ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CIVIL ENGINEERING

ADDIS ABABA UNIVERSITY

COMPUTER PROGRAM FOR COMAPRATIVE STUDY OF THE ANALASIS AND DESIGN OF PRESTRESSED CONCRETE BOX GIRDER AND PLATE GIRDER HIGHWAY BRIDGES

BY

SEYFE NIGUSSIE ADAMU

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IN

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BY

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I dedicate this Thesis to My Family

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ABSTRACT

Planning and designing of bridges is part art and part compromise, the most significant aspect of structural engineering. One of the initial choices the designer should make is to select the most appropriate bridge type for the site. While this choice is not always straight forward, selecting the right structure type is probably the important phase of designing a cost-effective bridge. The various types are ideally suited for different span lengths. For instance, on different standards, for spans ten to fifty meters cast in Place Post Tension Box Girder Bridges are usually chosen where as for spans ten to one hundred twenty meters Steel Plate Girder Bridge is preferred to be used respectively.

This study focused on developing computer program for the analysis and design of Cast in Place Post Tension Box Girder and Steel Plate Girder Bridges, for solving the design problem of economical span and demarking on the base of cost analysis.

A comparative study based on cost of materials is conducted to select and identify the economical span range of Cast in Place Post Tension Box Girder and Steel Plate Girder Bridges. The program is developed using visual Studio 2012. The developed program is illustrated using particular examples for both types of bridges. The study has come with solution based on the current construction prices. As per the study based on the current material cost seventy-meter span is the demarcation span for the two types of bridges. Within the overlap span length of the two bridges, Cast in Place Post Tensioned Box Girder Bridge is economical up to seventy-meter and beyond seventy-meter Steel Plate Girder Bride be economical.

Keywords: *Bridge, cost effective, cast in place post tensioned box girder, steel plate girder*

LIST OF SYMBOLS

Δ Aset	Anchor Set Length
Δ fL	Friction Loss at the Point of Known Stress Loss
ΔfpA	Jacking Stress Lost in the Prestress Steel due to Anchor Set
ΔfpES	Change in Stress due to Elastic Shortening Loss
ΔfpF	Change in Stress due to Friction Loss
α	Cabel Path Angle
Ag	Gross Area of Section
Aps	Area of Prestressing Strand
As	Area of Reinforcement
B	Stress Block Factor
bv	Shear Width
C	Distance between the Neutral Axis and Compressive Force
DC	Dead Load of Structural Components and Non Structural Attachments
dp	Distance from Extreme Compression Fiber to the Centroid of Prestressing tendon
dv	Shear Depth
DW	Dead Load of Wearing Surface and Utilities
E	Eccentricity
Ec	Modulus of Elasticity Concrete
Ect	Modulus of Elasticity of Concrete at Transfer or Time of Load Application
Ep	Modulus Elasticity Prestressing Strand
Es	Modulus of Elasticity of Reinforcing Steel
f'c	Concrete Compressive Strength
FC	Force Coefficient for Loss
FCf	Force Coefficient for Friction Loss
fcgp	Concrete Stress at the Center of Gravity of Prestressing Tendons
FCpA	Force Coefficient for Loss from Anchor Set
Δfi	Change in Force in Prestressing Tendon due to an Individual Loss

fpe	Effective Stress in the Prestressing Steel After Losses
fpj	Stress in the Prestressing Steel at Jacking
fps	Average Stress in Prestressing Steel at the Time for which the Nominal Resistance is Required
fpu	Tensile Strength Prestressing Strand
fpy	Yield Strength Prestressing Strand
fu	Tensile Strength of Reinforcing Steel
fy	Yield Strength of Reinforcing Steel
fy	Yield Strength of Reinforcing Steel
H	Superstructure Depth
h_f	Height of the Flange
Ig	Moment of Inertia of the Gross Concrete Section about the Centroidal axis
K	Friction Coefficient
L	Span Length of Bridge
LL	Live Load
MCp	Primary Moment Force Coefficient for Loss
MCs	Secondary Moment Force Coefficient for Loss
Mn	Nominal Resistance
Mr	Moment Resistance
Mu	Strength I Resistance
N	Number of Identical Prestressing Tendons
Nc	Number of Cells
Pj	Force in Prestress Strands before Losses
S	Web Spacing
Vu	Shear Stress
w	Uniformly Distributed Dead Load of the Slab System
X	Distance along Tendon
y	Distance from the Neutral Axis to a Point on Member Cross-section
Y_b	Distance from the Neutral Axis to a Point on Member Cross-section
μ	Coefficient of Friction

LIST OF ABBREVATIONS

AASHTO	American Association of State Highway and Transportation Officials
CIPPTBGB	Cast in Place Post Tension Box Girder Bridge
HL-93	Highway Load “93”
LRFD	Load Resistance Factor Design
SPGB	Steel Plate Girder Bridge

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1. Introduction

1.1. Background

Bridges affect people. People use them, and engineers design them and later build and maintain them. Bridges do not just happen. They must be planned and engineered before construction.
A bridge is a key element in a transportation system for three reasons. It likely controls the capacity of the system and highest cost per mile of the system. If the bridge fails, the system fails. If the width of a bridge is insufficient to carry the number of lanes required to handle the traffic volume, the bridge will be a constriction to the flow of traffic. If the strength of a bridge is deficient and unable to carry heavy trucks, load limits will be posted and truck traffic will be rerouted. The bridge controls both the volume and weight of the traffic carried by the system. (Barker & Puckett, 2007)

Bridges are expensive. The typical cost per mile of a bridge is many times that of the approach roads to the bridge. This is a major investment and must be carefully planned for best use of the limited funds available for a transportation system. When a bridge is removed from service and not replaced, the transportation system may be restricted in its function. Traffic may be detoured over routes not designed to handle the increase in volume. Users of the system experience increased travel times and fuel expenses. Normalcy does not return until the bridge is repaired or replaced. Because a bridge is a key element in a transportation system, balance must be achieved between handling future traffic volume and loads and the cost of a heavier and wider bridge structure. Strength is always a foremost consideration but so should measures to prevent deterioration. The designer of new bridges has control over these parameters and must make wise decisions so that capacity and cost are in balance, and safety is not compromised. (Barker & Puckett, 2007).

1.2. Objective

The objective of this thesis is to prepare a computer program for the Analysis and Design of the superstructure of cast in place post tensioned box girder and Steel Plate Girder

Bridges and use the result of the program to select the economical bridge type from the two type of bridge. In the study AASHTO LRFD Manual, internationally accepted standard, is used. The selection of type of bridge is done based on the demarcation span using cost as the basis of comparison. Thus from the result obtained, one can easily identify the demarcation span length during selection of the bridge type with a better degree of accuracy instead of giving a range of span lengths.

1.3. Content of the Thesis

This thesis consists of six chapters. The first chapter deals with the general background of bridge Design and objective of the thesis and outcome the study.

The second chapter is devoted to discuss the literature survey carried on types and classification of bridges how the span of bridges is determined, and problems associated with selection of bridge type, especially at around the boundary.

The third chapter deals about the design consideration of Cast in Place Post Tension Box Girder and Steel Plate Girder Bridges, with specific attention on loadings, material properties and design assumptions made. Moreover, it also addresses the design specification to be considered during analysis and design of bridges as per AASHTO LRFD Design Manuals and general standards.

