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EFFECTS OF WATERJET APPLICATION ON JOINING SURFACES OF EXTERNAL RETROFITTING TECHNIQUE

横浜国立大学

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SERIES, 8 Feb. 2012

Background

- After 1999 and 2011 earthquakes of Turkey and Japan, awareness of the population increased.
- Conventional retrofitting techniques are RC jacketing and adding shear walls to the frame openings.
- Recently FRP systems are started to use more largely. (Especially after it was mentioned in the Seismic Code.)

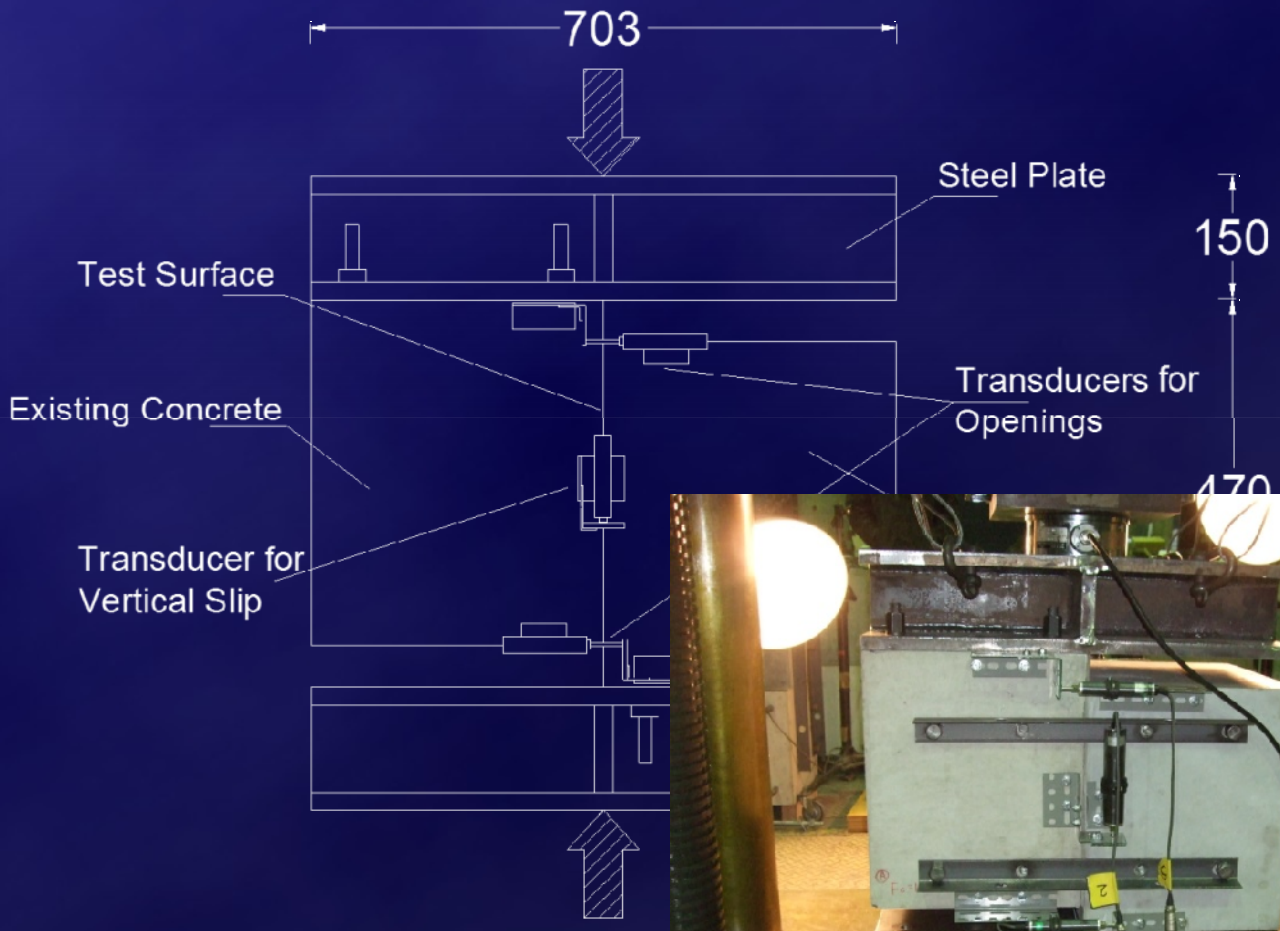
Introduction

- Nevertheless conventional strengthening methods are still generally applied techniques, new applications such as FRP systems and external reinforcing techniques are developed promising for a less construction time and more convenience to the inhabitants.
- The aim of this study is to reduce/minimize the amount of steel anchorages by increasing the friction resistance in the surface.

Introduction

- Waterjet(WJ) is a technique newly used in reinforced concrete building retrofitting.
- It is used to create a controlled roughness surface between existing and retrofitting concrete elements.

Test Setup

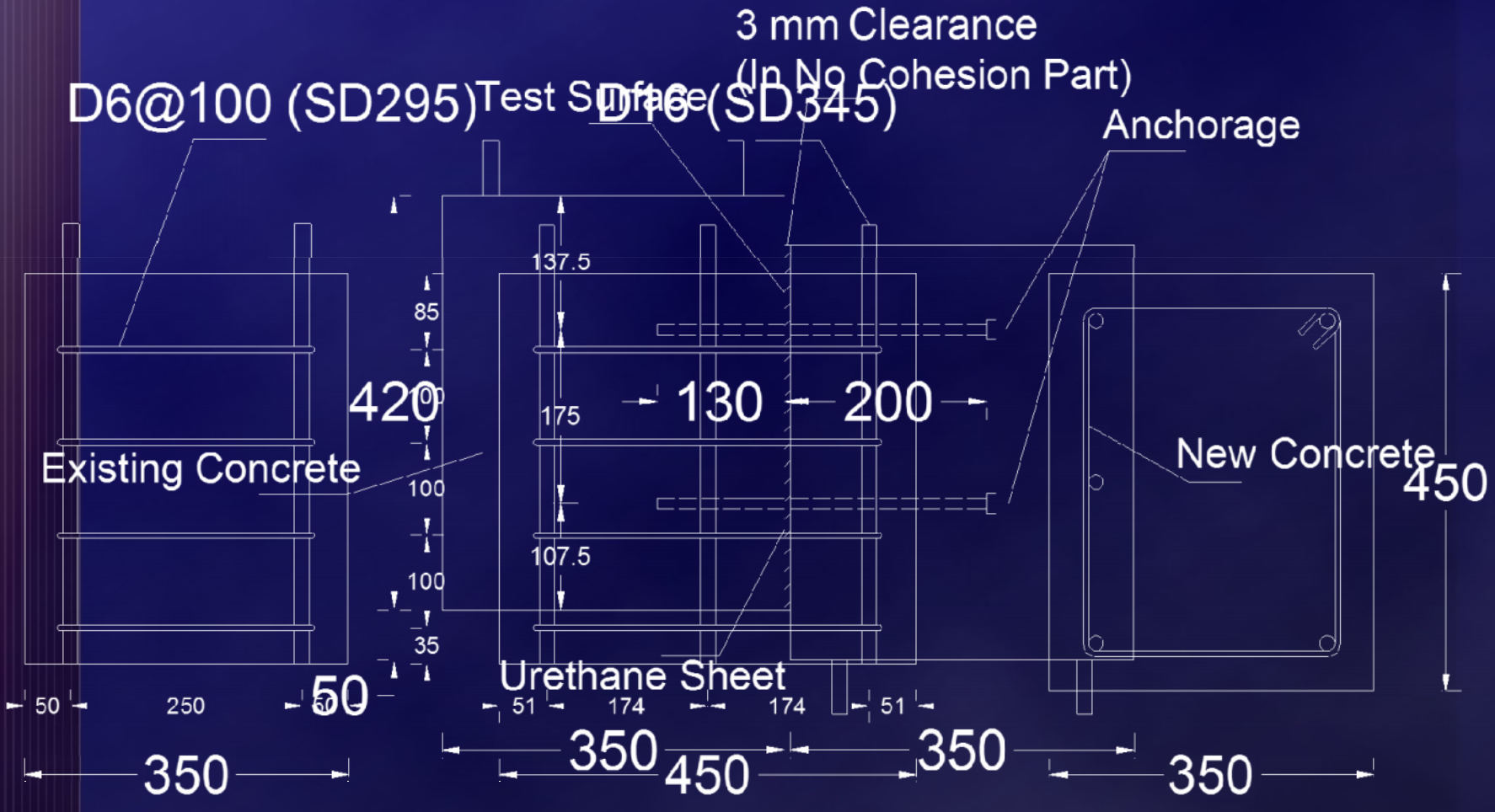


(unit : m

Specimen Geometry

Dimensions of the Specimen

Bar Arrangements



(unit : mm)

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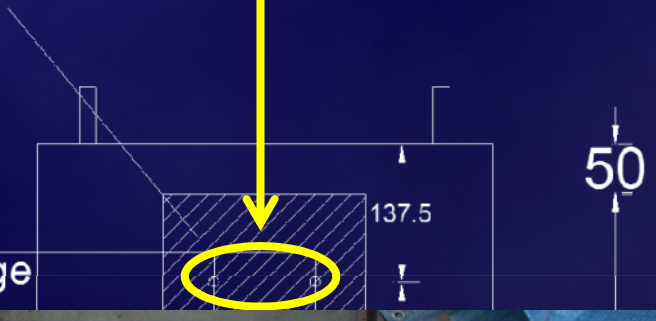
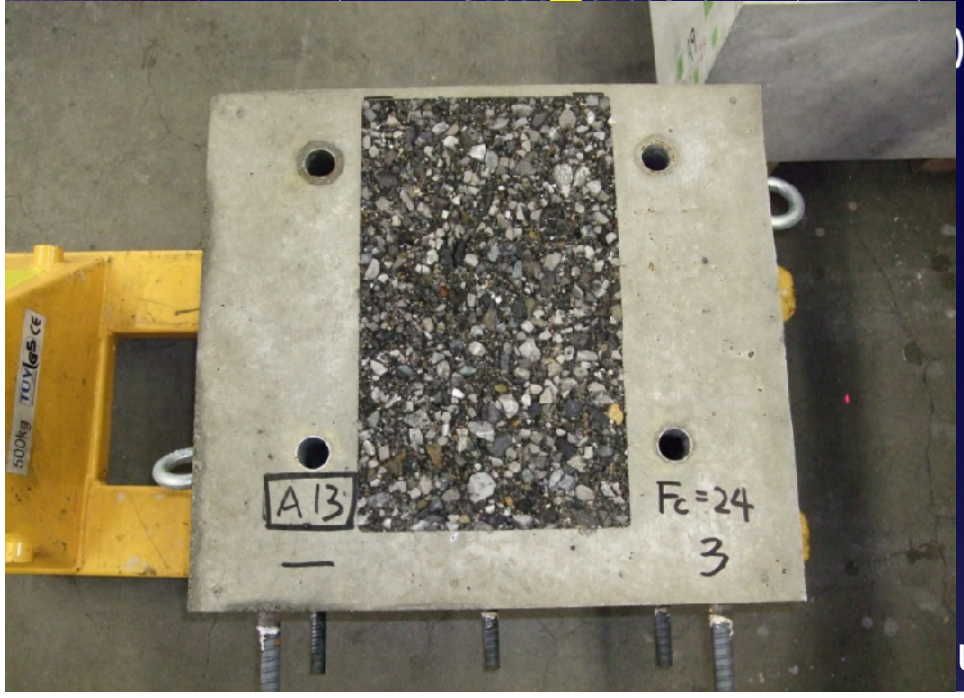
ıetry

