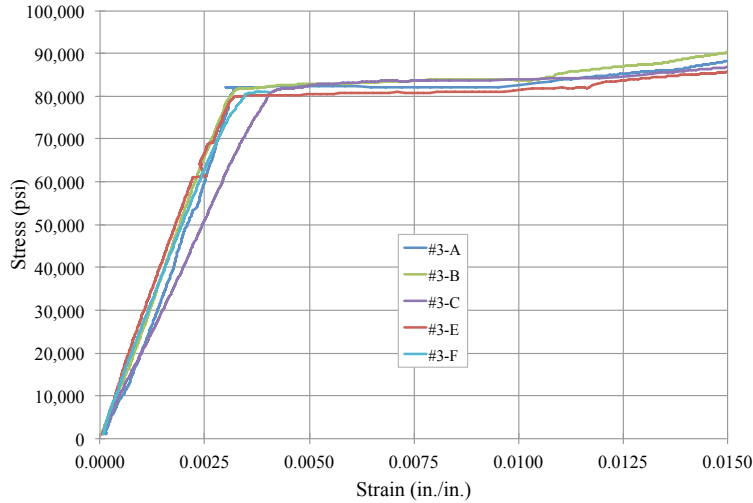
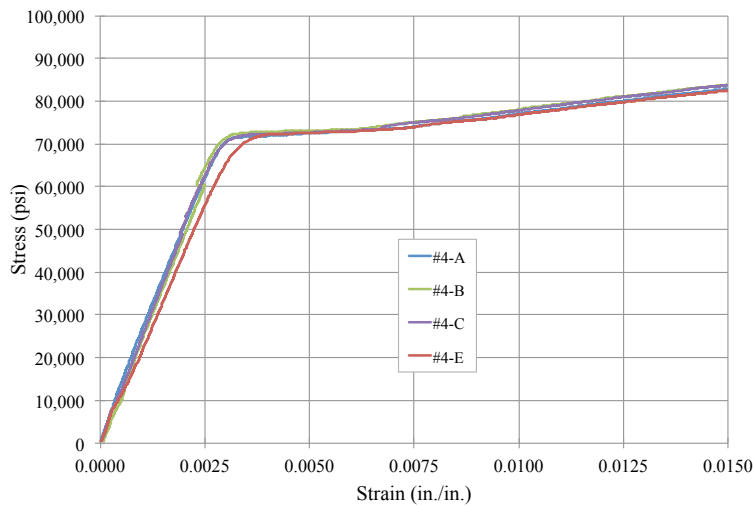