The fourth chapter includes the process of the program development using “Visual Studio 2012” and the flow charts for analysis and design of the two types of bridges.

The fifth Chapter includes design examples. Further, summary of the outputs, cost analysis for different spans and comparisons.

The last chapter of this thesis is containing the conclusions drawn from the outputs based on the developed program and the recommendations based on the findings.

1.4. Applications and Limitations

1.4.1. Applications

- The computer program developed will be applicable for the Analysis and Design of Superstructure of cast in place post tensioned box Girder and Steel Plate Girder Bridges of any span length.
- The program shall benefit Engineering Consultants and bridge constructors (contractors) in the checking and design review works and simplifies to look matters of optimal solution.

1.4.2. Limitations

- The cost analysis of bridges does consider only construction costs.
- Only the superstructure cost of the bridge is considered for economical analysis.
- The program is developed for single span bridges.

2. Fundamentals of Bridges Parameters

2.1. General

Factually, the structural design scheme of the bridge presents a complex problem for the structural designer despite the presence of modern technology and advanced computer facilities. The scope of such a problem encompasses the determination of general dimensions of the structure, the span system (i.e., number and length of spans), the choice of a rational type of substructure. In addition, within this scope, there is a demand to find the most advantageous solution to the problem in order to determine the maximum safety with minimum cost that is compatible with structural engineering principles. Fulfilling these demands will provide the proper solution to the technical and economic parameters, such as structure behavior, cost, safety, convenience, and external view. The design of the bridge usually starts with the development of a series of possible alternatives (Wai-Fah Chen, 2000).

By comparing alternatives, considering technical and economic parameters, the most expedient solution will be fined for the local site conditions. Now, the development and comparison of alternatives is the only way to find the most expedient solution. Factors influencing the choice of bridge scheme are various and their number is so great that obtaining a direct answer to what bridge scheme is most rational at a given local condition is a challenge. It is necessary to develop a few alternatives based on local conditions (geologic, hydrologic, shipping, construction, etc.) and apply the creative initiative of the designer to the choice of a structural solution. Providing structural schemes of bridge alternatives is a creative act. Computers can be used to determine the most advantageous span length and span system, to find the number of girders on the bridge having a top deck or the number of panels in the truss, and to choose the substructure.

However, using computers to make a choice of rational alternatives, considering a comparison of all technical and economic parameters, is impossible. Finding an optimum alternative using different points of view often leads to different conclusions. For example, the alternative may be the most advantageous by cost, but may require great expenditure on metal or require special erection equipment, which cannot be obtained. Some alternatives may not satisfy an architectural requirement, when considering city bridges. When using computers it is still impossible to refute the conventional design method, considering all problems of specific local condition, which are practically impossible to write into a computer program (Wai-Fah Chen, 2000).

2.2. Types/ Classification of Bridges

The type of superstructure chosen for a bridge can be based on a variety of factors ranging from maintenance considerations to personal preference. Specifically, some of the commonly used criteria in selecting the type of superstructure to be used are, Material function and availability, Construction cost, Speed of construction and constructability, Design complexity, Maintenance costs and life expectancy, Environmental concerns and Aesthetics.

Where there are no steadfast rules governing which of the factors listed above is more important than the other, one certainty is that the use of superstructure types varies geographically. Once a particular type of superstructure gains acceptance in a geographic region, it develops a certain critical mass that is difficult to alter in a different direction. Although no transportation system is homogenous, there will definitely exist a predominance of one type of superstructure system. The types of superstructures also change with the bridge span lengths. Each type of superstructure has span limitations beyond which it will become uneconomical. (Tonias, 2006)

Superstructures generally vary by support type (simply supported or continuous), design type (slab-on-stringer, arch, rigid frame, etc.), and material type (steel, concrete, timber, etc.). Obviously, there are varieties of combinations of the above. For example, a designer could choose to use a slab-on stringer superstructure with either steel or concrete girders. This superstructure could be simply supported or continuous, and so on. Discussed below are the major types of superstructures and their principal advantages and disadvantages that affect their design, construction, and maintenance. (Tonias, 2006)

Bridges can be classified depending on different mechanisms like, traffic type, life span, horizontal and vertical arrangements, span length, construction material and so on. Table 2.1 shows different classifications of bridges.

Table 2-1 Classification of bridge types (AAIT, 2012)

Traffic type/functionality - Road bridge - Railway bridge - Pedestrian bridge - Aqueduct - Viaduct - Equipment bridge	**Life Span** - Temporary bridges - Permanent bridges - Semi-permanent bridges	**Horizontal Arrangement** - Straight/Normal bridge - Skewed bridge - Curved bridge
Vertical Arrangement - Horizontal/ Flat/ Normal - Inclined	**Span** - $L \leq 6m$ (Culvert) - $7m < L \leq 15m$ (Small span bridges) - $16 \leq L \leq 50m$ (Medium span Bridges) - $50 \leq L \leq 150m$ (Large Span Bridges) - $L \geq 150m$ (Extra Large Span Bridges)	**Construction Materials** - Timber Bridges - Masonry Bridges - Reinforced Concrete Bridges - Prestressed Concrete Bridges - Steel Bridges
Span Arrangement - Simply Supported - Continuous - Cantilever	**Structural Forms** - Slab Bridges - Girder (Deck girder Bridges) - Box Girder - Portal Frame Bridges - Arch Bridges - Truss Bridges - Plate Girder Bridges - Cable Stayed Bridges - Suspension Bridges - Box Cell/ Box culvert	**Movements** - Movable Bridges - Fixed Bridges

2.2.1. Cast in Place Post-Tensioned Box Girder Bridges

Post-tensioned concrete box girders are widely used in the highway bridges. Post tensioning is one of methods of prestressing concrete. The concrete members are cast first. Then after the concrete has gained sufficient strength, tendons (strands of high strength steel wire) are inserted into preformed has ducts and tensioned to induce compressive stresses in the expected tensile stress regions of the member. Concrete must be free to shorten under the pre-compression. The strands are then anchored and a corrosion protection such as grout or grease, is installed (Gerwick, 1997).

The box-girder shape shown in Figure 2.1 is often used in Cast in Place Prestressed Concrete Bridges. The spacing of the girders can be taken as twice the depth. This type is used mostly for spans of 30 to 180 m. Structural depth-to-span ratios are 0.045 for simple spans, and 0.04 for continuous spans. The high torsional resistance of the box girder makes it particularly suitable for curved alignment such as those needed on freeway ramps (Wai-Fah Chen, 2000).

