USER BULLETIN 10

Joint Hinge Generator Spreadsheet for shear and bond slip behaviors

1. INTRODUCTION

This document describes an Excel spreadsheet, *Joint Hinge Generator*, which is developed to generate shear stress-strain and moment rotation curves of both exterior and interior beam-column joints with or without transverse reinforcement. The purpose of *Joint Hinge Generator* is to execute the mathematical calculations and derive shear stress-strain and moment rotation curves of rotational spring element ready for inputting into global frame analysis software. The spreadsheet includes two joint models: Model 1 and Model 2. Model 1 is based on Jeon (2013) and applicable to a wide range of joint types including interior and exterior joints with and without transverse reinforcement. Model 2 is based on Sharma et al. (2011) and applicable to exterior joints without transverse reinforcement only. The formulation and theoretical assumptions of Model 1 and Model 2 are discussed in detail in Suwal and Guner (2023a). To facilitate the calculation process, the spreadsheet tool (Suwal and Guner 2023b) is shared as a freeware for the use of practicing engineer. It can be downloaded from the following link:
https://www.utoledo.edu/engineering/faculty/serhan-guner/docs/7S-JointHingeGenerator.xlsx

This user bulletin presents the calculation process with flowcharts for both Model 1 (**Fig. 1**) and Model 2 (**Fig. 2**). In addition, the application and validation of the *Joint Hinge Generator* is presented for both interior and exterior joints with or without transverse reinforcement for Model 1 and for an exterior joint with no transverse reinforcement for Model 2. Five application and validation examples are presented in total.

This document is prepared by Nirmala Suwal (graduate student at the University of Toledo, OH, USA) as a part of project supervised by Dr. Serhan Guner

