	shear span/effective depth ratio
A_{ct}	area of concrete beneath mid-depth
α_E	modulus ratio of steel and concrete ($= E_s/E_c$)
a_g	maximum size of aggregates
A_s	cross sectional area of reinforcement
A_{sw}	cross sectional area of shear reinforcement
b	overall width of compression face of member
b_{eff}	effective width of concrete beam
b_w	width of the web on T, I or L-beams
β_r	crack angle
C	force in compression zone
c	height of compression zone
d	effective depth of a cross-section
d_s	diameter of bars
ΔT	difference of tension force in longitudinal reinforcement
ε_c	compressive strain in the concrete
E_c	modulus of elasticity of concrete
E_s	modulus of elasticity of reinforcing steel
ε_s	strain of longitudinal reinforcing steel
ε_t	strain of concrete in tension
F	concentrated loading
f'_c	uniaxial concrete compressive strength (ACI, CSA)
f_{ck}	characteristic compressive cylinder strength of concrete (DIN 1045-01, SN262)
f_{cm}	mean value of concrete cylinder compressive strength (DIN 1045-01, SN262)
f_{ct}	tensile/splitting tensile strength of concrete
f_s	nominal strength of reinforcement
f_{sd}	design strength value of steel at yielding
F_{Test}	concentrated loading in test
F_u	Ultimate loading in test
f_v	stress in shear reinforcement
γ	shear strain; partial factor
γ_F	partial factor for actions, F
G_F	fracture energy of concrete
h	height; overall depth of a cross-section
θ	angle
L	length of span
l_{ch}	characteristic length according to fracture mechanics

Notation

M	value of moment
M_{Ed}	design value of moment
M_{fl}	full flexural strength of beam
M_u	ultimate bending moment at failure
N	axial force
N_{Ed}	design value of normal force
q	distributed loading
ρ_l	reinforcement ratio of longitudinal reinforcement
s_{cr}	crack spacing
σ	normal stress
σ_1	principal compressive stress
σ_2	principal tensile stress
σ_c	axial stress of concrete in compression
σ_{co}	maximum concrete strength at elastic phase
σ_{cu}	compressive stress in the concrete at the ultimate compressive strain ϵ_{cu}
σ_t	axial stress of concrete in tension
σ_x	normal stress in x direction
σ_y	normal stress in y direction
τ	shear stress
T	tension force in longitudinal reinforcement
t	age of concrete (days)
τ_c	shear stress in concrete
τ_{cd}	design value of shear stress
τ_u	shear stress at failure
τ_{xy}	shear stress in xy plane
V	value of shear force
V_c	shear force in compression zone
V_{ca}	shear force carried by aggregate interlock
V_{cal}	shear bearing capacity in calculation
V_{cc}	shear resistance due to inclination of compression zone
V_{cr}	shear force carried by residual tensile stresses in concrete
V_d	shear force carried by dowel action
V_{Ed}	design value of applied shear force
V_p	shear resistance provided by prestressing steel
V_{Rd}	design value of shear resistance strength
V_{Rd}^α	design value of shear resistance strength of haunched beams
V_{Rm}	mean value of shear resistance strength of straight beams
V_{Rm}^α	mean value of shear resistance strength of haunched beams
V_s	shear resistance provided by transverse reinforcement
V_t	shear force in tension zone

V_{Test}	shear resistance measured at ultimate capacity in test
V_u	ultimate shear strength of concrete beam
w	width of critical shear crack
x	height of cracked zone
z	lever arm of internal forces

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Verzeichnis

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