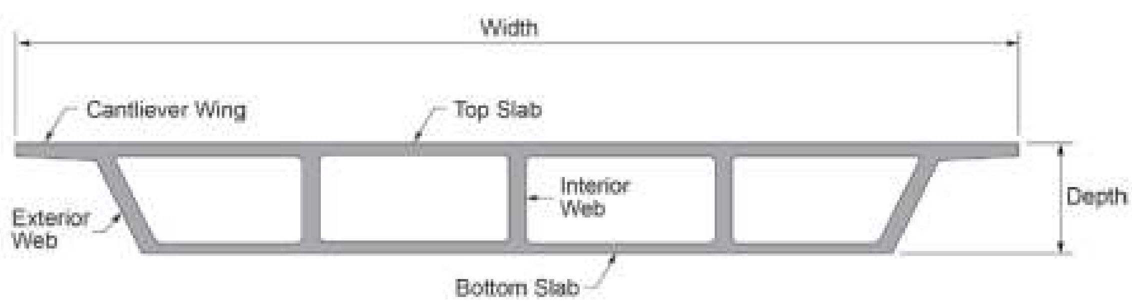


Figure 2.2 Multi-Cell Box Girder Cross

2.2.2. Steel Plate Bridges

A plate girder, like a rolled beam, has an I-type cross section. Rather than being hot-rolled, however, the girder is constructed from steel plate elements that are connected together with welds, bolts, or rivets. For modern highway bridges, shop welding is the most predominant method. Since the designer is specifying the section properties of the stringer (i.e., flange width and thickness, web depth, etc.) a greater economy of materials results. To reduce further the amount of steel used, plate girders can be varied in depth, or haunches, to accommodate regions of low and high moment and/or shear. Plate girders gain an advantage over rolled beams as span lengths become large. (Tonias, 2006)

A steel I-section may be a rolled section with or without cover plates or a built-up section (plate girder, Figure 2.2) with or without haunches consisting of top and bottom flange plates welded to a web plate. Rolled steel I-beams are applicable to shorter spans (less than 30 m) and plate girders to longer span bridges (about 30 to 90 m). A plate girder can be considered as a deep beam. The most distinguishing feature of a plate girder is the use of the transverse stiffeners that provide tension-field action increasing the post buckling shear strength. The plate girder may also require longitudinal stiffeners to develop inelastic flexural buckling strength (Wai-Fah Chen, 2000).

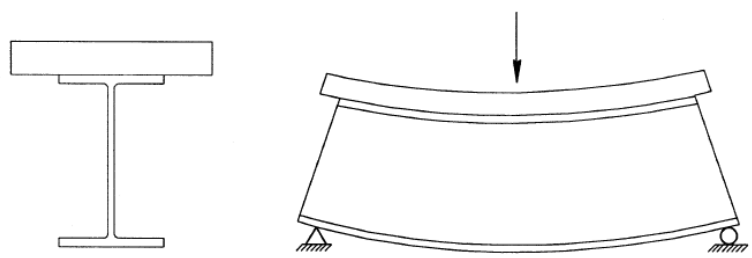


Figure 2.2 Non-composite section

2.3. Span Determination

It is customary to identify bridges as short-span, medium-span, and long-span depending on the span lengths. Presently there are not established criteria to define the range of spans for this classification, and practices vary. However, the following guidelines have been suggested (Narendra Taly, 1998)

i. Bridges in which the load effects are governed by a single actual vehicle on the span can be considered as short-span bridges (up to 20m).
ii. Bridges in which the maximum load effects are governed by a train of moving vehicles can be considered medium-span bridges (20-125m)
iii. Bridges in which the maximum load effects are caused by a train of stationary vehicles with minimum headway distances can be considered long-span bridges (longer than 125m).

2.4. Selection of Bridges

Once a preliminary span length has been chosen, comparative studies are conducted to find the bridge type best suited to the site. For each group of bridge spans (small, medium and large), experience has shown that certain bridge types are more appropriate than others.
In the selection of bridge type, there is no unique answer. For each span length range, there is more than one bridge type that will satisfy the design criteria. There are regional difference and preferences because of available materials, skilled workers, and knowledgeable contractors(Barker & Puckett, 2007).

2.5. Particular Problem of Selection

Design Manuals recommend span lengths to be criteria of selection of bridge types, for Cast in Place Post Tensioned Box Girder Bridges and Steel Plate Bridges.

Table 2-2 Casts in Place Post Tensioned Box Girder Bridge and Steel Plate Bridges Span Range

Code/Reference/ Manual	**Prestressed Concrete Box Girder Bridge**	**Plate Girder Bridge**
AACRA	10-50m	25-120m
ERA-BDM	30-150m	80-100m
Bridge Engineering Handbook	<30m	30-90m
Design of Highway Bridge	10-50m	25-50m
Analysis and Design of Reinforced concrete bridge(ACI-ASCE)	30-210m	
ICE manual of bridge Engineering	20-40m	
Minnesota Department of Transportation	Up to 45m	Up to 60m
California Department of Transportation	10-45m	

As shown in Table 2.2, different manuals recommend different spans for both Prestressed Concrete Box Girder Bridge and Plate Girder Bridge.

2.6. Design Problem

The design of the bridge usually starts with the development of a series of possible alternatives. By comparing alternatives, considering technical and economic parameters, the most practical solution will be found for the local site conditions. Now, the development and comparison of alternatives is the only way to find the most convenient solution. Factors influencing the choice of bridge scheme are various and their number is so great that obtaining a direct answer to what bridge type is most rational at a given local condition is a challenge. It is necessary to develop a few alternatives based on local conditions (geologic, hydrologic, shipping, construction, etc.) and apply the creative initiative of the designer to the choice of a structural solution. Providing structural schemes of bridge alternatives is a creative act, computers can be used to determine the most advantageous span length and span system, to find the number of girders on the bridge having a top deck or the number of panels in the truss, and to choose the substructure. However, using computers to make a choice of rational alternatives, considering a comparison of all technical and economic parameters, is impossible. Finding an optimum alternative using different points of view often leads to different conclusions. For example, the alternative may be the most advantageous by cost (Wai-Fah Chen, 2000).

There are various types of bridges ideally suited to different span lengths and there is significant overlap in the applicable ranges for the most common span ranges, so multiple bridge types are generally viable at most span ranges. Different manuals give different span lengths for selection of a particular bridge type, in this particular work Cast in Place Post Tension Box Girder versus Steel Plate Girder Bridge. Engineers are actually facing this critical problem during selection of bridge type.

3. Analysis and Design of Cast in Place Post Tensioned Box Girder Bridge and Steel Plate Bridges

3.1. General

The stage of design can begin after the selection of possible alternative bridge types that satisfy the function and aesthetic requirements of the bridge location has been completed. Justification involves calculations to demonstrate to those who have a vested interest that all applicable specifications, design, and construction requirements are satisfied (Barker & Puckett, 2007).

A general statement for assuring safety in engineering design is that the resistance of the components supplied exceed the demands put on them by applied loads, that is, When a particular loading condition reaches its limit, failure is the assumed result, that is, the loading condition becomes a failure mode. Such a condition is referred to as a limit state that can be defined as: A limit state is a condition beyond which a bridge system or bridge component ceases to fulfill the function for which it is designed (Barker & Puckett, 2007).

3.1.1. Material Properties

The primary materials needed for the design of Cast in Place Post Tensioned Box Girder Bridge are concrete, prestressing strand, and reinforcing steel and for Steel Plate Girder Bridge concrete, structural steel, and reinforcing steel.

3.1.1.1. Concrete

Compressive strength (f'c) is the characteristic that best gives an overall picture of the quality of a concrete. In the design of bridges, the compressive strength of concrete, f'c, is determined from tests on 150 mm cylinders at the age of 28 days, is used. In addition, for the computing of unit weight, the modulus of elasticity used is 2400kg/m3.

