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Bridges Post-Tension Superstructures

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ABSTRACT

Bridge projects come at the top of the vital national projects to which countries pay special attention and which require precise designs and correct implementation. The research paper presents one of the design methodologies for bridge superstructure as it achieves design safety and economic requirements and the associated duration and quality of implementation. Adopting the idea that the design of pre-stressed and pre-cast concrete systems in particular...
It leads to distinguished results in this regard, and some sketches and calculations of actual cases that have been applied have been included.

Keywords:
Bridges, Post-Tension, Superstructures

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الجسور الهياكل الفوقية ذات التوتر اللاحق

الخلاصة :

تأتي مشاريع الجسور على رأس المشاريع الوطنية الحيوية التي توليها الدول اهتماما خاصا والتي تتطلب تصميمات دقيقة وتنفيذا سليما. ويعرض البحث أحد مناهج تصميم البنية الفوقية للجسور حيث يحقق متطلبات السلامة التصميمية والاقتصادية ومدة وجودة التنفيذ المرتبطة بها. ويعتمد البحث على فكرة أن تصميم أنظمة الخرسانة مسبقة الإجهاد والمسبقة الصب على وجه الخصوص...
ويؤدي إلى نتائج متميزة في هذا الصدد، وقد تم تضمين بعض الرسومات والحسابات لحالات فعلية تم تطبيقها.

Introduction

In the field of civil engineering, pre stressed concrete structures are mainly considered one of the more recent types of constructions. The first successful applications of pre stressed concrete were done in the early 20th century and are attributed to the French engineer Eugène Freyssinet. He succeeded in replacing low-strength steel by using high-strength steel. For more than a century, pre stressed concrete structures have become a main common part of civil engineering since this type of construction material has multi applications in bridges engineering . According to records and measurements, more than 45% of bridges built in the United States since 2010 have been designed as pre stressed concrete structures .Recently , new materials such as ultra-high-performance concrete (UHPC) can improve the mechanical properties of these structures . The advantages of pre stressed concrete get from the essence of preloading of structures by compressive force. This load results in compressive stress that fully or partially counteracts tensile stress in the member, which is the crucial pitfall of plain concrete. Consequently, the invention of pre stressed concrete has enabled the design specially of long-span bridges or the reduction of concrete cross-sectional dimensions of the member. Moreover, in contrast to reinforced concrete, compressive stress in pre stressed concrete results in a crack-free structure with preserved stiffness, low deflections, and better protection against environmental problems. However, the design process is more complicated, and a higher level of quality control should be done

The starting of reinforced concrete bridges construction in the United States dates on 1890 by the construction of the Alvord Lake Bridge in San Francisco, California. Within many Advancements have been made, main features of construction stay unchanged. The work process needs construction of formwork to contain and provide shape and dimensions to the wet concrete.

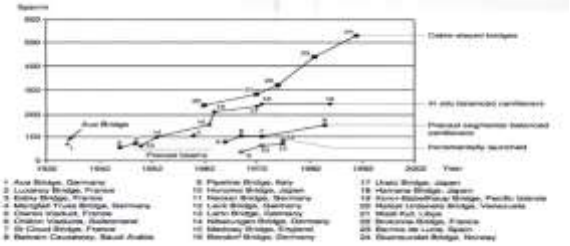
Formwork is supported by false work either resting on the ground surface or on prepared related foundations, until the structure hardened itself is self-supporting and formwork and/or false work can be removed. Unfortunately, bridges constructed with reinforced concrete considered are economical for relatively short spans.

Superstructure many types include flat slabs, beam with slabs, and box girders. In time, longer spans were achieved by using arch construction. Reinforced concrete box girder bridge construction flourished in the western part of the United States as a result of design , economy and local contractor experience. The California Department of Transportation (Caltrans) began constructing box girder bridges in the early 1950's. With the popularization of pre stressed concrete methodology in the early 1960's, Caltrans recognized further economy through the construction of many post-tensioned concrete box girder bridges. Refinements to post-tensioned box girder bridge construction continued in the United States in the second half of the 20th century. Fig 1-1

Fig 1-1

Today, cast-in-place post-tensioned box girder construction is used throughout the all countries

Longest pre stressed concrete bridges span length –year



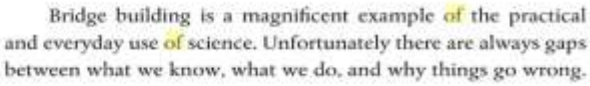
Bridges after and before construction

Bridges in service: In addition to the function of bridges in the field of transportation, they must add beauty and harmony with the environment to the space surrounding them

Bridges under construction: Bridge construction requires advanced technologies, such as the flying crane shown in the pictures, to transport and install the precast parts, As well as skilled, trained workers and high-quality materials

Importance of bridges

What are the advantages of bridges? Bridges allow for safe and efficient travel over water, valleys, and other obstacles. They can reduce travel time, improve transportation options and provide access to previously inaccessible areas


Bridge building is a magnificent example of the practical and everyday use of science. Unfortunately there are always gaps between what we know, what we do, and why things go wrong.