2. FLOWCHARTS

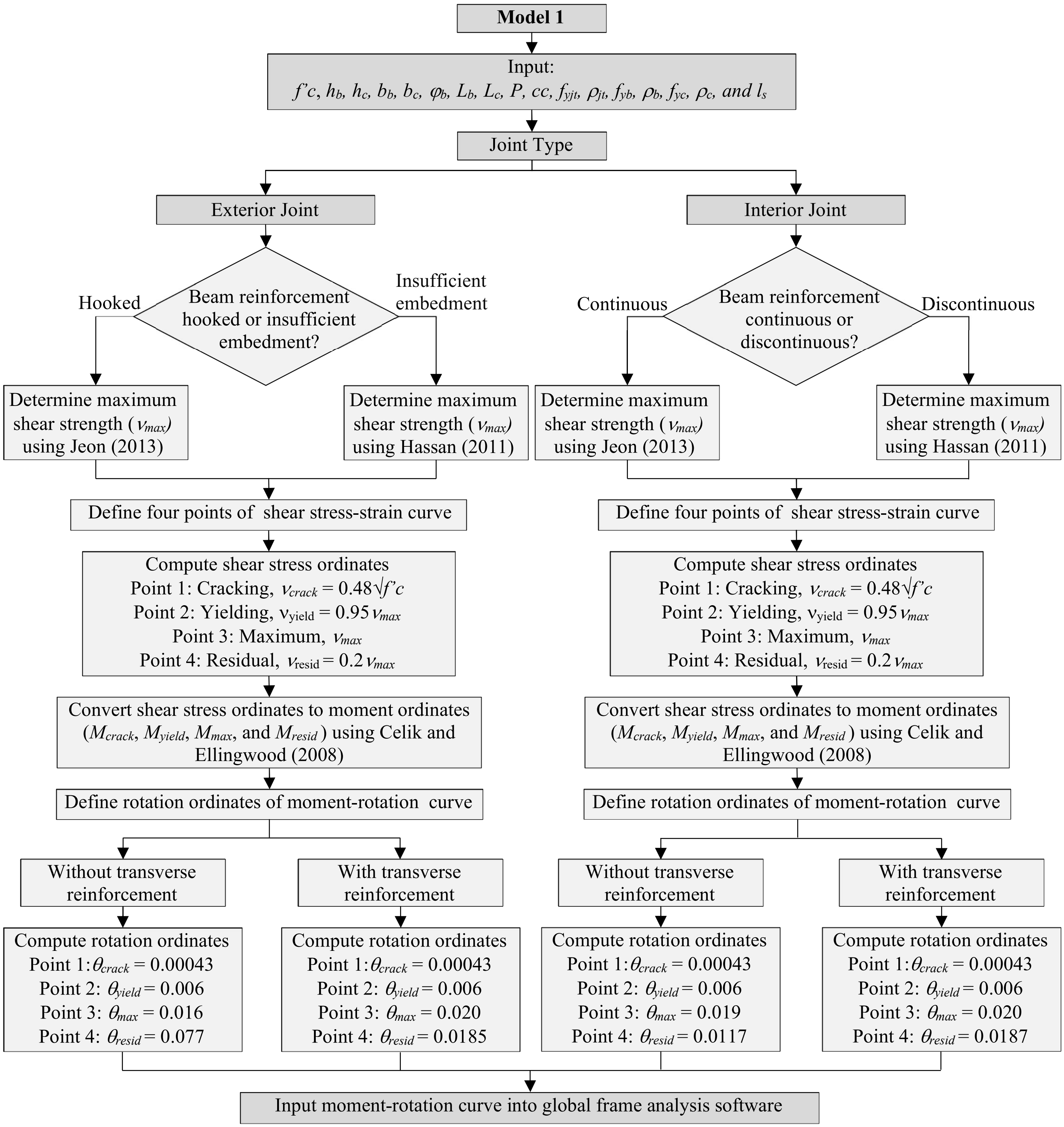


Fig. 1 Calculation process for *Joint Hinge Generator* for Model 1

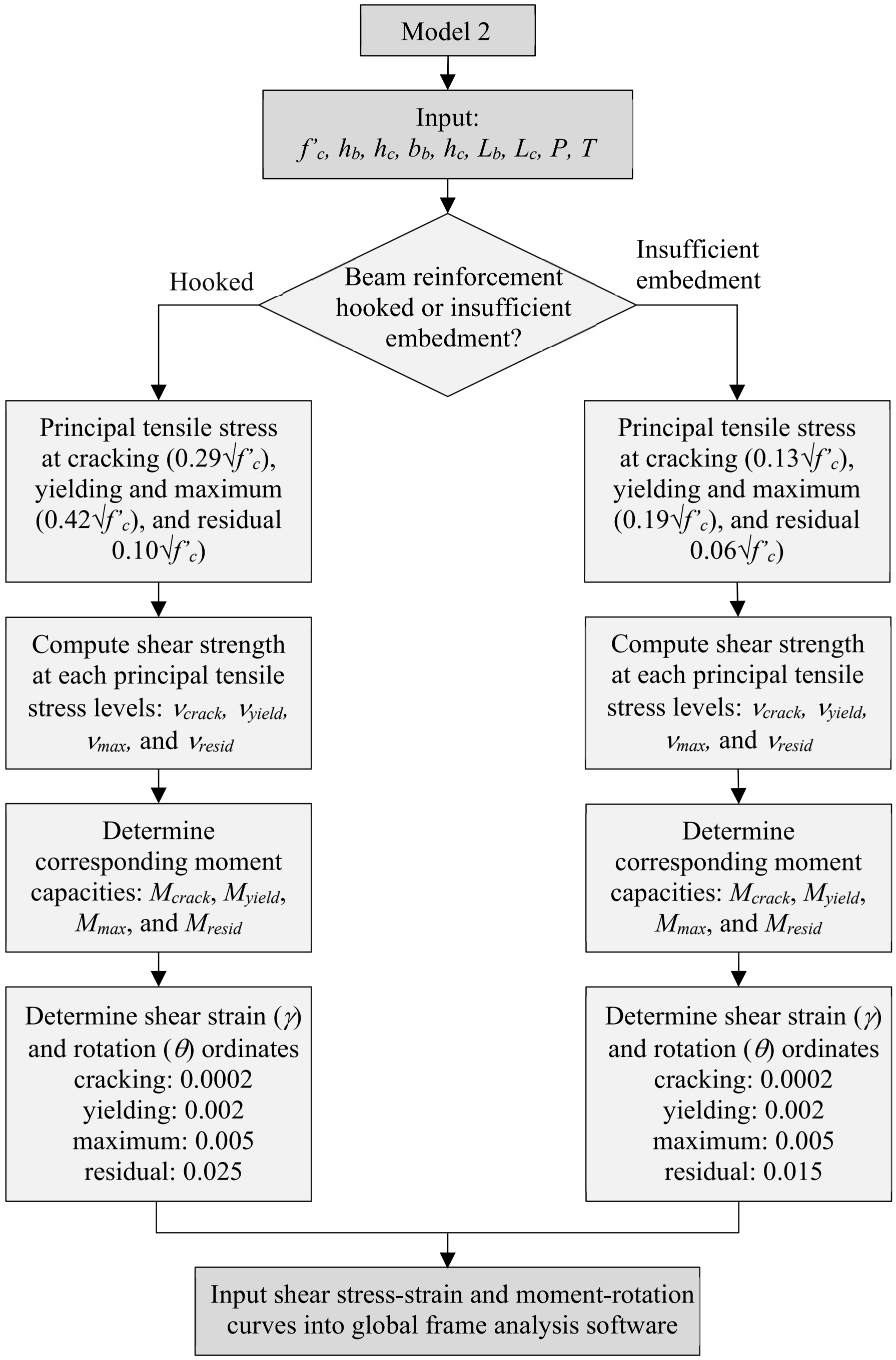


Fig. 2 Calculation process for *Joint Hinge Generator* for Model 2

SYMBOLS

f'_c	:	Concrete compressive strength
h_b	:	Beam depth
b_b	:	Beam width
h_c	:	Column depth
b_c	:	Beam width
φ_b	:	Longitudinal reinforcement diameter
L_b	:	Beam length from support to point of contraflexure (exterior joint), Beam length between two points of contraflexure (interior joint)
L_c	:	Column span between two points of contraflexure
P	:	Axial load applied to the column
cc	:	Concrete cover
f_{yb}	:	Beam longitudinal reinforcement strength
ρ_b	:	Beam longitudinal reinforcement ratio
f_{yc}	:	Column longitudinal reinforcement strength
ρ_c	:	Column longitudinal reinforcement ratio
f_{yjt}	:	Joint transverse reinforcement strength
ρ_{jt}	:	Joint transverse reinforcement ratio
l_s	:	Embedment length of beam reinforcement within joint
T	:	Tension force in the beam longitudinal reinforcement
v_{crack}	:	Cracking shear strength
v_{yield}	:	Yielding shear strength
v_{max}	:	Maximum shear strength
v_{resid}	:	Residual shear strength
γ_{crack}	:	Shear strain at cracking shear strength
γ_{yield}	:	Shear strain at yielding shear strength
γ_{max}	:	Shear strain at maximum shear strength
γ_{resid}	:	Shear strain at residual shear strength
M_{crack}	:	Cracking moment capacity
M_{yield}	:	Yielding moment capacity
M_{max}	:	Maximum moment capacity
M_{resid}	:	Residual moment capacity
θ_{crack}	:	Rotation at cracking moment
θ_{yield}	:	Rotation at yielding moment
θ_{max}	:	Rotation at maximum moment
θ_{resid}	:	Rotation at residual moment

