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Unconventional Reinforced Concrete Bridge Columns

ACI Spring 2014 Convention
March 23 - 25, Reno, NV

Confinement Model for Bridge Columns Using Cross Spirals

by

Riyadh A. Hindi, Associate Professor, Saint Louis University, Saint Louis, MO

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Confinement Model for Bridge Columns Using Cross Spirals

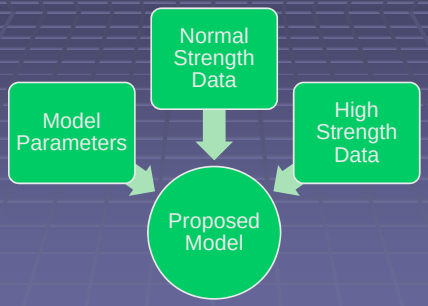
Riyadh Hindi, PhD, PEng
Jonathan West, MS

SAINT LOUIS UNIVERSITY

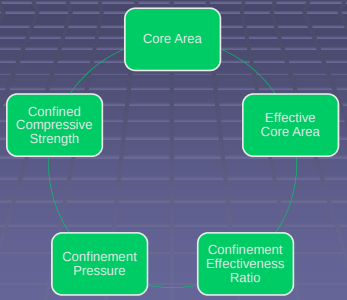
Objectives

- Modification of model parameters
- Prediction model for normal strength concrete
- Prediction model for high-strength concrete
- Theoretical stress-strain relationship for normal and high-strength concrete