Appendix F

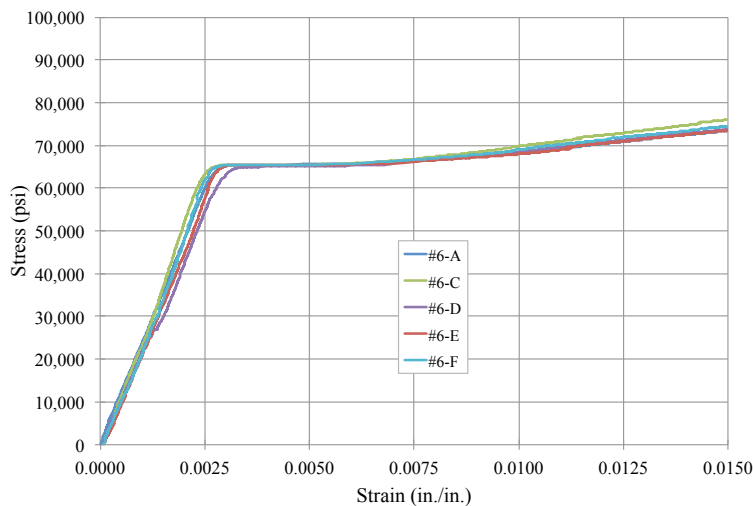
Material Properties and Mix Designs



(a) No. 3



(b) No. 4



(c) No. 6

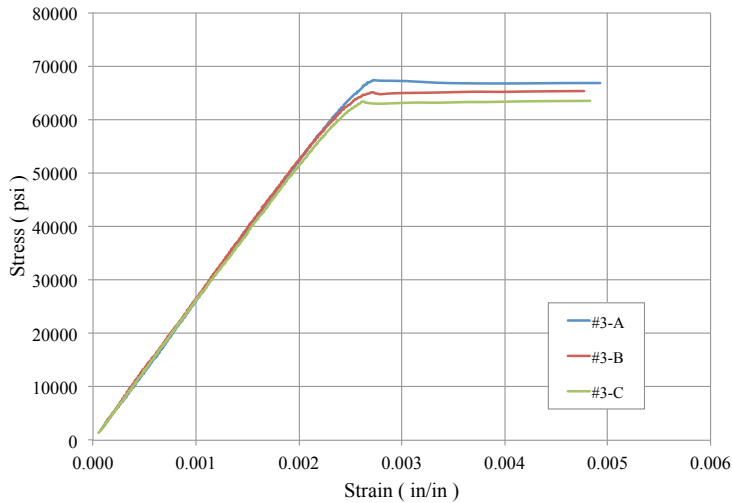
Figure F.1(a). Measured stress-strain relationships – AASHTO BI-36

Parameters for analytical model:

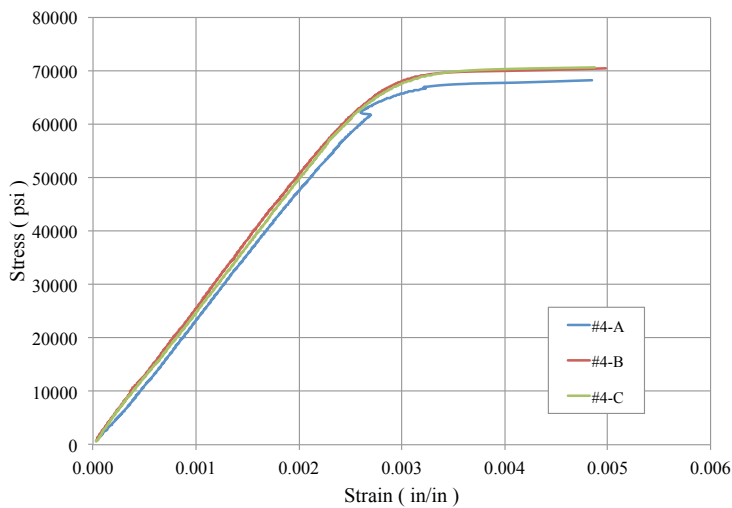
- f_y (yield strength) = 72.73 ksi
- f_u (ultimate strength) = 112.47 ksi
- E_s (modulus of elasticity) = 24,261 ksi
- E_{sh} = 1,190 ksi (modulus at the onset of strain hardening)
- ϵ_y = 0.00299 (yield strain)
- ϵ_{sh} = 0.006696 (strain at the onset of strain hardening)

Parameters for analytical model:

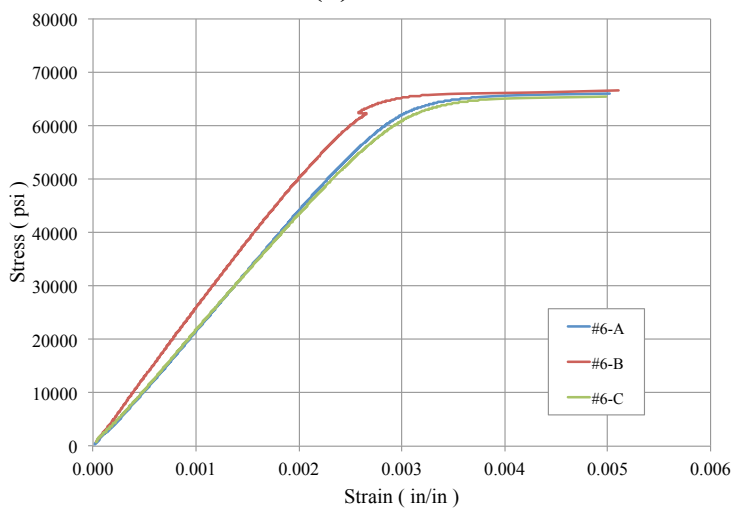
- f_y (yield strength) = 65.36 ksi
- f_u (ultimate strength) = 102.34 ksi
- E_s (modulus of elasticity) = 23,900 ksi
- E_{sh} = 1,009 ksi (modulus at the onset of strain hardening)
- ϵ_y = 0.00273 (yield strain)
- ϵ_{sh} = 0.00674 (strain at the onset of strain hardening)