ORAGE (Pa)

urface



Anchorage



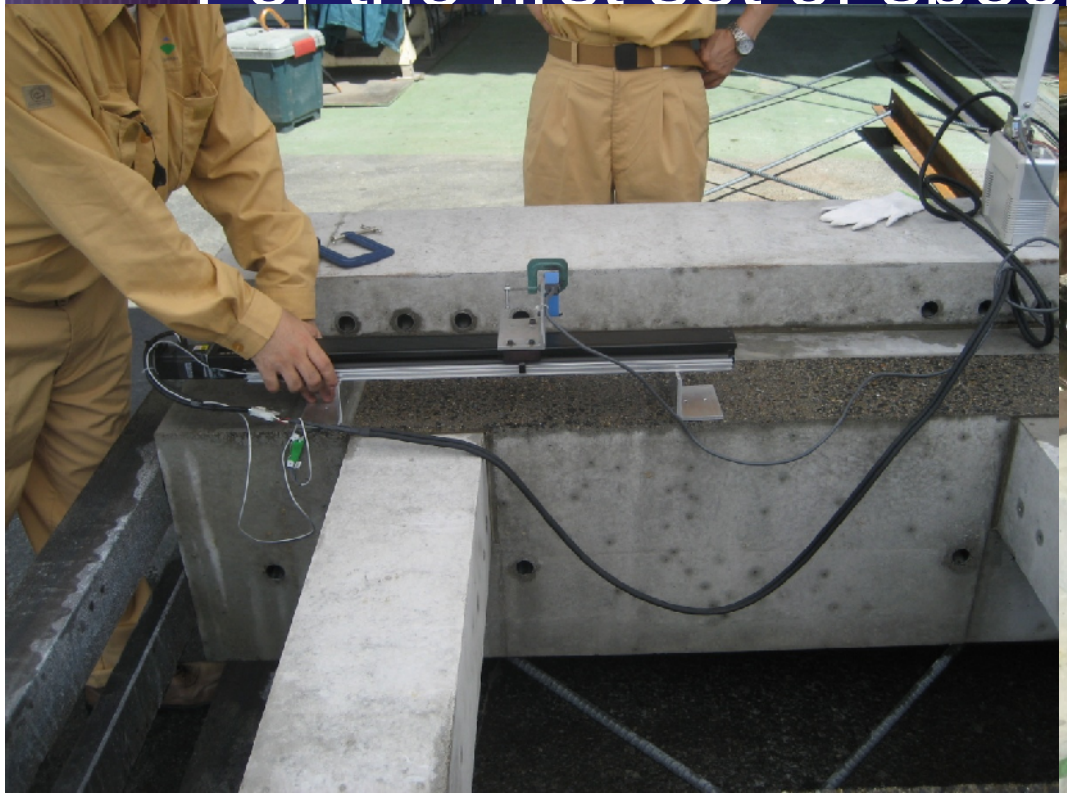
un

Waterjet (WJ)

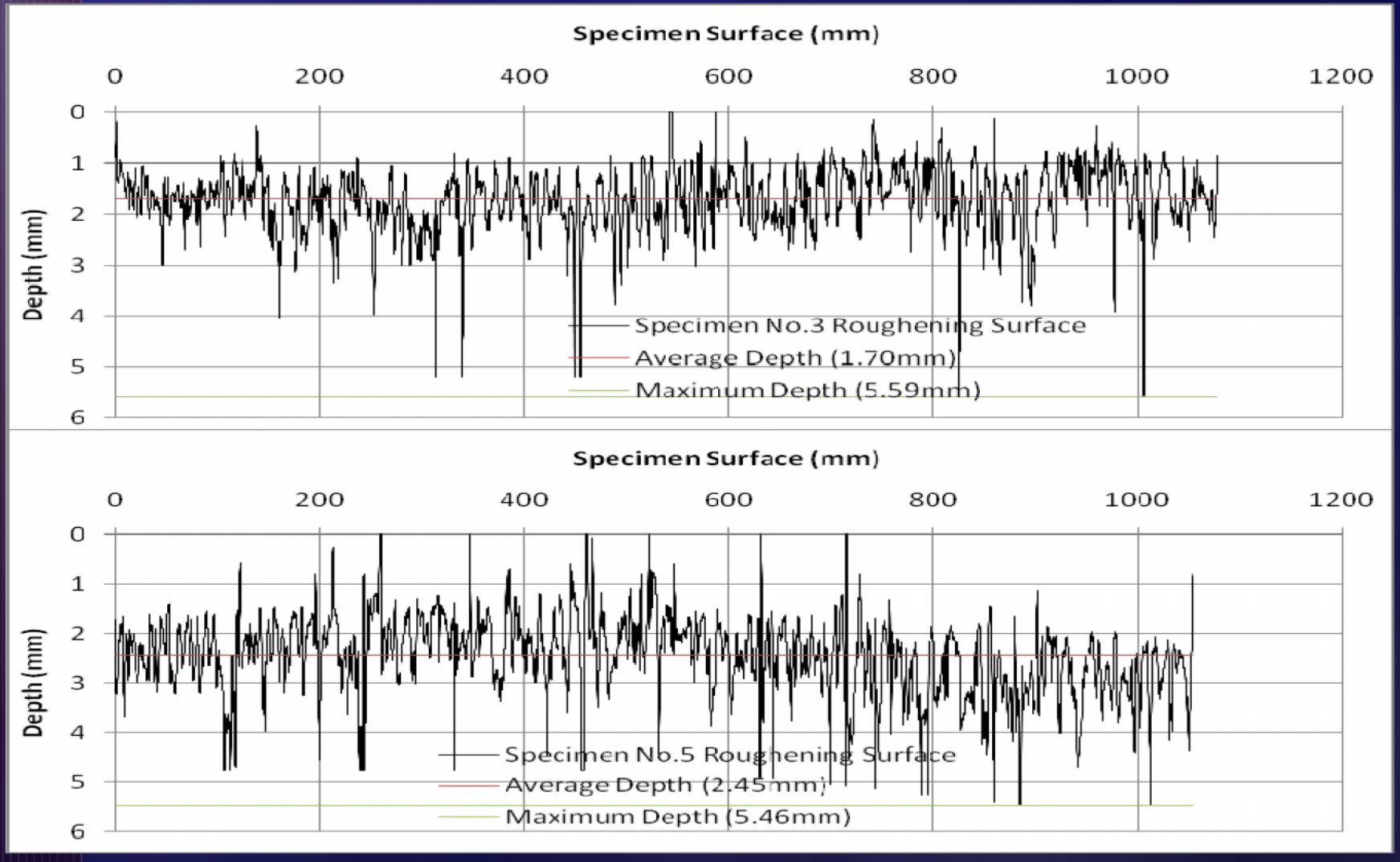
- Waterjet is the high pressured water spray, which is usually used to cut/smash the concrete elements.

Roughness

- The roughness term is used to identify the average depth of the friction surface.
- For the first set of specimens the design



Roughness


Specimen Surface (mm)
0
200
400
600
800
1000
1200
Depth (mm)
0
1
2
3
4
5
6
Specimen No.3 Roughening Surface
Average Depth (1.70mm)
Maximum Depth (5.59mm)
Specimen Surface (mm)
0
200
400
600
800
1000
1200
Depth (mm)
0
1
2
3
4
5
6
Specimen No.5 Roughening Surface
Average Depth (2.45mm)
Maximum Depth (5.46mm)

Material Properties

	Batch No.	Aggregate Type	σ_B [MPa]	f_{ctk} [MPa]	E_c [MPa]
Existing	1	crushed	13.99	1.36	23000
	2	round	17.15	1.72	22900
	3	crushed	24.87	2.39	32000
New	4	crushed	35.52	2.78	26900

(Material Test Results : Concrete)

	σ_y [MPa]	ε_y [%]	σ_u [MPa]	E_s [MPa]
D10(SD295)	385	0.21	522	1.89×10^5

(Material Test Results : Anchorage)

Database

SPECIMENS : 16
LOW STRENGTH : 9
NORMAL STRENGTH : 7
CRUSHED : 14
ROUND : 2
K=0 : 4
K=2mm : 7
K=3mm : 5
Pa=0 : 4
Pa=0.2(2-D10) : 8
Pa=0.4(4-D10) : 4

Specimen	σ_B [MPa]	Aggregate Type	Pa [%]	K [mm]
1	13.99	crushed	0.2(2-D10)	-
2	13.99	crushed	0.4(4-D10)	-
3	13.99	crushed	0	2/1.66
4	13.99	crushed	0.2(2-D10)	2/1.42
5	13.99	crushed	0.4(4-D10)	2/1.12
6	13.99	crushed	0	3/2.75
7	13.99	crushed	0.2(2-D10)	3/3.36
8	24.87	crushed	0.2(2-D10)	-
9	24.87	crushed	0.4(4-D10)	-
10	24.87	crushed	0	2/1.60
11	24.87	crushed	0.2(2-D10)	2/1.83
12	24.87	crushed	0.4(4-D10)	2/1.75
13	24.87	crushed	0	3/3.22
14	24.87	crushed	0.2(2-D10)	3/2.87
15	17.15	round	0.2(2-D10)	2/1.08
16	17.15	round	0.2(2-D10)	3/2.92

Results

Specimen	σ_B [MPa]	Pa [%]	K [mm]	Measured [MPa]	Calculated [MPa]	M/C
1	13.99	0.2(2-D10)	-	118	116.0	1.02
2	13.99	0.4(4-D10)	-	150	152.0	0.99
3	13.99	0	2/1.66	172	162.7	1.06
4	13.99	0.2(2-D10)	2/1.42	203	191.7	1.06
5	13.99	0.4(4-D10)	2/1.12	229	225.4	1.02
6	13.99	0	3/2.75	183	183.8	0.99
7	13.99	0.2(2-D10)	3/3.36	208	226.4	0.91
8	24.87	0.2(2-D10)	-	123	125.0	0.98
9	24.87	0.4(4-D10)	-	163	161.0	1.01
10	24.87	0	2/1.60	175	191.5	0.91
11	24.87	0.2(2-D10)	2/1.83	200	233.7	0.86
12	24.87	0.4(4-D10)	2/1.75	290	264.2	1.10
13	24.87	0	3/3.22	-	216.8	-
14	24.87	0.2(2-D10)	3/2.87	262	250.5	1.05
15	17.15	0.2(2-D10)	2/1.08	183	193.9	0.94
16	17.15	0.2(2-D10)	3/2.92	256	236.6	1.08

