

SC 벽체와 RC 벽체의 베이스플레이트형 이종접합부 실험연구

2019. 8.28

한금호



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I . 배경 및 목표

I . 배경 및 목표

배경

- APR+ 기술개발 (1,2단계) 연구개발 (2008~2012)
- KEPIC SNG, "강판콘크리트구조" 추록 발행 (2015, 2016)
- 2차 특정기술주제보고서(접합부) 인허가 진행 중

목표

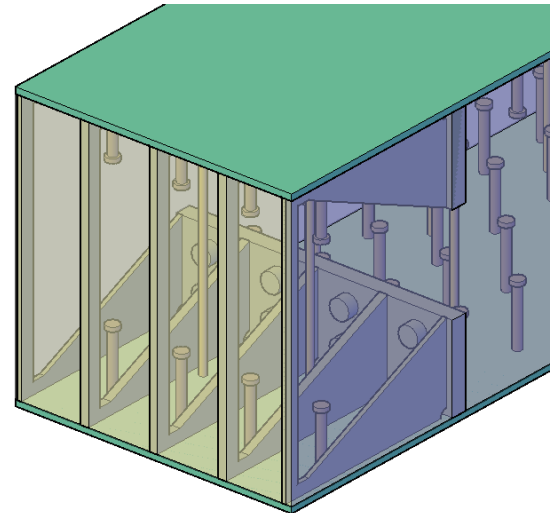
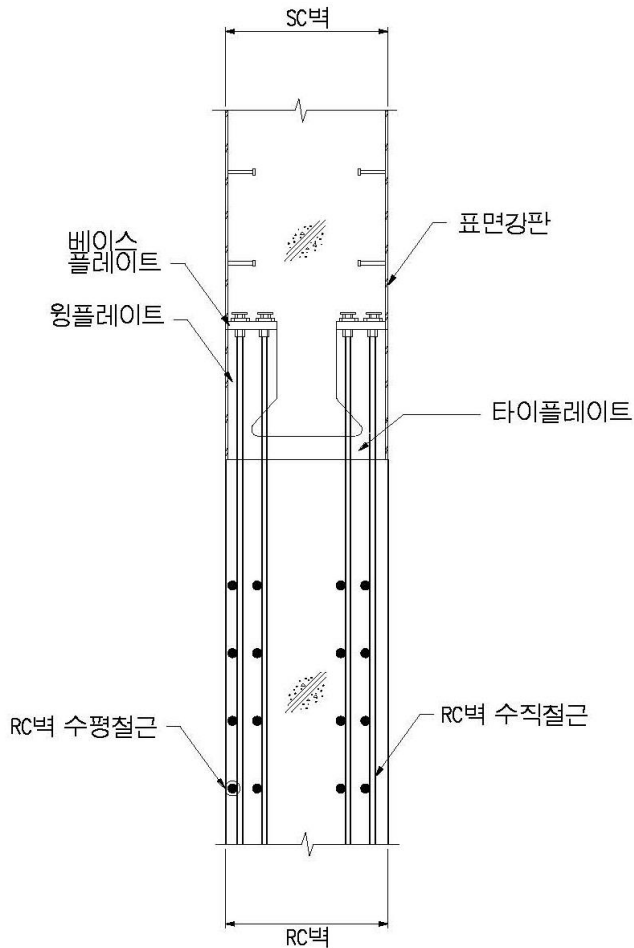
- SC-RC 베이스플레이트형 접합부 설계 이론 연구
- 실험을 통한 설계 이론 검증
- 접합부 설계 기술 개발 및 인허가 획득

II. 연구내용

1. 설계방법 개발
2. 실험 연구

1 설계방법 개발

➤ 베이스플레이트형 접합부 형상



▶ 전강도 설계법

KEPIC SNG 8.1.3

SNG 8.1.3 접합부 설계 기본원칙

접합부 설계는 다음의 전강도설계법 또는 부분강도설계법으로 하여야 한다.

(1) 전강도설계법

전강도설계법에서 접합부의 각종 강도들, 즉 인장강도, 압축강도, 휨강도, 변위전단강도, 변내전단 강도, 변위전단마찰강도 및 변내전단마찰강도 등은 각각 다음 조건들을 만족시켜야 한다.

$$\Omega R_{n,j} \leq \phi R_{d,j} \quad (8.1.1)$$

여기서, $R_{n,j}$: 접합부의 각종 소요강도로서, 구조해석 결과와 상관없이 피접합재의 설계강도 $\phi R_{d,j}$ 중에서 작은 값으로 한다.

Ω : 초과접합강도계수로서, 피접합재의 초과공칭강도비에 대한 접합재의 초과항복강도비의 비율이며 1.0 이상이고 1.25 이하로 한다.

ϕ : 접합부의 각종 강도감소계수

$R_{d,j}$: 접합부의 각종 공칭강도

Ω : 초과접합강도계수로서, 피접합재의 초과공칭강도비에 대한 접합재의 초과항복강도비의 비율이며 1.0 이상이고 1.25 이하로 한다.

AISC N690

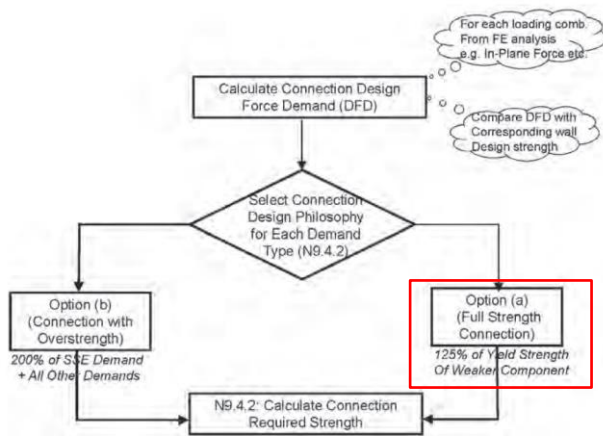


Fig. C-A-N9.4.1. Calculation of connection required strength.

