Session 39

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Effect of using new PS loss equations and transformed section properties on the design of PS Beams for the Service 3 check

Topic Description

Effect of using new PS loss equations, transformed section properties and better LL distribution is discussed. Effects are related to bottom beam stresses calculated for simple span PS beams.

Speaker Biography

Henry Bollmann is a Senior Structures Design Engineer working in the FDOT Central Office, Tallahasse Fl. Henry received his MSCE degree from the University of Florida in 1974 and has spent his entire professional career working in many facets of bridge engineering while focusing on design.

New Prestress Losses, Transformed Prestressing Steel, Better Live Load Distribution.

Effect on Beam Design ??

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NCHRP Report 496

Prestress Losses in

Pretensioned High-Strength

Concrete Bridge Girders

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NABIL AL-OMAISHI

University of Nebraska

Lincoln, NE

STEPHEN J. SEGUIRANT

Concrete Technology Corporation

Tacoma, WA

AND

JAMES G. GALLT

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2003

What caught my attention??:

If I use gross section properties or use transformed section properties when calculating stresses I should get close results if I "USE CORRECT THEORY".

Estimated PS losses due to creep and shrinkage may be less than what I have been accustomed to seeing for high strength concrete.

How are my designs effected by:

Proper theory applied ?

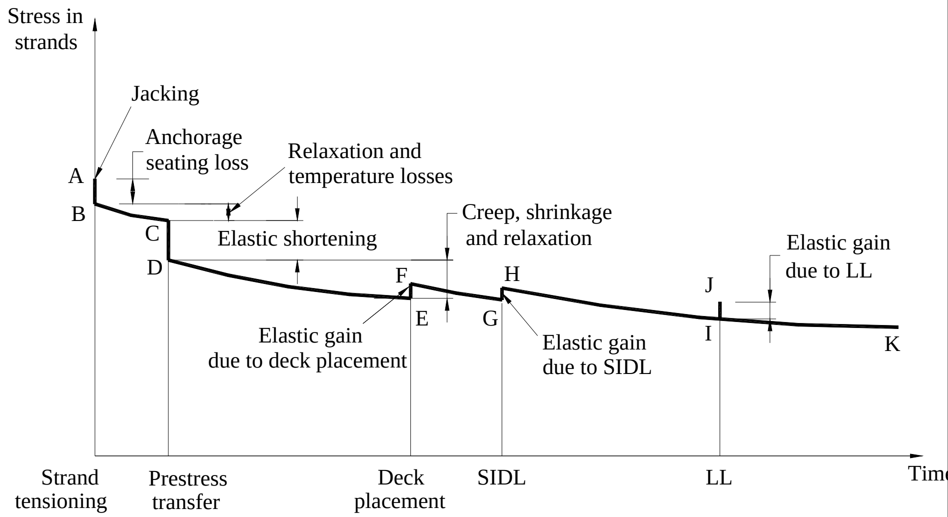
Less losses ?

S/5.5 versus say S/6.5 ?

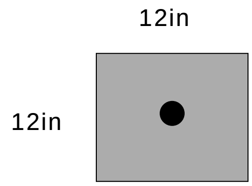
What is total effect?

Should I be using .8LL, Service 3 ??

Components of Prestress Losses



Elastic Shortening Losses are NOT required to be calculated when using Transformed Section Properties



As = 3 in2

PS = 200 ksi

Es = 29000 ksi

Ec = 4833 ksi

N = Es/Ec = 6

Transformed Section Properties

As * PS / Agross – holes + n * As = conc stress

3 * 200 / (12 *12) – 3 + (6 * 3) = 3.7736 ksi

That's it, finished ! NO ES calculated

Proof:

3.7736 / Ec 4833 = .0007808 conc strain

.0007808 * Es 29000 = 22.64 steel loss ksi

(200 – 22.64) *3 / (12 * 12) -3 = 3.7736 ksi

Gross Section Properties

Since PS force after transfer is a function of ES one estimates PS, say 180 ksi.

3 * 180 / 12 * 12 = 3.75 ksi

(n=6) * 3.75 = 22.5 ksi loss ?
200 – 22.5 = 177.5 close to assumption of 180

So ES loss must be explicitly accounted for !!

This an Elastic Loss of Tension in the steel.

Correct Theory Must Be Used:

Stresses calculated using Gross Section Properties WITH Elastic Gains / Losses

Gives comparable answer to:

Use of Transformed Properties WITHOUT Elastic Gaines / Losses

Simple Example follows to demonstrate this.

12 x 12 Conc section with 3 sq inch Gr 60 mild steel, 60 kip tension applied

Transformed
60 / (12*12) – 3 + (6 * 3) = **.3774 ksi tension** 39psi

Gross
60 / 12*12 = **.4167 ksi tension**

Elastic Gain in steel stress:
(n=6)(.4167) = 2.5 ksi tension

Loss of tension in concrete:
(2.5)(3) / 12 *12 = .0521 ksi comp 13psi

Approx concrete stress Gross **.3646 ksi tension**

AASHTO LRFD 2005 Formulas

Creep Coefficient $\psi_t = 1.90 k_{td} k_{la} k_s k_h k_f$

Shrinkage Strain $\varepsilon_{sh} = 480 \times 10^{-6} k_{td} k_s k_{hs} k_f$

Correction Factors

Concrete Strength, NEW!: $k_f = \frac{5}{1 + f'_{ci}}$

Time Development, simplified: $k_{td} = \frac{t}{61 - 4f'_{ci} + t}$

Volume-to-Surface Ratio, simplified: $k_s = 1.448 - 0.128(V/S)$

Humidity, simplified:

