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PREDICTED STRAND TRANSFER LENGTHS IN FULL SCALE AASHTO PRETENSIONED CONCRETE GIRDER

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Abstract. *This study investigates the transfer length of the full scale AASHTO pretensioned high strength lightweight concrete (HSLWC) girder by using nonlinear finite element analysis package (ANSYS). Specific parameters were included in the current investigation such as concrete cover (2 in (50mm) and 3 in (75 mm)), concrete compressive strength (8 ksi (55 MPa), 10 ksi (70 MPa), and 12 ksi (83 MPa)), concrete density (90 pcf (1440 kg/m^3) and 115 pcf (1840 kg/m^3)), strand strength (250 ksi (1750 MPa) and 270 ksi (1890 MPa)), strand spacing (2 in (50 mm) and 1.75 in (43.75 mm)) ,strand size (0.5 in. (12.7 mm) and 0.6 in. (15.2 mm)), and number of 0.5 in (12.7 mm) strand (8, 10, 12, 14, and 16 strands). The results showed that the tested parameters have little impact on the transfer length, but on the other hand these parameters have significant impact on the concrete strain and camber.*

1 INTRODUCTION

In pretensioned concrete structures, the transfer length is defined as the length over which the effective stresses transmitted from prestress cable or strand to the concrete. The manufacturing of pretensioned concrete girders divided into three main stages: Firstly, the prestressing reinforcement is tensioned up to allowable value according to design code; after that, the concrete girder is casted around the prestressing strands; and finally, the prestressing strand is released to transfer the prestressing force to concrete through the bond between the strands and the surrounding concrete. The evaluation of the real transmission length in pretensioned concrete structural girders is considered as a common problem. The complete concept of pretensioned concrete is based on the bond between the concrete and strand and the girder would not act integrally without bond.

During last fifteen years, it has been seen a successful utilization of high performance concretes (HPC) in the design and construction of bridge [1-6]. These HPC bridges were built with normal weight concrete with a density of about 240 kg/m^3. HPC are typically higher in strength with further durability than their normal counterparts due to the denser cement matrix (mineral admixtures) and lower water to cement ratio. These factors have strong impact on construction and design of highway bridges in terms of preferred structural and economic efficiencies.

2 DESCRIPTION OF NLFEA PROGRAM

2.1 Specimens Details and Material Properties

ANSYS software, version 12 was used to study the transfer length and the camber of HSLWC AASHTO Type II prestressed girders with 2 strands (12.7 mm in diameter and strength of 1890 MPa at the top flange) that include various parameters of investigation as shown in Table 1. The simulated specimens by ANSYS, for the purpose of organizing, are divided into seven groups to study the effect of the considered parameters on the transfer of prestressing strands in HSLWC, as shown in Table 1.

