Session 36

Ron Cook

University of Florida

Prevention of Splitting Failure at Ends of Prestressed Beams During Fabrication

Topic Description

Long-span, prestressed Bulb-T and U beams have exhibited vertical cracking at the ends of the beams during the transfer of the prestressing force in the strands to the members when the strands are cut during the construction process. This research project involved gathering information on all types of cracking commonly occurring during the construction process from the major manufactures of prestressed beams. This was followed by site visits to the manufacturer's facilities to observe the types of cracking that occur and then followed by development of an analytical model to assess the potential causes of vertical cracking. The results of the analytical model indicate that for long-span beams with a given number of strands, the coefficient of friction between the beam and the formwork and the temperature change between the time of casting and the time of de-tensioning are the primary concerns for the cause of vertical cracking. Other items identified regarding vertical cracking are the number of strands in the beam, the free-strand distance between beams, and the free-strand distance from the end beams to the bulkheads.

Speaker Biography

Dr. Ronald A. Cook, P.E., is Professor of Civil Engineering at the University of Florida. He is chairman of the ASCE 7 Wind Load Committee, chairman of ACI 355 Anchorage to Concrete, member of ACI 318 Subcommittee B on Reinforcement and Development and member of the International Association of Bridge and Structural Engineering Working Commission on Concrete Structures. His work experience includes 3 years in construction, 11 years in design, and the past 17 years in engineering education and research.

FICE/FDOT
Design Conference
2006

PREVENTION OF VERTICAL END CRACKING ON PRESTRESSED BEAMS DURING FABRICATION

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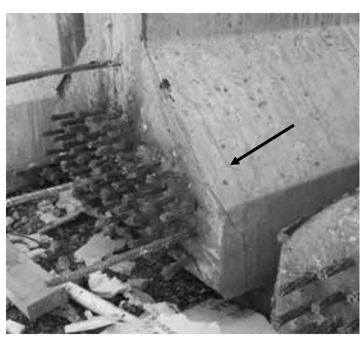
University of Florida
Department of Civil and Coastal Engineering

PROJECT OVERVIEW

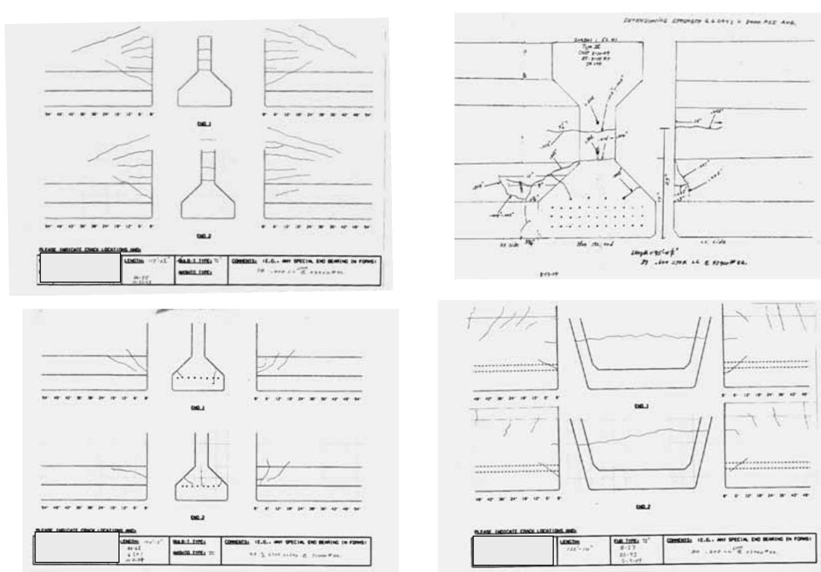
- Determine the causes of vertical cracks often found on the ends of Florida Bulb-T, and Florida U-beams beams
- The crack forms during the detensioning process
- Located in bottom flange a few inches from the end face



STEPS TO SOLUTION

- Identify types of cracks that occur in prestressed beams during detensioning and removal from casting bed
- Surveys sent to three manufacturers of FDOT prestressed beams
- Site visits to manufacturers
- Development of model to assess causes of vertical cracking