Beam-Column Joint Shear Stress-Strain and Moment-Rotation Curve Development (Jeon, 2013)

Validation with interior joint with transverse reinforcement (Guimaraes et al., 1992) - Specimen J5

Select Joint Type	Interior
Bottom reinforcement	Continuous

Input	
Output	

Cross-section properties

h_b (mm)	b_b (mm)	h_c (mm)	b_c (mm)	L_b (mm)	L_c (mm)	e (mm)	cc (mm)	*Transv.Beams*
508.0	406.0	508.0	508.0	5181.0	4237.0	0.0	50.0	0

Reinforcement properties

f_{yjt} (MPa)	ρ_{jt} (%)	f_{yb} (MPa)	ρ_b (%)	f_{yc} (MPa)	ρ_c (%)	φ_b (mm)	n_b	l_s (mm)
550.0	0.8%	561.0	2.3%	543.0	6.3%	27.8	6	400.0

Concrete Property

$f'c$ (MPa)	77.9

Axial Load

P (kN)	20.1

Output

BI	*JP*	*TB*	*JI*	ψ	ω	c (mm)	Aj (mm^2)
0.17	1.00	1.00	0.1	1.0	1.0	63.9	197225

v_{max}	15.0	MPa
τ_{actual_bond}	4.0	MPa
T	831.8	kN
v_{bond}	15.0	MPa

M_{max}	1651.1	kNm
M_{bond}	1651.1	kNm

Experimental Observation

v_{max} (MPa)	15.7

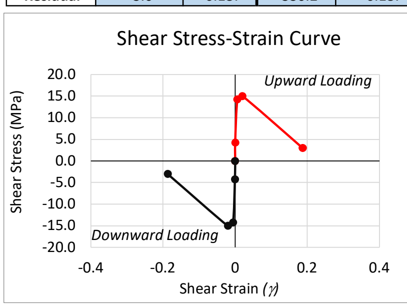
Final Output

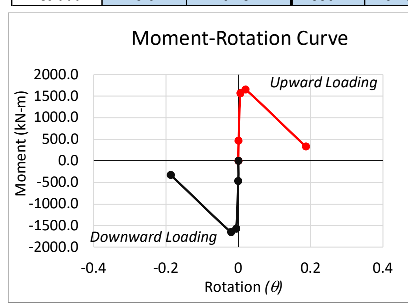
Downward Loading

	Shear Stress-Strain		*Moment-Rotation*	
Points	v **(MPa)**	γ	M **(kNm)**	θ
Origin	0.0	0	0.0	0
Cracking	-4.2	-0.00043	-466.0	-0.00043
Yielding	-14.3	-0.006	-1568.6	-0.006
Maximum	-15.0	-0.02	-1651.1	-0.02
Residual	-3.0	-0.187	-330.2	-0.187

Upward Loading

	Shear Stress-Strain		*Moment-Rotation*	
Points	v **(MPa)**	γ	M **(kNm)**	θ
Origin	0.0	0	0.0	0
Cracking	4.2	0.00043	466.0	0.00043
Yielding	14.3	0.006	1568.6	0.006
Maximum	15.0	0.02	1651.1	0.02
Residual	3.0	0.187	330.2	0.187





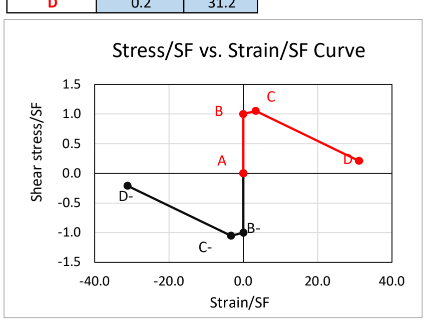
Frame Analysis Software Input

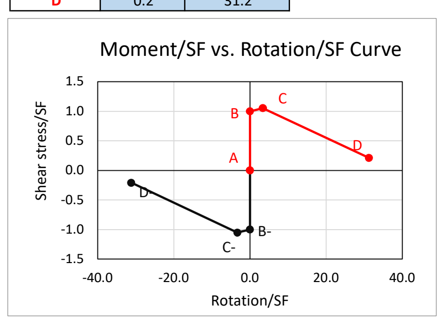
Define Shear Hinge			
		Positive	Negative
Use Yield Stress	Stress SF	14.3	14.3
Use Yield Strain	Strain SF	0.006	0.006

Define Moment Hinge			
		Positive	Negative
Use Yield Moment	Moment SF	1568.6	1568.6
Use Yield Rotation	Rotation SF	0.006	0.006

Point	**Stress/SF**	**Strain/SF**
D-	-0.2	-31.2
C-	-1.1	-3.3
B-	-1.0	0.0
A	0.0	0.0
B	1.0	0.0
C	1.1	3.3
D	0.2	31.2

Point	**Moment/SF**	**Rotation/SF**
D-	-0.2	-31.2
C-	-1.1	-3.3
B-	-1.0	0.0
A	0.0	0.0
B	1.0	0.0
C	1.1	3.3
D	0.2	31.2





Beam-Column Joint Shear Stress-Strain and Moment-Rotation Curve Development (Jeon, 2013)

Validation with interior joint without transverse reinforcement (Li et al., 2005) - Specimen AL1

Select Joint Type	Interior
Bottom reinforcement	Continuous

Input	
Output	

Cross-section properties

h_b (mm)	b_b (mm)	h_c (mm)	b_c (mm)	L_b (mm)	L_c (mm)	e (mm)	cc (mm)	*Transv.Beams*
400.0	200.0	400.0	200.0	4500.0	2460.0	0.0	50.0	0