Girder No.	Strand diameter, in.	Strand spacing, in.	Strand strength, ksi	Concrete cover, mm	Concrete strength, MPa	Concrete density, kg/m^3
Group 1 : Number of Strands						
1	0.5 (12.7 mm)	2 (50 mm)	8-G 270 (1890 MPa)	3 (75 mm)	70	1440
2	0.5 (12.7 mm)	2 (50 mm)	10-G 270 (1890 MPa)	3 (75 mm)	70	1440
3	0.5 (12.7 mm)	2 (50 mm)	12-G 270 (1890 MPa)	3 (75 mm)	70	1440
4	0.5 (12.7 mm)	2 (50 mm)	14-G 270 (1890 MPa)	3 (75 mm)	70	1440
5	0.5 (12.7 mm)	2 (50 mm)	16-G 270 (1890 MPa)	3 (75 mm)	70	1440
Group 2 : Concrete cover						
1	0.5 (12.7 mm)	2 (50 mm)	16-G 270 (1890 MPa)	2 (50 mm)	70	1440
2	0.5 (12.7 mm)	2 (50 mm)	16-G 270 (1890 MPa)	3 (75 mm)	70	1440
Group 3 : Concrete strength						
1	0.5 (12.7 mm)	2 (50 mm)	16-G 270 (1890 MPa)	2 (50 mm)	55	1440
2	0.5 (12.7 mm)	2 (50 mm)	16-G 270 (1890 MPa)	2 (50 mm)	70	1440
2	0.5 (12.7 mm)	2 (50 mm)	16-G 270 (1890 MPa)	2 (50 mm)	83	1440
Group 4 : Concrete density						
1	0.5 (12.7 mm)	2 (50 mm)	16-G 270 (1890 MPa)	2 (50 mm)	70	1440
2	0.5 (12.7 mm)	2 (50 mm)	16-G 270 (1890 MPa)	2 (50 mm)	70	1840
Group 5 : Strand strength						
1	0.5 (12.7 mm)	2 (50 mm)	16-G 250 (1750 MPa)	2 (50 mm)	70	1440
2	0.5 (12.7 mm)	2 (50 mm)	16-G 270 (1890 MPa)	2 (50 mm)	70	1440
Group 6 : Strand spacing						
1	0.5 (12.7 mm)	1.75 (43.75)	16-G 270 (1890 MPa)	2 (50 mm)	70	1440
2	0.5 (12.7 mm)	2 (50 mm)	16-G 270 (1890 MPa)	2 (50 mm)	70	1440
Group 7 : Strand size						
1	0.5 (12.7 mm)	2 (50 mm)	16-G 270 (1890 MPa)	2 (50 mm)	70	1440
2	0.6 (15.2 mm)	2 (50 mm)	16-G 270 (1890 MPa)	2 (50 mm)	70	1440

Table 1 : Simulated specimens (AASHTO Type II) and major parameters for investigation.

2.2 Element Types

SOLID65 was used to model the nonlinearly lightweight concrete with its capability in cracking, creep, crushing, and plastic deformation. LINK8 element was used to model the prestress strands and SOLID45 was used to model the steel plates at the supports.

2.3 Nonlinear Solution and Failure Criteria

Taking advantage of the symmetry in the pretensioned reinforced concrete girder and the applied prestressed force, half of the girder with proper boundary conditions was used in the nonlinear finite element analysis (NLFEA). This was carried out to reduce the computer disk space, computational time and requirements. In order to determine the appropriate mesh density, a convergence study was carried out. The bond between the strands and the concrete is assumed perfect. At the end of each load increment, Newton–Raphson equilibrium iterations provide convergence within tolerance limits equal to 0.001.

4 FINITE ELEMENT ANALYSIS RESULTS AND DISCUSSION

4.1 Effect of Number of Strands:

AASHTO Type II prestressed girders, 2 strands at the top flange, 41 ft long, 0.5 in strand diameter, 2 in strand spacing, G270 ksi strand strength, 3 in. concrete cover, 115 pcf concrete density, 10000 psi concrete strength were simulated for different numbers of strands at the bottom flange (Stress level) ranging from 8 to 12 at increment of 2. The FEA camber results for the simulated specimens were 0.2379 in, 0.3096 in, 3799 in, 4361 in, and 0.4856 in for specimen with number of strands 8, 10, 12, 14, and 16 strands show. Figure 1 shows the longitudinal web cracks for the simulated specimens while Figure 2 to Figure 5 show the stresses contour for the same specimen. The transfer length of the simulated specimens is shown in Figure 6.