Model Development



Model Parameters



Core Area

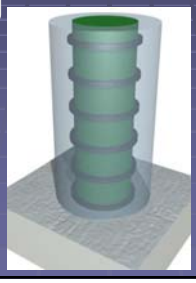
Confined Compressive Strength

Effective Core Area

Confinement Pressure

Confinement Effectiveness Ratio

Core Area



Core Area

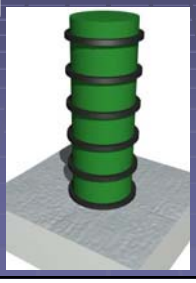
Confined Compressive Strength

Effective Core Area

Confinement Pressure

Confinement Effectiveness Ratio

Core Area



Core Area

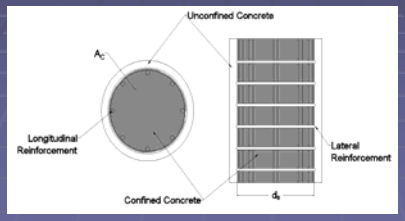
Confined Compressive Strength

Effective Core Area

Confinement Pressure

Confinement Effectiveness Ratio

Core Area



$$A_c = \frac{\pi}{4} d_s^2$$

Core Area

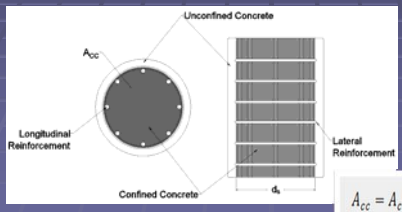
Confined Compressive Strength

Effective Core Area

Confinement Pressure

Confinement Effectiveness Ratio

Concrete Core Area



$$A_{cc} = A_c(1-\rho_{cc}) = A_c - \frac{\pi}{4} d_b^2 (n)$$

Core Area

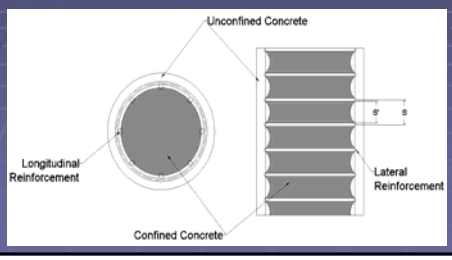
Confined Compressive Strength

Effective Core Area

Confinement Pressure

Confinement Effectiveness Ratio

Hoops



Core Area

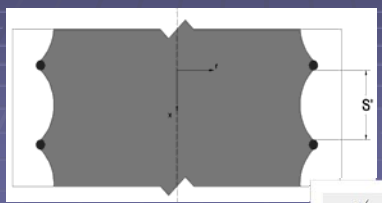
Confined Compressive Strength

Effective Core Area

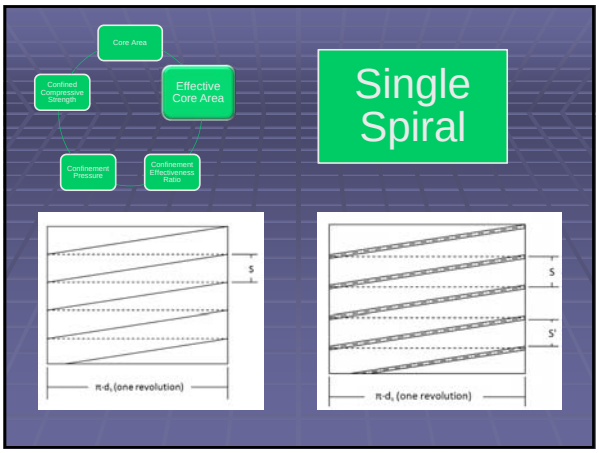
Confinement Pressure

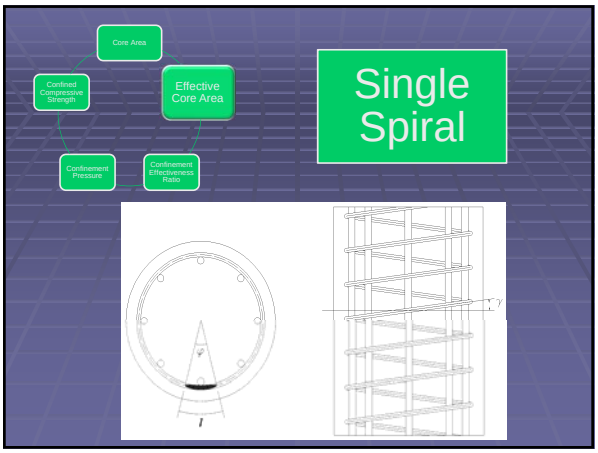
Confinement Effectiveness Ratio

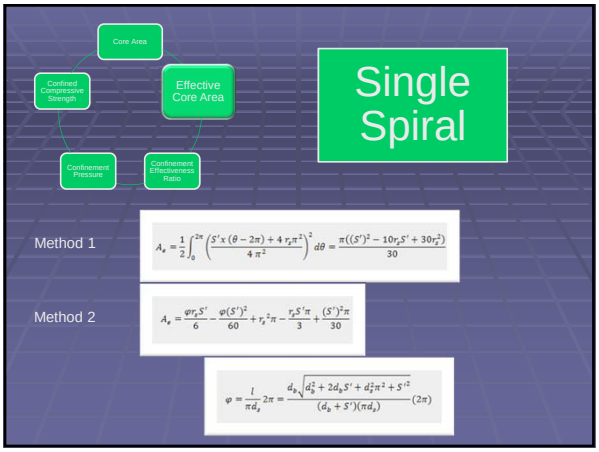
Hoops

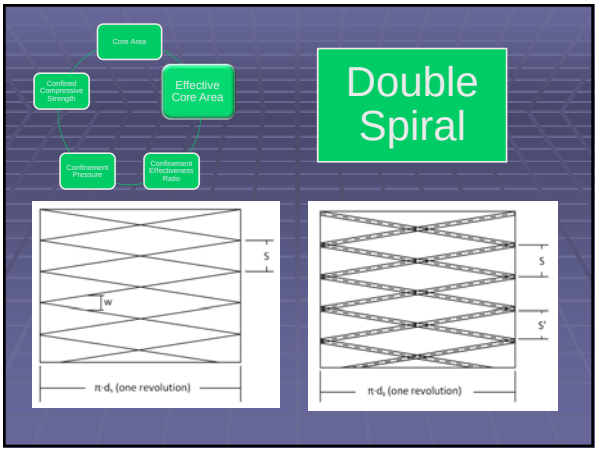


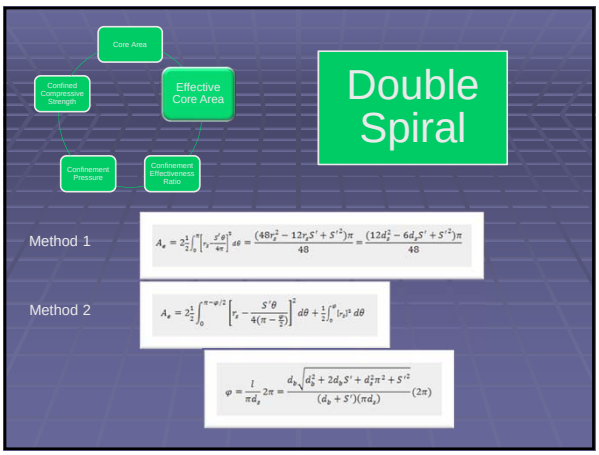
$$A_s = \frac{\pi}{4}\left(r_s - \frac{s'}{4}\right)^2 = \frac{\pi}{4}\left(d_s - \frac{s'}{2}\right)^2 = \frac{\pi}{4} d_s^2 \left(1 - \frac{s'}{2d_s}\right)^2$$