Material Properties

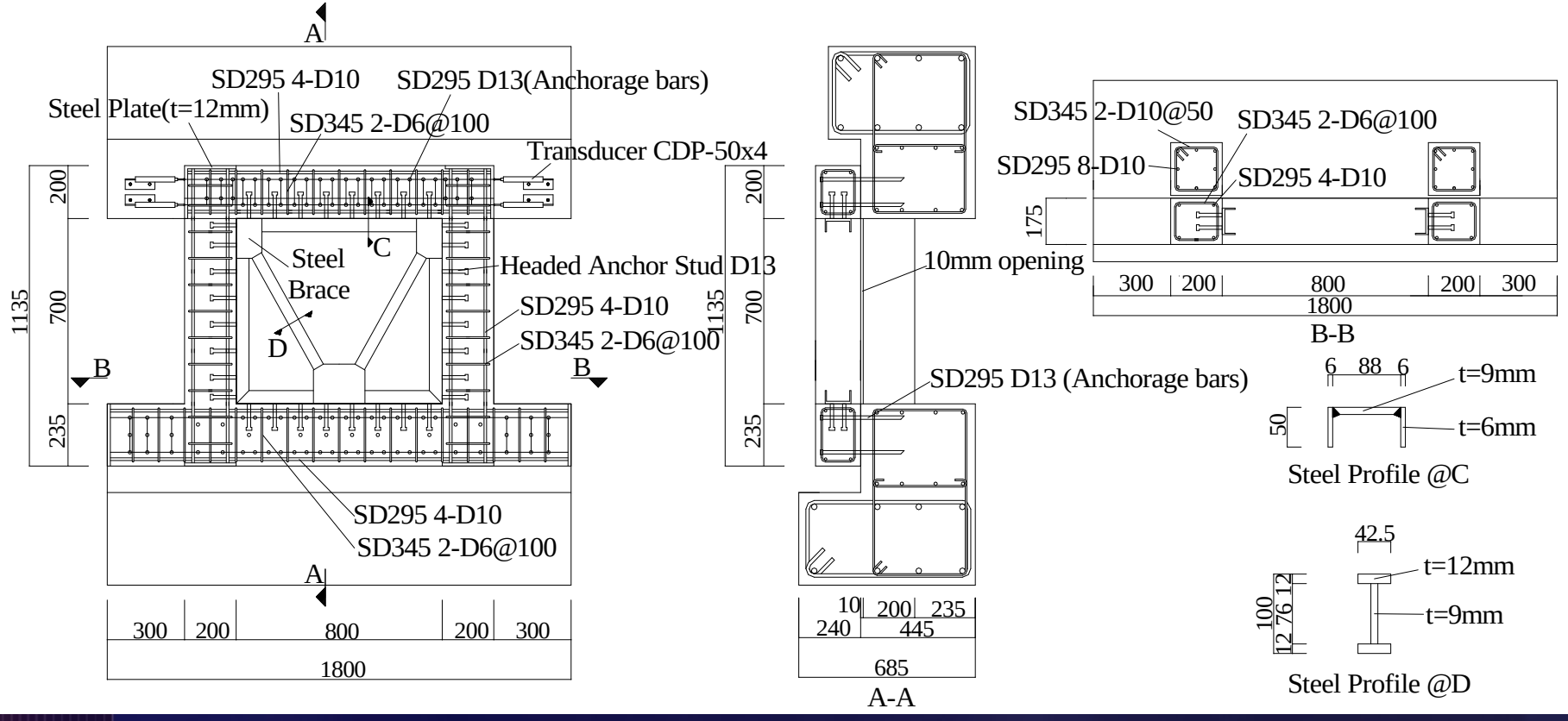
	Batch No.	Aggregate Type	σ_B [MPa]	f_{ctk} [MPa]	E_c [MPa]
Existing	1	crushed	20.14	1.70	30900
New	2	crushed	31.33	2.46	34100

(Material Test Results : Concrete)

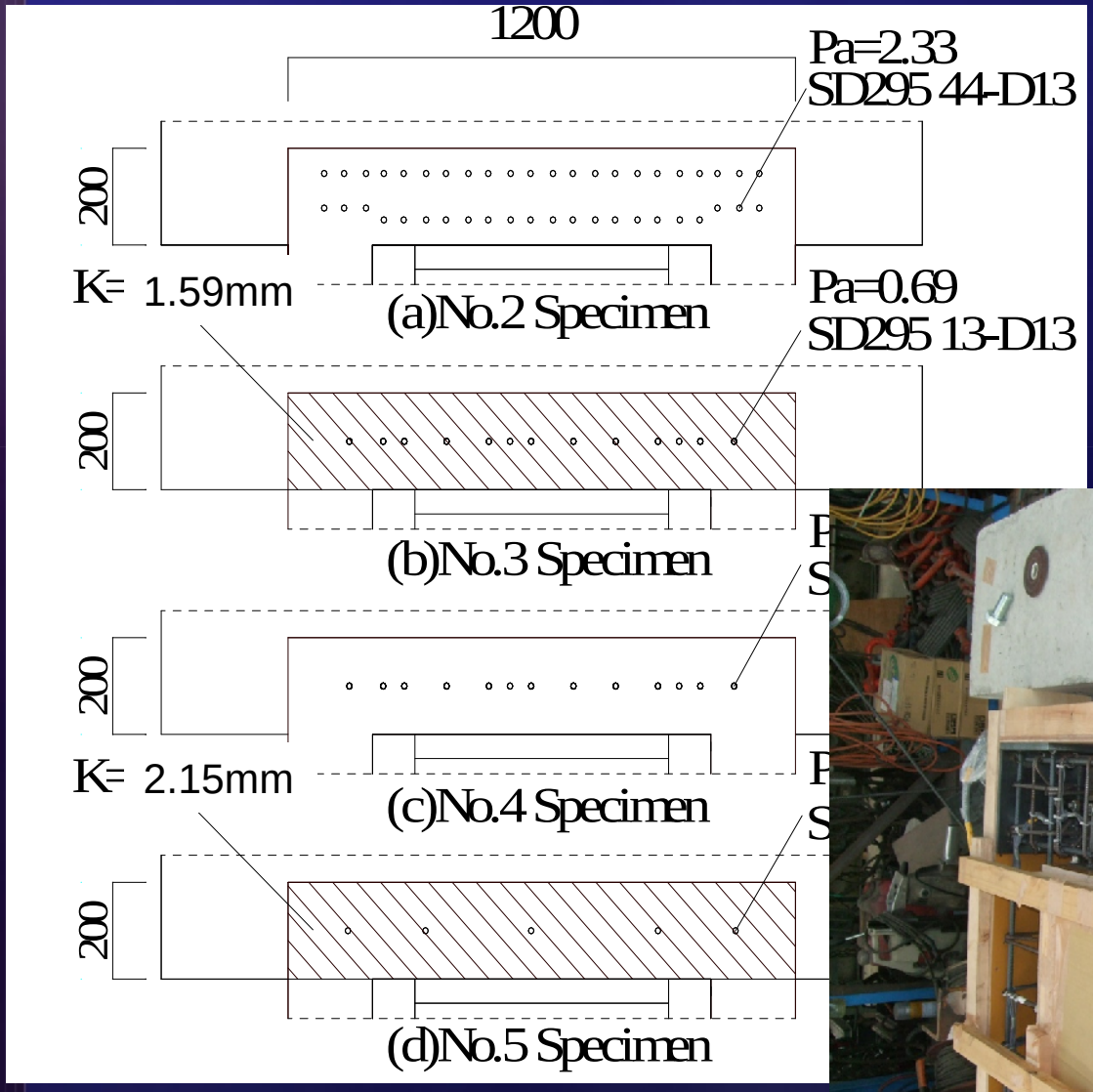
	σ_y [MPa]	ε_y [%]	σ_u [MPa]	E_s [MPa]
D13(SD295)	351	0.19	504	1.87×10^5

(Material Test Results : Anchorage)