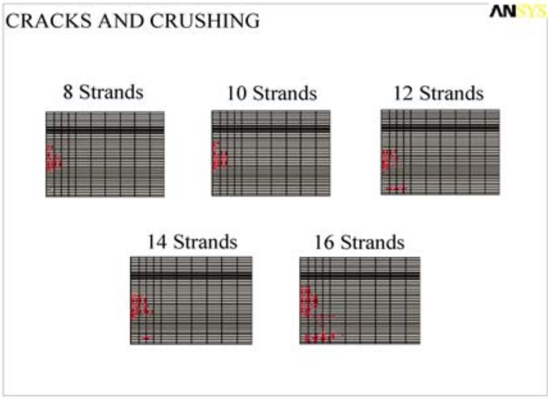

Figure 1. The longitudinal web cracks at different stress level

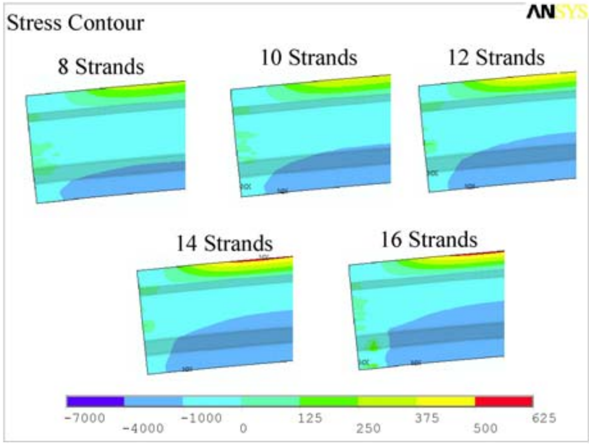

Figure 2. The Axial stress contour in X-direction at different stress level

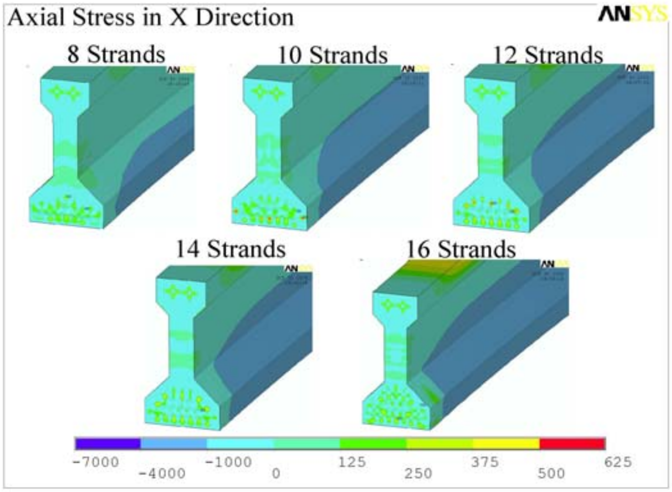

Figure 3. The Axial stress contour in X-direction at different stress level

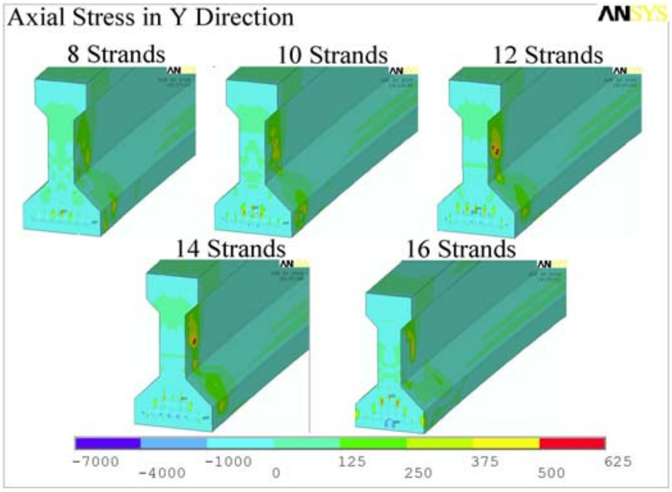

Figure 4. The Axial stress contour in Y-direction at different stress level

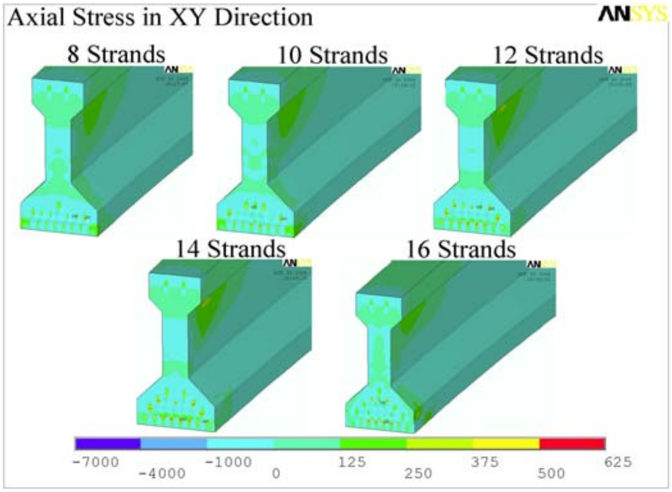

Figure 5. The Axial stress contour in X-Y-direction at different stress level

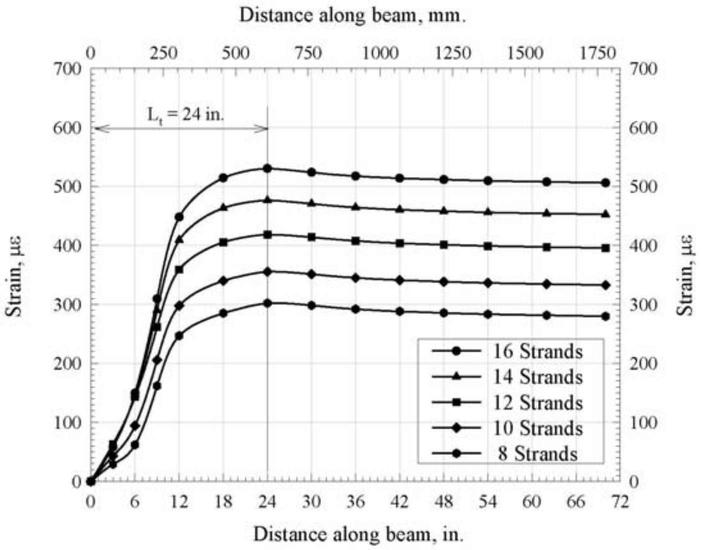

Figure 6. The transfer length at different stress level

4.2 Effect of Concrete Strength:

HSLWC AASHTO Type II prestressed girders, 2 strands at the top flange, 16 strands in the bottom flange, 41 ft long, 0.5 in strand diameter, 2 in. strand spacing, G270 ksi strand strength, 3 in concrete strength, 115 pcf concrete