Research problem

Bridge projects require the preparation of very precise engineering designs that can be implemented within the standard time and estimated cost. This places a burden on designers in choosing design alternatives that meet this purpose, starting from choosing the construction system and ending with loading and operating tests.

Choosing the appropriate methodology for each case is the basic approach to achieving construction safety, quality and not exceeding costs or times.

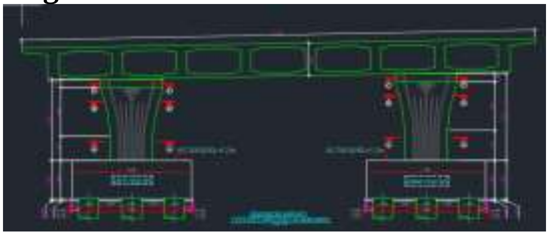
Research Target:

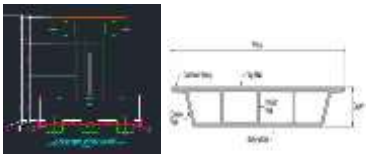
The research aims to simplify the methods of designing slabs, webs for bridges using post-tensioned concrete in accordance with the latest international codes as an alternative to typical reinforced concrete, especially in large spans, as one of the procedures for overcoming the research problem. as well as applying the same methodology for.. Bent caps.

Research Limits: locally and international. And in this research, space is limited according to regulatory procedures, So we will attempt to present the important elements of the design process and highlight the others, which can be addressed in future researches.

Typical Superstructure Cross Sections

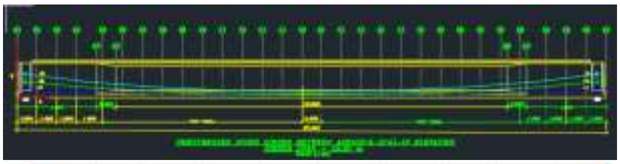
The superstructure is supported to the substructure (piers and bent piers) as shown in the sketches below. There are several types of concrete superstructure, including cross girders, beams and slabs. Sometimes the use of a steel beams may be resorted to in cases such as crossing a bridge over an obstacle that prevents the work of false work, and the location of the research is focused on cross girders with single or multi cells.

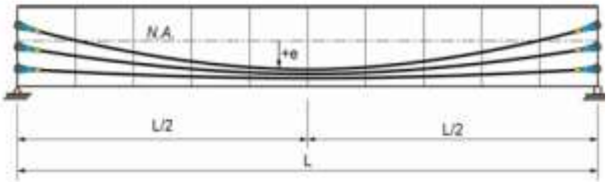




Longitudinal Layouts

Post-Tensioning





Loss of Pre stressing Force

Losses Related to Material Properties • Elastic shortening of concrete • Shrinkage of concrete• Creep of concrete

Losses Related to Physical Characteristics

- **Duct friction due to curvature• Wobble (unintentional friction) • Wedge Set (or Anchor Set) • Relaxation of pre stressing steel**

Post-Tensioning System Hardware

Live end Anchorage : should be designed for longitudinal tendons in girders the tendons are stressed by a jack on the force transfer unit by a bearing ring.

Dead end anchorage : non-accessible dead end of tendons ,the wedge are fixed by spring plate while forces are applied to the live end ,the pre stressing force in tendons is locked by the wedges in the anchor head

FIG1-3

Overview of Construction

False work and carriage:

Temporary formwork is used, as we mentioned previously, to stabilize the ceiling beam, but in bridges the formwork may be fixed on weak ground or across waterways or the like. This requires taking precautions and very precise technical measures to avoid any collapse. For long spans concrete is cast insitu as balanced cantilever using form travelers –Fig 1-4

Fig 1-4

Superstructure Formwork

10.3 Reinforcing and Post-Tensioning Hardware Placement

Fig1-5

Fig 1-6

Reinforcing and Post-Tensioning Hardware Placement

Placing and Consolidating Superstructure Concrete- Superstructure Curing

Post-Tensioning Operations

Multi-strand tendons are the most frequent choice for main longitudinal tendons for bridges. All the strands of one Longitudinal tendon are tensioned using a multi-strand jack.