EXAMPLES OF MANUFACTURER'S SURVEY



FIELD STUDY

Casting Beds

FIELD STUDY

Bulkheads

FIELD STUDY

Beams spaced closely together

FIELD STUDY

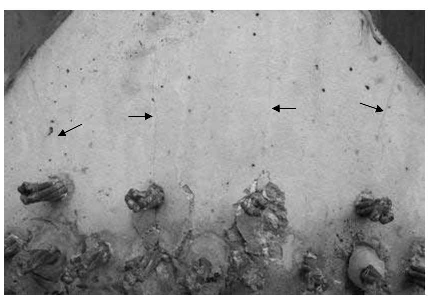
Cutting line

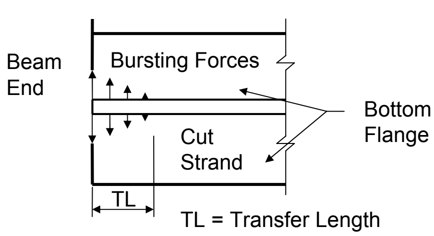
FIELD STUDY

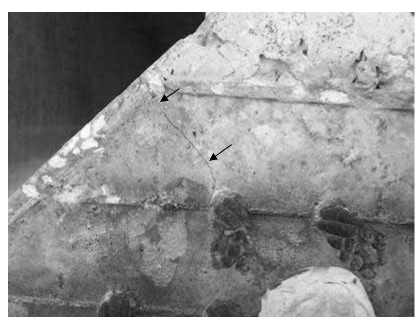
Beam movement: Beginning of cutting order

FIELD STUDY

Prestressed strand crack





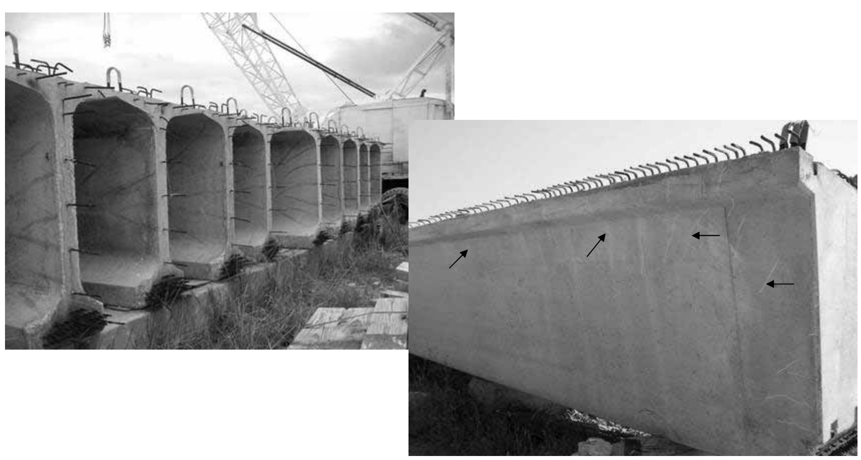


FIELD STUDY

Radial Cracking

FIELD STUDY

Radial Cracking



FIELD STUDY

Radial Cracking

- Likely cause is the lifting hook arrangement or the lifting procedure

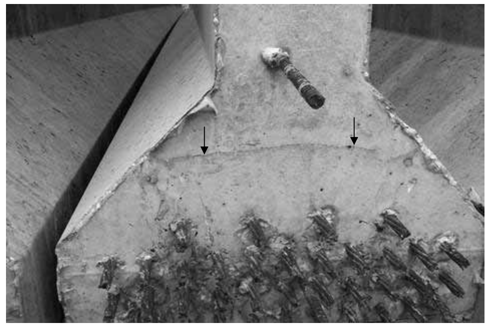
FIELD STUDY

Angular Cracking

- The angular crack forms due to shear stresses from the interaction of cut and uncut strands
- Changing the strand cutting pattern can reduce the occurrence of the angular crack (Kannel, French, Stolarski 1998)

FIELD STUDY

Column action crack

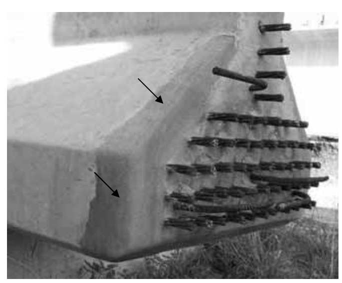



- Tension strains created between the prestressed bottom flange and the non-prestressed web region
- Possible prevention by adding additional horizontal mild steel in the web-flange region.

FIELD STUDY

Edge spall





- Beveled edges help

FIELD STUDY

Horizontal top flange crack

- Field personnel indicated that this crack is caused by the formwork pressing against the concrete as the beam cambers during detensioning.
- Can be prevented by providing space between the formwork and the concrete before detensioning begins.