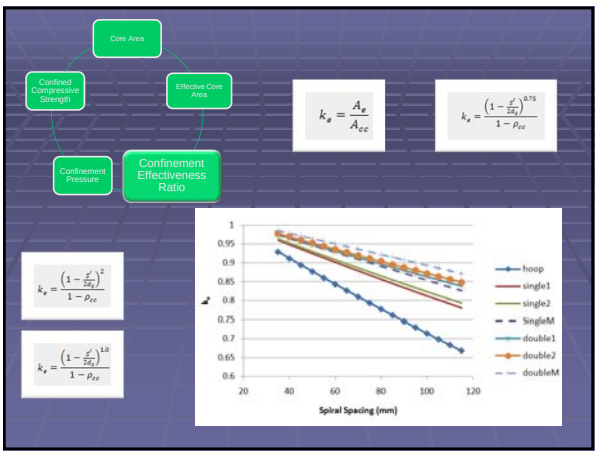

Core Area
Confined Compressive Strength
Effective Core Area
Confinement Pressure
Confinement Effectiveness Ratio
Single Spiral
s
π·d_s (one revolution)
s
s'
π·d_s (one revolution)

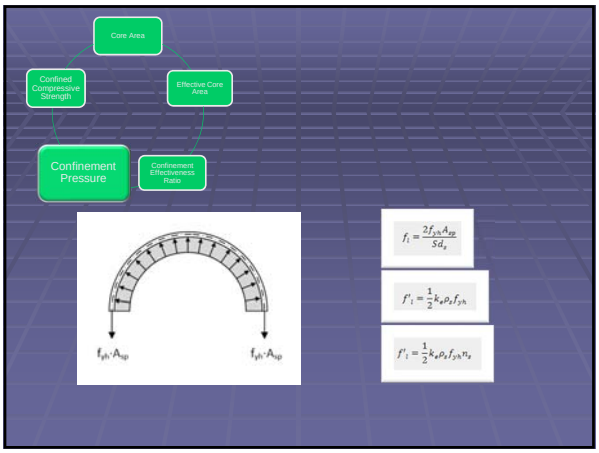

Core Area
Confined Compressive Strength
Effective Core Area
Confinement Pressure
Confinement Effectiveness Ratio
Single Spiral
s
l

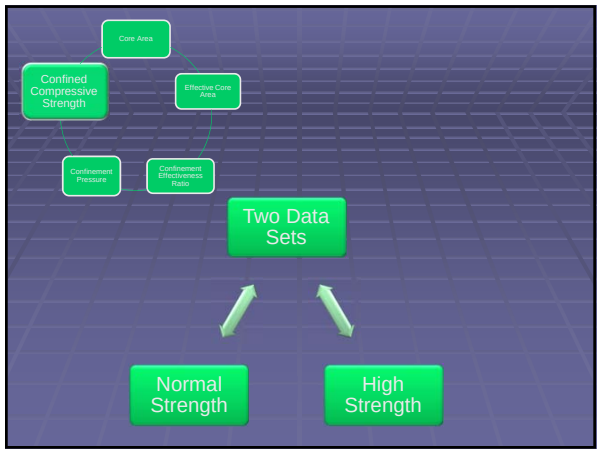

Core Area
Confined Compressive Strength
Effective Core Area
Confinement Pressure
Confinement Effectiveness Ratio
Single Spiral
Method 1
Method 2