(a) No. 3



(b) No. 4



(c) No. 6

Figure F.1(b). Measured stress-strain relationships – AASHTO BT-54

Ramberg-Osgood function parameters:

$$A = 0.001$$

$$B = 335$$

$$C = 8.5$$

$$f_u \text{ (ultimate strength) } = 107 \text{ ksi}$$

$$E_s \text{ (modulus of elasticity) } = 25,120 \text{ ksi}$$

$$\epsilon_f = 0.128 \text{ (failure strain)}$$

Ramberg-Osgood function parameters:

$$A = 0.005$$

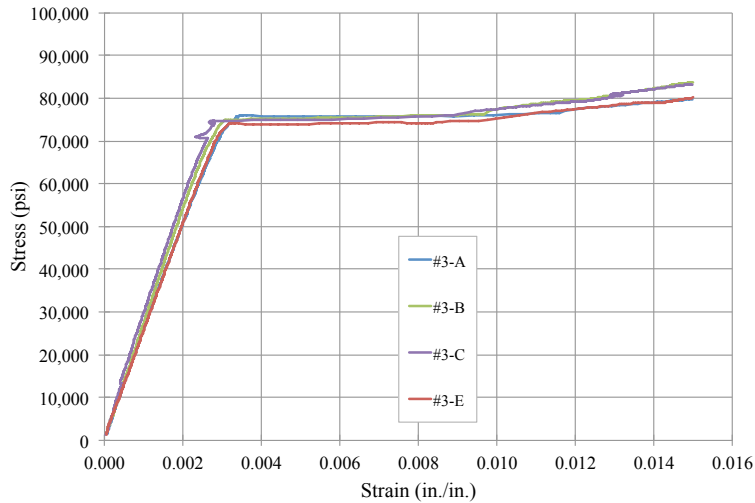
$$B = 345$$

$$C = 6.6$$

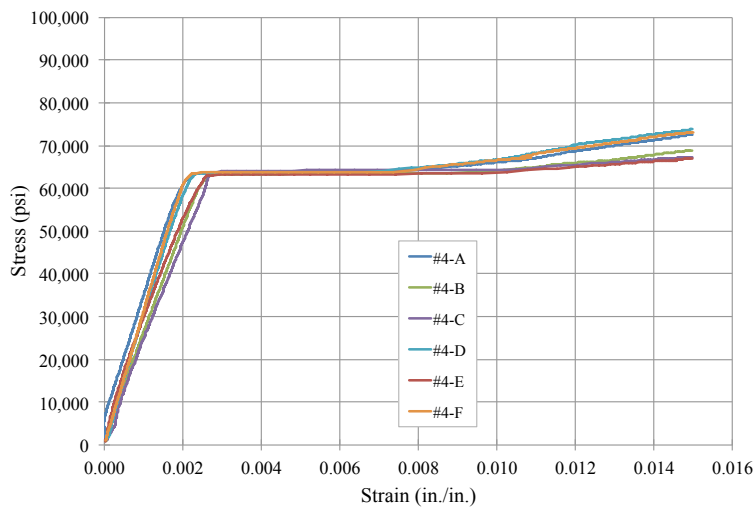
$$f_u \text{ (ultimate strength) } = 106 \text{ ksi}$$