Reinforcement properties

f_{yjt} (MPa)	ρ_{jt} (%)	f_{yb} (MPa)	ρ_b (%)	f_{yc} (MPa)	ρ_c (%)	φ_b (mm)	n_b	l_s (mm)
0.0	0.0%	473.0	1.1%	473.0	3.1%	20.0	2	400.0

Concrete Property

$f'c$ (MPa)	30.3

Axial Load

P (kN)	242.4

Output

BI	JP	TB	JI	ψ	ω	c (mm)	Aj (mm^2)
0.17	1.00	1.00	0.0	1.0	1.0	60.0	115600

v_{max}	6.1	MPa
τ_{actual_bond}	8.6	MPa
T	431.8	kN
v_{bond}	6.1	MPa

M_{max}	319.4	kNm
M_{bond}	319.4	kNm

Experimental Observation

v_{max} (MPa)	6.3

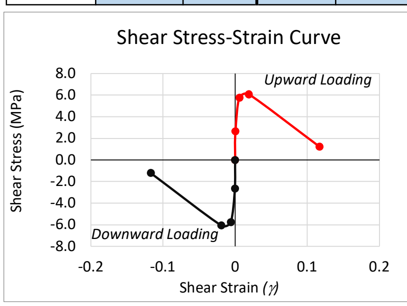
Final Output

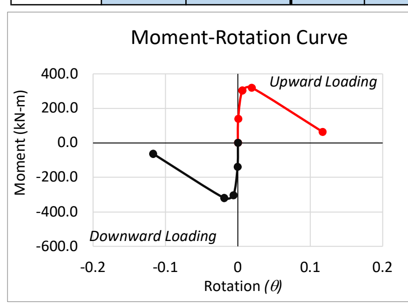
Downward Loading

	Shear Stress-Strain		*Moment-Rotation*	
Points	v (MPa)	γ	M (kNm)	θ
Origin	0.0	0	0.0	0
Cracking	-2.6	-0.00043	-139.0	-0.00043
Yielding	-5.8	-0.006	-303.4	-0.006
Maximum	-6.1	-0.019	-319.4	-0.019
Residual	-1.2	-0.117	-63.9	-0.117

Upward Loading

	Shear Stress-Strain		*Moment-Rotation*	
Points	v (MPa)	γ	M (kNm)	θ
Origin	0.0	0	0.0	0
Cracking	2.6	0.00043	139.0	0.00043
Yielding	5.8	0.006	303.4	0.006
Maximum	6.1	0.019	319.4	0.019
Residual	1.2	0.117	63.9	0.117





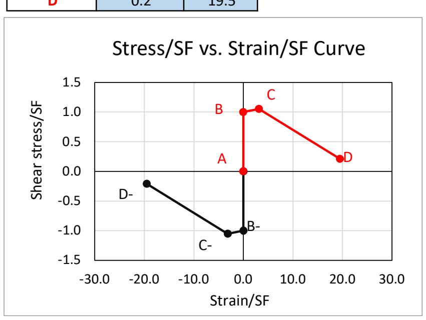
Frame Analysis Software Input

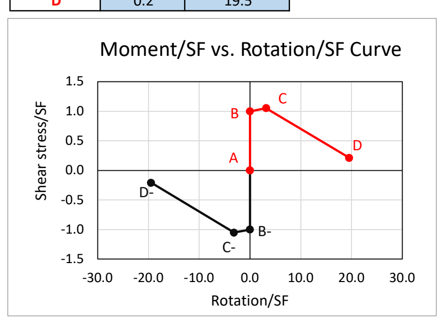
Define Shear Hinge			
		Positive	Negative
Use Yield Stress	Stress SF	5.8	5.8
Use Yield Strain	Strain SF	0.006	0.006

Define Moment Hinge			
		Positive	Negative
Use Yield Moment	Moment SF	303.4	303.4
Use Yield Rotation	Rotation SF	0.006	0.006

Point	**Stress/SF**	**Strain/SF**
D-	-0.2	-19.5
C-	-1.1	-3.2
B-	-1.0	0.0
A	0.0	0.0
B	1.0	0.0
C	1.1	3.2
D	0.2	19.5

Point	**Moment/SF**	**Rotation/SF**
D-	-0.2	-19.5
C-	-1.1	-3.2
B-	-1.0	0.0
A	0.0	0.0
B	1.0	0.0
C	1.1	3.2
D	0.2	19.5





Beam-Column Joint Shear Stress-Strain and Moment-Rotation Curve Development (Jeon, 2013)

Validation with exterior joint with transverse reinforcement (Eshani and Alameddine, 1991) - Specimen LL8

Select Joint Type	Exterior		**Input**	
Bottom reinforcement	Hooked		**Output**	

Cross-section properties

h_b (mm)	b_b (mm)	h_c (mm)	b_c (mm)	L_b (mm)	L_c (mm)	e (mm)	cc (mm)	*Transv.Beams*
508.0	318.0	356.0	356.0	1778.0	3581.0	0.0	50.0	0

Reinforcement properties

f_{yjt} (MPa)	ρ_{jt} (%)	f_{yb} (MPa)	ρ_b (%)	f_{yc} (MPa)	ρ_c (%)	φ_b (mm)	n_b	l_s (mm)
437.0	1.2%	437.0	1.5%	437.0	2.8%	25.4	4	400.0