The sequence and procedure of stressing tendons should be clearly shown on the contract plans or approved shop drawings and must be followed on site.

Post-tensioning strands pushed or pulled through ducts to make a tendon. Pushing should be done with care using a protective metal “ preferred” or plastic caps provided by the post-tensioning system supplier so that the strands do not get caught by or introduce damage to the duct. Sometimes it is easier to pull the entire tendon bundle of strands through the duct together using a special steel wire sock or other device securely attached to the end of the bundle-Fig1-7

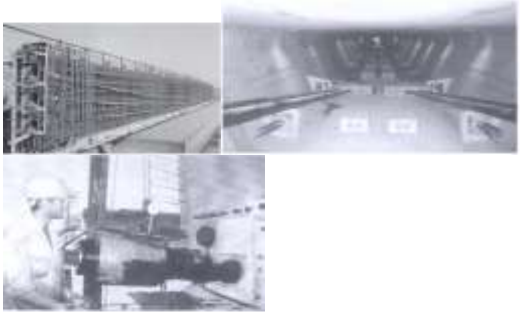


Fig1-7

Tendon Grouting and Anchor Protection

Pre stressing Strands

Strands for post-tensioning are manufactured of high tensile strength steel wire conforming to ASTM A416. A strand may be comprised of 7 individual wires, with six wires helically wound to a long pitch around a center “king” wire.

Strand common sizes are 0.5 inch and 0.6 inch diameter, with nominal cross-sectional areas of 0.153 in2 and 0.217 in2, respectively. So the majority of post-tensioning hardware and stressing equipment is based on these sizes,

the use of 0.62 inch diameter strand has been increasing.

Large diameter strands are used in cable-stayed bridges and mining applications in the United States and post-tensioning tendons in Europe and Japan. Seven-wire pre stressing strands of 0.7 in-. diameter were introduced for the first time in pretension application in North America on the Pacific Street and I-680 bridge in Omaha, Nebraska

Tensile Strength

The Precast Concrete Institute presents the stress-strain relationship up to the ultimate capacity of the strand.

For 270 ksi strand, the relationships presented by PCI are:

For $\varepsilon ps \le 0.0086$,

.$Ƒps=28500(\varepsilon ps)$

For $\varepsilon ps > 0.0086$,

.$Ƒps=270-(0.04)/(\varepsilon ps-.007)$

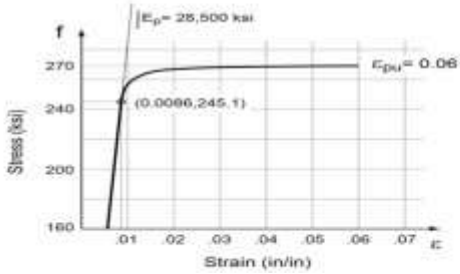


Fig1-8

Pre stressing with Post-Tensioning

- The disadvantage of ordinary reinforced concrete is: the reinforcing steel in reinforced concrete is placed in the concrete to resist flexural stresses applied to the member by applied loads. The concrete resists the loads to a certain point, after which it cracks and the reinforcing steel is engaged. Once the steel is engaged in resisting tensile forces, the concrete no longer does.
- Pre stressed concrete was an idea of structural designers since P.H. Jackson of the United States (U.S.) patented his idea in 1888
- For example, metallurgists had not yet discovered high strength steel, which combined the needed high compressive forces in a minimal amount of steel with low relaxation characteristics that minimized creep and post-stress deformations in the pre stressing steel; therefore, the idea hibernated until Freyssinet reexamined it in the early twentieth century, the first to actively promote pre stressed concrete.
- The use of pre stressed concrete is an appropriate solution to avoid the use of reinforced concrete, which may require large concrete sections and dense steel for the forest "see FIG 1-9 for example.