density were simulated for different concrete strengths (8000, 10000, and 12000 psi). The FEA transfer length results are shown in Figure 7 and the camber results for the simulated specimens were 0.5712 in, 0.5047 in, and 0.4605 in for specimen with concrete strength 8000, 10000, and 12000 psi, respectively.

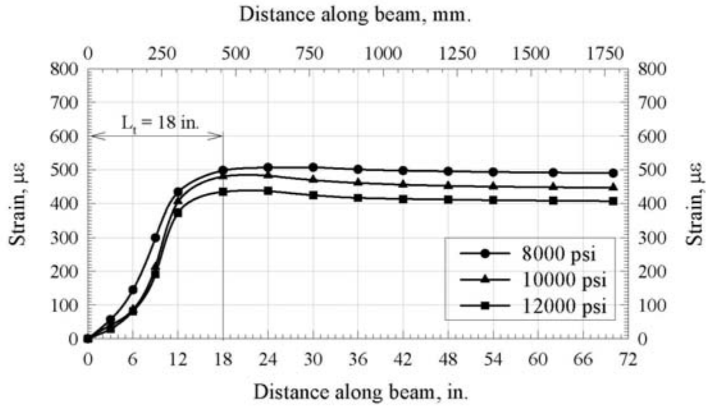

Figure 7. The transfer length at different concrete strength

4.3 Effect of Concrete Density:

HSLWC AASHTO Type II prestressed girders, 2 strands at the top flange, 16 strands in the bottom flange, 41 ft long, 0.5 in strand diameter, 2 in. strand spacing, G 270 ksi strand strength, 10000 psi concrete strength, 3 in concrete cover, and the main variables were the concrete density (90 and 115 pcf). The FEA transfer length results were shown in Figure 8 and the caber results for the simulated specimens were 0.5146 in and 0.5047 in for specimen with concrete density 90 and 115 pcf, respectively.