Concrete Property

$f'c$ (MPa)	55.8

Axial Load

P (kN)	294.0

Output

BI	JP	TB	JI	ψ	ω	c (mm)	Aj (mm^2)
0.12	0.75	1.00	0.1	1.0	1.0	62.7	130606

v_{max}	7.0	MPa	M_{max}	686.8	kNm
τ_{actual_bond}	8.4	MPa			
T	1069.9	kN			
v_{bond}	7.0	MPa	M_{bond}	686.8	kNm

Experimental Observation

v_{max} (MPa)	7.8

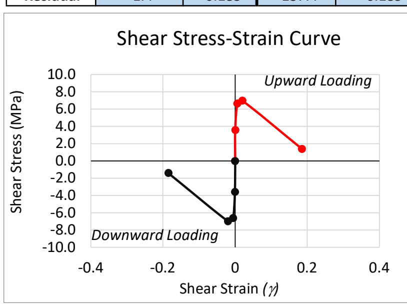
Final Output

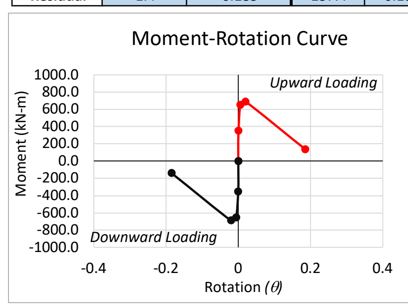
Downward Loading

	Shear Stress-Strain		*Moment-Rotation*	
Points	v **(MPa)**	γ	M **(kNm)**	θ
Origin	0.0	0	0.0	0
Cracking	-3.6	-0.00043	-352.7	-0.00043
Yielding	-6.6	-0.006	-652.5	-0.006
Maximum	-7.0	-0.02	-686.8	-0.02
Residual	-1.4	-0.185	-137.4	-0.185

Upward Loading

	Shear Stress-Strain		*Moment-Rotation*	
Points	v **(MPa)**	γ	M **(kNm)**	θ
Origin	0.0	0	0.0	0
Cracking	3.6	0.00043	352.7	0.00043
Yielding	6.6	0.006	652.5	0.006
Maximum	7.0	0.02	686.8	0.02
Residual	1.4	0.185	137.4	0.185





Frame Analysis Software Input

Define Shear Hinge

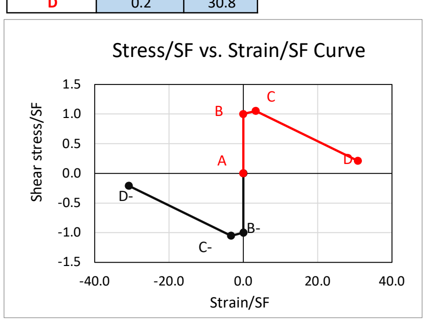
		Positive	Negative
Use Yield Stress	Stress SF	6.6	6.6
Use Yield Strain	Strain SF	0.006	0.006

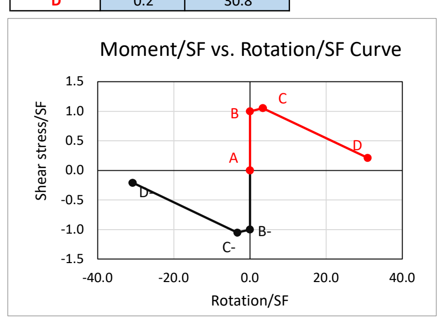
Define Moment Hinge

		Positive	Negative
Use Yield Moment	Moment SF	652.5	652.5
Use Yield Rotation	Rotation SF	0.006	0.006

Point	Stress/SF	Strain/SF
D-	-0.2	-30.8
C-	-1.1	-3.3
B-	-1.0	0.0
A	0.0	0.0
B	1.0	0.0
C	1.1	3.3
D	0.2	30.8

Point	Moment/SF	Rotation/SF
D-	-0.2	-30.8
C-	-1.1	-3.3
B-	-1.0	0.0
A	0.0	0.0
B	1.0	0.0
C	1.1	3.3
D	0.2	30.8





Beam-Column Joint Shear Stress-Strain and Moment-Rotation Curve Development (Jeon, 2013)

Validation with exterior joint without transverse reinforcement (Pantelides et al., 2017) - Specimen Test Unit 1

Select Joint Type	Exterior		**Input**	
Bottom reinforcement	Straight Embedment		**Output**	

Cross-section properties

h_b (mm)	b_b (mm)	h_c (mm)	b_c (mm)	L_b (mm)	L_c (mm)	e (mm)	cc (mm)	*Transv.Beams*
406.0	406.0	406.0	406.0	1879.6	3200.0	0.0	43.5	0

Reinforcement properties

f_{yjt} (MPa)	ρ_{jt} (%)	f_{yb} (MPa)	ρ_b (%)	f_{yc} (MPa)	ρ_c (%)	φ_b (mm)	n_b	l_s (mm)
0.0	0.0%	459.0	1.7%	460.0	3.0%	28.7	4	152.4

Concrete Property

$f'c$ (MPa)	33.1

Axial Load

P (kN)	545.6

Output

BI	*JP*	*TB*	*JI*	ψ	ω	c (mm)	Aj (mm^2)
0.24	0.75	1.00	0.0	1.0	1.0	57.8	121226

v_{max}	5.4	MPa	M_{max}	344.6	kNm		
τ_{actual_bond}	7.2	MPa					
T	394.1	kN					
v_{bond}	2.9	MPa	M_{bond}	186.1	kNm		

