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Means and Methods of Evaluating Reinforced Concrete Structures

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Assessment of Concrete T Beams Strengthened with Enlarged Reinforced Section

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Objectives

- Strengthening of T Beams by Reinforced Section Enlargement using Ducon System
- Testing of T Beams for Shear Behavior
- Assessment of T Beams for Shear Behavior

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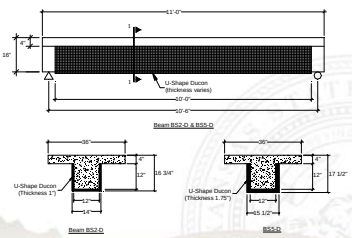
Beam Specimen Details

Shear Beams - Test Matrix

Specimen ID	Type	Testing	DUCON Enlargement			Geometry				Long. Steel (in^2)		Transv. Steel	$f'_{c,test}$ (psi)	$f_{y,test}$ (ksi)	$f_{y,t,test}$ (ksi)
			Layout	Thickness (in.)	Mesh Layers	Length (ft.)	bw (in.)	h (in.)	bf (in.)	tf (in.)	L (ft.)	Top (in^2)	Bottom (in^2)				
BS2-D	Beam	Shear	U-Shape	1	7	10'-0"	12	16	36	4	11	(6) #4	1.20	(3) #10	3.81	#3 @ 10"	4810	68	73.56
BS5-D	Beam	Shear	U-Shape	1.75	15	10'-0"	12	16	36	4	11	(6) #4	1.20	(3) #10	3.81	#3 @ 12"	4810	68	73.56



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DUCON ½" x ½" Wire Mesh Reinforcement

- Alloy: Low Carbon Steel Welded Mesh Material C9D (Per ASTM 1008)
- Wire Properties: Elongation min. 10% Tensile: 450N/mm² (+/-50N/mm²)
- Mesh: ½" x ½" Bidirectional Wire Mesh (Pitch ½")
- Wire Size: 0.03937" (1.0mm)
- Standard Roll Size: 60" (1500mm) x 165' (50m)

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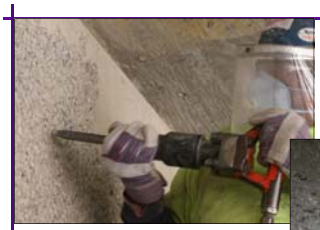
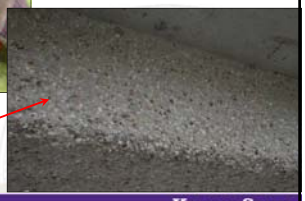
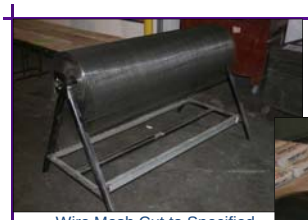
Surface Preparation





Roughened Surface to ¼" Amplitude

External Steel Fabrication



Wire Mesh Cut to Specified Dimensions:
BS2-D = 10 feet long,7 Layers
BS5-D = 10 feet long, 15 Layers

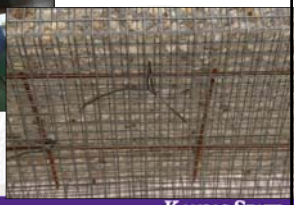
External Steel Fabrication

DUCON Wire mesh bent to U-shaped configuration prior to installation

BS2-D: Steel Installation

DUCON Mesh Installation

BS2-D: Steel Installation

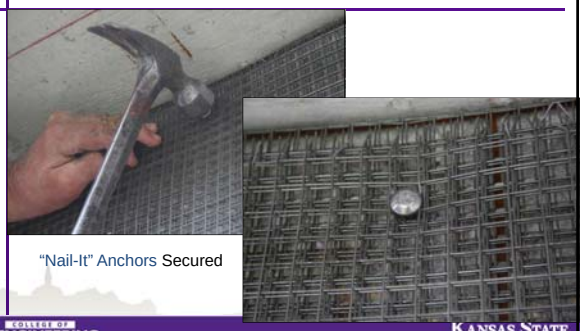


Securing DUCON Mesh to Spacer Mesh

BS2-D: Anchoring Ducon Mesh

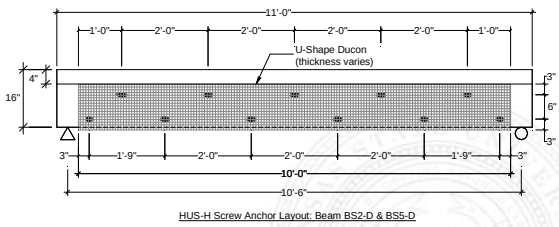
Drilling and Installing "Nail-It" Anchors