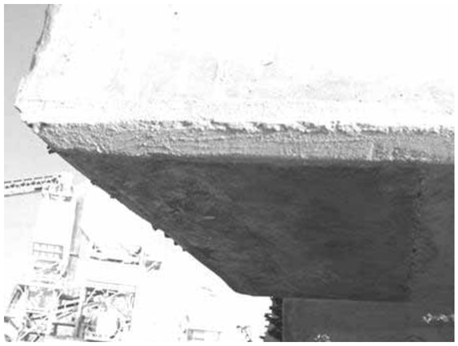
FIELD STUDY

Vertical crack

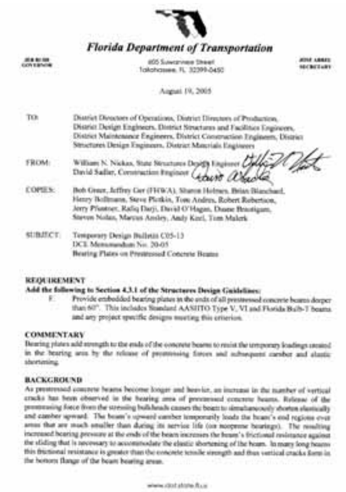
- The vertical crack is caused by the resisting forces in the uncut strands during the detensioning process (Mirza, Tawfik 1978)
- This is directly coupled with the friction force at the end of the member during detensioning

<u>FIELD STUDY</u>

Steel bearing plate



Temporary Design Bulletin C05-13
August 19, 2005



Florida Department of Transportation

August 19, 2005

TO: District Directors of Operations, District Directors of Production, District Design Engineers, District Structures and Facilities Engineers, District Maintenance Engineers, District Construction Engineers, District Structures Design Engineers, District Materials Engineers

SUBJECT: Temporary Design Bulletin C05-13
DCE Memorandum No. 20-05
Bearing Plates on Prestressed Concrete Beams

REQUIREMENT
Add the following to Section 4.3.1 of the Structures Design Guidelines:
F. Provide embedded bearing plates in the ends of all prestressed concrete beams deeper than 60". This includes Standard AASHTO Type V, VI and Florida Bulb-T beams and any project specific designs meeting this criterion.

COMMENTARY
Bearing plates add strength to the ends of the concrete beams to resist the temporary loadings created in the bearing area by the release of prestressing forces and subsequent camber and elastic shortening.

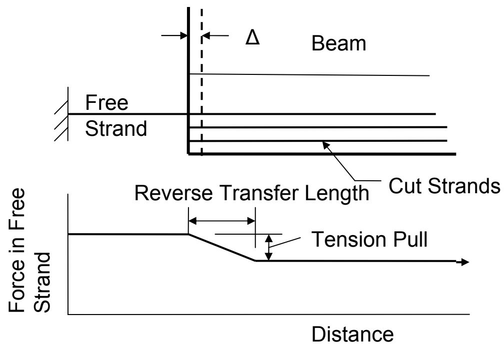
BACKGROUND
As prestressed concrete beams become longer and heavier, an increase in the number of vertical cracks has been observed in the bearing area of prestressed concrete beams. Release of the prestressing force from the stressing bulkheads causes the beam to simultaneously shorten elastically and camber upward. The beam's upward camber temporarily loads the beam's end regions over areas that are much smaller than during its service life (on neoprene bearings). The resulting increased bearing pressure at the ends of the beam increases the beam's frictional resistance against the sliding that is necessary to accommodate the elastic shortening of the beam. In many long beams this frictional resistance is greater than the concrete tensile strength and thus vertical cracks form in the bottom flange of the beam bearing areas.

Model for Predicting Vertical End Splitting

- Because a transfer length is required, the ends of prestressed beams are vulnerable to tension strains in the concrete
- The way to prevent the vertical crack is to reduce the tension strains in the transfer length region of the prestressed beam
- This is accomplished by two things:
    1) Reduce Tension Pull
    2) Reduce Friction Force

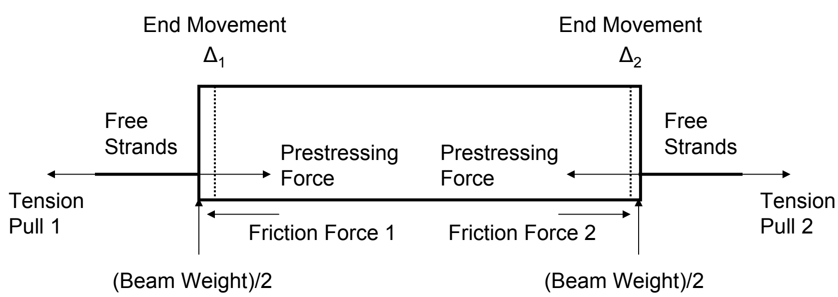
Model for Predicting Vertical End Splitting