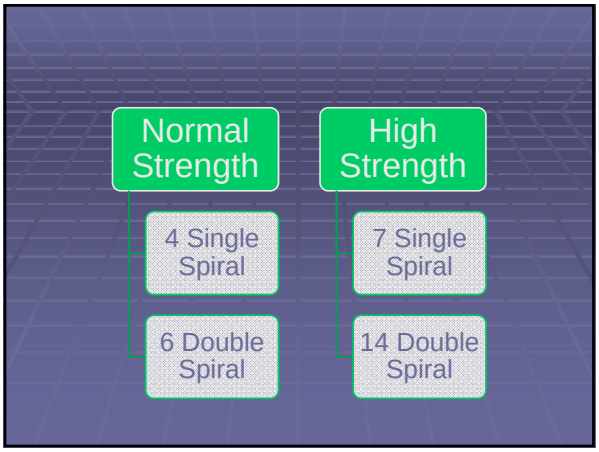

Core Area
Confined Compressive Strength
Effective Core Area
Confinement Pressure
Confinement Effectiveness Ratio
Double Spiral
s
w
π·d_s (one revolution)
s
s'
π·d_s (one revolution)

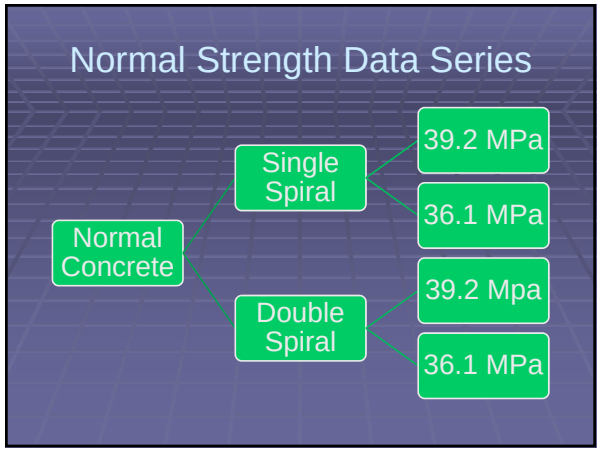

Core Area
Confined Compressive Strength
Effective Core Area
Confinement Pressure
Confinement Effectiveness Ratio
Double Spiral
Method 1
Method 2


Core Area
Confined Compressive Strength
Effective Core Area
Confinement Pressure
Confinement Effectiveness Ratio
Spiral Spacing (mm)
hoop
single1
single2
SingleM
double1
double2
doubleM



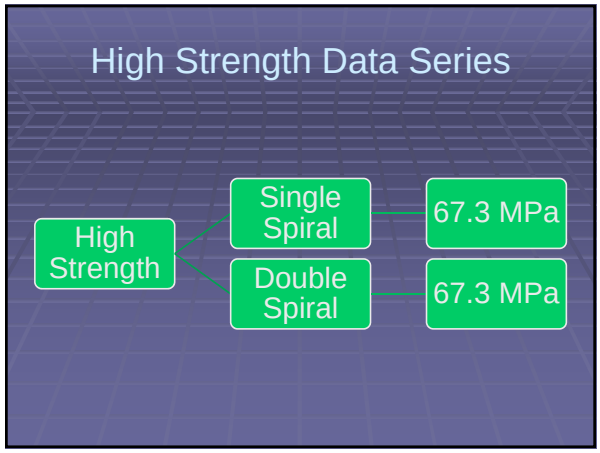






Normal Strength Data Series

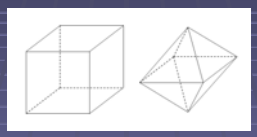
Specimen	Method						Exp. f'_{cc} (MPa)
	S with $2\rho_s$		S/2 with ρ_s		Modified Model		
	Mander	Bing	Mander	Bing	Bing	Proposed	
25 s 6	67.09	66.96	67.09	66.96	66.96	67.09	63.5
25 s 6	63.51	68.33	63.51	68.33	68.33	63.51	60.5
35 s 6	59.61	53.82	59.61	53.82	53.82	59.61	66.1
35 s 6	56.24	53.55	56.24	53.55	53.55	56.24	59
35 x 6	73.86	81.60	75.89	86.33	83.59	74.73	82.2
35 x 6	70.05	84.05	71.99	88.98	86.14	70.88	71
50 x 6	64.02	61.12	66.41	65.61	63.02	65.05	63
50 x 6	60.53	61.86	62.84	66.85	63.97	61.53	58.8
70 x 6	56.40	49.38	59.11	53.07	50.88	57.55	59.1
70 x 6	53.10	48.39	55.75	52.69	50.15	54.23	59
st dev	1.524311	2.820215	1.365484	3.026255	2.849316	1.424495	