BS2-D: Anchoring Ducon Mesh



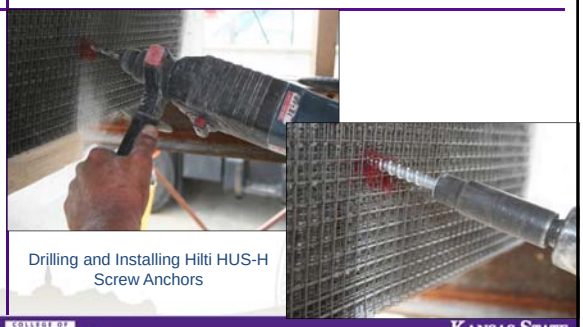
"Nail-It" Anchors Secured

Screw Anchor Layout



HUS-H Screw Anchor Layout: Beam BS2-D & BS5-D

Screw Anchor Installation



Drilling and Installing Hilti HUS-H Screw Anchors

Screw Anchor Installation

Formwork Installation

Construction of Form Panels (3/4" Plywood, 3/4" Plywood, 2"x4" frame, 3/4"x3/4" min. air vents, etc.)

Formwork Installation

Form Panel Placement

Formwork Installation

Securing Form to Concrete
(Hilti HUS-H Screw Anchors)

Formwork Installation

Bottom Form Installation

Formwork Installation

DUCON Slurry Mixing

DUCON Slurry Testing

Slump Flow Test
(10" slump)

DUCON Slurry Testing

Compressive Strength Testing
(2"x2"x2" Cube Mold)

DUCON Slurry Pumping

Slurry Pumped into Forms
(2" hose line connection)

DUCON Slurry Pumping

Slurry Pumped into Forms
(Material Flow – Plexiglass Window)

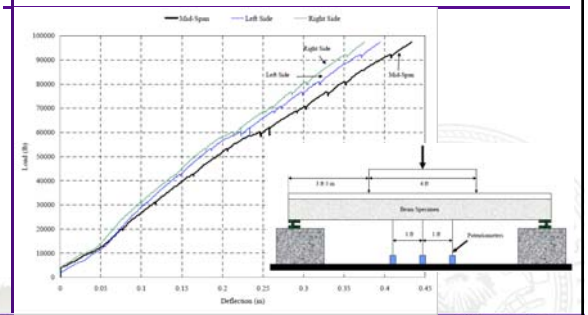
Finished Beams BS2-D & BS5-D

BS5-D Beam

BS2-D Beam

Testing of BS-5 at NCSU

Testing of BS5 at NCSU



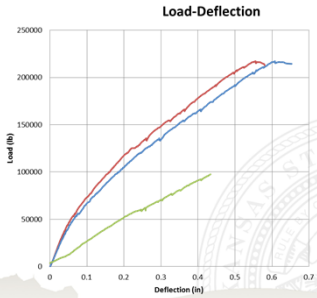
Testing of BS5-D at K-State

- Beam Setup

Testing of BS5-D at K-State

- Beam Failure

Testing of BS5-D at K-State



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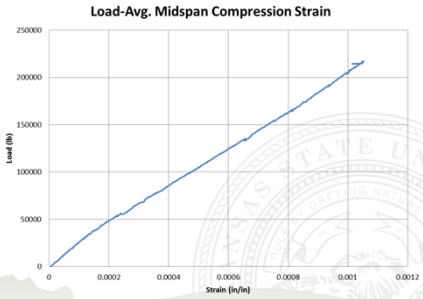

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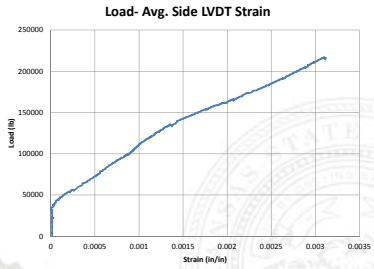

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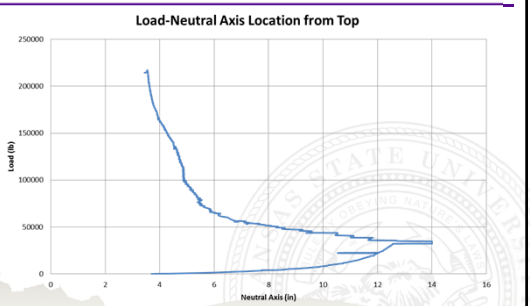
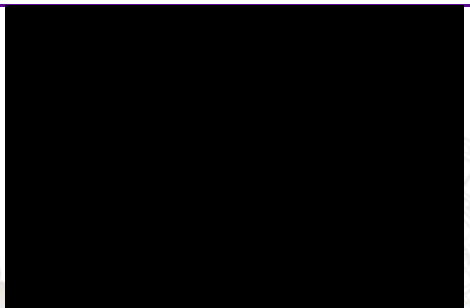