- Tension Pull = Resisting force in uncut strands
- Created from:
  1) Stretch of uncut strands as beams move
  2) Temperature change in the strands between the time of beam casting and strand cutting



Model for Predicting Vertical End Splitting

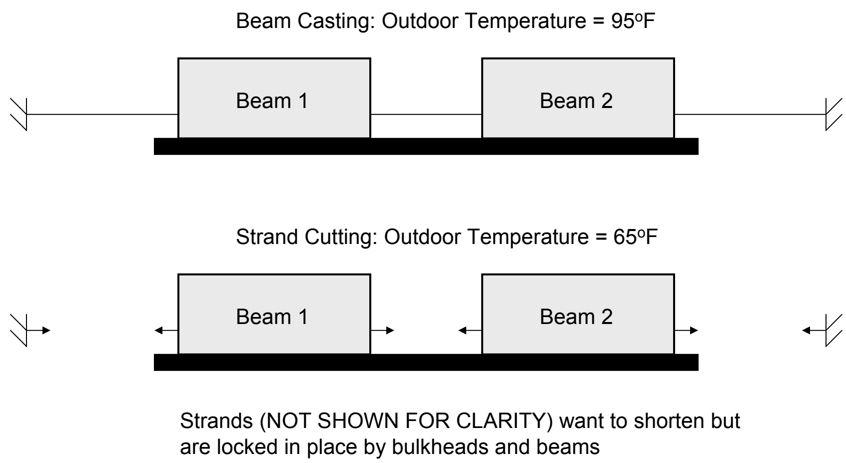
Friction



Max Friction Force = μ_s(Beam Weight)/2

Model for Predicting Vertical End Splitting

Tension Pull: Temperature



Model for Predicting Vertical End Splitting

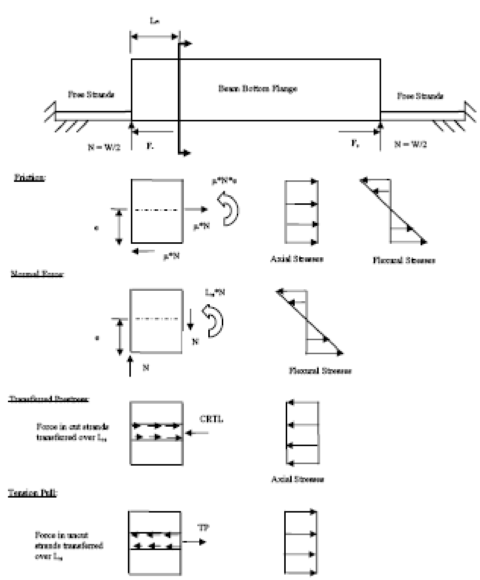
Variables that need to be considered:

1) Length of free strands
2) Concrete modulus of elasticity
3) Friction coefficient
4) Temperature change
5) Debonding lengths
6) Number of debonded strands
7) Number of prestressing strands
8) Jacking force per strand
9) Cross-sectional area of beam
10) Beam length
11) Beam spacing configuration on the casting bed

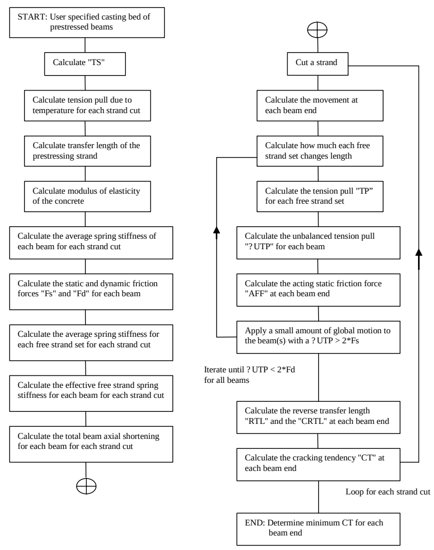
Model for Predicting Vertical End Splitting

- Due to the large number of variables that can affect the magnitudes of the tension pull and the friction force it was necessary to determine which variables were the most significant.
- To accomplish this an analytical model was created that allowed the user to determine relative significance of each variable.
- This was accomplished by altering one input variable at a time while holding all the other variables fixed and determining the sensitivity to each input alteration.