High Strength Data Series

Specimen	Method						Exp. f'_{cc} (MPa)
	S with $2\rho_l$		S/2 with ρ_l		Modified Model Parameters		
	Mander	Bing	Mander	Bing	Mander	Bing	Proposed	
50 s 8	93.72	73.27	93.72	73.27	93.72	73.27	75.8183	76
50 x 8	114.36	89.07	116.08	90.90	115.05	89.79	102.051	104.4
100 x 8	91.42	72.18	93.57	73.19	92.34	72.60	73.4173	70
40 s 10	99.73	76.72	99.73	76.72	99.73	76.72	84.7927	75.5
40 x 10	123.92	100.24	125.46	102.26	124.50	100.99	110.544	111.2
80 x 10	97.55	75.37	99.54	76.60	98.39	75.87	82.9532	81.9
50 s 10	93.40	73.11	93.40	73.11	93.40	73.11	75.2719	77.9
50 x 10	109.14	85.50	110.77	87.32	109.78	86.21	97.4951	99.6
100 x 10	91.17	72.07	93.25	73.04	92.06	72.47	72.9128	74.4
55 s 10	90.90	71.95	90.90	71.95	90.90	71.95	70.7336	66.1
55 x 10	109.75	84.56	111.46	86.16	110.44	85.20	97.4251	95.7
110 x 10	88.67	71.04	90.76	71.89	89.57	71.40	68.0425	72.8
60 s 10	88.77	71.08	88.77	71.08	88.77	71.08	66.3127	68.7
60 x 10	106.23	81.50	107.96	82.96	106.94	82.09	93.6325	96.6
120 x 10	86.56	70.28	88.65	71.04	87.46	70.59	63.1906	75.6
50 s 12	92.85	72.85	92.85	72.85	92.85	72.85	74.3348	69.3
50 x 12	108.28	84.57	109.83	86.26	108.89	85.24	96.6557	97.2
100 x 12	90.73	71.88	92.71	72.78	91.58	72.25	72.0332	75.7
50 s 14	92.76	72.80	92.76	72.80	92.76	72.80	74.1684	77
50 x 14	112.81	87.48	114.38	89.08	113.43	88.11	100.469	106.5
100 x 14	90.67	71.85	92.61	72.73	91.50	72.22	71.8861	70.2
st dev	3.79763	2.01897	4.04093	1.79701	3.89708	1.93072	1.0254	

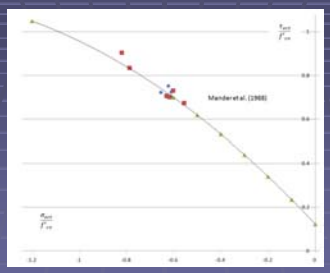
Octahedral Stress



$$\sigma_{OCT} = \frac{1}{3}(\sigma_1 + \sigma_2 + \sigma_3) = \frac{1}{3}(-f'_l - f'_l - f'_{cc}) = -\frac{f'_{cc}}{3} - \frac{2f'_l}{3}$$

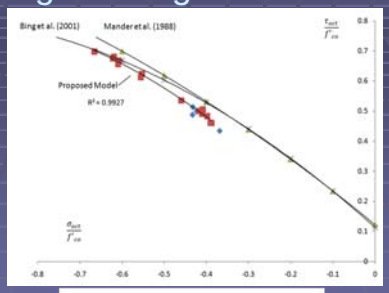
$$\tau_{OCT} = \frac{\sqrt{2}}{3}(f'_{cc} - f'_l)$$

Normal Strength Concrete



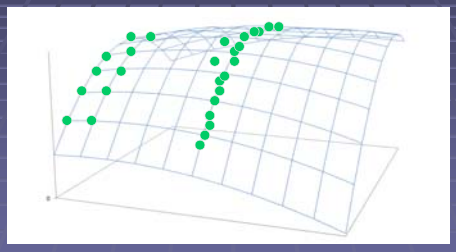
$$f'_{cc} = f'_{co}\left(-1.254 + 2.254\sqrt{1 + 7.94\frac{f'_l}{f'_{co}}} - 2\frac{f'_l}{f'_{co}}\right)$$