$$E_s \text{ (modulus of elasticity) } = 23,140 \text{ ksi}$$

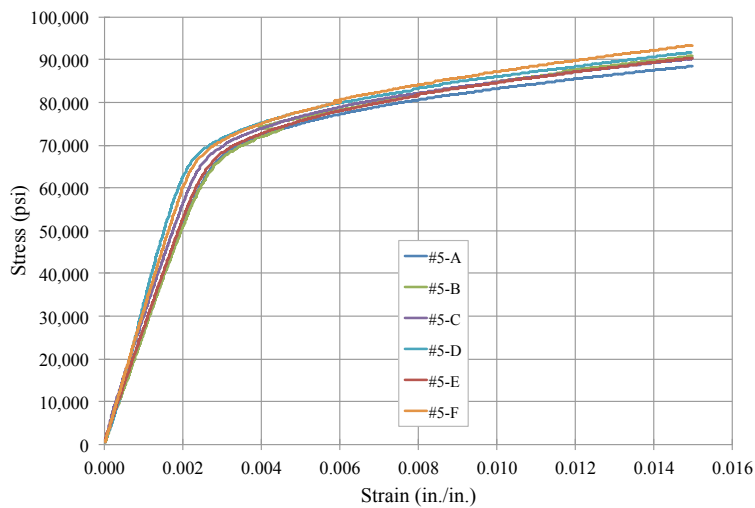
$$\epsilon_f = 0.128 \text{ (failure strain)}$$



(a) No. 3



(b) No. 4



(c) No. 5

Figure F.1(c). Measured stress-strain relationships – AASHTO Type III-a and III-b

Parameters for analytical model:

f_y (yield strength) = 63.6 ksi

f_u (ultimate strength) = 100.33 ksi

E_s (modulus of elasticity) = 28,000 ksi

E_{sh} = 1,030 ksi (modulus at the onset of strain hardening)

ϵ_y = 0.00227 (yield strain)

ϵ_{sh} = 0.00811 (strain at the onset of strain hardening)

Ramberg-Osgood function parameters:

A = 0.05

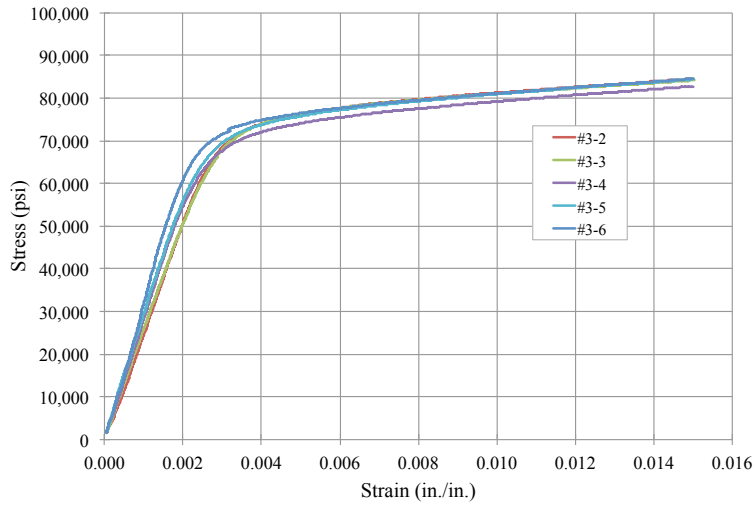
B = 395

C = 5.1

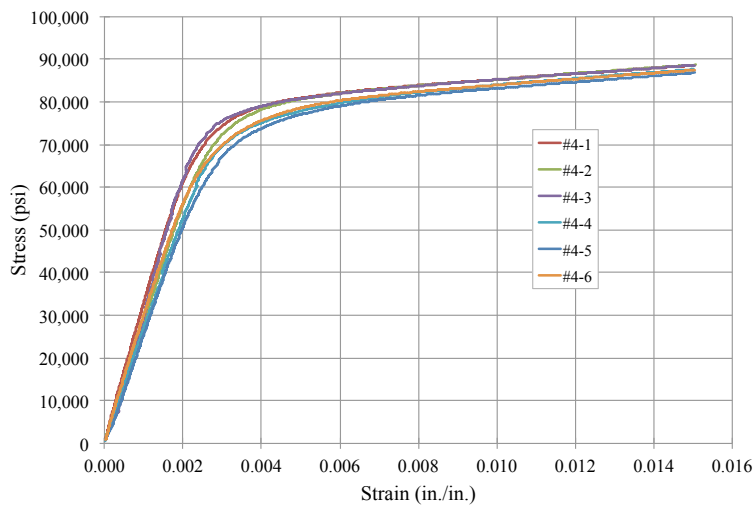
f_u (ultimate strength) = 106 ksi

E_s (modulus of elasticity) = 29,000 ksi

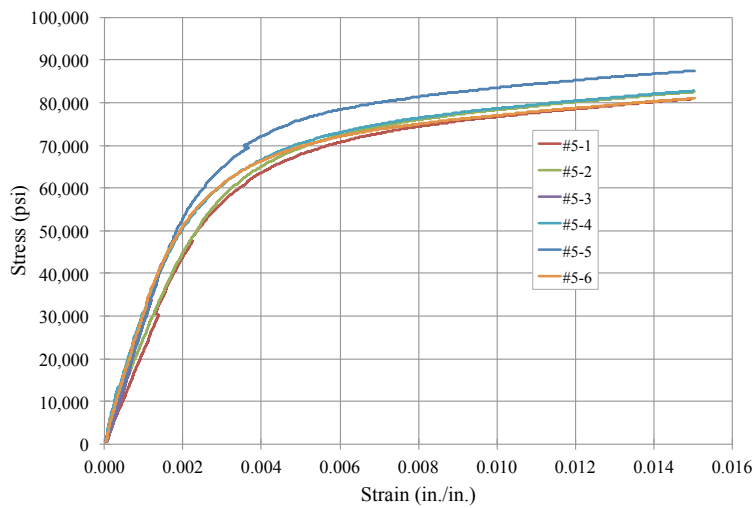
ϵ_f = 0.128 (failure strain)



(a) No. 3



(b) No. 4



(c) No. 5

Figure F.1(d). Measured stress-strain relationships – Nebraska NU-1100

Ramberg-Osgood function
parameters:

$$A = 0.028$$

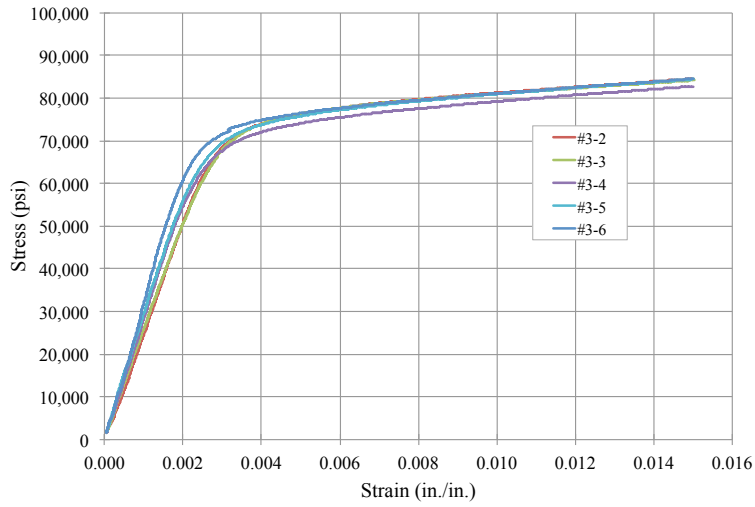
$$B = 371$$

$$C = 4.95$$

$$f_u \text{ (ultimate strength)} = 106 \text{ ksi}$$

$$E_s \text{ (modulus of elasticity)} = 29,000 \text{ ksi}$$

$$\epsilon_f = 0.254 \text{ (failure strain)}$$



Ramberg-Osgood function parameters:

$$A = 0.05$$

$$B = 386$$

$$C = 7.3$$

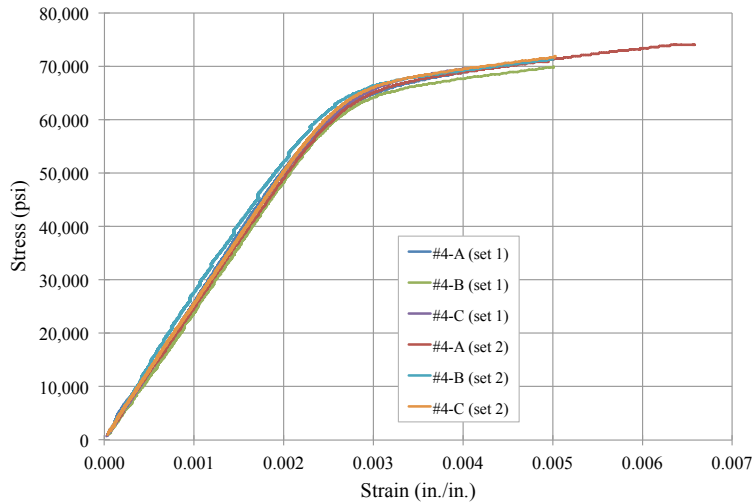
$$f_u \text{ (ultimate strength) } = 106 \text{ ksi}$$