Model for Predicting Vertical End Splitting

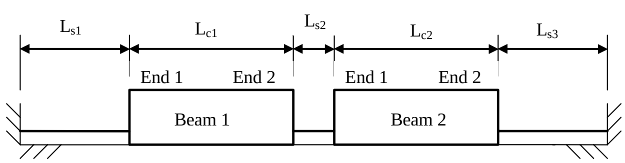


Flow Chart for MathCAD Program



Analytical Model Results

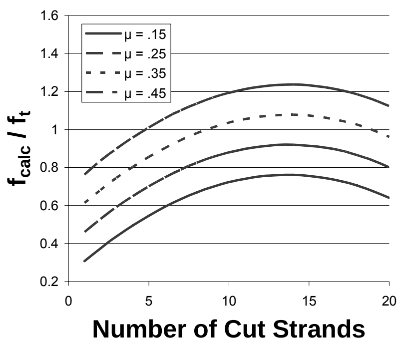
Model Test Case Benchmark Values

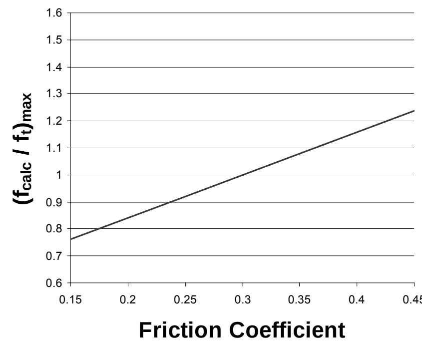


Variable	Value	Variable	Value
Type of Beam	BT-72	L_{s1}	40ft
L_{c1}	140ft	L_{s2}	3ft
L_{c2}	140ft	L_{s3}	40ft
			.600
Number of Strands	40	Strand Type	270ksi
Jacking Force per Strand	44k	Debonded Strands	#37 5ft
Concrete Release Strength	8ksi		#38 5ft
Unit Weight of Concrete	150pcf		#39 5ft
Temperature Change	0		#40 5ft
Static Coefficient of Friction	0.45	Camber	2.5in
Dynamic Coefficient of Friction	0.40		