ACI 349

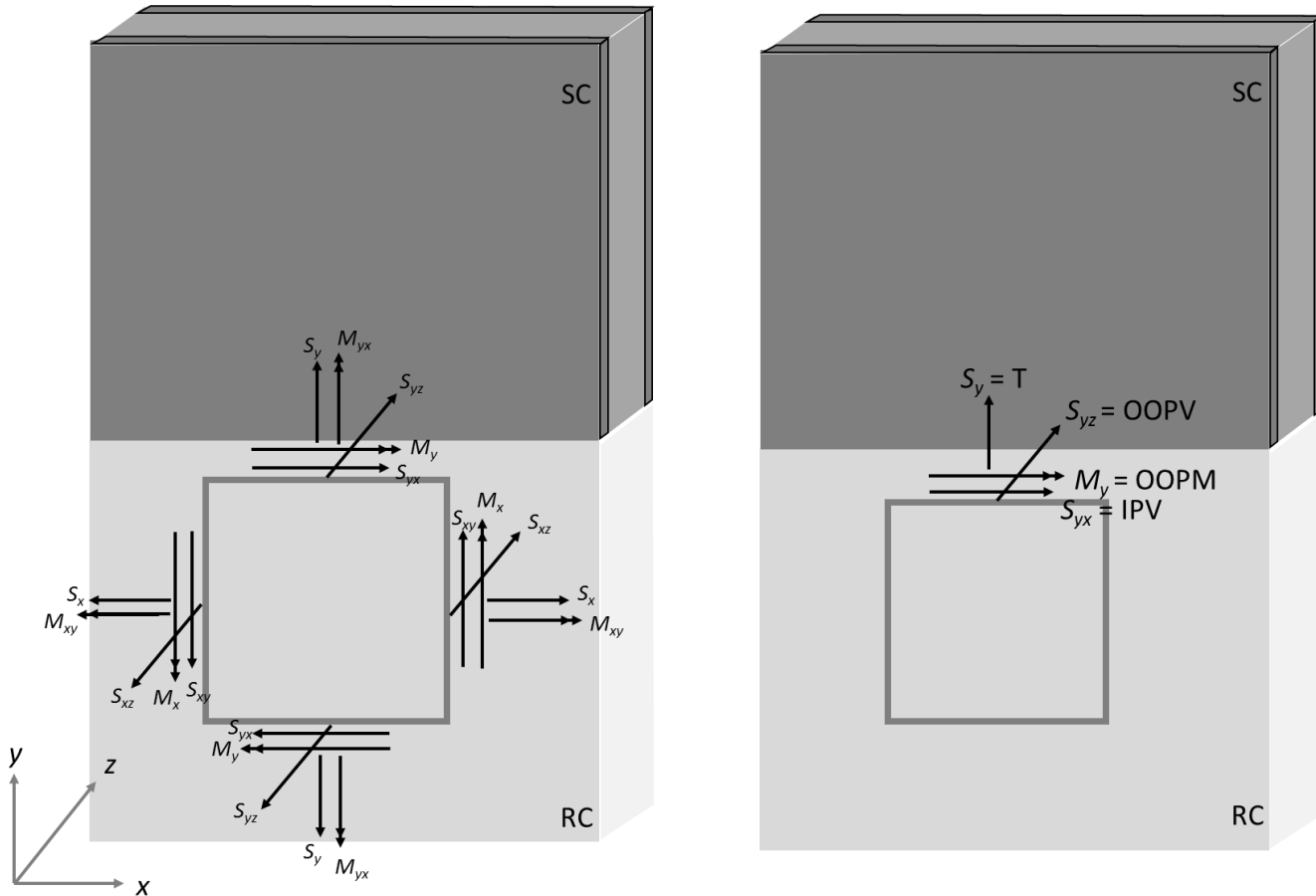
12.14.3.4 A full mechanical connection shall develop in tension or compression, as required, at least 125% of specified yield strength f_y of the bar.

21.2.5—Reinforcement in members resisting earthquake-induced forces

Reinforcement resisting earthquake-induced flexural and axial forces in frame members and in wall boundary elements shall comply with ASTM A 706. ASTM A 615 Grades 40 and 60 reinforcement are permitted in these members if (a) the actual yield strength based on mill tests does not exceed the specified yield strength by more than 18,000 psi (retests shall not exceed this value by more than an additional 3000 psi) and (b) the ratio of the actual ultimate tensile strength to the actual tensile yield strength is not less than 1.25.