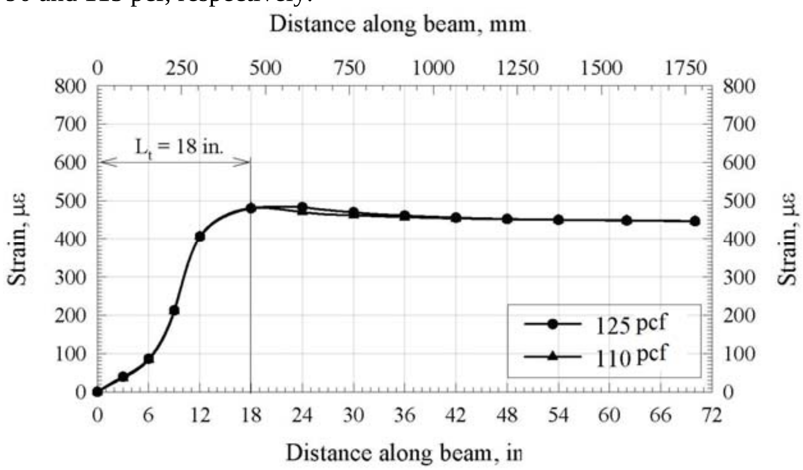

Figure 8. The transfer length at different concrete density

4.4 Effect of Concrete Cover:

HSLWC AASHTO Type II prestressed girders, 2 strands at the top flange, 16 strands in the bottom flange, 41 ft long, 0.5 in strand diameter, 2 in strand spacing, G270 ksi strand strength, 10000 psi concrete strength, 115 pcf concrete density were simulated at different concrete cover depths (2 and 3 in). The FEA transfer length results were shown in Figure 9 and the camber results for the simulated specimens are 0.5674 in and 0.5047 in for specimen with concrete cover 2 in and 3 in, respectively.

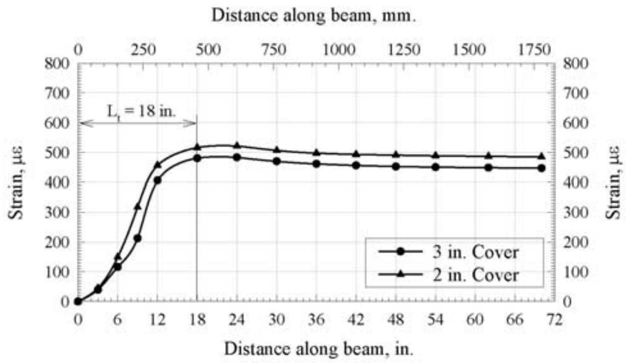

Figure 9. The transfer length at different concrete cover

4.5 Effect of Strand Size:

HSLWC AASHTO Type II prestressed girders, 41 ft long, 2 in strand spacing, G270 ksi strand strength, 10000 psi concrete strength, 115 pcf concrete density, 3 in concrete cover, and strand size of 0.5 in and 0.6 in, and , 2 strands at the top flange, 16 strands in the bottom flange for 0.5in The FEA transfer length results are shown in Figure 10 and the camber results for the simulated specimens were 0.5047 in and 0.5093 in for specimen with strand size 0.5 in and 0.6 in, respectively.