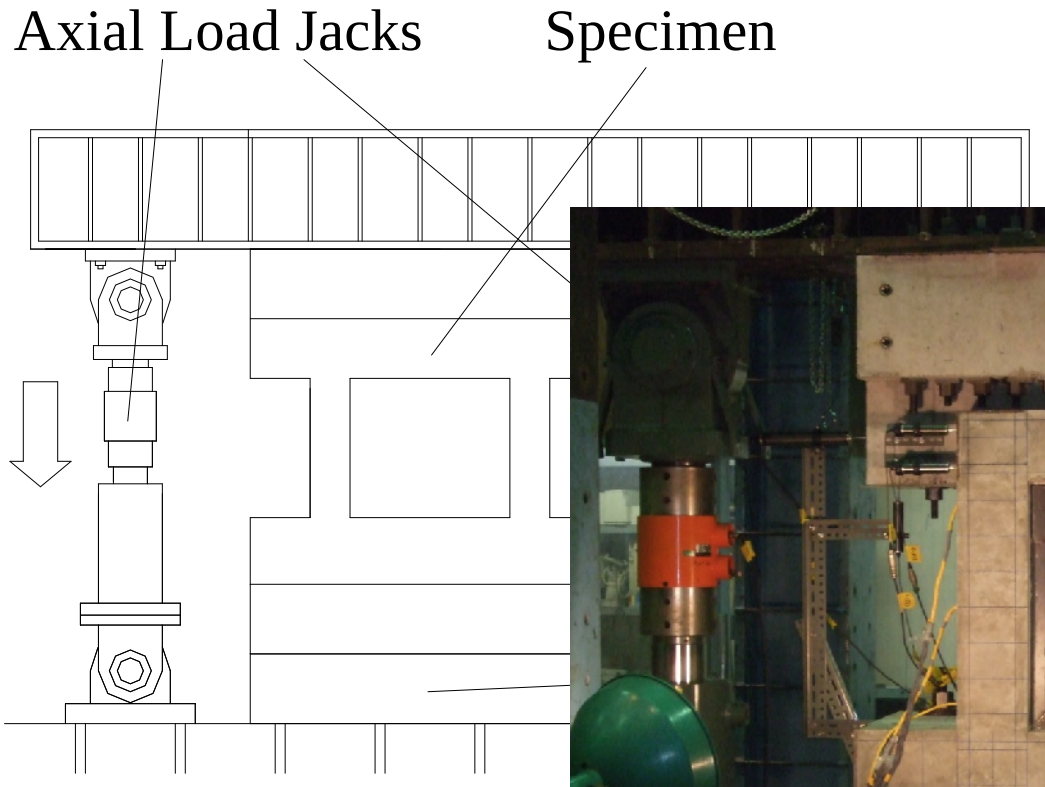
Specimen Geometry



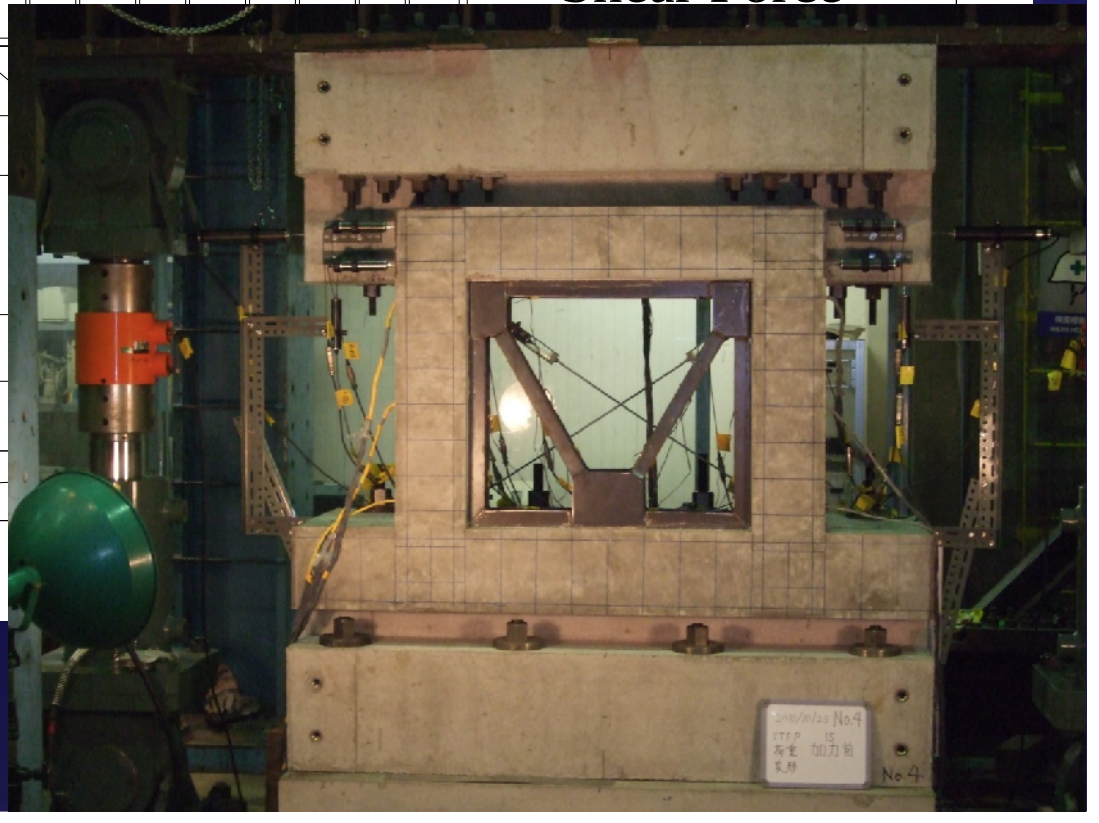
Specimen Geometry



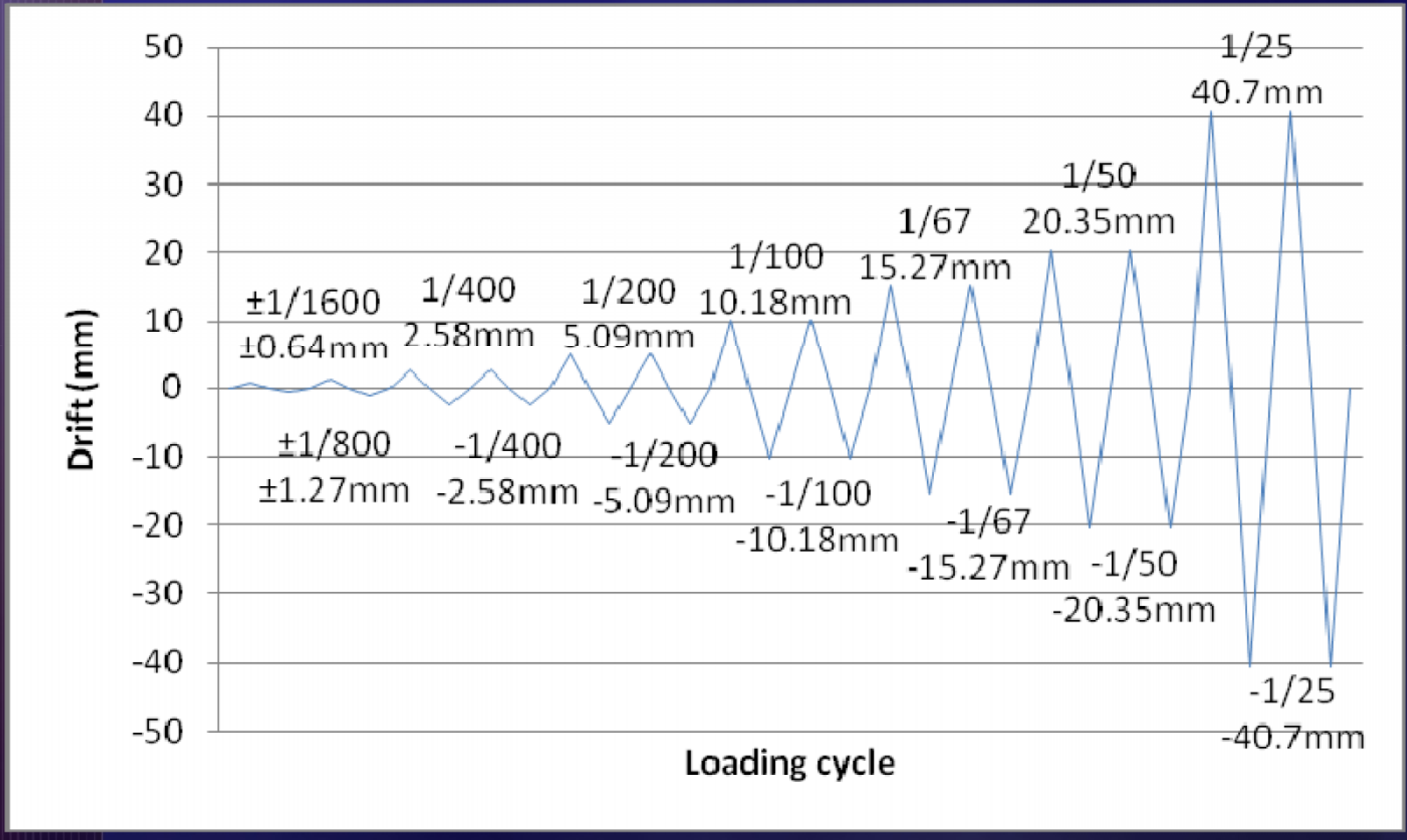
Test Setup



Actuators for Shear Force



Loading Method



Database

Control Specimen

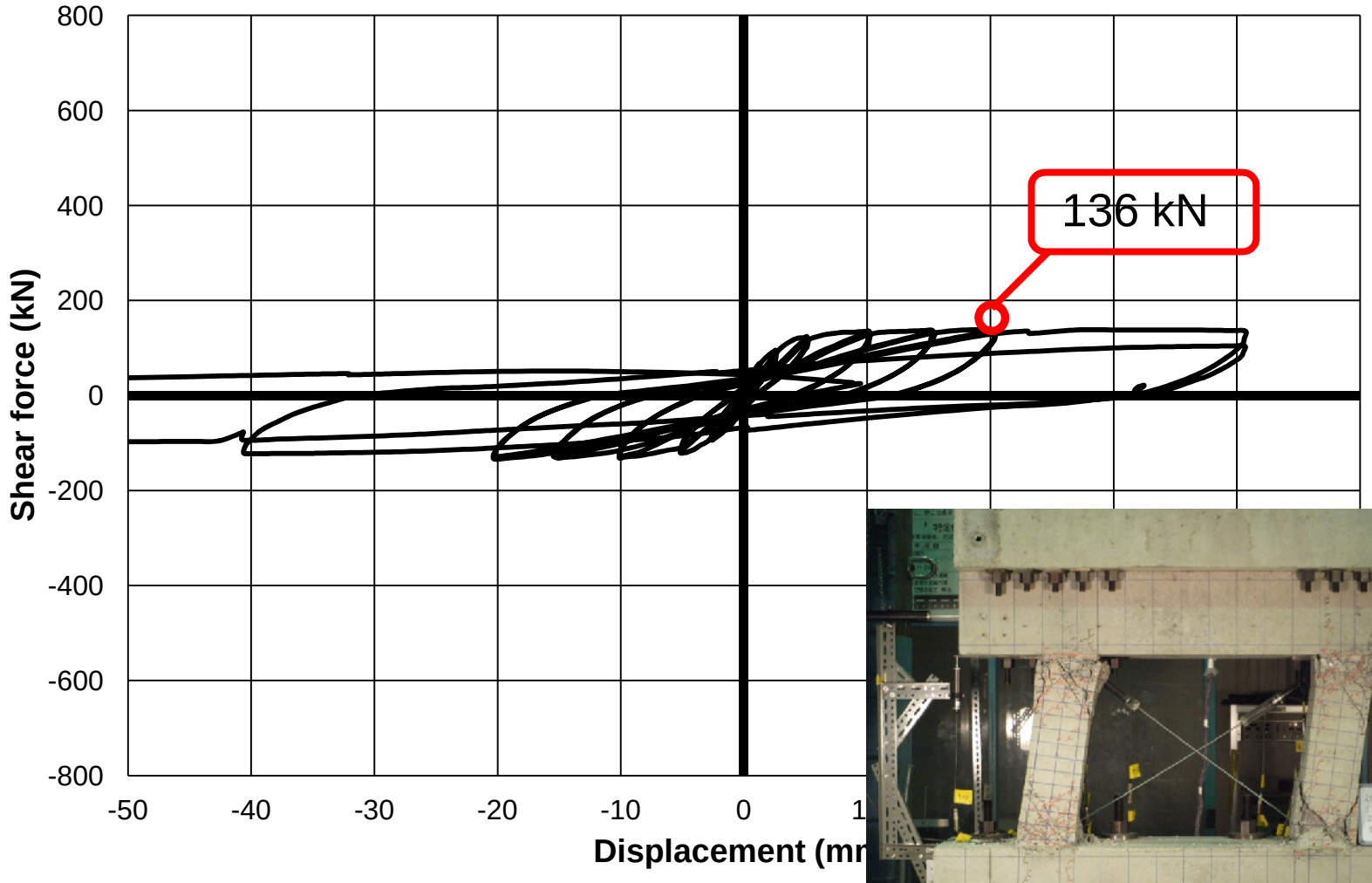
Manual Specimen