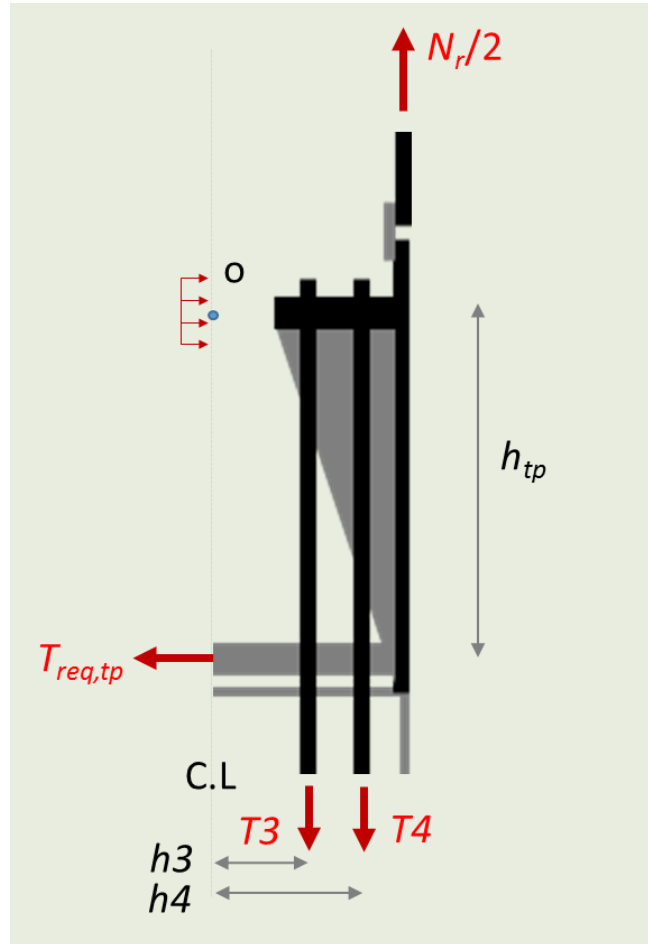
1 설계방법 개발

➤ 하중 전달 구조



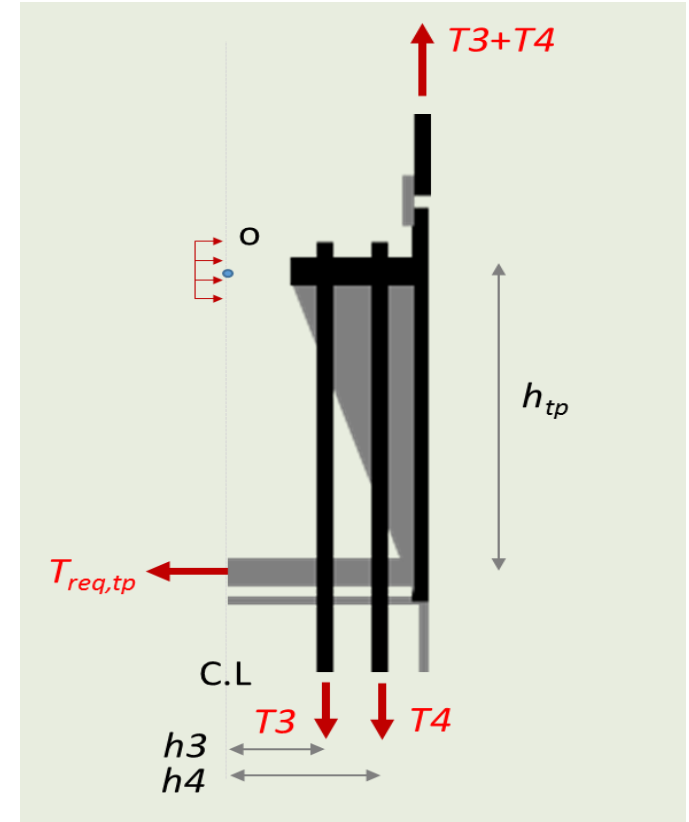
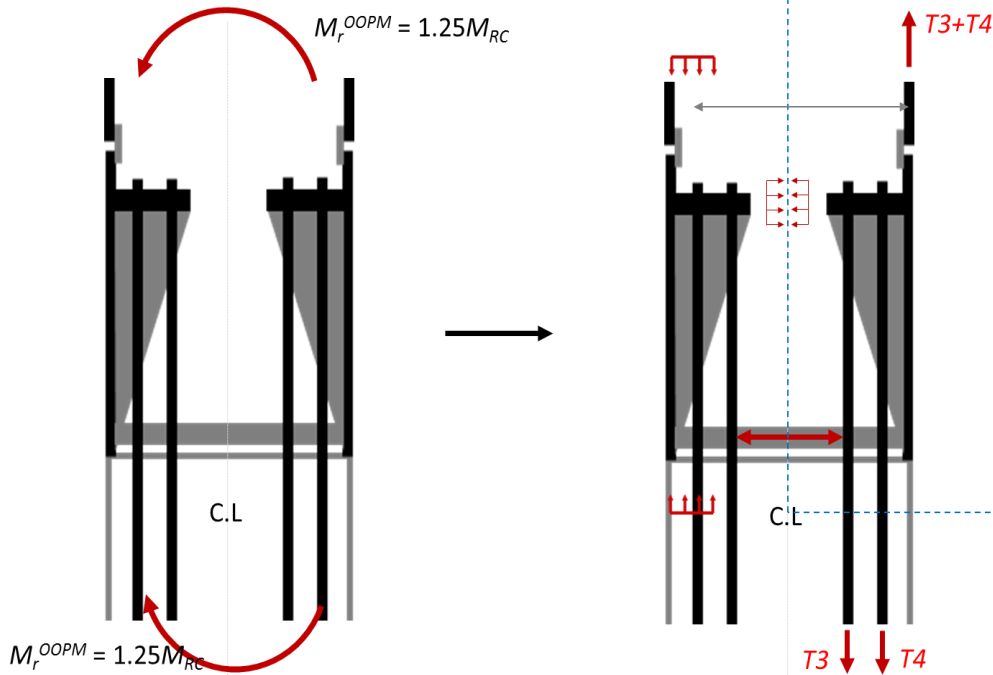
1 설계방법 개발

➤ 하중전달 - 인장력



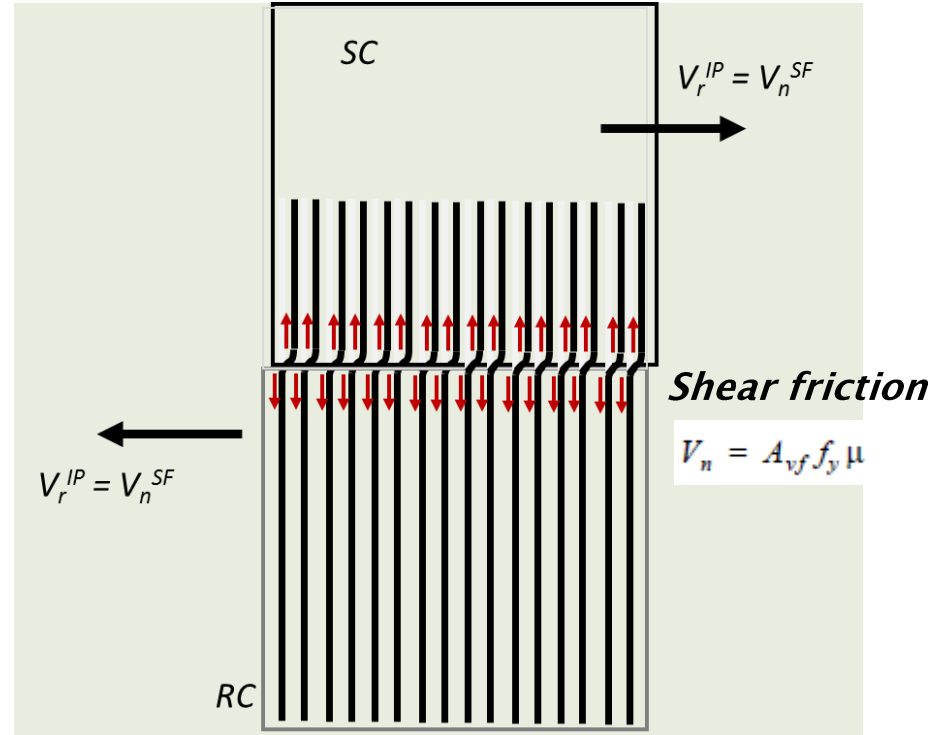
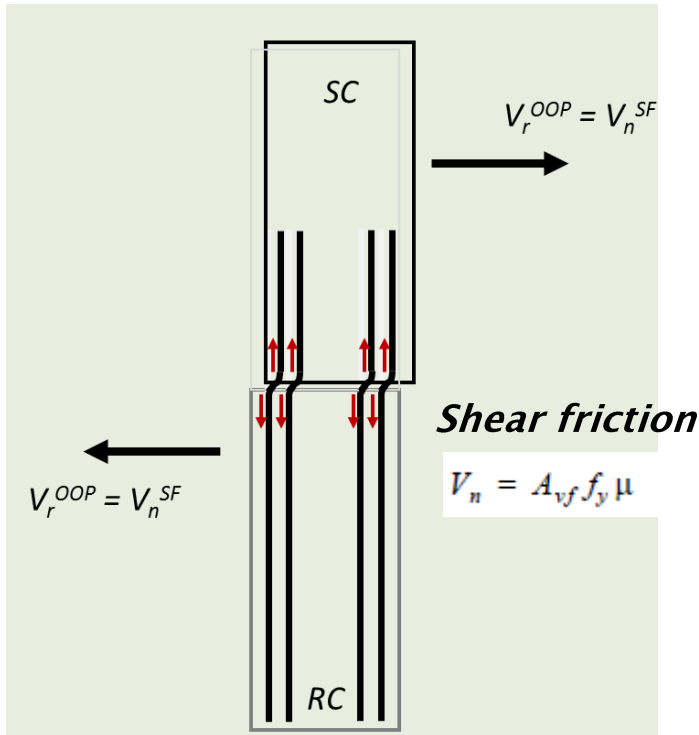
1 설계방법 개발