FIG1-9

- In all elements subjected to positive tensile moments, this results in downward deflection, and the value of the deflection arrow must not exceed the value allowed in the code or specifications.
- In the case of bridges, as a result of the increase in spans and the intensity of the loads at the same time, controlling the deflection values becomes difficult, so pre stressed concrete is resorted to by exposing the section to compressive forces through tendons designated for that, which generally take the form of the distribution of moments across the element, and as a result of the forces with the eccentricity that occurs with respect to the neutral axis, moments are generated. There is an upward camber that is balanced with deflection,FIG1-10

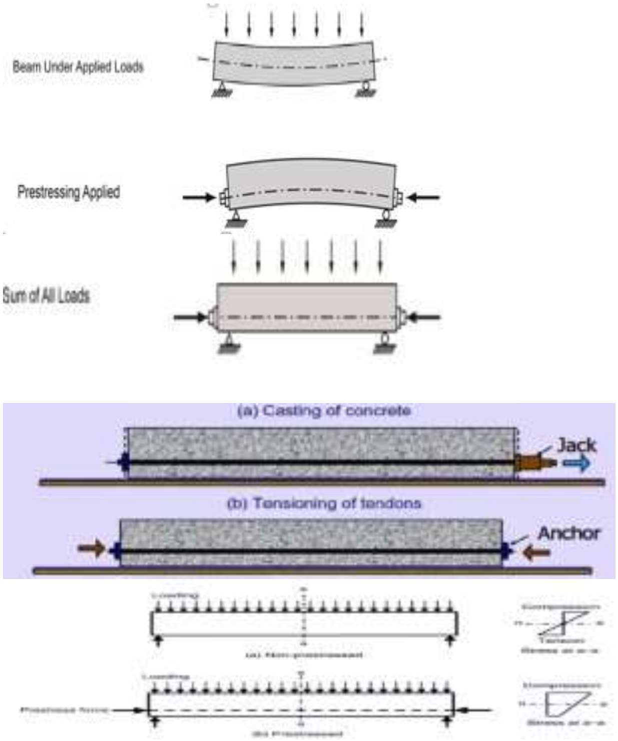


Fig1-10

Cross Section Properties and Sign Convention

As for the box section of bridge roofs, it usually consists of the top slab It is some distance away from the neutral axis"c1" , bottom slab with "c2" and vertical or inclined webs and is formed in the form of a calculated number of smaller box units, FIG 1-11

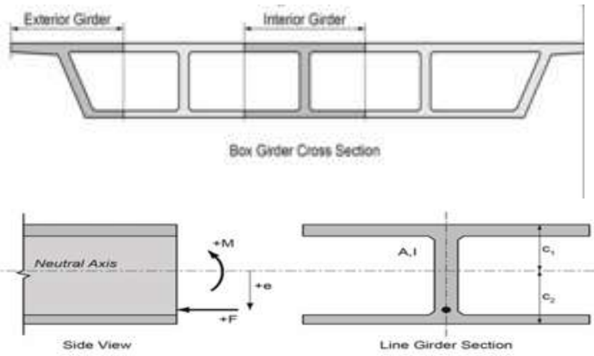
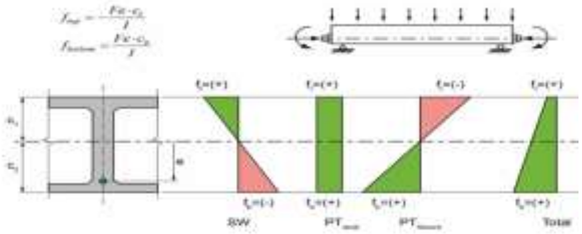


Fig 1-11

Selection of Pre stressing Force for a Given Eccentricity

The section is exposed to positive and negative stresses as a result of the self-weights and the forces of pre-stressing and their counterparts of flexure, and the sum of the upper stresses and their lower counterparts represent the sum of the stresses on the section, FIG 1-12



Self weight ,Axial and Eccentric pre stress stresses

Fig1-12

.ƒt=top stress=(F/A)-((F*e*c1)/I) +(M*c1/I)

.ƒb=bottom stress=(F/A)+((F*e*c2)/I) -(M*c2/I)

The permissible stress in the concrete at the bottom of the girder:

ρ=dimensional parameter=I/(A*c1*c2)

M ab =(ƒa*I)/(c2

.fa: permissible concrete stress

Mab= F*ρ *c1+ Fe- M

Moment required to produce the permissible tensile stress at the bottom-most fiber of girder

Mab (T)= =3* SQRT (fc”)*I/C2

Moment required to produce the permissible tensile stress at the top-most fiber of girder

Mat (T)= =3* SQRT (fc”)*I/C1

Moment required to produce the permissible compressive stress at the bottom-most fiber of girder