Reduced Anchorage with/without WJ Specimens

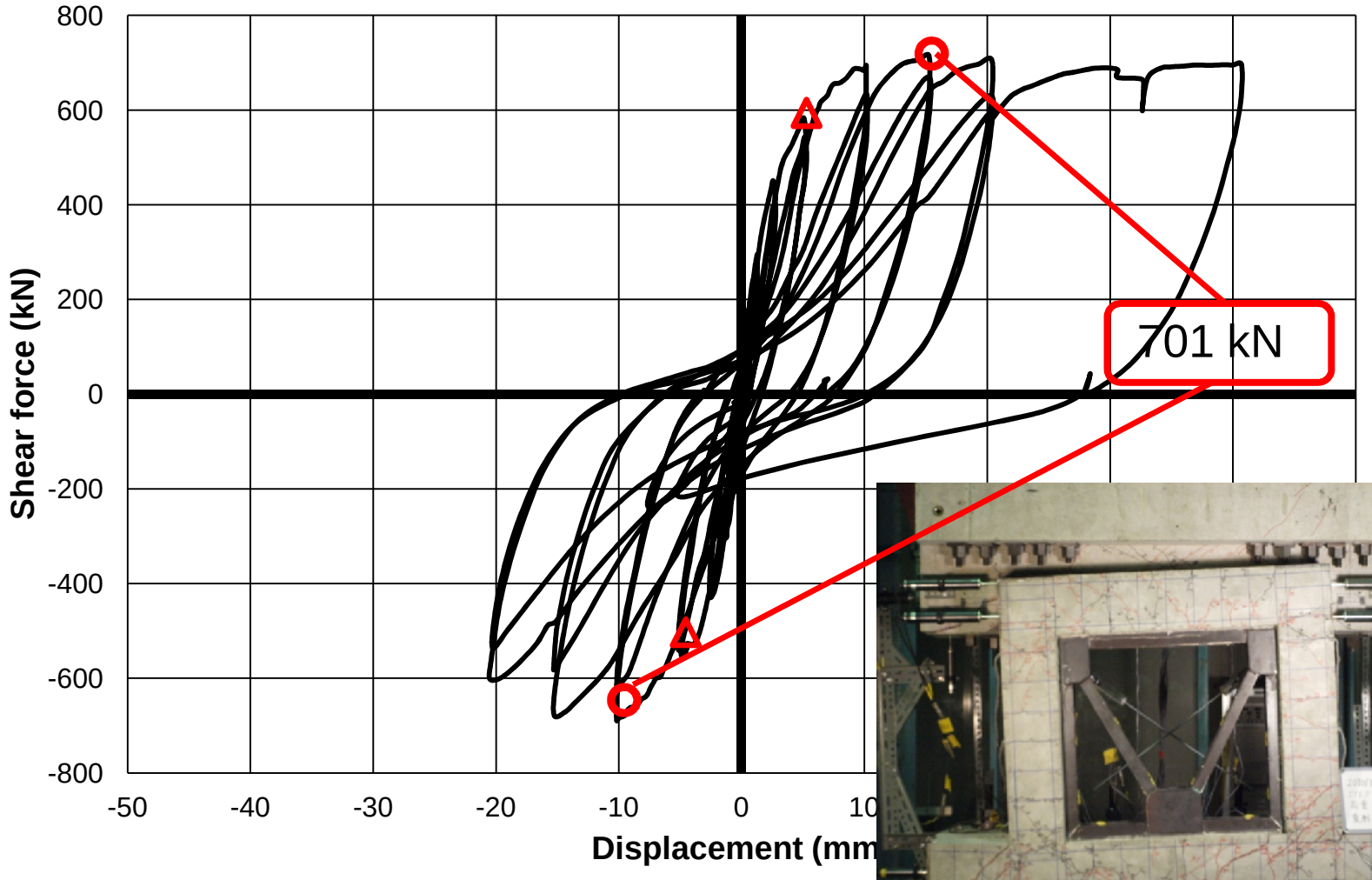
Specimen	Remark	Pa [%]	K [mm]
1	-	-	-
2	Manual	2.33(44-D13)	-
3	0.3xManual	0.69(13-D13)	2/1.59
4	0.3xManual	0.69(13-D13)	-
5	0.1xManual	0.26(5-D13)	2/2.15

Manual mentioned above is Manual for External Seismic Retrofit of Existing Reinforced Concrete Buildings.