3.1.1.2. Prestressing Strand

Strands for post-tensioning are made of high tensile strength steel wire conforming to ASTM A416. A strand is comprised of seven individual wires, with six wires helically wound to a long pitch around a center “king” wire. Strand is most commonly available in two nominal sizes, 12mm and 16mm diameter, with nominal cross-sectional areas of $113mm^2$ and $200.96mm^2$, respectively.

All strands should be Grade 1860MPa low relaxation, seven-wire strand conforming to the requirements of ASTM A416 “Standard Specification for Steel Strand, Uncoated Seven Wire Strand for Prestressed Concrete.” ASTM A416 provides minimum requirements for mechanical properties (yield, breaking strength, elongation) and maximum allowable dimensional tolerances.

3.1.1.3. Reinforcing Steel

Reinforcing steel shall be in accordance with AASHTO 2005. For this study reinforcing steel with a yield stress of 420MPa is used. AASHTO 2005 permits the use of reinforcing steels with yield stresses greater than 420, up to 520, with the approval of the Owner. The modulus of elasticity of the reinforcing steel is 200,000MPa as per AASHTO 2005.

3.1.2. Assumptions

The following assumptions are made in developing the program.

I. Abutments are assumed the same for both Cast in Place Post Tensioned Box Girder and Steel Plate Bridges of the same span length. Thus, design of abutments and its associated costs are not taken into account for cost comparisons.

II. Although the dead loads of railings, curbs and posts are considered during the analysis, design and in quantity computations, it is assumed that the loads are the same for the same span of both Cast in Place Post Tensioned Box Girder and Steel Plate Bridges.

3.1.3. Design Specification

In this study design portions for the bridges is in accordance with the AASHTO LRFD Bridge Design Specifications, 3_{rd} Edition (AASHTO 2005) with the design methodology of Load and Resistance Factor Design (LRFD).

3.1.4. Loading

The engineer must consider all the possible loads that are expected to be induced on the bridge during its service life. Such loads are divided into two broad categories: permanent loads and transient loads. The permanent loads remain on the bridge for an extended period, usually for the entire service life. Such loads include the self-weight of the girders and deck, wearing surface, curbs, parapets and railings, utilities, luminaries, and pressures from earth retainments. Transient loads typically include gravity loads due to vehicular, railway, and pedestrian traffic as well as lateral loads such as those due to water, wind and earthquakes.

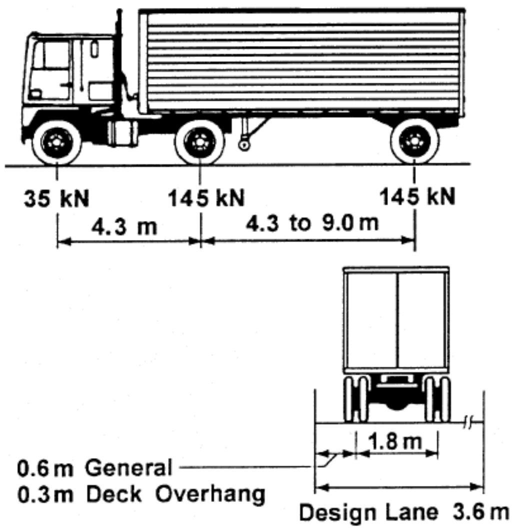
In addition, all bridges experience temperature fluctuations on a daily and seasonal basis and such effects must be considered. Depending on the structure type, other loads such as those from creep and shrinkage may be important, and finally, the superstructure supports may move, inducing forces in statically indeterminate bridges (Barker & Puckett, 2007).

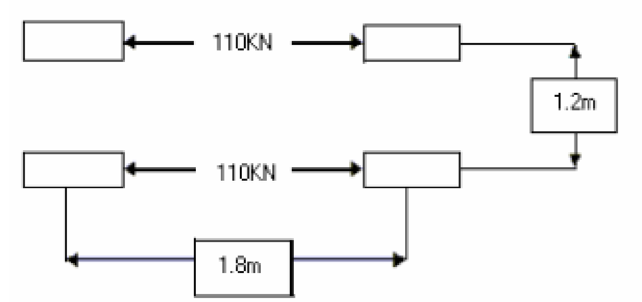
The LRFD Specification refers to the weights of the following as “permanent loads”:the structure, Formwork that becomes part of the structure, Utility ducts or casings and contents, Signs, Concrete barriers, Wearing surface and/or potential deck overlay, Other elements deemed permanent loads by the design engineer and owner and Earth pressure, earth surcharge, and down drag.

In addition, for transient loads although the automobile is the most common vehicular live load on most bridges, the truck causes the critical load effects. The design vehicular live load was replaced in 1993 because of heavier truck configurations on the road today, and because a statistically representative, notional load was needed to achieve a “consistent level of safety.” The notional load that was found to best represent “exclusion vehicles,” i.e., trucks with loading configurations greater than allowed but routinely granted permits by agency bridge rating personnel, was adopted by AASHTO and named “Highway Load ’93” or HL93. The mean and standard deviation of truck traffic was determined and used in the calibration of the load factors for HL93. It is notional in that it does not represent any specific vehicle. The distribution of loads per the LRFD Specification is more complex than in the Standard Specifications for Highway Bridge Design. This change is warranted because of the complexity in bridges today, increased knowledge of load paths, and technology available to be more rational in performing design calculations. The result will be more appropriately designed structures (Wai-Fah Chen, 2000).

The AASHTO “design vehicular live load,” HL93, is a combination of a “design truck” or “design tandem” and a “design lane.” A shorter, but heavier, design tandem is new to AASHTO and is combined with the design lane if a worse condition is created than with the design truck. Superstructures with very short spans, especially those less than 12m in length, are often controlled by the tandem combination. The AASHTO design truck is shown in Figure 3.1. The variable axle spacing between the 145kN loads is adjusted to create a critical condition for the design of each location in the structure. In the transverse direction, the design truck is 3 m wide and may be placed anywhere in the standard 3.6-m-wide lane. The wheel load, however, may not be positioned any closer than 0.6 m from the lane line, or 0.3 m from the face of curb, barrier, or railing (Wai-Fah Chen, 2000).

The AASHTO design tandem consists of two 110-kN axles spaced at 1.2 m on center. The AASHTO design lane loading is equal to 9.3 N/mm and emulates a caravan of trucks. Similar to the truck loading, the lane load is spread over a 3-m-wide area in the standard 3.6-m lane. The lane loading is not interrupted except when creating an extreme force effect such as in “patch” loading of alternate spans. Only the axles contributing to the extreme being sought are loaded. When checking an extreme reaction at an interior pier, two design trucks with 4.3-m spacing between the 145-kN axles are to be placed on the bridge with a minimum of 15 m between the rear axle of the first truck and the lead axle of the second truck. Only 90% of the truck and lane load is used. This procedure differs from the Standard Specification that used shear and moment riders (Wai-Fah Chen, 2000).