Mab (c) =0.6*(fc”)*I/c2

Moment required to produce the permissible compressive stress at the top-most fiber of girder

Mat (c) =0.6*(fc”)*I/c1

Pre stressing Force

For bottom

- F=Min.pre stressing to limit the bottom girder tension ≥(M+Mabт)/(ρc1+e)
- F=Max.pre stressing permissible to not overstress limit the bottom of the girder ≤ (M+Mab**c**)/(ρc1+e)
- F=Max.pre stressing permissible to not exceed the minimum tension in the top of the girder ≤(M-Mat)/(e-ρc2)
- F=The minimum pre stressing permissible to not over compress the top of the girder ≥ M-Mat)/(e-ρc2)

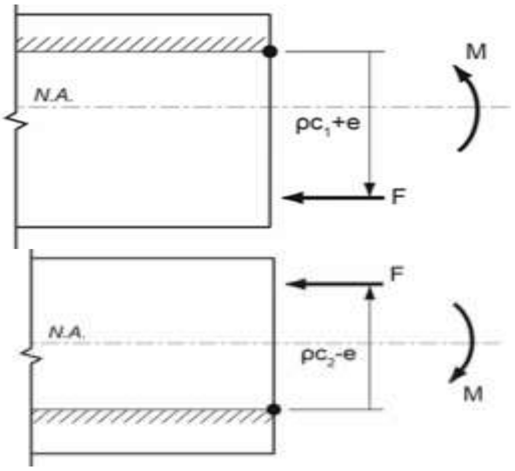


Fig1-13

- The distribution of stresses varies according to whether the pre-stressed forces are upper or lower and what results from their distance from the neutral axis by a distance equal to the eccentricity plus the dimension factor.FIG1-14

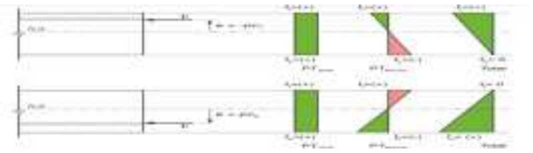


FIG 1-14

Permissible Eccentricities for a Given Pre stressing Force

Most of Equations for determining pre stressing force for a given eccentricity were developed in part 11.

These equations may be used to solve for the pre stressing force at a critical section.

With the required pre stressing force established, the tendon profile must be established such that the stress limitations are respected along the entire length of the member. Allowable ranges of eccentricity as a function of pre stressing force can be determined in a fashion similar to those of the previous section.

For simple, span girder

Bottom eccentricity

The eccentricity limits established by allowable stress at the top of the girder can be Expressed as:

$$e=\left(\frac{M+M_{ab}}{F}\right)-\rho c_1$$

Using these equations along with maximum and minimum allowable stresses, we can define ranges of eccentricity.

For stress control on the bottom of the girder:

$$\left(\frac{M+M_{ab(L)}}{F}\right)-\rho c_1 \le e \le \left(\frac{M+M_{ab(C)}}{F}\right)-\rho c_1$$

Top eccentricity

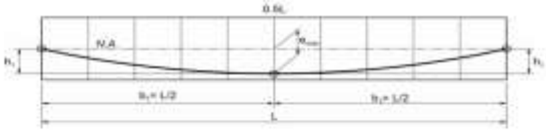
Likewise, the eccentricity limits established by allowable stress at the top of the girder can be expressed as:

$$e=\left(\frac{M-M_{at}}{F}\right)+\rho c_2$$

For stress control on the top of the girder:

$$\left(\frac{M-M_{at(C)}}{F}\right)+\rho c_2 \le e \le \left(\frac{M-M_{at(L)}}{F}\right)+\rho c_2$$

Equivalent Forces Due To Post-Tensioning and Load Balancing



The parabolic bending moment shape caused by the post-tensioning can be equated to the bending moment created by

the application of a uniform load distributed along the span length. For a load p, the simple span bending moment is:Mp(x)=-(p*x^2)/2 +p*I*x/2

The Equivalent uniform load = P **equivalent**

$$p_{equivalent}=\frac{8Fe_{\max}}{L^2}$$

Equivalent forces resulting from pre-stressing (fig1-15)

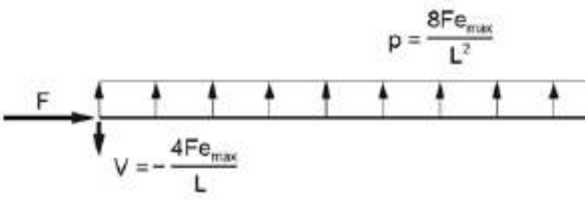


Fig1-15

Tendon Profiles—Parabolic Segments

Parabolic segments

Using parabolic segments, tendon profiles may be developed which enhance post-tensioning effectiveness.