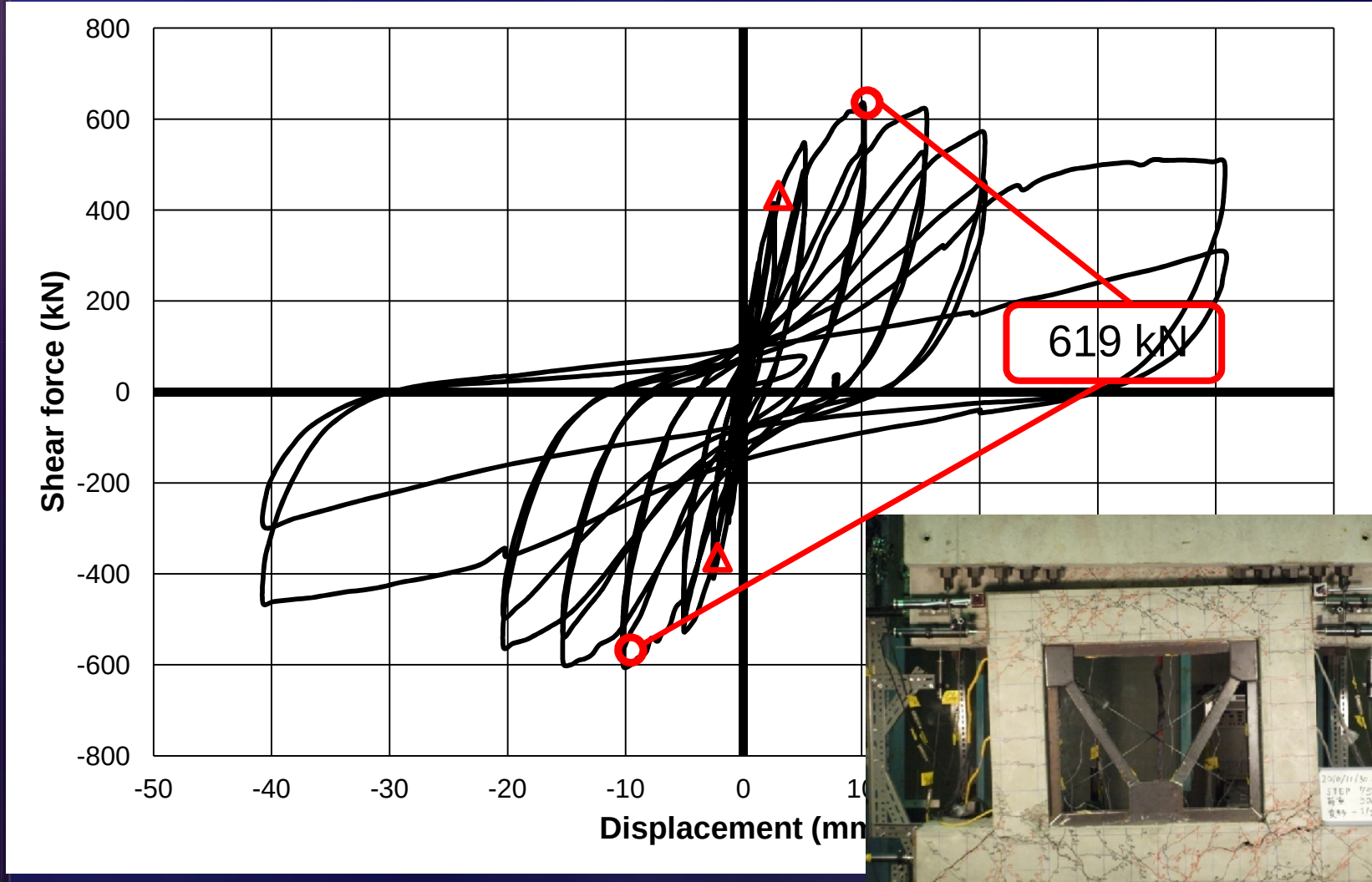
Results - Specimen No.1



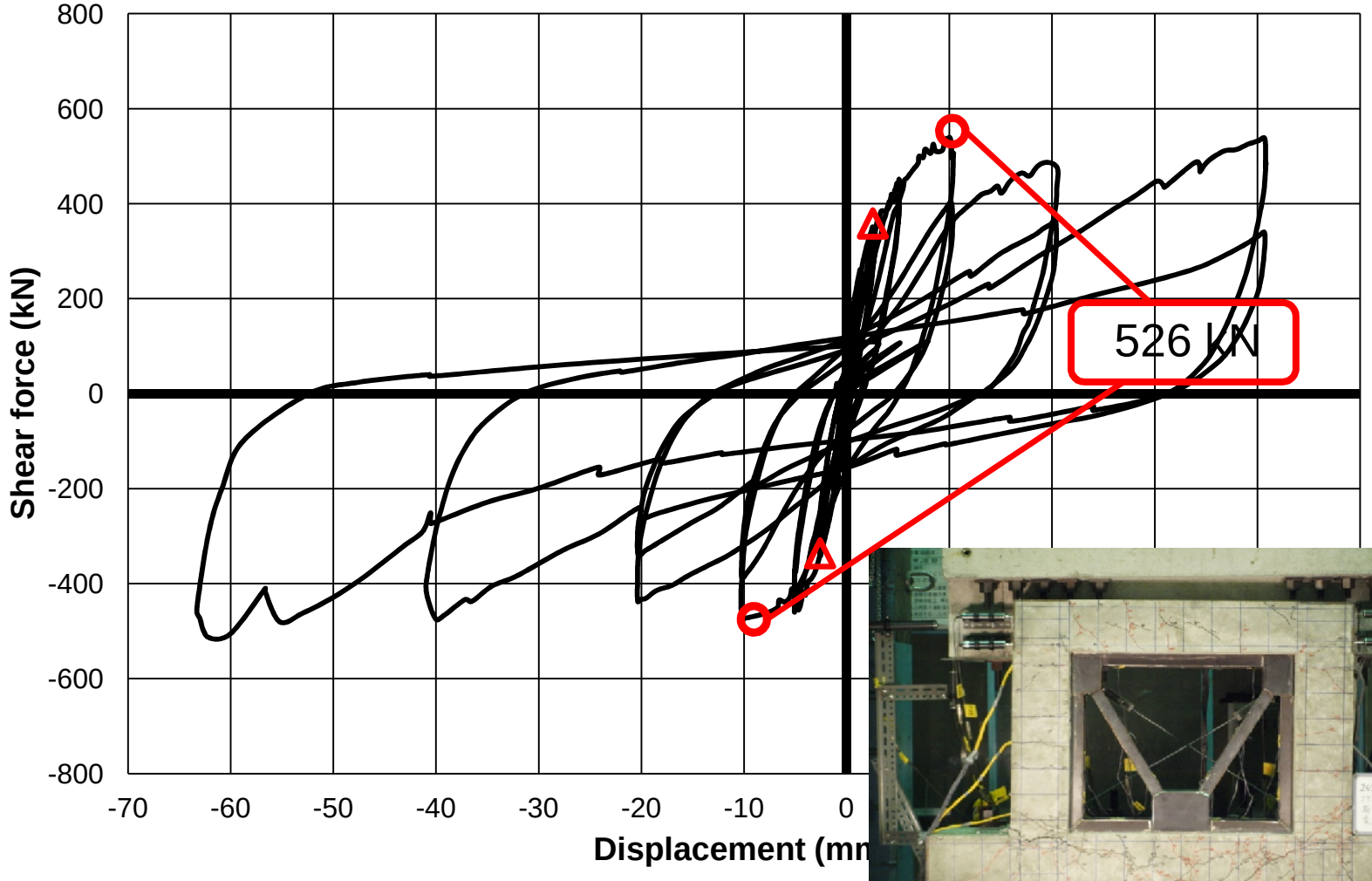
Results - Specimen No.2



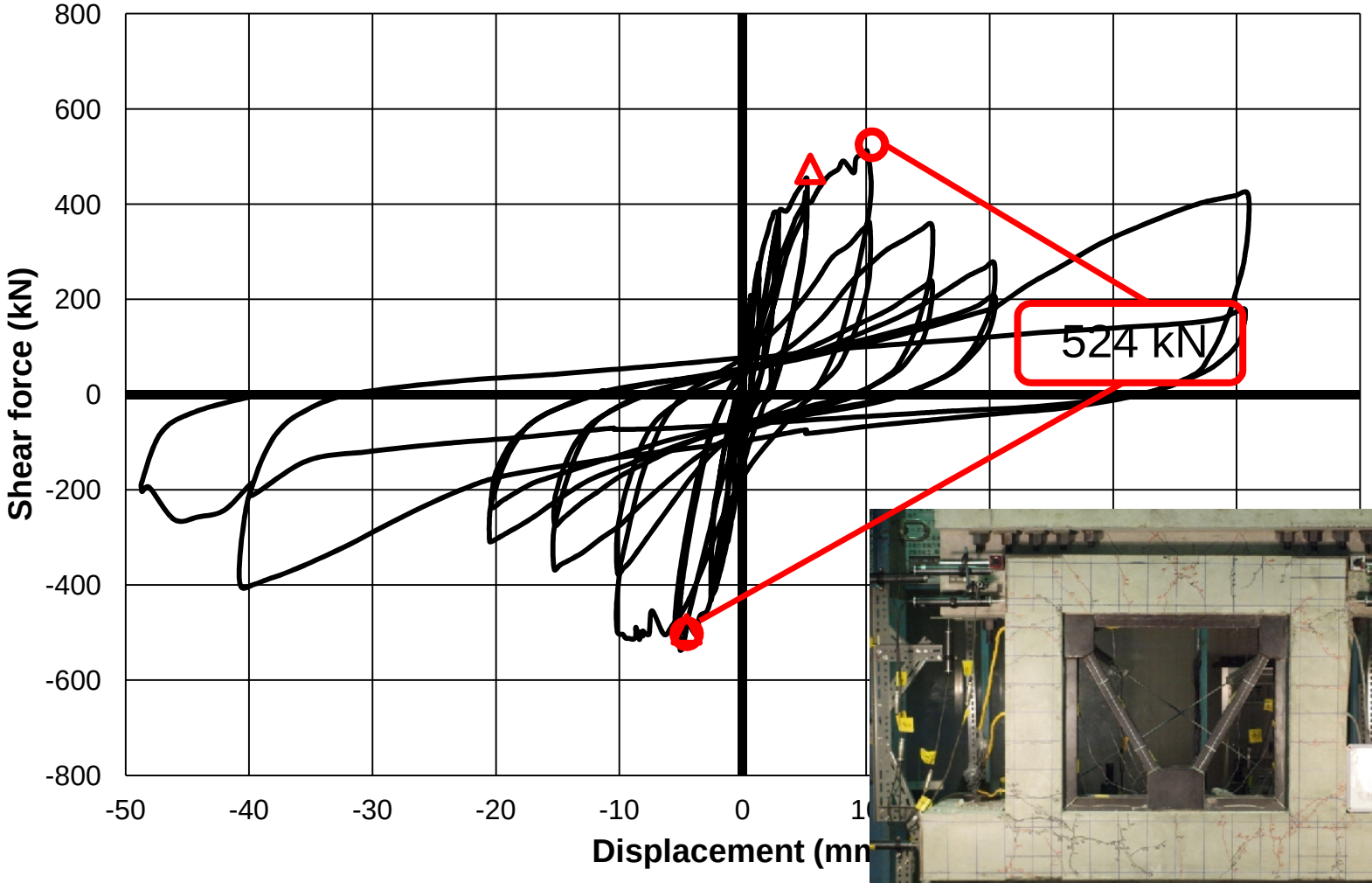
Results - Specimen No.3



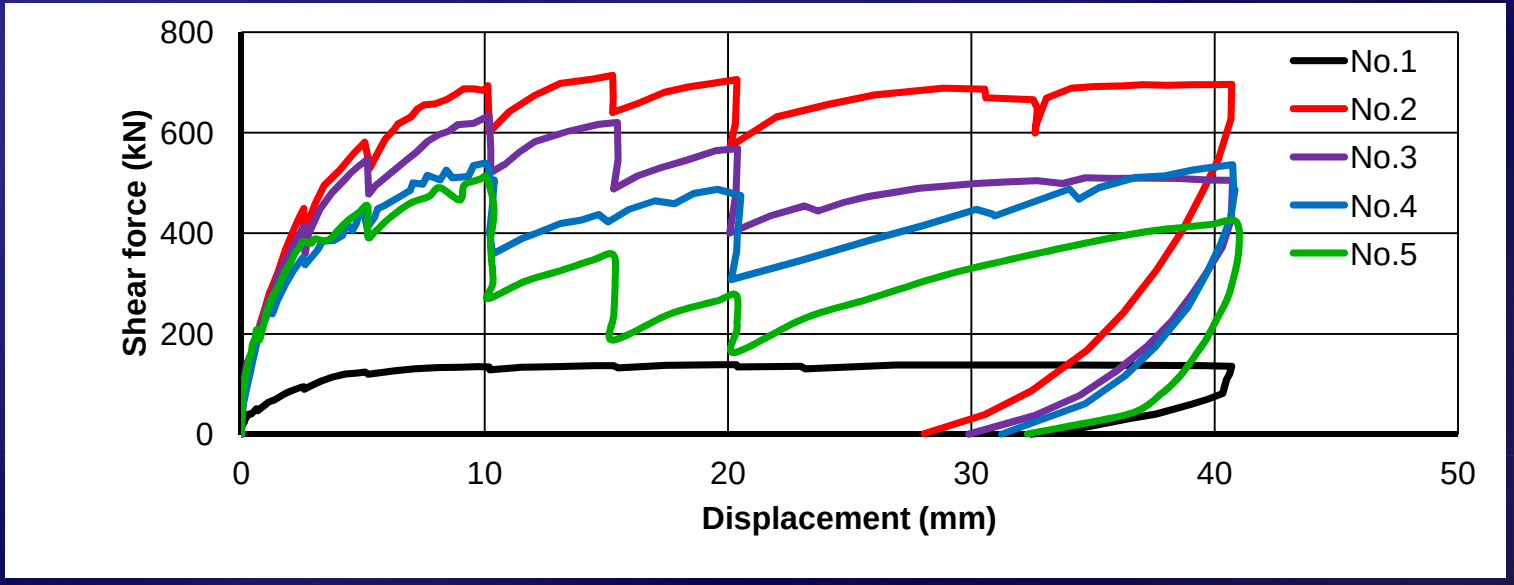
Results – Specimen No.4



Results - Specimen No.5

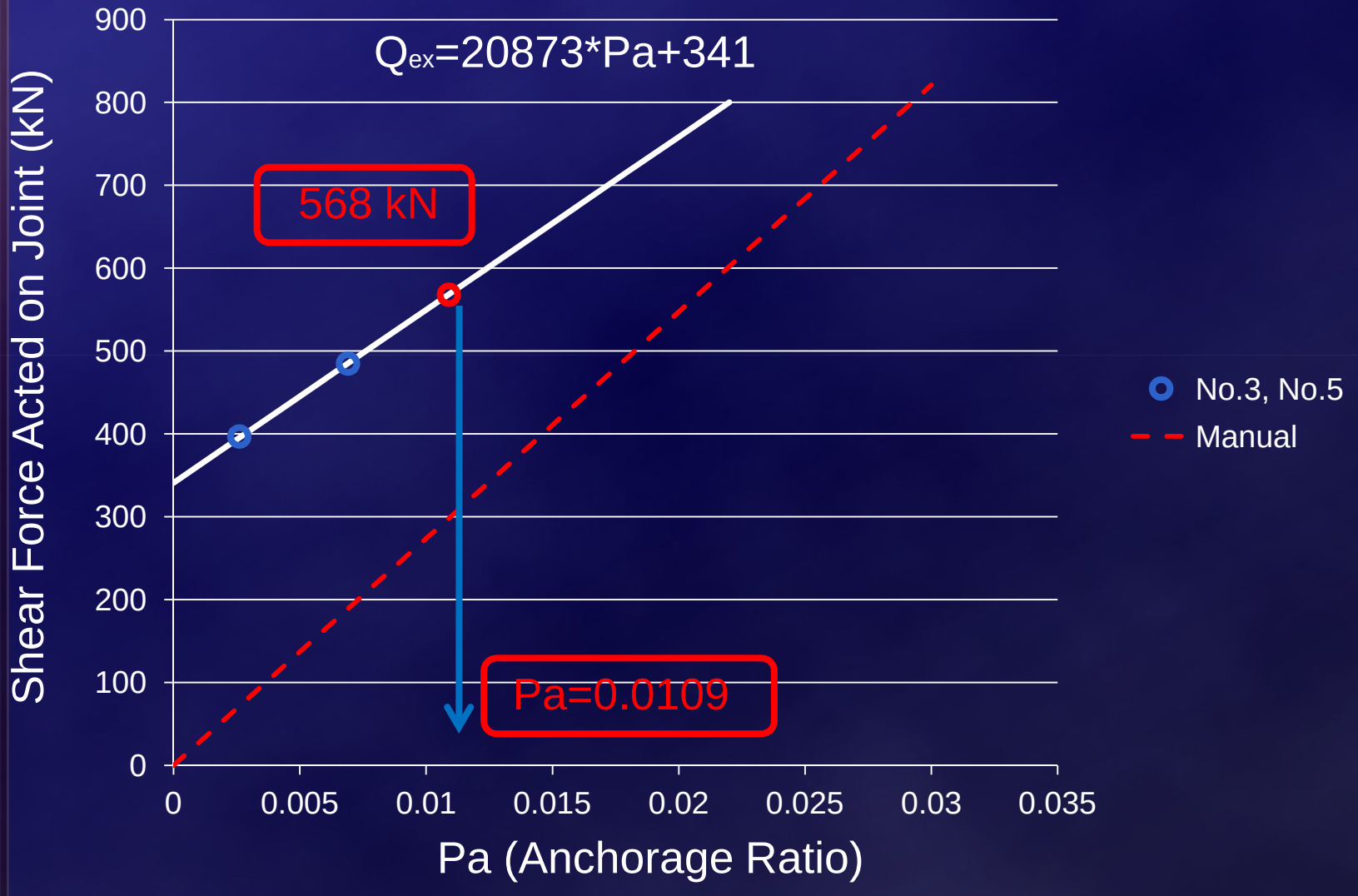


Results - Summary



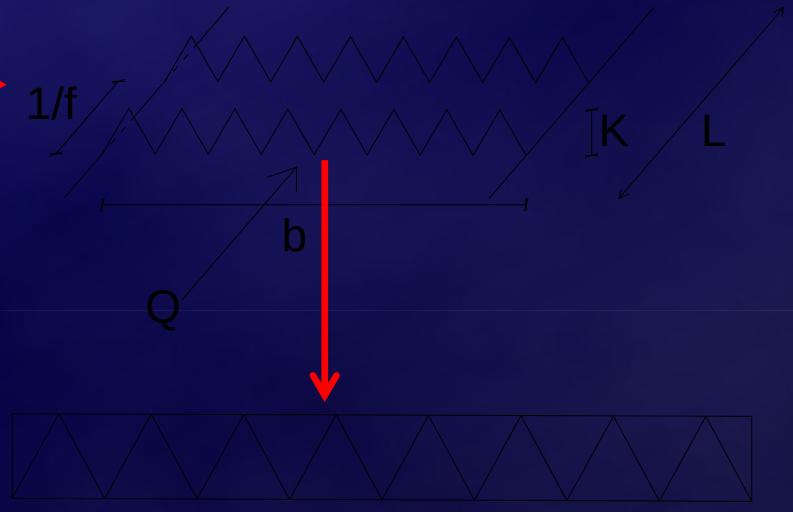
Specimen	Pa [%]	K [mm]	Q [kN]		
			max.	min.	ave.
1	-	-	138.8	-133.5	136.2
2	2.33(44-D13)	-	713.9	-688.8	701.4
3	0.69(13-D13)	2/1.59	633.9	-603.4	618.7
4	0.69(13-D13)	-	539.5	-512.9	526.2
5	0.26(5-D13)	2/2.15	511.9	-536.1	524.0

Results - Anchorage Ratio



Model

$$Q_{fric} = 0.8PaA_c f_y + A_c K_1$$



$$Q_{fric/n} = \alpha\phi K b \sigma_B \qquad n = fL \qquad Q_{fric} = nQ_{fric/n}$$

b (mm)	L (mm)	σ_B (N/mm²)	ϕ	f (1/mm)	Q_{fric} Eq. (kN)	Q_{fric} Fig. (kN)
200	1200	20.1	0.5	1/12.5	361	341

Conclusions

- The first specimen set shows that the roughness surface contributes to the shear strength capacity efficiently.
- For the second set, all specimens with external retrofitting enhanced their lateral load carrying capacities according to control specimen efficiently.
- Waterjet roughening technique applied specimens achieved effective contribution to their shear capacities in their joining surfaces. With 30% of the necessary anchorage bars, Specimen No.3 reached the 88% of the capacity of the manual specimen No.2. Also the roughening created by waterjet technique on the joining surface can be controlled depending on concrete axial compressive strength and waterjet nozzle distance.