Experimental Observation

v_{max} (MPa)	5.2
v_{bond} (MPa)	2.5

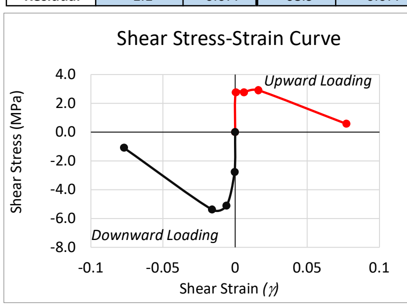
Final Output

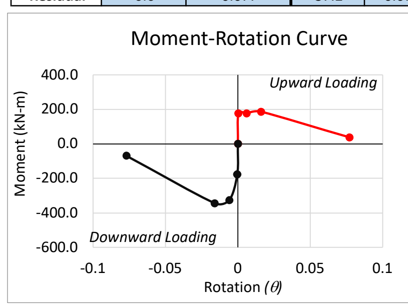
Downward Loading

Points	*Shear Stress-Strain* v (MPa)	γ	*Moment-Rotation* M (kNm)	θ
Origin	0.0	0	0.0	0
Cracking	-2.8	-0.00043	-176.7	-0.00043
Yielding	-5.1	-0.006	-327.4	-0.006
Maximum	-5.4	-0.016	-344.6	-0.016
Residual	-1.1	-0.077	-68.9	-0.077

Upward Loading

Points	*Shear Stress-Strain* v (MPa)	γ	*Moment-Rotation* M (kNm)	θ
Origin	0.0	0	0.0	0
Cracking	2.8	0.00043	176.7	0.00043
Yielding	2.8	0.006	176.8	0.006
Maximum	2.9	0.016	186.1	0.016
Residual	0.6	0.077	37.2	0.077





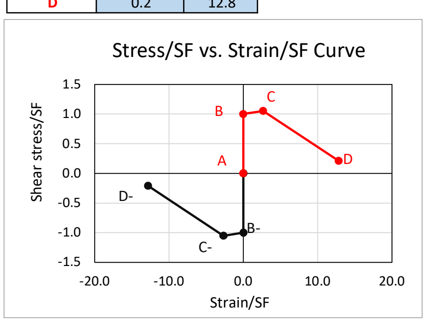
Frame Analysis Software Input

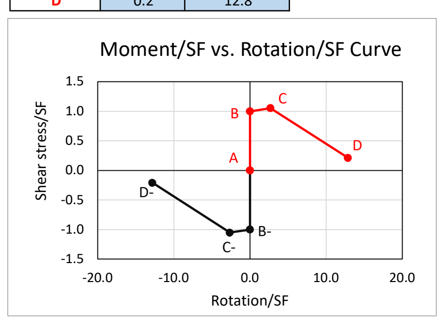
Define Shear Hinge		Positive	Negative
Use Yield Stress	Stress SF	2.8	5.1
Use Yield Strain	Strain SF	0.006	0.006

Define Moment Hinge		Positive	Negative
Use Yield Moment	Moment SF	176.8	327.4
Use Yield Rotation	Rotation SF	0.006	0.006

Point	Stress/SF	Strain/SF
D-	-0.2	-12.8
C-	-1.1	-2.7
B-	-1.0	0.0
A	0.0	0.0
B	1.0	0.0
C	1.1	2.7
D	0.2	12.8

Point	Moment/SF	Rotation/SF
D-	-0.2	-12.8
C-	-1.1	-2.7
B-	-1.0	0.0
A	0.0	0.0
B	1.0	0.0
C	1.1	2.7
D	0.2	12.8



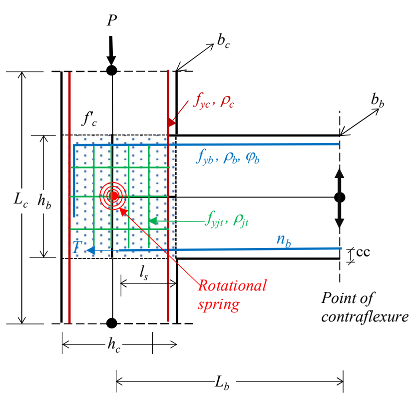


DEFINITIONS:

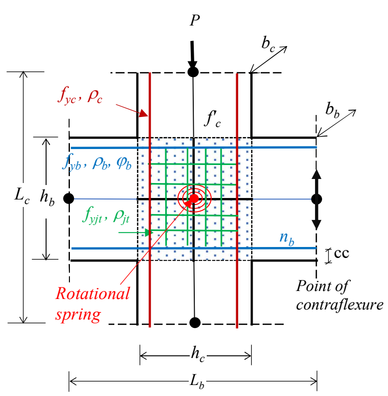
f'_c (MPa)	*Concrete compressive strength*
h_b (mm)	*Depth of beam*
b_b (mm)	*Width of beam*
h_c (mm)	*Depth of column*
b_c (mm)	*Width of column*
L_c (mm)	*Span of column between two points of contraflexure*
L_b (mm)	*Span of beam from center of joint to the point of contraflexure*
cc (mm)	*Concrete cover*
Transv.Beams	*Number of transverse beams*
e (mm)	*Eccentricity between beam and joint geometric centers*
f_{yjt} (MPa)	*Yield strength of joint transverse reinforcement*
ρ_{jt}	*Joint transverse reinforcement percentage*
f_{yb} (MPa)	*Yield strength of beam longitudinal reinforcement*
ρ_b	*Beam top longitudinal reinforcement percentage*
f_{yc} (MPa)	*Yield strength of column longitudinal reinforcement*
ρ_c	*Column longitudinal reinforcement percentage*
BI	*Beam reinforcement index*
JP	*Joint plane factor*
TB	*Confinement factor*
JI	*Joint index factor*
φ_b (mm)	*Diameter of beam bottom longitudinal reinforcement*
ψ	*Reinforcement factor, 1 for φ_b >19mm and 1.25 for φ_b <19mm*
ω	*Transverse beam confinement factor for exterior joint*
c (mm)	*Sum of concrete cover and half of beam longitudinal reinforcemenr diameter*
Aj (mm^2)	*Area of joint*
n_b	*Number of beam longitudinal reinforcement with short embedment*
l_s (mm)	*Length of beam reinforcement embedment inside the joint*
P (kN)	*Axial load applied to the column*
T (kN)	*Tension force in beam bottom reinforcement*
v_{max} (MPa)	*Shear strengh capacity of joint*
τ_{actual_bond} (MPa)	*Bond stress capacity*
v_{bond} (MPa)	*Shear strength due to short embedment of beam bottom reinforcement*
M_{max} (kNm)	*Moment capcity equivalent to v_{max}*
M_{bond} (kNm)	*Moment capacity equivalent to v_{bond}*
γ	*Shear strain*
θ	*Rotation*