$$E_s \text{ (modulus of elasticity) } = 29,000 \text{ ksi}$$

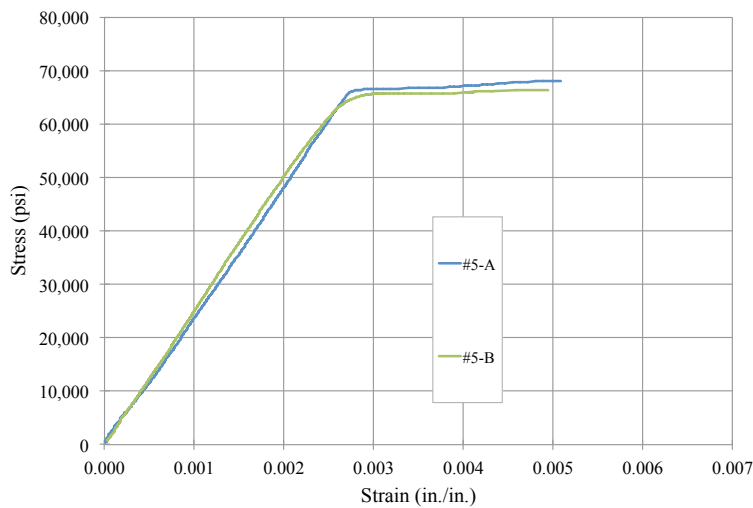
$$\epsilon_f = 0.12 \text{ (failure strain)}$$

(d) No. 6

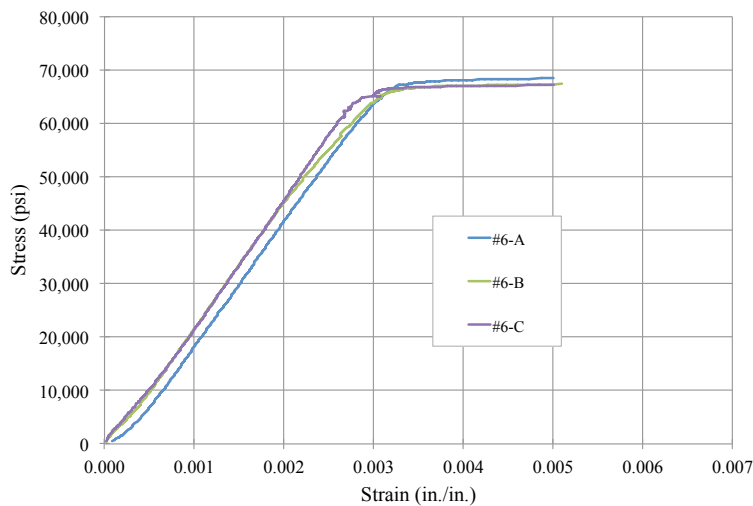
Figure F.1(d) (cont.). Measured stress-strain relationships – Nebraska NU-1100



(a) No. 4



(b) No. 5



(c) No. 6

Ramberg-Osgood function parameters:

$$A = 0.04$$

$$B = 380$$

$$C = 5$$

$$f_u \text{ (ultimate strength)} = 109 \text{ ksi}$$

$$E_s \text{ (modulus of elasticity)} = 26,500 \text{ ksi}$$

$$\epsilon_f = 0.15 \text{ (failure strain)}$$

Parameters for analytical model:

$$f_y \text{ (yield strength)} = 67.1 \text{ ksi}$$

$$f_u \text{ (ultimate strength)} = 105.3 \text{ ksi}$$

$$E_s \text{ (modulus of elasticity)} = 24,500 \text{ ksi}$$

$$E_{sh} = 1,030 \text{ ksi (modulus at the onset of strain hardening)}$$

$$\epsilon_y = 0.00274 \text{ (yield strain)}$$

$$\epsilon_{sh} = 0.00811 \text{ (strain at the onset of strain hardening)}$$

Table F.1. Mix designs

(a) AASHTO BI-36

Mix		Girder	
Provider		AASHTO BI-36: Prestress Services Industries, Melborne, KY	
Design f'_c	psi	6,000	
Cast date		12/11/14	
Item	Qty	Qty	Source
Cement	lbs/cy	733	Prestress Services, Type III
Fine agg	lbs/cy	1158	Prestress Services, Concrete Sand
Coarse agg	lbs/cy	1719	Prestress Services, 40% Crushed
Water	lbs/cy	264	Prestress Services Well Water
HRWR	oz/cy	22	Grace Construction Products, Zyla R
Stabilizer	oz/cy	--	--
Water Reducing and Retarding	oz/cy	51.3	Grace Construction Products, Adva Cast 575
Air Entraining	oz/cy	14.3	Grace Construction Products, Terapave
Corrosion Inhibitor	oz/cy	512	Grace Construction Products, DCI
w/c		0.36	
Slump	in.	8	
Air content	%	5	

Table F.1. (cont.) Mix designs

(b) AASHTO BT-54

Mix		<u>Girder</u>		<u>Deck Slab</u>	
Provider		AASHTO BT-54: Prestress Services Industries, Melborne, KY		Prestress Services Industries, Melborne, KY	
Design f'_c	psi	15,000		6,000	
Cast date		11/3/15		11/5/15	
Item	Qty	Qty	Source	Qty	Source
Cement	lbs/cy	940	Prestress Services, Type III	658	Prestress Services, Type III
Fine agg	lbs/cy	1104	Prestress Services, Concrete Sand	1199	Prestress Services, Concrete Sand
Coarse agg	lbs/cy	1588	½ × ¼ Iron Mountain Trap Rock	1779	Prestress Services, 40% Crushed
Fly Ash	lbs/cy	85	Prestress Services	--	--
Silica Fume	lbs/cy	85	Prestress Services	--	--
Water	lbs/cy	233	Prestress Services Well Water	224	Prestress Services Well Water
HRWR	oz/cy	277.5	BASF, MaterGlenium 7920	270	W.R. Grace, Adva Cast 575
Stabilizer	oz/cy	66.6	BASF, MasterSure Z 60	--	--
Water Reducing and Retarding	oz/cy	66.6	BASF, MasterSet Delvo	270	W.R. Grace, Zyla R
Air Entraining Admixture	oz/cy	--	--	1.5	W.R. Grace, Terapave AEA
Corrosion Inhibitor	oz/cy	--	--	512	Grace Construction Products, DCI
w/c		0.248		0.38	
Slump	in.	SCC ¹		Not reported	
Air content	%	1.3		Not reported (design of 6%)	

¹Spread was 27.75 inches, VSI of 0.

Table F.1. (cont.) Mix designs

(c) AASHTO Type III-a

Mix		<u>Girder</u>		<u>Deck Slab</u>	
Provider		AASHTO Type III: Prestress Services Industries, Lexington, KY		Hilltop Resources, Cincinnati, OH	
Design f'_c	psi	6,000		5,000	
Cast date		11/5/14		1/28/15	
Item	Qty	Qty	Source	Qty	Source
Cement	lbs/cy	650	Prestress Services, Type III	565	Holcim Ste, Genevieve, Type I/II
Fine agg	lbs/cy	1458	Prestress Services, Concrete Sand	1466	Hilltop, Concrete Sand
Coarse agg	lbs/cy	1600	Prestress Services, #9 Rock	1720	Hilltop, #8 Gravel
Water	lbs/cy	240	Prestress Services Well Water	275	Cincinnati
HRWR	oz/cy	35.8	Grace Construction Products, Zyla R	45.2	Master Builders, Polyheed 1725
Stabilizer	oz/cy	--	--	22.6	Master Builders, Pozzoloth 80
Water Reducing and Retarding	oz/cy	58.5	Grace Construction Products, Adva Cast 575	--	--
Air Entraining	oz/cy	9.75	Grace Construction Products, Terapave	--	--
Corrosion Inhibitor	oz/cy	256	Grace Construction Products, DCI	--	--
w/c		0.368		0.49	
Slump	in.	8		9	
Air content	%	5		1.5	