Conclusions

- Similar deformation values can be obtained with waterjet technique applied specimens.
- In the range of this study and the according to the calculations, amount of the anchorage bar percentage, Pa can be reduced more than 50%. Instead of 2.33% anchorage, with 1.09% of anchorage bar ratio and a friction surface with an average depth value of 1.87mm, specimen No.2 can transfer the same level of lateral loading to the retrofitting frames.

ありがとうございます。
TEŞEKKÜRLER.
THANK YOU.

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Further

- Detailed analysis of the second set of specimens.
- Evaluation of the ultimate strengths.
- Analysis of a full-scale retrofitted building.

Background

-
-
-
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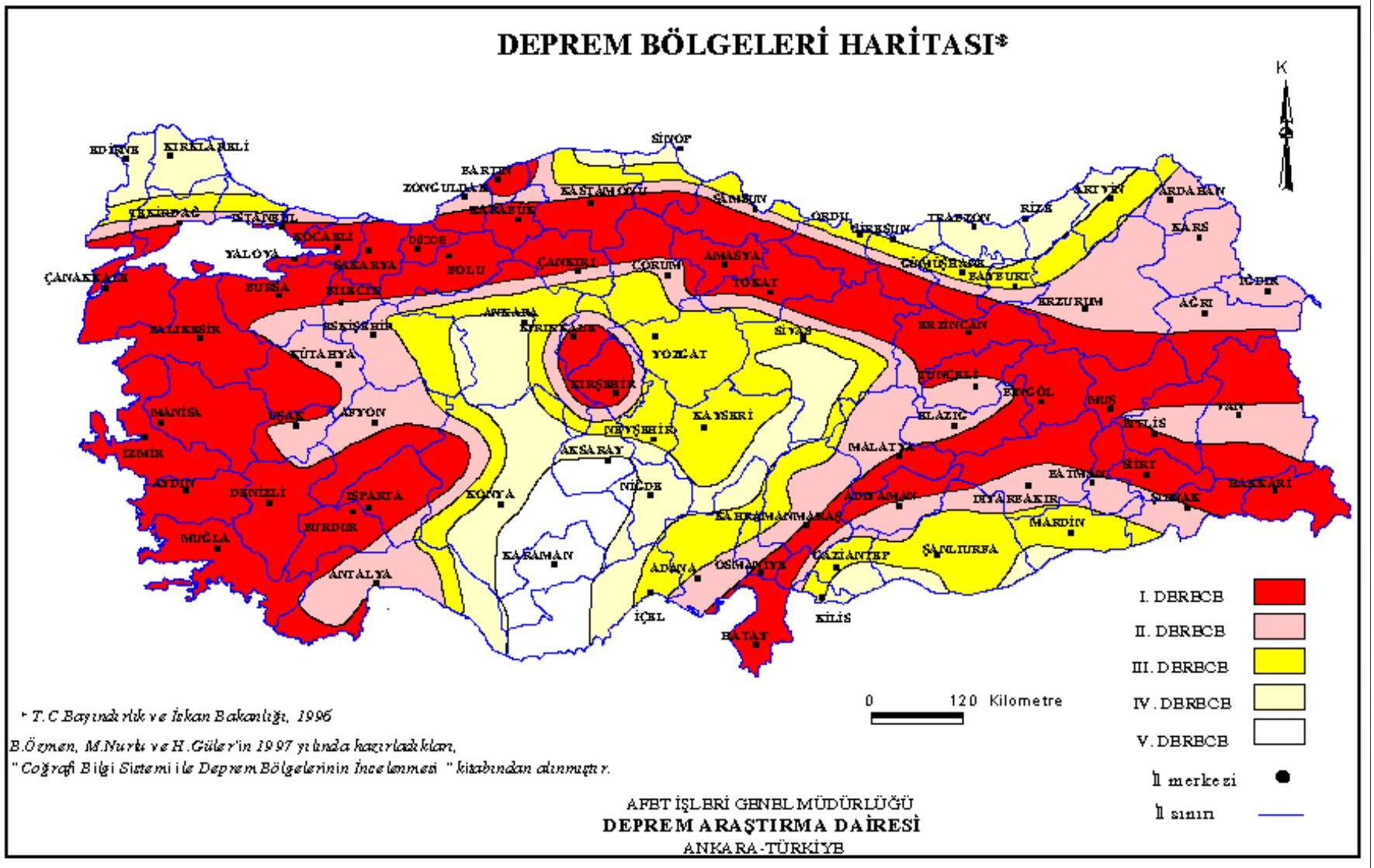
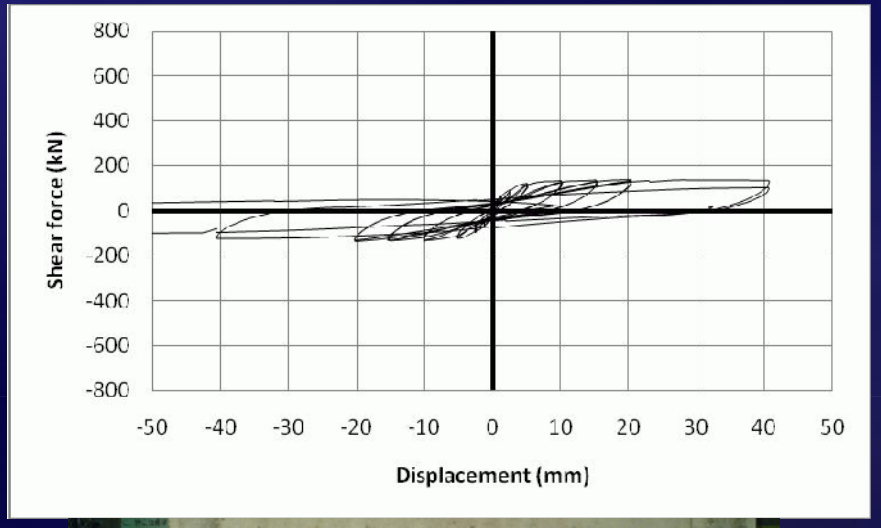

DEPREM BÖLGELERİ HARİTASI*
K
I. DERECE
II. DERECE
III. DERECE
IV. DERECE
V. DERECE
İl merkezi
İl sınırı
0 120 Kilometre
* T.C Bayındırlık ve İskan Bakanlığı, 1996
B.Özmen, M.Nurlu ve H.Güler'in 1997 yılında hazırladıkları,
"Coğrafi Bilgi Sistemi ile Deprem Bölgelerinin İncelenmesi" kitabından alınmıştır.
AFET İŞLERİ GENEL MÜDÜRLÜĞÜ
DEPREM ARAŞTIRMA DAİRESİ
ANKARA-TÜRKİYE

Background

- In 1999 earthquakes of Kocaeli(Golcuk) and Duzce, 17500 people died according to official reports. (Lost people were not considered as dead in these reports, with these causalities reaches 50000.) 320000 building damaged and 600000
- Accord
one fift
buildin