Figures 1-16 and 1-17 show the more typical layout of tendon profile for continuous bridges. Figure 1-16 shows

the profile for an end span of a continuous unit. Figure 1-19 shows the profile for the interior span.

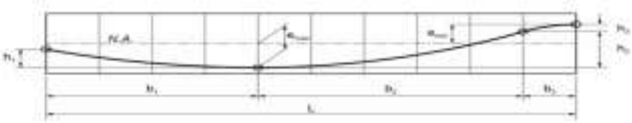


Fig1-16 :Typical End span Tendon profile for continuous superstructures

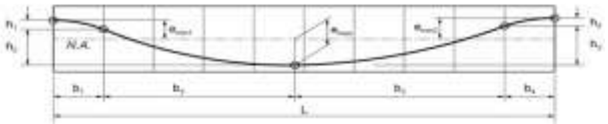


Fig 1-17 : Typical Interior span Tendon profile for continuous superstructures

Conjugate beam method : End rotations are found by the conjugate beam method .

The conjugate beam method, developed by Heinrich Muller-Breslau in 1865, is one of the methods used to determine the slope and deflection of a beam. The method is based on the principle of statics.

A conjugate beam is defined as a fictitious beam whose length is the same as that of the actual beam, but with a loading equal to the bending moment of the actual beam divided by its flexural rigidity, EI

The conjugate beam method takes advantage of the similarity of the relationship among load, shear force, and bending moment, as well as among curvature, slope, and deflection –Example :FIG 1-18

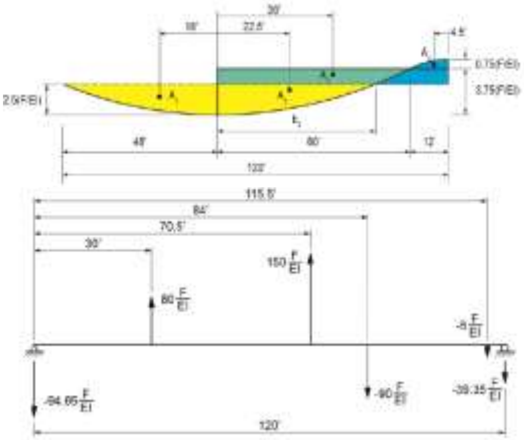


FIG 1-18

Ex : Curvature diagram for pre stressing " using conjugate beam method

The reactions (end rotations) are:

$$\theta_{left} = 94.65\left(\frac{F}{EI}\right) \qquad \theta_{right} = 39.35\left(\frac{F}{EI}\right)$$

Preliminary Design

Introduction: Pre stressed concrete is used in a wide range of buildings, bridges and civil structures as its improved performance can allow longer spans, lower structural thickness and material savings compared to simple reinforced concrete. In bridges, with the increase and variety of loads and large spans, the use of pre stressed concrete becomes more important. In order to achieve structural safety and economical concrete sections-see FIG 1-19 as example

Span range for different deck types

FIG 1-19

Establish Bridge Layout

Project Design Criteria

Each bridge design projects brings with a set of Planning, technical and site specific criteria that need to be considered in establishing the bridge layout. Engineers, designers and planners from various disciplines work to achieve a wide range of owner requirements for the new facility.

The most common of these are:

• Nature and function of the facility/geography to be spaned. • Site natural and topography.

• Vertical and horizontal clearances.

• Horizontal alignment, profile grade, and super elevation of the proposed bridge.

• Number and widths of lanes and shoulders (highway bridges), dynamic clearance envelopes for trains (rail and transit bridges).

• Subsurface, Soil and geotechnical investigations. • Environmental conditions and constraints.

• Bridge and Site drainage. • Limits of Rights-of-Way. • Utility ,infrastructure requirements/conflicts. • Permitting. Authorities• Maintenance of Traffic. • Applicable codes, specifications and regulations.

Framework design criteria

Working within the framework of the project design criteria, the bridge engineer begins primary design by selecting the following:

• Bridge type. • Pier and abutment locations, resulting in bridge span lengths and overall length.

• Length of bridge among expansion joints. • Superstructure cross section.