Creep: $k_{hc} = 1.56 - 0.008H$

Shrinkage: $k_{hs} = 2.00 - 0.014H$

Loading Age (Creep): $k_{la} = t_i^{-0.118}$

2005 LRFD Approximate

Long-Term Loss:

$$\Delta f_{pLT} = 10.0\frac{f_{pi}A_{ps}}{A_g}\gamma_h\gamma_{st} + 12.0\gamma_h\gamma_{st} + 2.5 = 25.580\,\text{ksi}$$

Example of Detailed Method Derivation:

Prestress Loss due to Creep of Girder caused by Deck Weight & SIDL

$$\Delta\varepsilon_p = \Delta\varepsilon_c$$

$$\frac{\Delta P_p}{A_{ps}E_p} = \frac{\Delta f_{cdp}}{E'_{c3}} - \left(\frac{\Delta P_p}{E''_{c1}A_{nc}} + \frac{\Delta P_p}{E''_{c1}}\frac{e^2_{pnc}}{I_{nc}}\right)$$

$$\frac{\Delta P_p}{A_{ps}E_p} = \frac{\Delta f_{cdp}}{E_c}\psi_{bdf} - \left(\frac{\Delta P_p}{E_{ci}A_{nc}} + \frac{\Delta P_p}{E_{ci}}\frac{e^2_{pnc}}{I_{nc}}\right)(1+\chi\psi_{bif})$$

$$E'_{c3} = \frac{E_c}{\psi_{bdf}} \qquad E''_{c1} = \frac{E_{ci}}{1+\chi\psi_{bif}}$$

$$\Delta f_{pCD2} = \frac{\Delta P_p}{A_{ps}} \qquad K_{df} = \frac{1}{1+n_i\rho_{nc}\alpha_{nc}(1+\chi\psi_{bif})}$$

$$\Delta f_{pCD2} = n\Delta f_{cdp}\psi_{bdf}K_{df}$$

Example calculations: loss due to girder shrinkage between deck placement and final time:

Transformed section coefficient (5.9.5.4.3-2)

$$K_{df} = \frac{1}{1+\frac{E_p}{E_{ci}}\frac{A_{ps}}{A_c}\left(1+\frac{A_g e^2_{pc}}{I_g}\right)\left(1+0.7\psi_b(t_f,t_i)\right)}$$

Gross versus net section properties? Net is exact, gross is approx.

Shrinkage of Girder Concrete

Time of Deck Placement to Final Time

$$\varepsilon_{bif} = -k_{vs}k_{hs}k_f k_{td}\, 0.48x10^{-3}$$

$$\varepsilon_{bif} = -(0.7480)(1.0200)(0.8333)(0.9980)(0.00048) = -0.00030 \text{ in / in}$$

$$\varepsilon_{bdf} = \varepsilon_{bif} - \varepsilon_{bid} = (-0.00030) - (-0.00025) = -0.00005 \text{ in / in}$$

$$\Delta f_{pSD} = \varepsilon_{bdf} E_p K_{df} = (-0.00005)(28500)(0.8634) = -1.23 \text{ ksi}$$

Beam age when slab cast	Bottom stress All loads	Difference
1 days	269 psi Ten	
10	311	42 psi
30	327	16
70	339	12
110	346	7
150	350	4
190	354	4
360	363	9
500	368	5
10000	405	37
20000	509	104

Jensen Beam 145 ft, FBT78,Fc' 8500

Bottom Fiber Stress Comparisons

Method	Stress (psi)
2004 All loads (Gross)	876 (T)
2006 Refined all loads (Trans)	337 (T)
LT Losses 2004	670 (T)
LT Losses 2006	510 (T)

876 – Loss diff 160 – Gains 379 = 337

SR20/Apalach 110 ft, FBT72, Fc' 6000

Bottom Fiber Stress Comparisons

Method	Stress (psi)
2004 All loads (Gross)	450 (T)
2006 Refined all loads (Trans)	310 (T)
LT Losses 2004	355 (T)
LT Losses 2006	411 (T)

450 + loss diff 56 – Gains 196 = 310

Compare steel stress losses due to Creep + Shrink + Relax (KSI)

	Jensen	SR20
LRFD 04	30	24
LRFD 06 refined	21	26
LRFD Approx 06	22	27
FDOT Beam Prog	29	22
FDOT MathCad	30	24

Where did the difference in LTL PS Losses come from (KSI) ?

	Jensen	SR20
LTL to deck place	-16.437	-19.634
LTL deck to final	- 4.299	- 6.328
Total:	21 ksi	26 ksi

Compression gains at bottom fiber by using latest methods (psi):

	Jensen	SR20
Gross/Transform	379	196
From losses	160	-56
S/6.5 vs S/5.5	200 (HL93)	130 (HS20)
Total	739	270

Note 20% of the HL93 load produces 297 psi at Jensen.

At SR20 .8HL93 produces 169 psi more tension than HS20+5%

With all these refinements known why not eliminate service 3 now?

We have decided to keep Service 3, at least until service calibration is completed.

Perhaps the .8LL should be .7LL or 1.1LL ?

THANK YOU

Excel Spreadsheet I used: Available on www.structuresprograms.unomaha.edu