***NOTES:**

The Joint Model 1 is applicable to interior/exterior joints with or without transverse reinforcement
1. Ductile Joints are those with joint transverse reinforcement ratio is greater than 0.
2. Non-Ductile Joints are those with zero transverse reinforcement ratio within the joint



Exterior Joint



Interior Joint

Beam-Column Joint Shear Stress-Strain and Moment-Rotation Curve Development (Sharma et al., 2011)

Validation with exterior joint without transverse reinforcement (Pantelides et al., 2017) - Specimen Test Unit 1

Joint Type	Exterior
Bottom Reinforcement	Straight Embedment

Input	
Constant	
Output	

Input Parameters

f'_c (MPa)	h_b (mm)	h_c (mm)	b_b (mm)	b_c (mm)	L_b (mm)	L_c (mm)	P (kN)	σ_a (MPa)
33.1	406.0	406.0	406.0	406.0	1676.0	3200.0	545.6	3.3

p_t coef.	Cracking	Yielding	Maximum	Residual
Positive	0.29	0.42	0.42	0.1
Negative	0.13	0.19	0.19	0.06

Top Reinforcement

$T_{(assumed)}$ (kN)	724.9	967.7	967.7	342.2

Outputs:	**Cracking**	**Yielding**	**Maximum**	**Residual**
p_t (MPa)	1.7	2.4	2.4	0.6
α	1.0	1.0	1.0	1.0
σ (MPa)	7.1	8.4	8.4	5.1
V_{jv} (kN)	632.1	843.8	843.8	298.4
V_{jh} (kN)	632.1	843.8	843.8	298.4
V_c (kN)	92.8	123.9	123.9	43.8
V_b (kN)	158.0	211.0	211.0	74.6
M (kNm)	264.9	353.6	353.6	125.0
$T_{(final)}$ (kN)	**724.9**	**967.7**	**967.7**	**342.2**
ΔT	0.0	0.0	0.0	0.0
v_{jh} (MPa)	**3.8**	**5.1**	**5.1**	**1.8**
v_{max} (MPa)	0.56	0.75	0.75	0.27
M_{max} (kNm)	264.9	353.6	353.6	125.0
$v_{jh,exp}$ (MPa)	5.2 MPa (Experimental)			

Bottom Reinforcement

$T_{(assumed)}$ (kN)	407.5	530.7	530.7	247.5

Outputs:	**Cracking**	**Yielding**	**Maximum**	**Residual**
p_t (MPa)	0.7	1.1	1.1	0.3
α	1.0	1.0	1.0	1.0
σ (MPa)	5.5	6.1	6.1	4.6
V_{jv} (kN)	355.4	462.8	462.8	215.8
V_{jh} (kN)	355.4	462.8	462.8	215.8
V_c (kN)	52.2	67.9	67.9	31.7
V_b (kN)	88.8	115.7	115.7	54.0
M (kNm)	148.9	193.9	193.9	90.4
$T_{(final)}$ (kN)	**407.5**	**530.7**	**530.7**	**247.5**
ΔT	0.0	0.0	0.0	0.0
v_{jh} (MPa)	**2.2**	**2.8**	**2.8**	**1.3**
v_{max} (MPa)	0.32	0.41	0.41	0.19
M_{max} (kNm)	148.9	193.9	193.9	90.4
$v_{jh,exp}$ (MPa)	2.5 MPa (Experimental)			

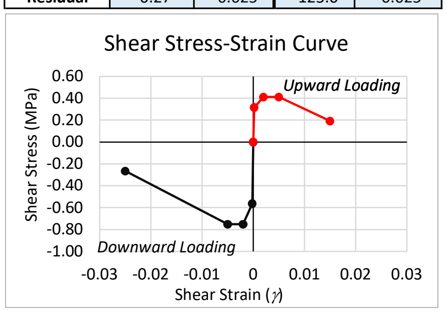
Final Output

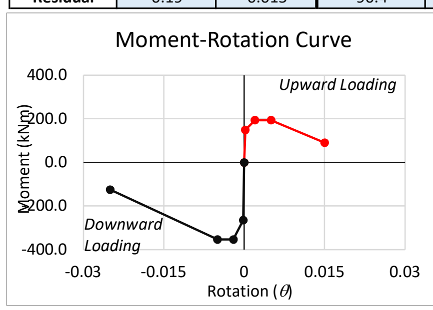
Downward Loading

	Shear Stress-Strain		**Moment-Rotation**	
Points	**v (MPa)**	**γ**	**M (kNm)**	**θ**
Origin	0.00	0	0.0	0
Cracking	-0.56	-0.0002	-264.9	-0.0002
Yielding	-0.75	-0.002	-353.6	-0.002
Maximum	-0.75	-0.005	-353.6	-0.005
Residual	-0.27	-0.025	-125.0	-0.025