Table F.1. (cont.) Mix designs

(d) AASHTO Type III-b

Mix		<u>Girder</u>		<u>Deck Slab</u>	
Provider		AASHTO Type III: Prestress Services Industries, Lexington, KY		Hilltop Resources, Cincinnati, OH	
Design f'_c	psi	10,000		5,000	
Cast date		11/12/14		3/12/15	
Item	Qty	Qty	Source	Qty	Source
Cement	lbs/cy	733	Prestress Services, Type III	565	Holcim Ste, Genevieve, Type I/II
Fine agg	lbs/cy	1267	Prestress Services, Concrete Sand	1466	Hilltop, Concrete Sand
Coarse agg	lbs/cy	1695	Prestress Services, #9 Rock	1720	Hilltop, #8 Gravel
Water	lbs/cy	246	Prestress Services Well Water	275	Cincinnati
HRWR	oz/cy	44	Grace Construction Products, Zyla R	45.2	Master Builders, Polyheed 1725
Stabilizer	oz/cy	--	--	22.6	Master Builders, Pozzoloth 80
Water Reducing and Retarding	oz/cy	70	Grace Construction Products, Adva Cast 575	--	--
Air Entraining	oz/cy	11	Grace Construction Products, Terapave	--	--
Corrosion Inhibitor	oz/cy	256	Grace Construction Products, DCI	--	--
w/c		0.368		0.49	
Slump	in.	8		9	
Air content	%	5		1.5	

Table F.1. (cont.) Mix designs

(e) Nebraska NU-1100

Mix		<u>Girder</u>		<u>Deck Slab</u>	
Provider		Nebraska NU-1100: Coreslab Structures, Omaha, NE		Hilltop Resources, Cincinnati, OH	
Design f'_c	psi	10,000		5,000	
Cast date		9/4/14		10/24/14	
Item	Qty	Qty	Source	Qty	Source
Cement	lbs/cy	562	Ash Grove, Type III	565	Holcim Ste, Genevieve, Type I/II
Fine agg	lbs/cy	843	Coreslab, Class 5 Sand	1466	Hilltop, Concrete Sand
		700	Coreslab, #8 Platte River Sand	--	--
Coarse agg	lbs/cy	1274	Coreslab, 3/4" Nebraska Limestone	1720	Hilltop, #8 Gravel
Fly ash	lbs/cy	123	Coreslab, Type C fly ash	--	--
Slag cement	lbs/cy	173	Lafarge #120 slag	--	--
Water	lbs/cy	242	Omaha	275	Cincinnati
HRWR	oz/cy	95	Adva 530	45.2	Master Builders, Polyheed 1725
Stabilizer	oz/cy	26	Grace Construction Products, Daratard 17	22.6	Master Builders, Pozzoloth 80
w/c		0.28		0.49	
Slump	in.	Self consolidating		9	
Air content	%	5		1.5	

Table F.1. (cont.) Mix designs

(f) Texas U-40

Mix		<u>Girder</u>		<u>Deck Slab</u>	
Provider		Texas U-40: Texas Concrete, Inc. – Victoria, Texas		Hilltop Resources, Cincinnati, OH	
Design f'_c	psi	10,000		5,000	
Cast date		5/7/15		6/26/14	
Item	Qty	Qty	Source	Qty	Source
Cement	lbs/cy	670	Alamo Type 3	565	Holcim Ste, Genevieve, Type I/II
Fine agg	lbs/cy	1068	Texas Concrete, Inc, Concrete Sand	1466	Hilltop, Concrete Sand
Coarse agg	lbs/cy	1776	Texas Concrete, Inc, Crushed Rock	1720	Hilltop, #8 Gravel
Water	lbs/cy	278	Prestress Services Well Water	275	Cincinnati
HRWR	oz/cy	70	BASF, MaterGlenium 7700	45.2	Master Builders, Polyheed 1725
Stabilizer	oz/cy	--	--	22.6	Master Builders, Pozzoloth 80
Water Reducing and Retarding	oz/cy	20	BASF, MasterSet R 300	--	--
w/c		0.278		0.49	
Slump	in.	8		9	
Air content	%	5		1.5	