Design Tandem Load

Figure 3.1-1 AASHTO-LRFD Design Truck, Design Tandem and Design Lane Load

3.1.5. Dynamic Load Allowance

This factor accounts for hammering when riding surface discontinuities exist, and long undulations when settlement or resonant excitation occurs. If a component such as a footing is completely below grade or a component such as a retaining wall is not subject to vertical reactions from the superstructure, this increase is not taken. Wood bridges or any wood component is factored at a lower level, i.e., 1.375 for deck joints, 1.075 for fatigue, and 1.165 typical, because of the energy absorbing characteristic of wood. Likewise, buried structures such as culverts are subject to the dynamic load allowance but are a function of depth of cover, (Wai-Fah Chen, 2000)

Table 3-1 1 Dynamic Load Allowance (AASHTO 2005)

Limit State	Dynamic Load Allowance, IM
Fatigue and Fracture Limit State	15%
All Other Limit States	33%

3.1.6. Multiple Presences of Live-Load Lanes

Multiple presence factors modify the vehicular live loads for the probability that vehicular live loads occur together in a fully loaded state. The factors are shown in Table 3.2. These factors should be applied prior to analysis or design only when using the lever rule or doing three-dimensional modeling or working with substructures. Sidewalks greater than 600 mm can be treated as a fully loaded lane. If a two-dimensional girder line analysis is being done and distribution factors are being used for a beam-and-slab type of bridge, multiple presence factors are not used because the load distribution factors already consider three-dimensional effects. For the fatigue limit state, the multiple presence factors are also not used.

Table 3-2 Multiple Presence Factors

Number of Lanes Loaded	Multiple Presence Factor, m
1	1.20
2	1.00
3	0.85
>3	0.65

3.1.7. Live Loads Distribution Factor

Live loads Occupy random positions both longitudinally and transversely. Live load distribution factors are used to get variation in response for different load positions in longitudinal direction. Random transverse location of loads affects live load shared by various beams. This Distribution factors are used from AASHTO 2005.

3.1.8. Load Factors and Load Combinations

Load and Resistance Factor Design (LRFD) takes into account both the statistical mean resistance and the statistical mean loads. The fundamental LRFD equation includes a load modifier (η), load factors (γ), force effects (Q), a resistance factor (φ), a nominal resistance (Rn), and a factored resistance (Rr = φRn). LRFD provides a uniform level of safety throughout the entire bridge, in which the measure of safety is a function of the variability of the loads and the resistance.

The first set of design factors applies to all force effects and is AASHTO LRFD represented by the Greek letter η (eta) in the Specifications. These factors are related to the ductility, redundancy, and operational importance of the structure. A single, combined eta is required for every structure. When a maximum load factor from AASHTO LRFD is used, the factored load is multiplied by eta, and when a minimum load factor is used, the factored load is divided by eta. All other loads, factored in accordance with AASHTO LRFD, are multiplied by eta if a maximum force effect is desired and are divided by eta if a minimum force effect is desired. In this design example, it is assumed that all eta factors are equal to 1.0.

$\eta D = 1.0 \quad \eta R = 1.0 \quad \eta I = 1.0$

For loads for which the maximum value of γi is appropriate

$\eta = \eta D*\eta R*\eta I$ and $\eta \geq 0.95$

For loads for which the minimum value of γi is appropriate:

$$\eta = \frac{1}{\eta D*\eta R*\eta I} \text{ and } \eta \leq 1.00$$

The following is a summary of other design factors from the AASHTO LRFD Bridge Design Specifications.

Table 3-3 Load Combinations and Load Factors

Load Combination and Load Factors								
Limit State	Load Factors							
	DC		DW		LL	IM	WS	WL
	Max	Min	Max	Min				
Strength I	1.25	0.90	1.50	0.65	1.75	1.75	-	-
Strength Ill	1.25	0.90	1.50	0.65	-	-	1.40	-
Strength V	1.25	0.90	1.50	0.65	1.35	1.35	0.40	1.00
Service l	1.00	1.00	1.00	1.00	1.00	1.00	0.30	1.00
Service ll	1.00	1.00	1.00	1.00	1.30	1.30	-	-
Fatigue	-	-	-	-	0.75	0.75	-	-

Table 3-4 Resistance Factors

Resistance Factor		
Material	Type of Resistance	Resistance Factor, Φ
Structural Steel	For flexure	1.00
	For shear	1.00
	For axial compression	0.90
	For bearing	1.00
Reinforced concrete	For flexure and tension	0.90
	For shear and torsion	0.90
	For axial compression	0.75
	For compression with flexure	0.75 to 0.9 linear interpolation

3.2. A step by Step Analysis and Design

3.2.1. Deck Slab Design

Bridge decks are an integral part of the bridge structure by providing the direct riding surface for motor vehicles. In addition, bridge decks directly transfer load from the moving traffic to the major load-carrying members.

3.2.1.1. Concrete Deck Types

There are two main types of concrete decks, cast-in-place, and precast. The most common type used in Caltrans is the cast-in-place reinforced concrete deck. The other type is used depending on the various conditions like location, traffic, cost, seismicity schedule, and aesthetics (Wai-Fah Chen, 2000).

A cast-in-place concrete deck is a thin concrete slab, either using normal reinforcement or prestressing steel, usually between 175 and 300mm, with reinforcing steel interspersed transversely and longitudinally throughout the slab. There are several advantages to using a reinforced concrete deck. One of the major advantages is its relatively low cost. Other advantages are ease of construction and extensive industry use. Even though cast-in-place concrete decks have advantages, there are disadvantages using this particular type of deck, such as cracking, rebar corrosion, and tire noise. A large cost of bridge maintenance is in maintaining the riding surface. Lack of deck crack control can lead to rebar corrosion and increased life cycle cost, not to mention a poor riding surface for the public.

Precast concrete decks consist of either precast reinforced concrete panels or prestressed concrete panels. These panels can serve either as the final deck surface or as a temporary deck to allow placement of a final cast-in-place concrete deck. The advantage of a precast concrete deck is in the acceleration of the construction schedule. Precast panels allow for quicker placement, which, in principle, speeds up overall bridge construction.

3.2.1.2. Structural Behavior of Concrete Decks

It is accepted and widely known that the primary structural behavior of a concrete deck is not pure flexure, but a complex behavior known as internal arching. Concrete slabs behave quite differently than concrete beams under a given load. Research has shown that when a concrete slab starts to crack, the load is initially resisted by a combination of flexure stresses and membrane stresses. The stresses and strain create cracks in three dimensions around the wheel footprint. The way internal arching works is as cracks develop in the bottom of the slab and the slab's neutral axis shifts upward, compressive stresses develop above the neutral axis to resist further opening of the cracks. The concrete portion above the crack is in a purely elastic state. Therefore, what results is a domed shaped compression zone around the load. The compressive membrane stresses do not resist the loading completely. There is a small flexural component that also resists the loading as well. However, the controlling structural mechanic is the membrane compressive stresses created in the upper parts of the slab (Department of Transportation, 2015).

For the deck to fail, as the load is increased the deflection also increases. The section around the load becomes overstrained and this results in a cone-shaped section of failed concrete. Therefore, the primary failure mode is punching shear.

3.2.1.3. Loading

The loads that constitutes in the design of slab bridges are: self-weight of the slab including loads due to railings, posts and curbs, self-weight of the wearing surface if exists. In addition Equivalent distributed live loads of vehicular loads (truck loads, lane loads and tandem loads), per meter width of strip. These loads are distributed across the strips, both in the interior and edge strips.