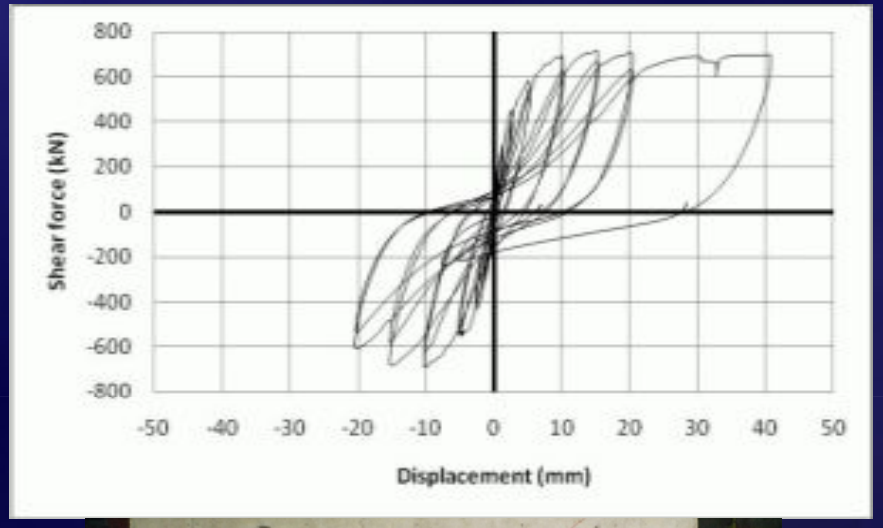
Results - Specimen No.1

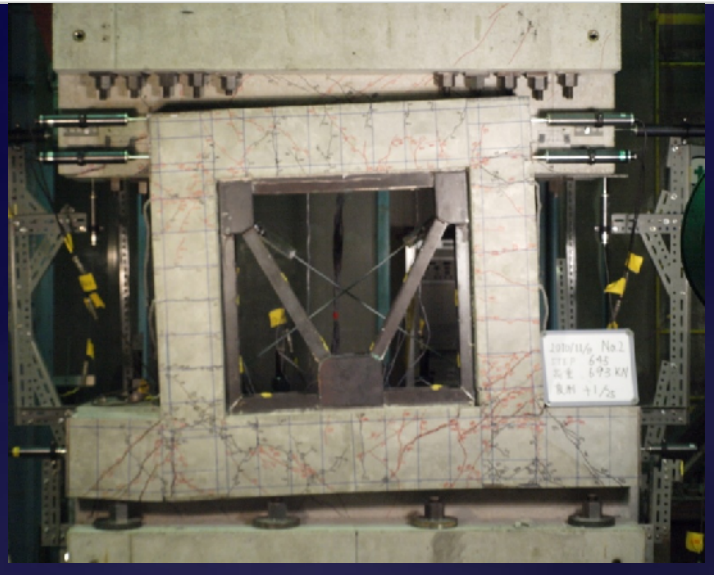
- Control specimen.
- Started to yield 1/100 cycle.
- Max. applied shear force values are 138.8 kN and -133.5 kN in 1/50 and -1/50 cycles, respectively.



Results - Specimen No.2

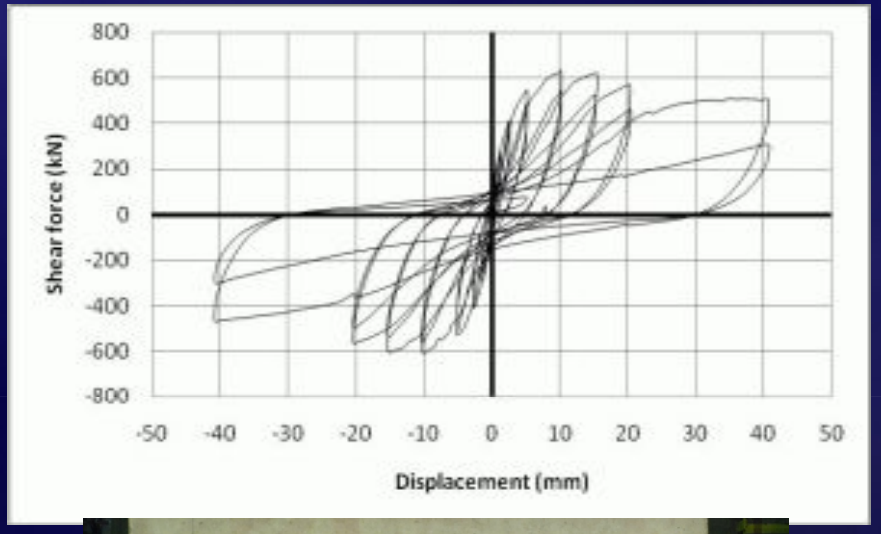
- Pa=2.33%, K=0.
- Max. applied shear force values are 713.9 kN and -688.8 kN in 1/67 and -1/100 cycles, respectively.
- Due to eccentricity, severe damages observed.
- No.2, designed according to the manual, achieved the maximum efficiency by increasing the capacity 5.15 times.





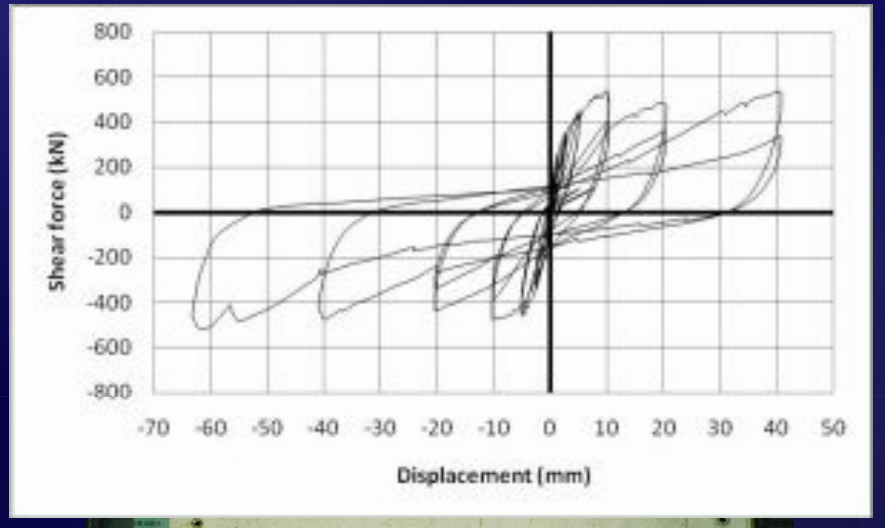
Results - Specimen No.3

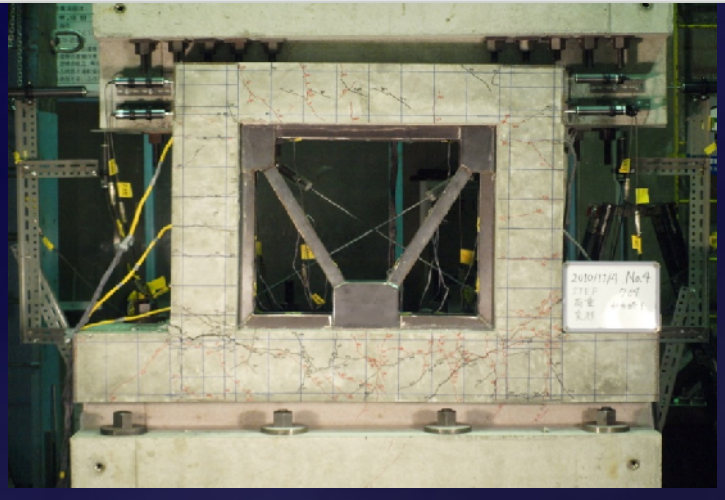
- Pa=0.69%, K=1.70mm.
- Max. applied shear force values are 633.9 kN and -603.4 kN in 1/100 and -1/100 cycles, respectively.
- Increased the capacity by 4.54 times with only 30% of the required amount of the anchorage bars.



Results – Specimen No.4

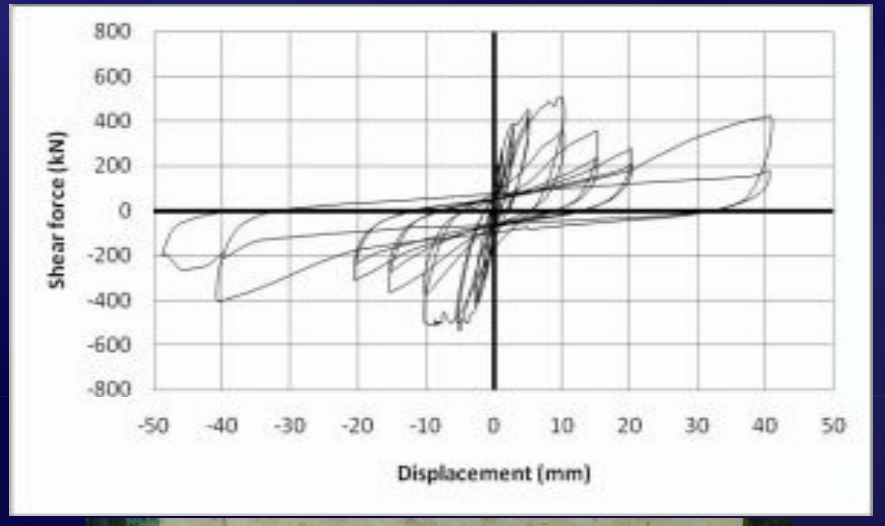
- Pa=0.69%, K=0.
- Max. applied shear force values are 539.5 kN and -512.9 kN in 1/100 and -1/100 cycles, respectively.
- Increased the capacity by 3.86 times with 30% of the required amount.

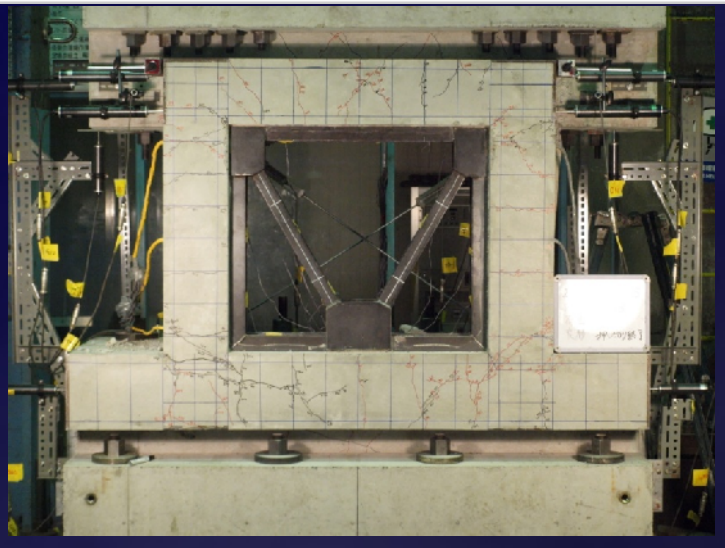




Results - Specimen No.5

- Pa=0.26%, K=2.45mm.
- Max. applied shear force values are 511.9 kN and -536.1 kN in 1/100 and -1/100 cycles, respectively.
- Increased the capacity by 3.85 times with 10% of the required amount.





Results - Displacement

	R_u (Rad)			
Specimen	1	2	3	5
(+)	+1/25	+1/25	+1/25	+1/75
(-)	-1/25	-	-1/27	-1/79

Specimen No.2, which is designed according to the manual and No.3, which has 0.3 times of anchorage bars of the manual specimen, behave almost same.

Manual mentioned above is Manual for External Seismic Retrofit of Existing Reinforced Concrete Buildings published by The Japan Building Disaster Prevention Association.