➤ 하중전달 - 면외힘



1 설계방법 개발

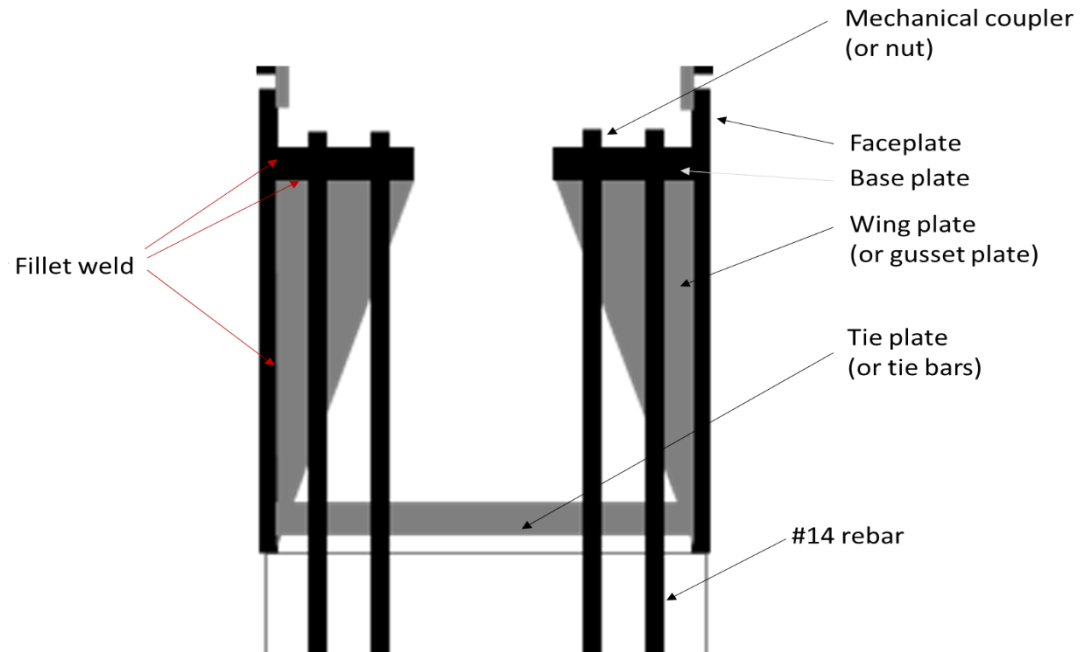
➤ 하중전달 - 면외전단, 면내전단



1 설계방법 개발

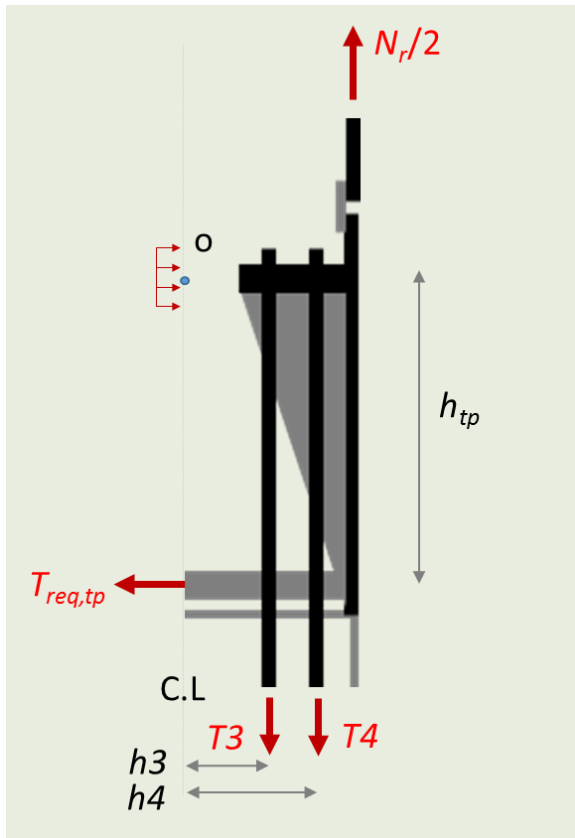
➤ 설계방법

- Tie Plate
- Base Plate
- Wing Plate



1 설계방법 개발

➤ 설계방법-Tie Plate



Required Strength

$$T_{req,tp} = \frac{\left[\frac{N_r}{2} \times \left(\frac{t_{wall}}{2} - \frac{t_p}{2} \right) \right] - (T_3 \times h_3 + T_4 \times h_4)}{h_{tp}}$$

$$T_3 = T_4 = 1.25 A_{s,r} F_{y,r} \quad (\text{전강도 설계법})$$

Plate Design

D2. TENSILE STRENGTH

The *design tensile strength*, $\phi_t P_n$, and the *allowable tensile strength*, P_n/Ω_t , of tension members shall be the lower value obtained according to the *limit states* of *tensile yielding* in the gross section and *tensile rupture* in the net section.

(a) For tensile yielding in the gross section:

$$P_n = F_y A_g \quad (D2-1)$$

$$\phi_t = 0.90 \text{ (LRFD)} \quad \Omega_t = 1.67 \text{ (ASD)}$$

(b) For tensile rupture in the net section:

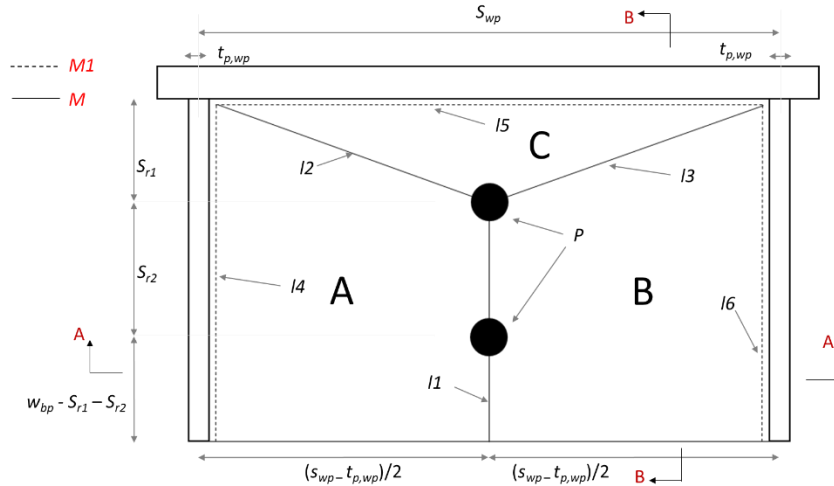
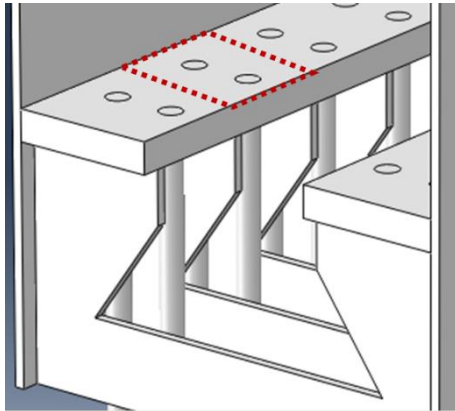
$$P_n = F_u A_e \quad (D2-2)$$

$$\phi_t = 0.75 \text{ (LRFD)} \quad \Omega_t = 2.00 \text{ (ASD)}$$

1 설계방법 개발

➤ 설계방법-Base Plate

- Yield Line Analysis (per AISC DG 16)



Required Strength

$$M = \frac{2 \times 1.25 A_{z,r} F_{y,r} \times \Delta}{(2l_1\theta_1 + 2l_2\theta_2 + 2l_3\theta_2 + l_4\theta_1 + l_5\theta_1 + l_3\theta_2)}$$

Plate Design

F1. GENERAL PROVISIONS

The design flexural strength, $\phi_b M_n$, and the allowable flexural strength, M_n/Ω_b , shall be determined as follows:

(1) For all provisions in this chapter

$$\phi_b = 0.90 \text{ (LRFD)} \quad \Omega_b = 1.67 \text{ (ASD)}$$

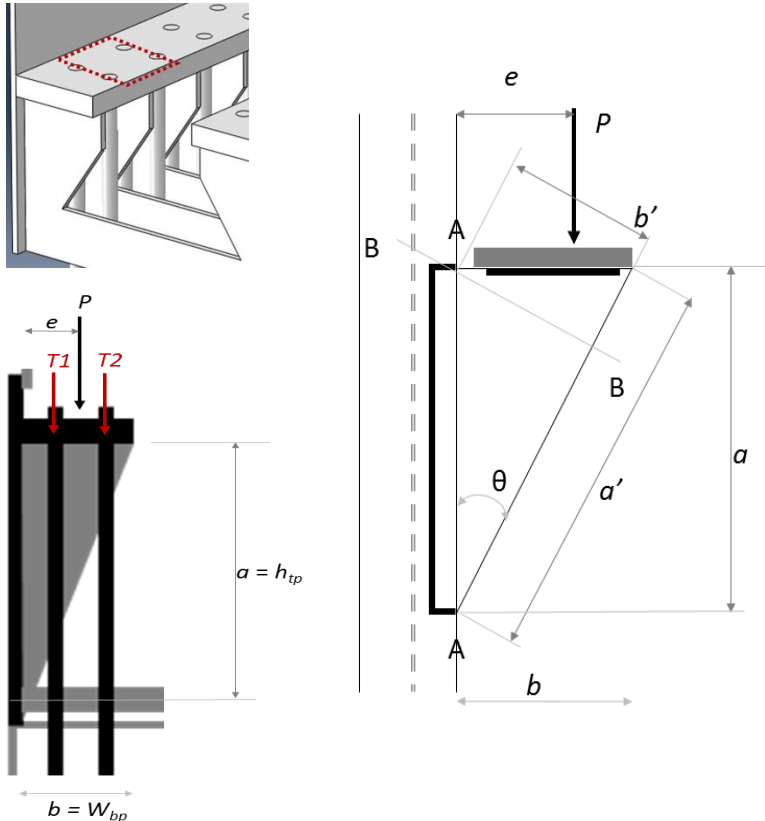
1. Yielding

$$M_n = M_p = F_y Z_x$$

(F2-1)

1 설계방법 개발

➤ 설계방법-Wing Plate



Demand at A-A

$$\text{Shear} = P (=1.25A_{s,r}F_{y,r})$$

$$\text{Flexure} = P \times e$$

Available Strengths at A-A per AISC manual Part 15

$$\phi M_n^{A-A} = \phi F_{y,wp} \times Z \quad \text{Flexure} (\phi=0.9)$$

Demand at B-B

$$\text{Normal} = P \cos\theta$$

$$\text{Shear} = P \sin\theta$$

$$\text{Flexure} = M_u^{B-B} = Pe - N_u^{B-B} \left(\frac{b'}{2} \right)$$

Available Strengths at B-B per AISC manual Part 15

$$\text{Normal} (\phi=0.9) \quad \phi N_n^{B-B} = F_{cr} t_{p,wp} b'$$

$$\text{Shear} (\phi=1.0) \quad \phi V_n^{B-B} = \phi 0.60 F_{y,wp} t_{p,wp} b'$$

$$\text{Flexure} (\phi=0.9) \quad \phi M_n^{B-B} = \frac{F_{cr} t_{p,wp} b'^2}{4}$$

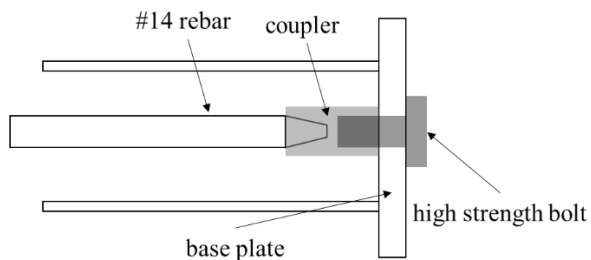
Interaction of normal and flexural strengths at B-B per AISC manual Part 15

$$\frac{N_u^{B-B}}{\phi N_n^{B-B}} + \frac{M_u^{B-B}}{\phi M_n^{B-B}} \leq 1.0$$

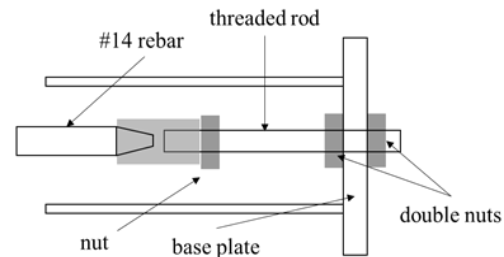
2 실험 연구

➤ 실험 종류

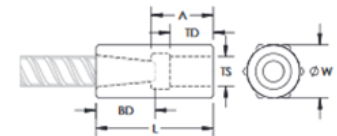
Specimen	Loading	Scale	Rebar-Base plate
1	면외휨	Full	Coupler
2	면외휨	Full	Double Nut
3	면외전단	Full	Coupler
4	면외전단	Full	Double Nut
5	면내전단	Small	Coupler
6	면내전단	Small	Double Nut