• Abutment and Pier types and dimensions. • Probable foundation types and dimensions.

Span Layout and Length

Example :

Cross Section Selection

Superstructure Depth

D=0.04*L

Superstructure Width

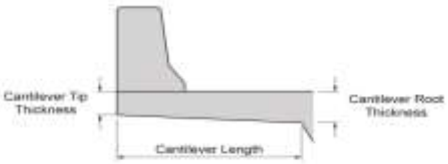
Highway and traffic researches performed for the example project have shown that the new bridge will carry three travel lanes in just one direction only. The lane widths for the bridge are 1 ft and the 2 shoulders widths are 10' each. The client has standard concrete barrier railing that is 1.75 ft wide. The resulting width of roadway is 59'-6" is shown in figure 1-20.

Fig1-20–Bridges Width and Roadway features

Cross Section Member Sizes

This section provides guidance for the primary sizing of the members that comprise the box girder cross section. Members shown are:

• Cantilever Wings.



In case of cantilever lengths between 5 ft to 8 ft the root thickness may be estimated as

t_c= 12+(Lc-5)

- Webs.

$$p_{DL} = t_{ave}(B)(0.15kcf) + p_b + p$$

tave= average superstructure thickness(ft)
B=bridge width (ft)
Pb=weight of barrier(k/ft)
Pws=weight of wearing surface (k/ft)

$$b_{total} = \frac{P_{DL} . L_{max}}{2(0.8h)\tau_{allow}}$$

Tallow=5 *sqrt (fc")

- Top Slab.

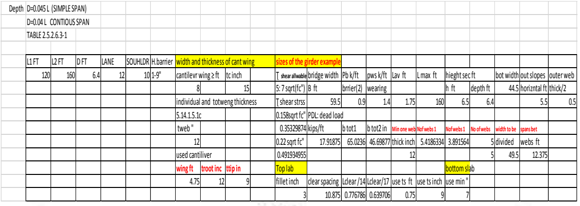
AASHTO LRFD Article 9.7.1.1 states that, unless approved by the Owner, the minimum top slab thickness, excluding grooving and grinding, should be not less than 7".

- Bottom Slab.

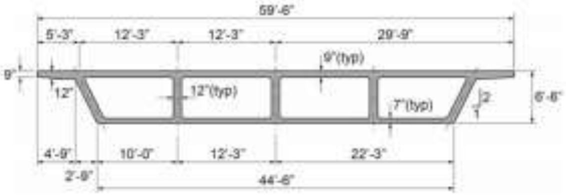
AASHTO LRFD Article 5.14.1.5.1b submit criteria for the minimum thickness of bottom slabs:

- Minimum thickness OF Bottom slab is 5.5 inches.
- The distance between webs of non-pre stressed girders or fillets divided by 16
- The clear span between haunches, fillets, or webs divided by 30, unless transverse ribs are used.

Next table show the box girder thicknesses and dimensions calculation



Depth	D=0.045 L (SIMPLE SPAN)																				
	D=0.04 L CONTIOUS SPAN																				
	TABLE 2.5.2.6.3-1																				
	L1 FT	L2 FT	D FT	LANE	SOUHLDR	H.barrier	width and thickness of cant wing				sizes of the girder example										
	120	160	6.4	12	10	1-9"	cantilevr wing ≥ ft		tc inch		T shear allwable	bridge width	Pb k/ft	pws k/ft	Lav ft	L max ft	hieght sec ft		bot width	out slopes	outer web
							8		15		5: 7 sqrt(fc")	B ft	brrier(2)	wearing			h ft	depth ft	44.5	horizntal ft	thick/2
							individual and totweng thickness				T shear strss	59.5	0.9	1.4	1.75	160	6.5	6.4		5.5	0.5
							5.14.1.5.1c				0.158sqrt fc"	PDL: dead load									
							tweb "				0.35329874	kips/ft	b tot1	b tot2 in	Min one web	Nof webs 1	Nof webs 1	No of webs	width to be	spans bet	
							12				0.22 sqrt fc"	17.91875	65.0236	46.69877	thick inch	5.4186334	3.891564	5	divided	webs ft	
							used cantiliver				0.491934955				12			5	49.5	12.375	
							wing ft	troot inc	ttip in		Top lab						bottom slab				
							4.75	12	9		fillet inch	clear spacing	Lclear /14	Lclear/17	use ts ft	use ts inch	use min "				
											3	10.875	0.776786	0.639706	0.75	9	7				



Longitudinal Analysis

Approach

Longitudinal analyses can be performed by any computerized solutions specifically for post-tensioned structures. General structural analysis programs may also be used with attentiveness to developing necessary load cases. Hand calculations as the Method of Joint Flexibilities presented are equally appropriate for longitudinal analysis, especially during primary design.