3.2.1.4. Design Limit States

3.2.1.4.1. Service Limit State

Concrete decks are designed to meet the requirements for Service I limit state (AASHTO 2005). Service limit state is used to control excessive deformation and cracking. According to the California amendment, deck slabs shall be designed for Class 2 exposure,

3.2.1.4.2. Strength Limit State

Concrete decks must be designed for Strength I limit state. Because concrete deck slabs are usually designed as tension-controlled reinforced concrete components, the resistance factor is Φ=0.9 (AASHTO 2005). Strength II limit state typically is not checked for deck designs. The permit vehicle axle load does not typically control deck design. The spacing of flexure reinforcement controls concrete cracking. To improve crack control in the concrete deck, the reinforcement has to be well distributed over the area of maximum tension. Therefore, AASHTO 2005 requires steel reinforcement spacing to satisfy the following:

$$S \leq \frac{100\gamma_e}{\beta_s f_{ss}} - 2d_c \quad \text{--}3.2$$

$$\beta_s = 1 + \frac{d_c}{0.7(h-d_c)} \quad \text{--}3.3$$

Where:

γ_e = Exposure factor, 1 for class 1 and 0.75 for class 2

d_c=thickness of concrete cover measured from extreme tension fiber to center of flexural reinforcement

h= overall depth

f_{ss}= tensile stress in steel reinforcement

S= spacing

3.2.1.4.3. Fatigue Limit State

Concrete decks supported by multi-girder systems are not required to be investigated for fatigue.

3.2.1.5. Methods of Analysis

The most typical deck system used is a cast-in-place deck slab spanning transversely over a series of girders. This type of deck shall be designed using an approximate elastic method. Dead load analysis shall be based on a strip method using the following simplified moment equation for both positive and negative moments:

$\frac{wS^2}{10}$, for deck slabs that are continuous over three spans or more

$\frac{wS^2}{8}$, for all other cases

Where: S = the effective span length

w = the uniformly distributed dead load of the slab system

The unfactored live load moments obtained from AASHTO 2005 Section 4, Appendix A, Table A4-1. Negative moment values should be based on a distance of 0.0 inch from the centerline of girder to the design section.

3.2.1.6. Deck Thickness

The specifications require that the minimum thickness of a concrete deck, excluding any provisions for grinding, grooving and sacrificial surface, should not be less than 175mm (AASHTO, 2005). Thinner decks are acceptable if approved by the bridge owner. For slabs with depths less than 1/20 of the design span, consideration should be given to prestressing in the direction of that span in order to control cracking. Most jurisdictions require a minimum deck thickness of 200mm, including the 12mm integral wearing surface.

In addition to the minimum deck thickness requirements of AASHTO 2005, some jurisdictions check the slab thickness using the provisions of AASHTO 2005. The provisions in this article are meant for slab-type bridges and their purpose is to limit deflections under live loads. Applying these provisions to the design of deck slabs rarely controls deck slab design.

3.2.1.7. Overhang Design

Bridge deck overhangs must be designed to satisfy three different design cases. In the first design case, the overhang must be designed for horizontal (transverse and longitudinal) vehicular collision forces. For the second design case, the overhang must be designed to resist the vertical collision force. Finally, for the third design case, the overhang must be designed for dead and live loads. For Design Cases 1 and 2, the design forces are for the extreme event limit state. For Design Case 3, the design forces are for the strength limit state. In addition, the deck overhang region must be designed to have a resistance larger than the actual resistance of the concrete parapet

3.2.1.7.1. Overhang Thickness

For decks supporting concrete parapets, the minimum overhang thickness is 200mm (AASHTO, 2005), unless a lesser thickness is proven satisfactory through crash testing of the railing system.

3.2.2. Cast in Place Post Tensioned Box Girder Bridge Analysis and Design

Post tensioning is one of methods of prestressing concrete. The concrete members are cast first. Then after the concrete has gained sufficient strength, tendons (strands of high strength steel wire) are inserted into preformed has ducts and tensioned to induce compressive stresses in the expected tensile stress regions of the member. Concrete must be free to shorten under the pre-compression. The strands are then anchored and a corrosion protection such as grout or grease, is installed (Gerwick, 1997).

Before further discussing prestressing, we should compare it with conventionally reinforced concrete. Prior to gravity loading, the stress level in conventional reinforced concrete is zero. The reinforcing steel is only activated by the placement of the gravity load. The concrete and reinforcing steel act as a composite section. However, once the tensile capacity of the concrete surrounding the longitudinal reinforcement has been surpassed, the concrete cracks. Prestressed concrete activates the steel prior to gravity loading through prestressing the reinforcement. This prevents cracking at service loads in prestressed concrete.

Prestressed concrete utilizes high strength materials effectively. Concrete is strong in compression, but weak in tension. High tensile strength of prestressing steel and high compressive strength of concrete can be utilized more efficiently by pre-tensioning high strength steel so that the concrete remains in compression under service loads activated while the surrounding concrete is compressed. The prestressing operation results in a self-equilibrating internal stress system that accomplishes tensile stress in the steel and compressive stress in the concrete that significantly improves the system response to induced service loads (Collins, 1997).

The primary objectives of using prestressing is to produce zero tension in the concrete under dead loads and to have service load stress less than the cracking strength of the concrete along the cross section. Thus the steel is in constant tension. Because of this, the concrete remains in compression under service loads throughout the life of the structure. Both materials are being activated and used to their maximum efficiency. Figure 3.3 shows elastic stress distribution for a prestressed beam after initial prestressing.

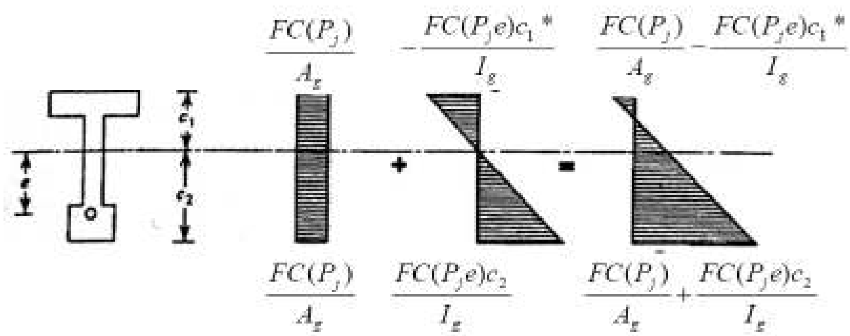


Figure 3.2 Elastic Stresses in an Uncracked Prestress Beam.

$$fpe = \frac{FC(Pj)}{Ag} \pm \left[\frac{FC(Pje)y}{Ig} + \frac{MCs(Pj)y}{Ig}\right] \quad \text{-- 3.1}$$

Where: Ag = gross area of section (mm^2)

e = eccentricity of resultant of prestressing with respect to the centroid of the cross section. Always taken as a positive (m)

FC = force coefficient for loss

fpe = effective stress in the prestressing steel after losses (MPa)

Ig = moment of inertia of the gross concrete section about the centroidal axis, neglecting reinforcement (mm^4)

Pj = force in prestress strands before losses (MPa)

MCs = secondary moment force coefficient for loss (m)

y = distance from the neutral axis to a point on member cross-section (mm.)