Coupler



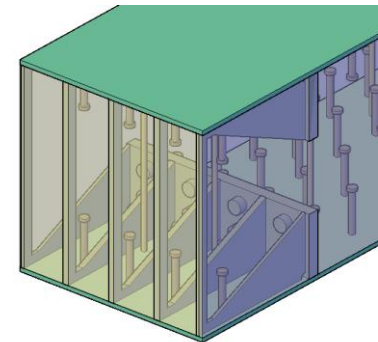
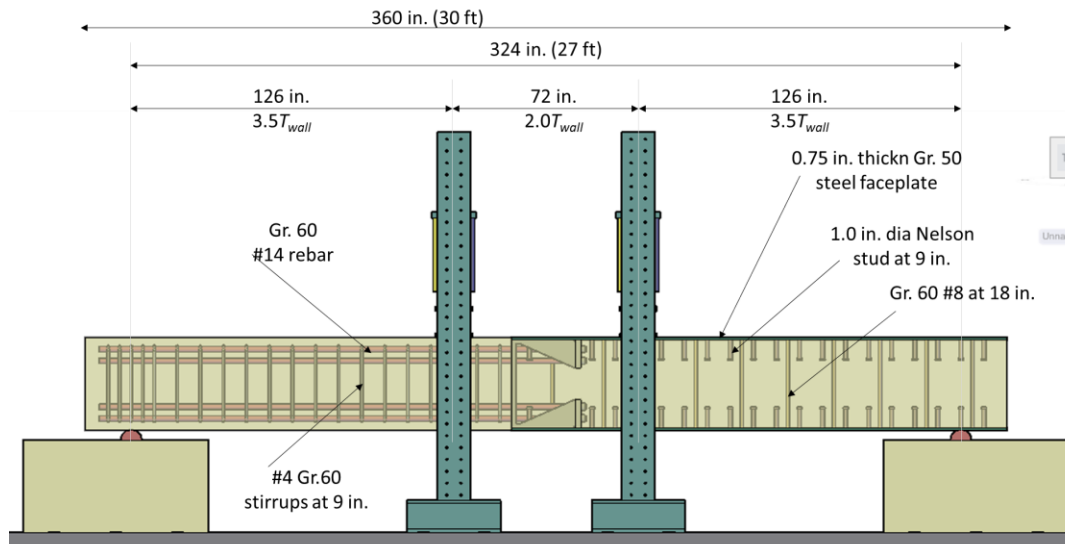
Double Nut



➤ 실험체 제원 - 면외힘실험

▶ Test Specimen - OOPF

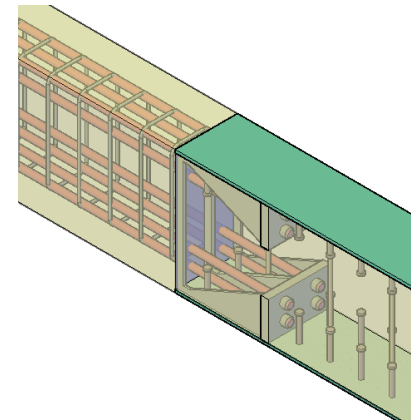
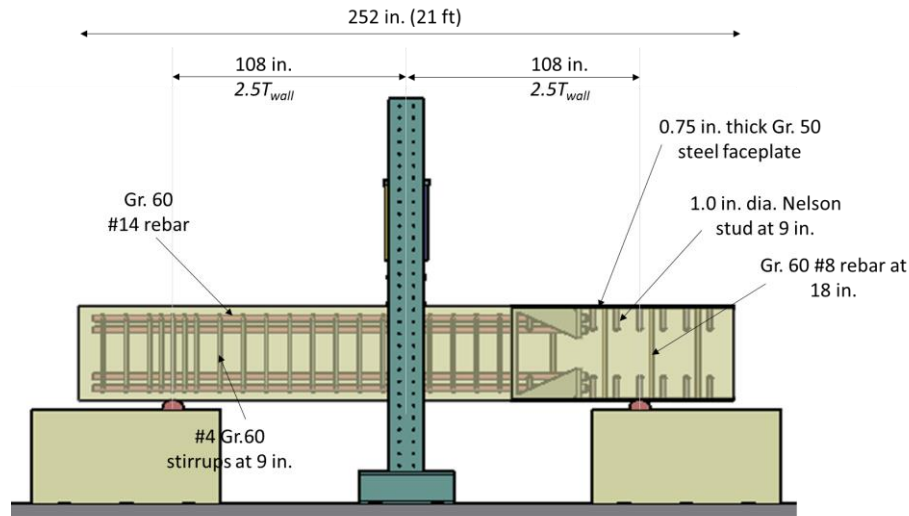
- 36 in. wide, 36 in. deep
- Concrete ($f_c' = 4000$ psi, expected $f_c' = 6000$ psi)
- RC
 - Gr. 60 #14 rebar @ 9 in.
 - Gr. 60 #4 stirrup @ 9 in.
- SC
 - 0.75 in. thick Gr. 50 plate
 - 2.0 in. thick Gr. 50 base plate
 - 1.0 in. thick Gr. 50 wing plate
 - 1 in. stud anchor @ 9 in.
 - Gr. 60 #8 rebar (ties) @ 18 in.



➤ 실험체 제원 - 면외전단실험

▶ Test Specimen - OOPV

- 18 in. wide, 36 in. deep
- Concrete ($f_c' = 4000$ psi, expected $f_c' = 6000$ psi)
- RC
 - Gr. 60 #14 rebar @ 9 in.
 - Gr. 60 #4 stirrup @ 9 in.
- SC
 - 0.75 in. thick Gr. 50 plate
 - 2.0 in. thick Gr. 50 base plate
 - 1.0 in. thick Gr. 50 wing plate
 - 1 in. stud anchor @ 9 in.
 - Gr. 60 #7 rebar (ties) @ 18 in.