Analysis by Method of Joint Flexibilities

Span types , Properties and Characteristic Flexibilities

Analyses "Left and Right "

Carry-Over Factors

Effect of a one Unit Uniform Load

Moments due to

Dead load "DC"
Wearing Surface load "DW"
Live load "HL-93"
Thermal Gradient (TG)
Post-Tensioning Secondary Moments

Required Pre stressing Force After Losses

$$F \geq \frac{M + M_{ab}}{\rho c_1 + e}$$

$$F \geq \frac{M - M_{at}}{e - \rho c_2}$$

$$M = M_{DC} + M_{DW} + 0.8M_{LL+I} + 0.5M_{TG} + M_2(F)$$

$$M = M_{sum} + M_2(F)$$

Mmax is the summation of all bending moments except the secondary moments from pre stressing

By substituting then

$$F \geq \frac{M_{sum} + M_{ab}}{\rho c_1 + e - M_2}$$

$$F \geq \frac{M_{sum} - M_{at}}{e - \rho c_2 - M_2}$$

$$M_{ab} = -\frac{0.19\sqrt{f'_c}(I)}{c_2}$$

$$M_{at} = -\frac{0.19\sqrt{f'_c}(I)}{c_1}$$

Pre stressing Losses and Tendon Sizing for Final Design (Pjack)

Post-tensioned concrete girders are widely used in bridge structures. Long-term pre stressed losses due to the shrinkage and creep of concrete in post-tensioned girders are less than those in pre tensioned girders because of the higher value of non-pre stressed steel present in the former, and also the fact that post-tensioning may take place a long while after a girder has been cast and when the concrete has reached a mature age. Two common methods can be used to evaluate long-term pre stressed losses in post-tensioned girders. One is a refined method and the other is a simplified method. A numerical parametric study conducted with these methods has shown that strength of concrete , the percentage of non-pre stressed steel, the relative humidity, and the age of concrete at post-tensioning are equally important for the evaluation of pre stress losses. Because the post-tensioning of a bridge girder in a long multi-span bridge may be done at a concrete long age between 100 and 200 days, when an appreciable quantity of shrinkage has already occurred, an accurate account of the incremental shrinkage strain from the time of post-tensioning is as essential as that of the ultimate shrinkage strain. The calculation of this incremental strain depends on an accurate equation to estimate the increase of shrinkage strain with time over the entire shrinkage period.Generaly for accurate design .Following losses should be calculated and to be taken in considerations when calculating post-tension forces :-

- **Losses from Friction, Wobble, and Anchor Set**
- **Losses from Elastic Shortening**
- **Losses from Concrete Shrinkage**
- **Losses from Concrete Creep**
- **Losses from Steel Relaxation**
- **Total of Losses and Tendon Sizing**

Service Limit State Stress Verifications

In This stage presents stress summaries for essential load cases at service limit states. Flexural stresses should be verified after the tendons are stressed and before grouting procedures, after the bridge is open to transportation and before losses of long-term, and the bridge in operation beyond long-term losses have achieved.

A verification of principal stresses in webs is made with the bridge in operation and after losses of long-term have occurred.

then Calculate f top and f bottom for following cases considering allowable stress “fa” :-

- **Service Flexure—Temporary Stresses (Only DC and PT) .**

fa=0.6 *fci” -compression

- **Service Limit State III Flexure beyond Losses of Long-Term**

fa =-0.19 *sqrt (fc”) -tension

fa=0.6*φ_w*fc” -compression

- **Service Limit State III Flexure Before Losses of Long-Term**

fa =-0.19 *sqrt (fc”) -tension

fa=0.6*φw*fc” -compression

Principal Tension at Webs after Losses

Calculate : shear force acting-stress acting-live load distribution factors

Calculate features of Mohr’s Circle with these stresses are :Ϭ max , Ϭ min and The maximum principal tension and if RFT . is adequately or not

Optimizing the Post-Tensioning Layout

Conclusion

Choosing the correct construction system and expanding the applications of pre stressed concrete, whether for precast or cast-in-place superstructures or bent caps for spans and related loads, is the safest method and achieves the economic component and quality requirements in the ideal time frames.

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