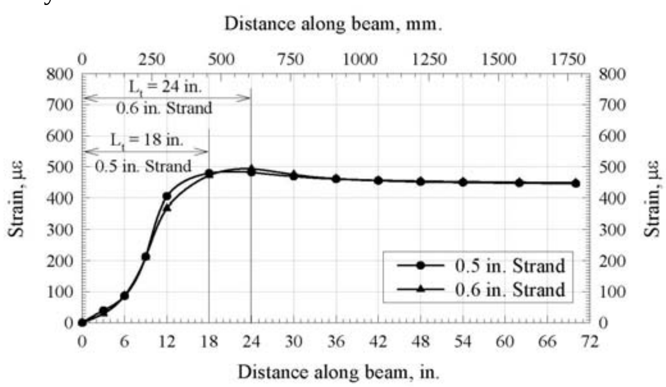

Figure 10. The transfer length at different strand size

4.6 Effect of Strand Spacing:

HSLWC AASHTO Type II prestressed girders, 2 strands at the top flange, 16 strands in the bottom flange, 41 ft long, 0.5 in strand diameter, G 270 ksi strand strength, 10000 psi concrete strength, 115 pcf concrete density, 3 in concrete cover were simulated at different values of strand spacing (2 in and 1.75 in). The FEA transfer length results are shown in Figure 11 and the camber results for the simulated specimens were 0.5047 in and 0.5564 in for specimen with strand spacing 2 in and 1.75 in respectively.

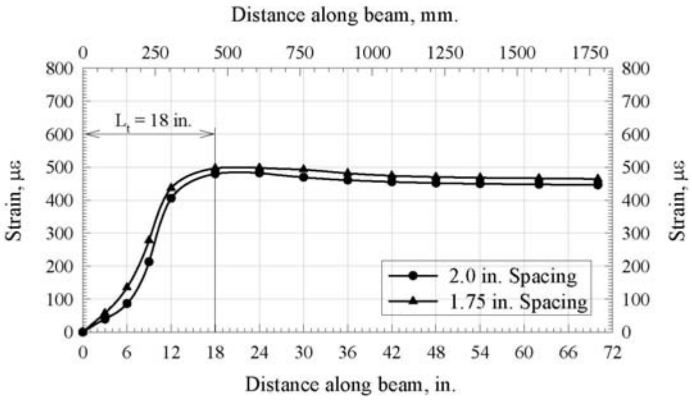

Figure 11. The transfer length at different strand spacing

4.7 Effect of Strand Strength:

HSLWC AASHTO Type II prestressed girders, 41 ft long, 0.5 in strand diameter, 2 in strand spacing, 3 in concrete cover, 10000 psi concrete strength, 115 pcf concrete density, were simulated at different strand strengths of G270 and G250. The FEA transfer length results are shown in Figure 12 and the camber results for the simulated specimens were 0.5047 in and 0.4879 in for specimen with strand strength G270 and G250, respectively.

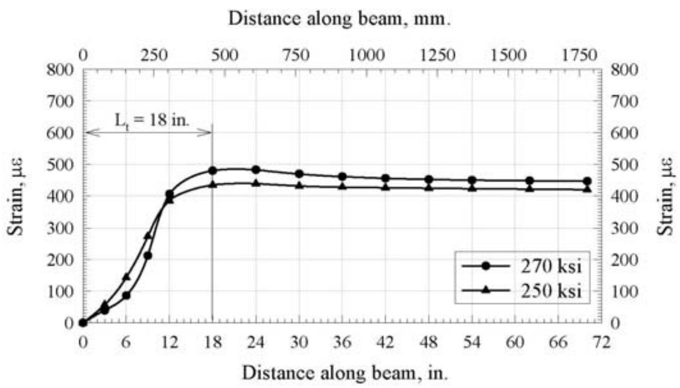

Figure 12. The transfer length at different strand strength

5 CONCLUSIONS

This study investigates the transfer length of the full scale AASHTO pretensioned high strength lightweight concrete (HSLWC) girder by using nonlinear finite element analysis package (ANSYS). Specific parameters were included in the current investigation such as concrete cover, concrete compressive strength, concrete density, strand strength, strand spacing, strand size, and number of 0.5 in strand. The investigated results showed that the tested parameters have little impact on transfer length. On the other hand, these parameters have significant impact on concrete strain and camber.

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