Analytical Model Results

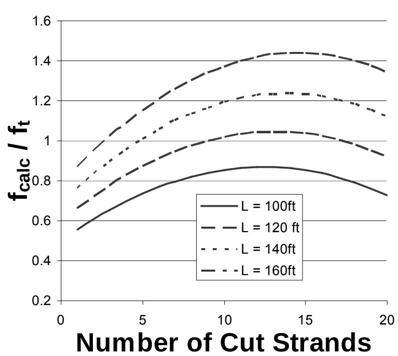
Coefficient of Friction

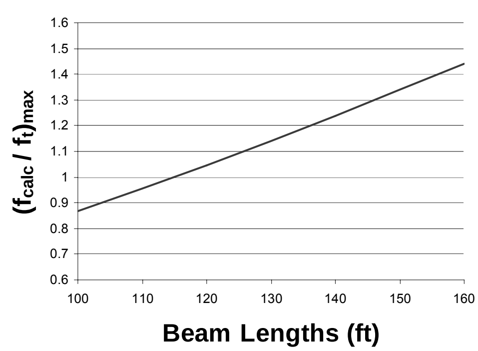




Analytical Model Results

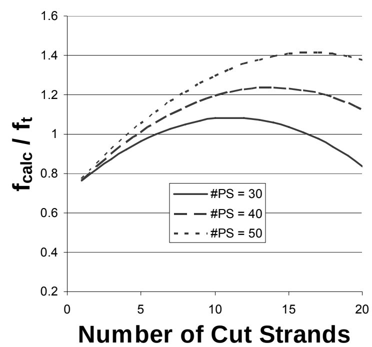
Beam Length

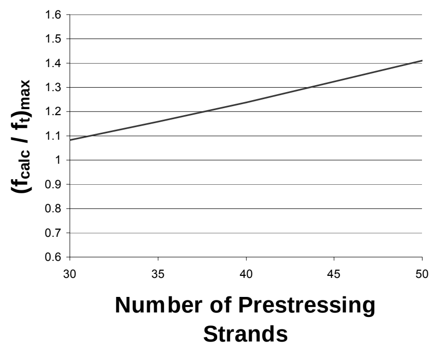




Analytical Model Results

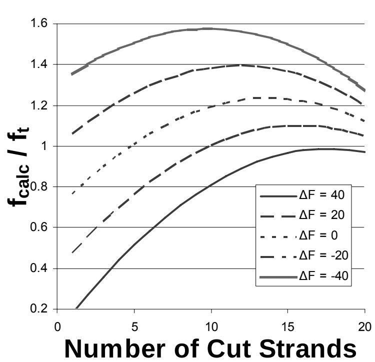
Number of Prestressing Strands

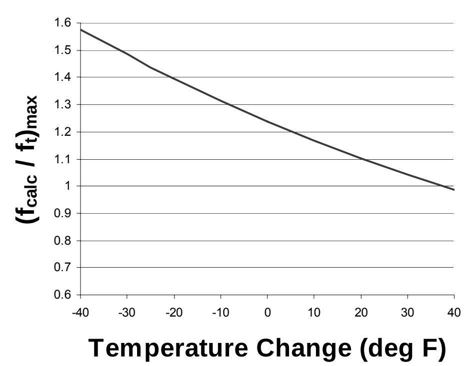




Analytical Model Results

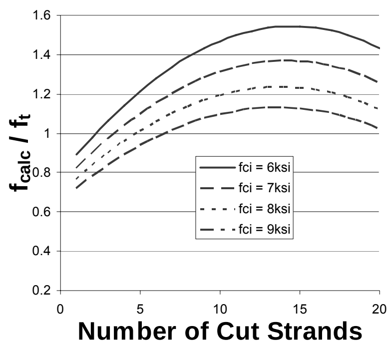
Temperature Change between Casting and Detensioning

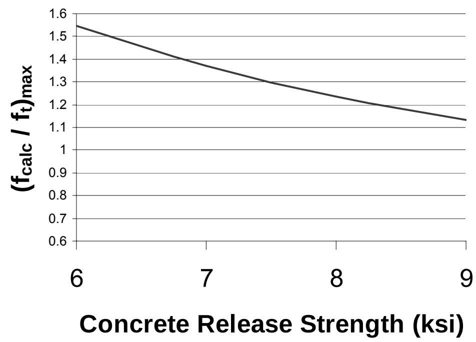




Analytical Model Results

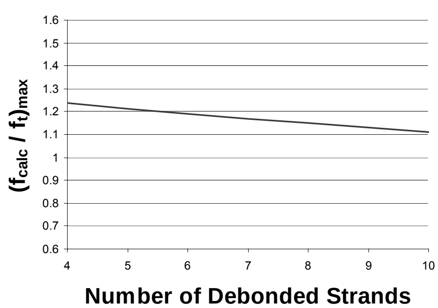
Concrete Strength at Detensioning



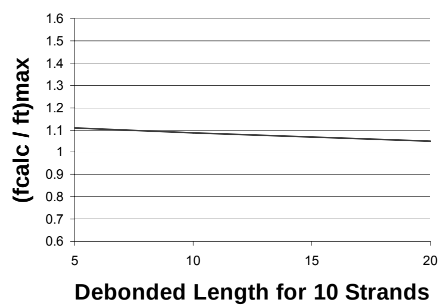


Analytical Model Results

Number of Debonded Strands

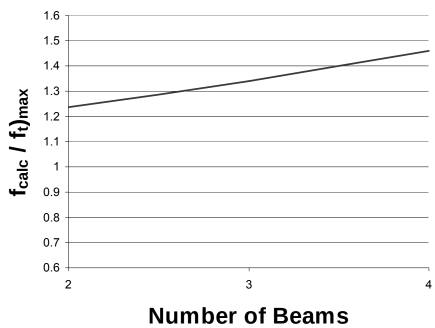


Length of Debonded Strands

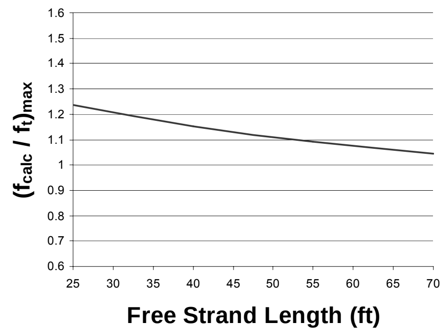


Analytical Model Results

Number of Beams



Length of End Strands



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Conclusion

The most significant variables are:

1) Coefficient of friction
2) Beam length
3) Number of strands
4) Temperature drop between the time of beam casting and the time of detensioning
5) Concrete strength at detensioning

The first three are really interrelated. The best solution is to reduce the coefficient of friction (e.g. adding a steel plate).