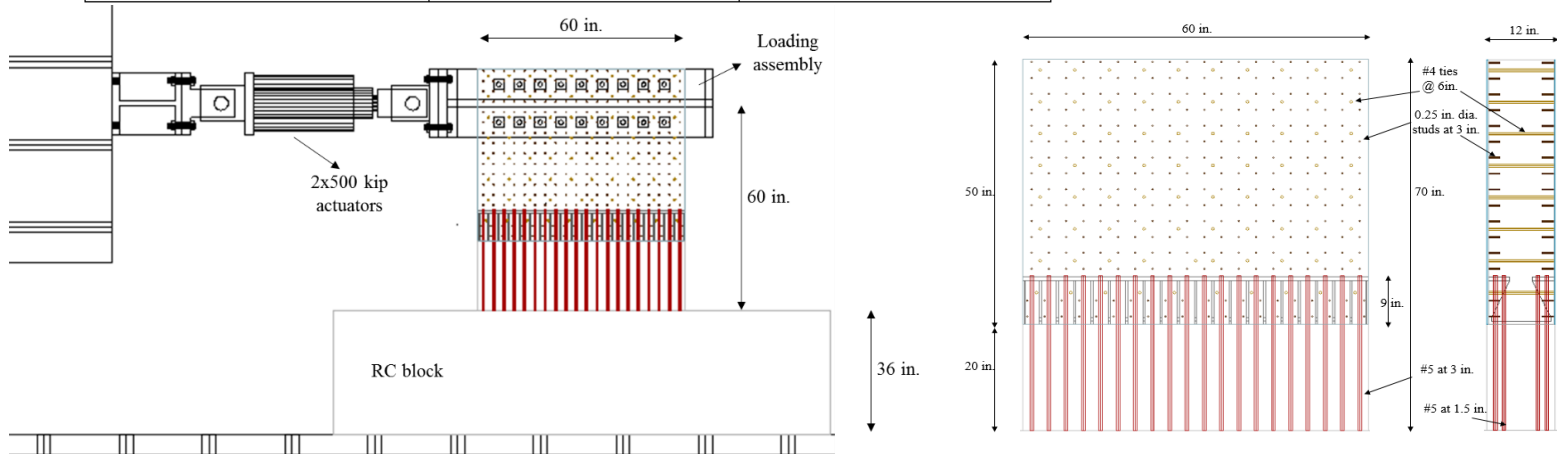


2 실험 연구

➤ 실험체 제원 - 면내전단실험

● Test Specimen - IPV

Property	Full-Scale	1:3 Scale
Wall thickness	36 in.	12 in.
Faceplate thickness	0.75 in.	0.25 in.
Main rebar	#14	#5
Main rebar spacing	9 in.	3 in.
Stud anchor	1 in. diameter	0.25 in. diameter
Stud spacing	9 in.	3 in.
Tie bar	#8	#4
Tie bar spacing	18 in.	6 in.
Baseplate	11 in. wide, 2 in. thick	3.75 in. wide, 0.625 in. thick
Tie plate	1.75 in. wide, 1 in. thick	0.625 in. wide, 0.375 in. thick
Wing plate	1 in. thick	0.375 in. thick



III. 연구 결과

1. 실험 전 해석
2. 결과분석

1 실험 전 해석

➤ 해석 개요

- 해석프로그램 : ABAQUS, LS-Dyna
- 해석 모델

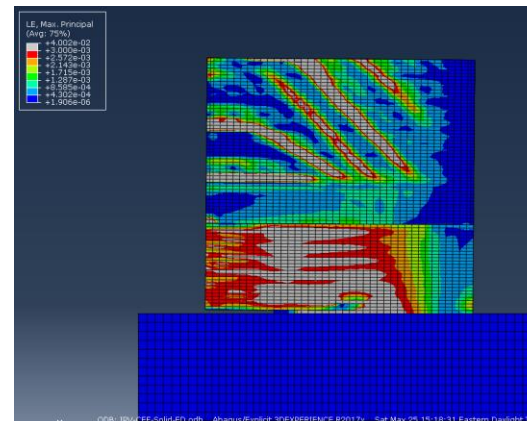
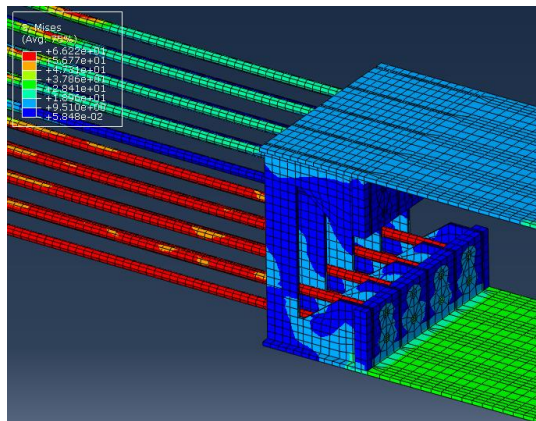
Rebar, Steel Plate, Concrete : C3D8R (8 node element)

Stirrups, Stud & ties : 2 node beam element

General contact between steel faceplate and concrete

Rebars and stirrups embedded in RC

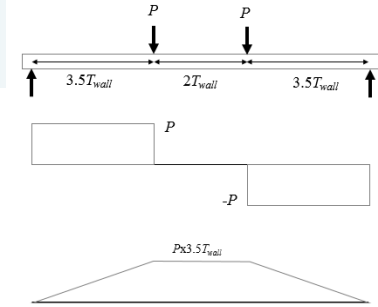
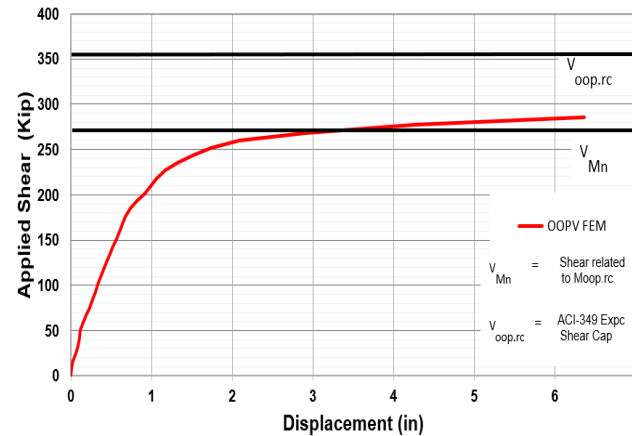
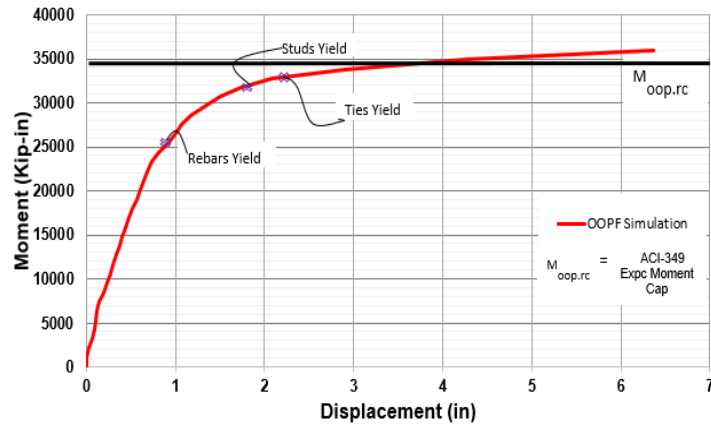
Base plate, wing plate, studs, and ties embedded in SC