High Strength Concrete

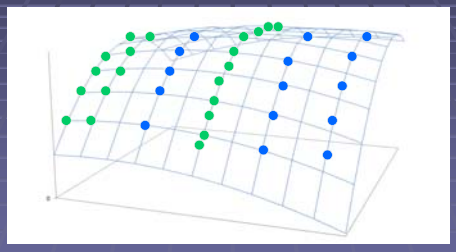


$$f'_{cc} = f'_{co}\left(0.581 + \sqrt{-0.498 + 14.64\frac{f'_l}{f'_{co}}} - 2\frac{f'_l}{f'_{co}}\right)$$

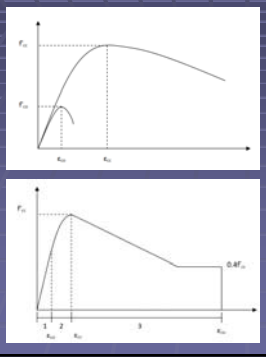
Normal and High Strength Data



Normal and High Strength Data



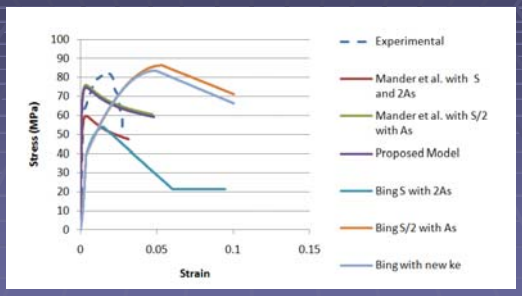
Stress-Strain Relationships



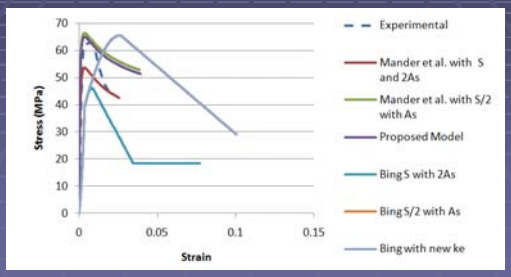
Mander et al. (1988)

Bing et al. (2001)

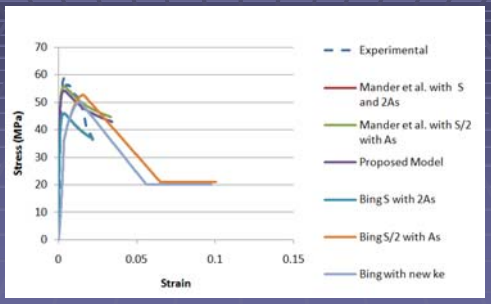
Normal Strength 25X6-1



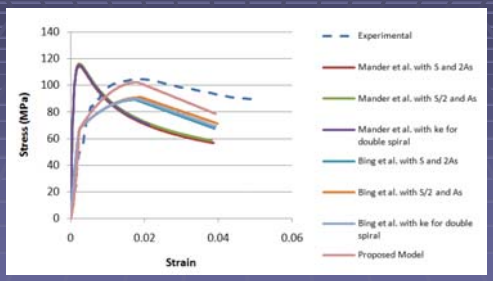
Normal Strength 35X6-1



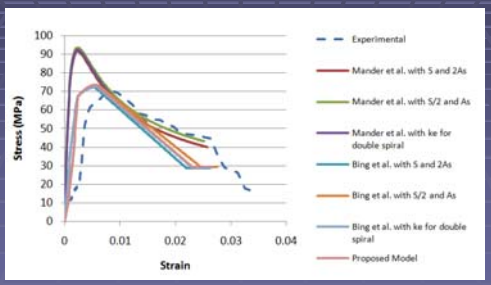
Normal Strength 70X6-2



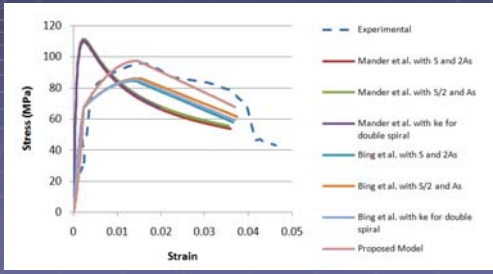
High Strength 50X8



High Strength 100X8



High Strength 55X10



Conclusions

- Mander et al. model modification
- Normal strength concrete follows Mander et al. prediction model
- High-strength concrete does not follow the Mander et al. or Bing et al.
- Stress-Strain relationship for normal strength is best described by Mander et al.
- Stress-Strain relationship for high-strength is best described by Bing et al.

Thank You

Questions?