The prestressing force effect is accomplished by two components of the general equation shown above as Equation 3.1. The first component is uniform compression stress due to the axial prestressing force. The second component is the bending stress caused by eccentricity of the prestressing steel with respect to the center of gravity of the cross section. This creates a linear change in stress throughout the beam cross section (Figure 3.2.). It is noted that the distance from the neutral axis to the fiber in question y, (y is the general term, c1 and c2 which are more specific terms shown in Figure 3.2.), may result in a negative value for the bending part of the equation. It is possible the prestressing force will create tension across the center of gravity from the tendon, and therefore part of the beam section may be in tension prior to applying load.

The use of prestressed concrete has its advantages and limitations. Some limitations are its low superstructure ductility, the need for higher concrete compressive strengths, and larger member sizes to accommodate ducts inside the girders.

Post-tension box girder superstructures are commonly used due to their low costs, their performance throughout the life of the structure, and contractor's experience with the structure type. Post-tensioning also allows for thinner superstructures. A continuous superstructure increases the stiffness of the bridge frame in the longitudinal direction and gives the designer the option to fix the columns to the superstructure, reducing foundation costs.

3.2.2.1. Girder Layout and Structural Section

Section design is a very important tenant of structure design. An efficient section maximizes the ability of a structure to carry applied loads while minimizing self-weight. Basic mechanics of materials theory shows that the further away the majority of a material lies from the centroid of the shape, the better that shape is at resisting moment. A shape such as a basic "I" is perfect for maximizing flexural strength and minimizing weight. The placement of I-girders side by side results in a box; which is easier to construct and has seismic advantages over individual I-girders.

Determination of the typical section of a bridge has been made a simple process. Creation of a typical section begins with the calculation of structure depth for a given span length. Table 3.5. lists (AASHTO, 2005) minimum structural depth for various structural spans.

Table 3-5 Traditional Minimum Depth for Constant Depth Superstructures (AASHTO, 2005)

Superstructure		Minimum depth (including Deck) When variable depth member are used ,values may be adjusted to account for change in relative stiffness of positive and negative moment section	
Material	Type	Simple Span	Continuous Span
Reinforced Concrete	Slab with main reinforcement parallel to traffic	1.2(s+3000)/30	(s+3000)/30>=165mm
	T-Beam	0.07L	0.065L
	Box Beam	0.06L	0.055L
	Pedestrian Structure Beams	0.035L	0.033L
Prestressed Concrete	Slab	0.03L>=165mm	0.027L>=165mm
	CIP Box Beam	0.045L	0.040L
	Precat I-Beam	0.045L	0.040L
	Pedestrian structure Beams	0.033L	0.030L
	Adjacent Box Beams	0.030L	0.025L
Steel	Overall Depth of Composite I Beam	0.040L	0.032L
	Depth of I-Beam Portion of composite I -Beam	0.0330L	0.0270L
	Trusses	0.10L	0.10L

3.2.2.2. Superstructure Design

3.2.2.2.1. Section Properties

Usual design practice is to determine moments and stresses at tenth points using computer programs. For this project, only the critical locations will be investigated.

The section properties have been calculated subtracting the 12mm wearing surface from the top slab thickness. However, this wearing surface has been included in weight calculations. Section properties are yb, yt, Inertia and Area.

3.2.2.2.2. Dead Loads

In LFRD design, the dead load must be separated between DC loads and DW loads since their load factors differ. The DC loads include the self-weight of the superstructure plus 0.5KN/m^2 for lost deck formwork, the intermediate diaphragm and barriers. The DW load includes the Future Wearing Surface and any utilities.

3.2.2.2.3. Live Loads

The HL-93 live load in the LRFD specification is used.The maximum design lane load moment at mid span from the design lane load is caused by loading the entire span. The force effects from the design lane load shall not be subject to a dynamic load allowance. At mid span, the moment equals the following:

$$M = \frac{w*(l^2)}{8} \quad \text{--} \ 3.4$$

The maximum design truck design truck moment results when the truck is located with the middle axle at mid span. And maximum design tandem moment results when the tandem is located with one of the axles at mid span.

3.2.2.2.4. Live Load Distribution

The LRFD Specification has made major changes to the live load distribution factors. However, for a Cast in Place Concrete Box Girder Bridge a unit design is allowed by multiplying the interior distribution factor by the number of webs. From AASHTO 2005, a cast-in-place concrete multicell box is classified as a typical cross section type (d). The live load distribution factor in the table is valid when all the variables are within the range of applicability as shown next:

Nc = number of cells $Nc \geq 3$

S = web spacing (mm) $2100 \leq S \leq 4000$

L = span length of beam (mm) $18000 \leq L \leq 73000$

3.2.2.2.5. Dynamic Load Allowance

The dynamic load allowance IM equals 33% for the strength and service limit states.

3.2.2.2.6. Application Design Live Loads

By inspection, the moment from the combination higher from design truck and design lane load and the combination of design tandem and design lane load will be taken. Dynamic load allowance does not apply to the design lane load. The maximum live load plus dynamic load allowance including distribution factor and skew effect at mid span equals the following: =LL + IM

3.2.2.2.7. Load Combinations

The LRFD Specification has made major changes to the group load combinations. Several limit states must be considered in design. Limit states for this problem are as follows:

STRENGTH I – Basic load combination relating to the normal vehicular use of the bridge without wind.

$Mu = 1.25(DC) + 1.50(DW) + 1.75(LL + IM)$ --3.5

SERVICE II – Load combination relating to normal operational use of the bridge including wind loads to control crack width in reinforced concrete structures.

$Ms = 1.0(DC + DW) + 1.00(LL + IM)$ --3.6

SERVICE III – Load combination relating only to tension in prestressed concrete superstructures with the objective of crack control.

$Ms = 1.0(DC + DW) + 0.80(LL + IM)$ --3.7

3.2.2.3. Prestress Design

3.2.2.3.1. Prestressing Cable Layout

To induce compressive stress along all locations of the bridge girder, the prestressing cable path must be raised and lowered along the length of the girder. A typical continuous girder is subjected to negative moments near fixed supports, and positive moments near mid-span. Eccentricity determines the stress level at a given location on the cross-section. In order to meet the tension face criteria the location of the prestressing cable path will be high (above the neutral axis) at fixed supports, low (below the neutral axis) at mid spans, and at the centroid of the section near simply supported connections. The shape of the cable path is roughly the same as the opposite sign of the dead load moment.

For simple support span at the mid span the cable path should be as low as possible. However, care must be taken to ensure that the cable path can be physically located where assumed. A check on the center of gravity at the ends and at mid span is required once the area of prestressing steel is determined.