1 실험 전 해석

➤ 해석 결과

- 면외힘 해석

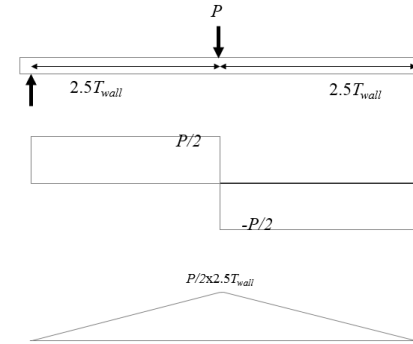
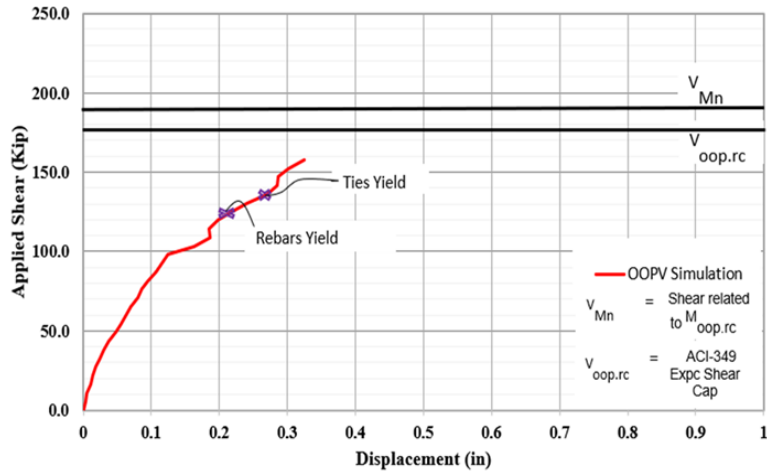


Theoretical (a)			Analytical (b)			Ratio b/a
$M_{oop.rc}$ kip-in	V_{Mn} kip	P_{Ult} kip	$M_{oop.rc}$ kip-in	V_{Mn} kip	P_{Ult} kip	
34520	274	548	35954	285	571	1.04

1 실험 전 해석

➤ 해석 결과

- 면외전단 해석



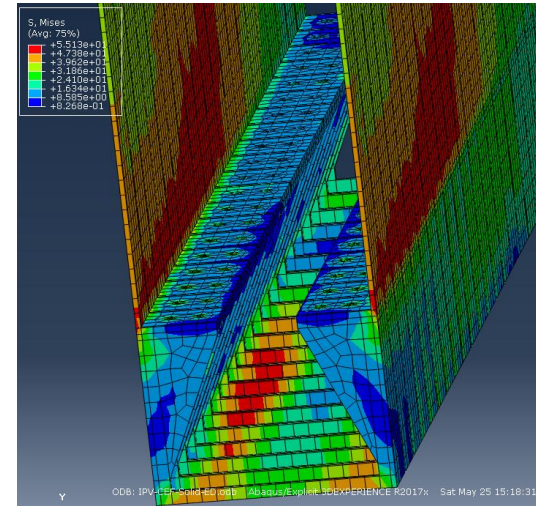
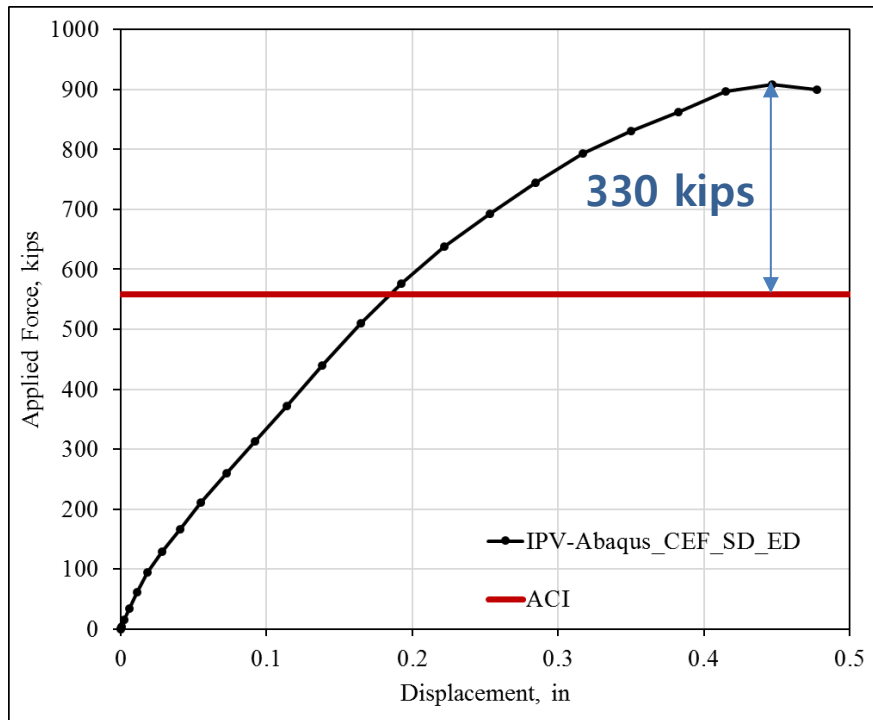
$$P_{V_{oop.rc}} := 2V_{oop.rc} = 358.13 \text{ kip} < P := \frac{2M_{oop.rc}}{2.5 \cdot t_{wall}} = 383.603 \text{ kip}$$

Theoretical (a)			Analytical (b)			Ratio b/a
M_{ACI} kip-in	V_{Mn} kip	P_{Ult} kip	M_{ACI} kip-in	V_{Mn} kip	P_{Ult} kip	
17260	191	383	14198	160	320	0.84

1 실험 전 해석

➤ 해석 결과

- 면내전단 해석



LATER

IV. 추가 연구 계획

추가 연구 계획

➤ 면내 전단 실험

- 일정: 2019년 8월 말

➤ 매개변수 연구

- 목적: 다양한 설계 변수의 영향 확인
- 매개변수: 재료(Steel Strength, Concrete Strength),
형상(Plate Thickness, tie plate area 등)
- 실험 검증 해석을 통한 모델 검증 (ABAQUS, LS-Dyna)
- 설계방법 검증

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Last and Always

최고의 안전은
명예와
현실입니다