Upward Loading

	Shear Stress-Strain		**Moment-Rotation**	
Points	**v (MPa)**	**γ**	**M (kNm)**	**θ**
Origin	0.00	0	0.0	0
Cracking	0.32	0.0002	148.9	0.0002
Yielding	0.41	0.002	193.9	0.002
Maximum	0.41	0.005	193.9	0.005
Residual	0.19	0.015	90.4	0.015





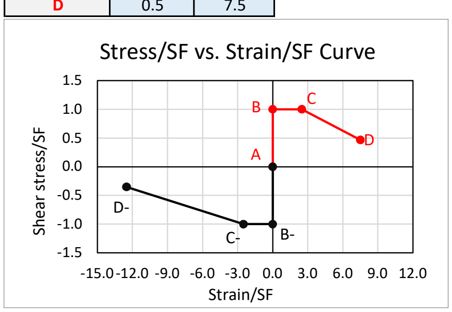
Frame Analysis Software Input

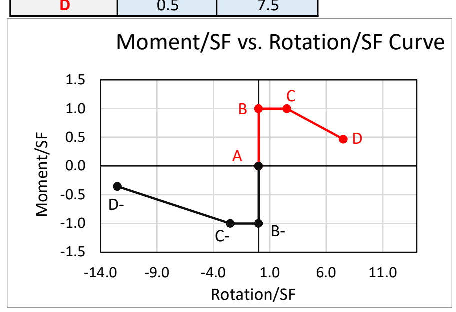
Define Shear Hinge			
		Positive	Negative
Use Yield Shear Stress	Stress SF	0.41	0.75
Use Yield Shear Strain	Strain SF	0.002	0.002

Define Moment Hinge			
		Positive	Negative
Use Yield Moment	Moment SF	193.9	353.6
Use Yield Rotation	Rotation SF	0.002	0.002

Point	**Stress/SF**	**Strain/SF**
D-	-0.4	-12.5
C-	-1.0	-2.5
B-	-1.0	0.0
A	0.0	0.0
B	1.0	0.0
C	1.0	2.5
D	0.5	7.5

Point	**Moment/SF**	**Rotation/SF**
D-	-0.4	-12.5
C-	-1.0	-2.5
B-	-1.0	0.0
A	0.0	0.0
B	1.0	0.0
C	1.0	2.5
D	0.5	7.5





DEFINITIONS:

***f'_c* (MPa)**	*Concrete compressive strength*
***h_b* (mm)**	*Depth of beam*
***b_b* (mm)**	*Width of beam*
***h_c* (mm)**	*Depth of column*
***b_c* (mm)**	*Width of column*
***L_c* (mm)**	*Span of column between two points of contraflexure*
***L_b* (mm)**	*Span of beam from face of column to point of load application*
P (kN)	*Axial load in column*
***σ_a* (MPa)**	*Axial stress in column ($P/(h_c.b_c)$)*
***p_t* (MPa)**	*Principal tensile stess level*
T (kN)	*Tension force in beam reinforcement*
***ΔT* (kN)**	*$T_{(final)}$ - $T_{(assumed)}$*
α	*Joint aspect ratio (h_b/h_c)*
***σ* (MPa)**	*Vertical joint shear stress*
***V_{jv}* (kN)**	*Vertical joint shear force*
***V_{jh}* (kN)**	*Horizontal joint shear force*
***V_c* (kN)**	*Column shear force*
***V_b* (kN)**	*Beam shear force*
***v_{max}* (MPa)**	*Shear strength capacity*
M (kNm)	*Moment capacity*
θ	*Rotation*

NOTES:

1. Joint Model 2 is only applicable for exteior joints with zero transverse reinforcement inside the joint.

*2. **$T_{(Final)}$** should be equal to **$T_{(assumed)}$**.*

3. Several iteration (trial and error) is done until $T_{(Final)}$ equals $T_{(Assume)}$.

*4. **Goal Seek** is used such that $T_{(assume)}$ equals $T_{(final)}$.*

5. Steps of Goal Seek

*i) Click **Data** in tab bar*

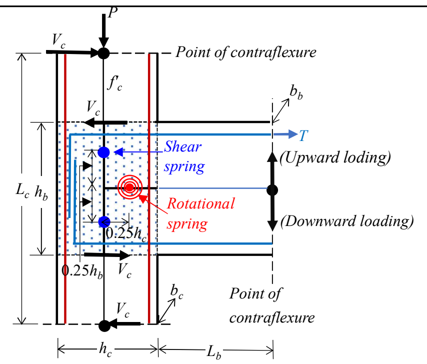
*ii) Go to **What-if Analysis***

*iii) Click **Goal Seek***

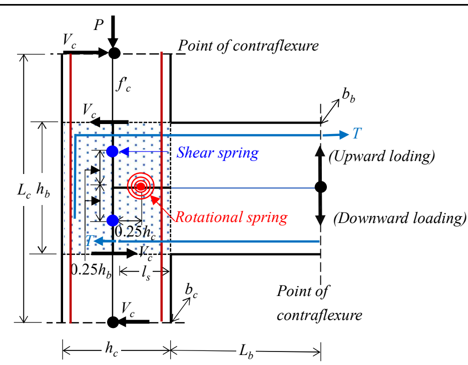
*iv) Set value = **ΔT***

*v) To value = "**0**"*

*vi) By changing cell = **$T_{(assumed)}$***



Exterior joint with hooked beam reinforcement



Exterior joint with straight embedment of beam bottom reinforcement

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