Testing of BS5-D at K-State



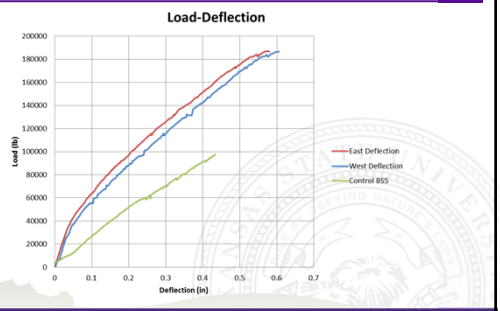
Testing of BS2-D at K-State

- Beam Setup

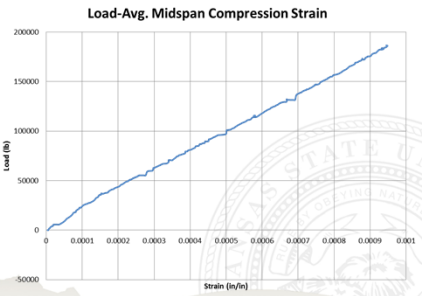
Testing of BS2-D at K-State

- Beam Failure

Testing BS2-D at K-State



Testing BS2-D at K-State



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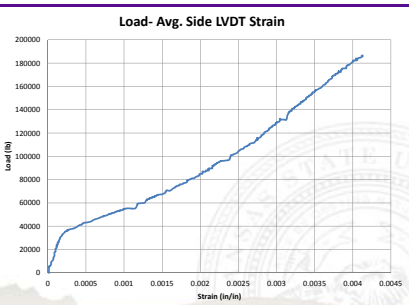

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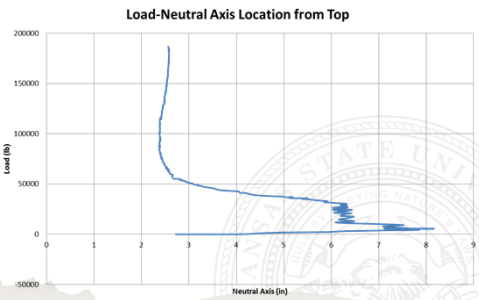
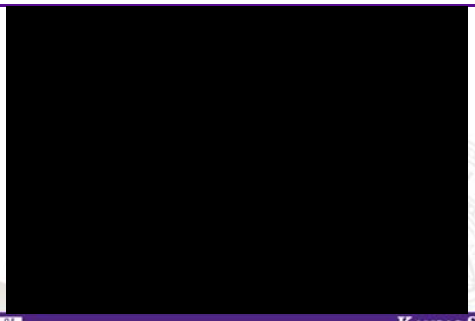


Testing of BS2-D at K-State



Assessment of BS5

- Computing shear capacity using the modified compression field theory

$$\epsilon_s = \frac{|M_u|/d_v + |V_u|}{E_s A_s} = 0.001835$$

$$\beta = \frac{4.8}{1 + 750\epsilon_s} = 2.02$$

$$\theta = 29° + 3500\epsilon_s = 35.42°$$

$$V_c = 0.0316\beta\sqrt{f'_c}\,b_v d_v = 22.91 \text{ k}$$

$$V_s = \frac{A_v f_{yt} d_v Cot\theta}{s} = 25.37 \text{ k}$$

$$V_n = V_c + V_s = 48.28 \text{ k}$$

$$P_n = 96.57 \text{ k}$$

$$P_{n\,exp} = 97.6 \text{ k}$$

Assessment of BS5-D

- Computing shear capacity using the modified compression field theory

$$\epsilon_s = \frac{|M_u|/d_v + |V_u|}{E_s A_s} = 0.003163$$

$$\beta = \frac{4.8}{1 + 750\epsilon_s} = 1.423$$

$$\theta = 29° + 3500\epsilon_s = 40°$$

$$V_c = 0.0316\beta\sqrt{f'_c}\,b_v d_v = 21.16 \text{ k}$$

$$V_s = \frac{A_v f_{yt} d_v Cot\theta}{s} = 85.64 \text{ k}$$

$$V_n = V_c + V_s = 106.8 \text{ k}$$

$$P_n = 213.6 \text{ k}$$

$$P_{n\,exp} = 216.6 \text{ k}$$

Assessment of BS2-D

- Computing shear capacity using the modified compression field theory

$$\epsilon_s = \frac{|M_u|/d_v + |V_u|}{E_s A_s} = 0.003088$$

$$\beta = \frac{4.8}{1 + 750\epsilon_s} = 1.448$$

$$\theta = 29° + 3500\epsilon_s = 39.81°$$

$$V_c = 0.0316\beta\sqrt{f'_c}\,b_v d_v = 19.37 \text{ k}$$

$$V_s = \frac{A_v f_{yt} d_v Cot\theta}{s} = 55.45 \text{ k}$$

$$V_n = V_c + V_s = 74.82 \text{ k}$$

$$P_n = 149.63 \text{ k}$$

$$P_{n\,exp} = 187.6 \text{ k}$$

Conclusions

- The DUCON system is relatively simple to apply and effective to act as section enlargement
- The shear capacity was shown by testing to increase significantly
- The failure mode varies from shear cracking to shear debonding
- The modified compression field theory predicts the shear capacity reasonably well

Questions