3.2.2.3.2. Area Prestressing Steel

The amount of prestressing steel required is controlled by the tension in the bottom fiber at midspan. The area of steel is calculated by assuming a final loss, using that loss to determine the required area of steel and then verifying the calculated losses. In addition to the Service III limit state, the tension reinforcing is also controlled by the requirement of zero tension from the effective prestress and all dead loads. Per the LRFD Bridge Practice Guidelines the allowable tension is:

Basic Stress Equation:

$$Pj.\frac{FCf}{A} + \frac{PJ.(em).(FCf).yb}{I} - \left[\frac{\sum(gM)*(yb)}{I}\right] + \text{Allowable Tension} = 0 \quad \text{-------------------3.8}$$

Solving for the jacking force results in the following design equation:

$$Pj = \frac{\left(\left[\frac{\Sigma(\partial M)*(y_b)}{I}\right] - \text{Allowable Tension}\right)}{\frac{FCf}{A}+\frac{(e_m).(FCf).y_b}{I}}$$ --3.9

3.2.2.3.3. Prestress Losses

Elastic shortening losses require that the number of tendons in the bridge be known. The above estimate of 15 tendons will be used to calculate the elastic shortening losses. Elastic shortening losses can be calculated directly with a rather lengthy equation in lieu of a trial and error method.

$$\Delta f_{pE} = \frac{\left(\mathrm{A_{ps}}(\mathrm{FC_i})\ \mathrm{f_{pj}}\left(\mathrm{I}+\mathrm{A}*e_m{}^2\right)-(e_m\mathrm{MgA})\right)}{(\mathrm{Aps}(\mathrm{I}+\mathrm{A}*e_m{}^2)+(\mathrm{A.I.Eci}\ /\mathrm{Ep}\ ).(2.\mathrm{N}/\mathrm{N}-1))}$$ ------------------------------3.10

3.2.2.3.4. Verify Cable Path at Mid span

From previous calculations, each web will have three ducts large ducts holding a maximum 22 strands. The ducts must clear the three layers of diameter 16mm reinforcing in the bottom slab.

3.2.2.3.5. Flexural Resistance

The flexural resistance of the structure must exceed the factored loads. Strength I loads should be compared to the flexural resistance.

$Mr = \phi Mn < \Sigma\ \gamma\ M$ ---3.11

Where Mr = Resistance Moment

Φ = Resistance Factor

Mn = Nominal Moment

STRENGTH I:

The resistance factor ϕ = 0.95 for flexure of cast-in-place prestressed concrete.

$$f_{ps} = f_{pu}(1 - k\frac{c}{dp}$$ --3.12

$$c = \frac{A_{ps}*f_{pu} + As*fy - As'*fy\prime}{0.85*fc'*\beta_1*b + kA_{ps}\left(\frac{fpu}{d_p}\right)}$$ --3.13

$$M_n = A_{ps}\, f_{ps}\left(dp - \frac{a}{2}\right) + A_S\; f_y\; \left(d_s - \frac{a}{2}\right) - A'_S f_y \left(d'_s - \frac{a}{2}\right) + 0.85 * f'_c (b - b_w)\beta_1 h_f * \left(\frac{a}{2} - \frac{h_f}{2}\right) \quad \text{-- } 3.14$$

3.2.2.4. Shear Design

In-depth shear design will be performed at the critical location near the abutment. The critical shear is located a distance dv from the support. The parabolic cable path complicates the determination of dv. To simplify the issue use dv = 0.72h for determining the critical location.

3.2.2.4.1. Live Load Distribution

The live load distribution factor for shear will be determined based on the provisions for a whole width design. From AASHTO LRFD Table 4.6.2.2.3a-1, a cast-in-place concrete multicell box is classified as a typical cross section type (d).

3.2.2.4.2. Determine Analysis Model

The sectional model of analysis is appropriate for the design of typical bridge webs where the assumptions of traditional beam theory are valid. Where the distance from the point of zero shear to the face of the support is greater than 2d, the sectional model may be used. Otherwise, the strut-and-tie model should be used.

3.2.2.4.3. Shear Depth

Effective shear depth taken as the distance, measured perpendicular to the neutral axis, between the resultants of the tensile and compressive forces due to flexure.It is maximum of the following criteria:

a. $d_v = 0.9 * d_e$ where $d_e = \frac{A_{ps} f_{ps} d_p + A_S f_y d_s}{A_{ps} f_{ps} + A_S f_s} = d_p$ --------------------------3.15

b. $d_v = 0.72 * h$

c. $d_v = \frac{M_n}{A_S f_y + A_{ps} f_{ps}}$ --3.16

3.2.2.4.4. Shear Width

The LRFD Specification requires that web width be adjusted for the presence of voided or grouted ducts. For ungrouted ducts, 50% of the width should be subtracted from the gross width and for grouted ducts, 25% should be subtracted. When the structure is first prestressed, the ducts are ungrouted. For this condition of dead load and prestressing, the shear should be checked with the 50% reduction for ducts. For the final condition, the ducts are grouted and only the 25% reduction is required.

Vu ≤ ϕVn = ϕ(0.25f'cbvdv + Vp) --3.17

3.2.2.4.5. Crack Angle

The LRFD method of shear design involves several cycles of iteration. The first step is to estimate a value of θ, the angle of inclination of diagonal compressive stress. Since the formula is not very sensitive to this estimate assume that θ = 26.5 degrees. This simplifies the equation somewhat by setting the coefficient 0.5 cot θ = 1.0.

3.2.2.4.6. Strain

There are two formulae for the calculation of strain for sections containing at least the minimum amount of transverse reinforcing. The first formula is used for positive values of strain, while the second formula is used for negative values.

Formula for ε x for positive values:

$$\epsilon_X = \frac{\frac{|M_u|}{d_v} + 0.5N_u + 0.5|V_U - V_P|\cot\theta - A_{ps}f_{po}}{(A_{ps}E_p + A_sE_s)}$$ --3.18

Formula for ex for negative values:

$$\epsilon_X = \frac{\frac{|M_u|}{d_v} + 0.5N_u + 0.5|V_U - V_P|\cot\theta - A_{ps}f_{po}}{2*(A_{ps}E_p + A_sE_s + A_cE_c)}$$ --3.19

3.2.2.4.7. Concrete Shear Strength

The nominal shear resistance from concrete, Vc, is calculated as follows:

$V_c = 0.0316\beta\sqrt{f_c'}\ b_v\ d_v$ --3.20

3.2.2.5. Prestress Losses For Post Tensioning

Throughout the life of a prestressed concrete girder, the initial force applied to the pre-stress tendons significantly decreases. This decrease in the force is called loss. Loss of stress in a girder can revert a location previously in compression to tension, or increase a tension stress. This may be very dangerous when stress in concrete is near its stress limit. Because of the significant impact to the structure of these losses, losses must be quantified and accounted in design.

The coefficients are usually used to estimate the reduction factor in initial force to find a final prestressing force. These coefficients are called force and moment coefficients. Both coefficients are used to determine a jacking force, as most losses are both functions of and dependant of jacking force. These force coefficients are given as the sum of lost force of each component of loss divided by the allowable stress in the tendon.

$FC_{pT} = (1 - \frac{\sum \Delta f_i}{f_{ps}})$ --3.21

Where:

FCpT = force coefficient for loss

Δ fi = change in force in prestressing tendon due to an individual loss (mpa)

fps = average stress in prestressing steel at the time for which the nominal resistance is required

$MC_P = (FC_{pT}) * (e_x)$ --3.22

Where:

MCp = primary moment force coefficient for loss (m)

FCpT = total force coefficient for loss

ex = eccentricity as a function of x along parabolic segment (m)

The force coefficient is defined as one at the jacking location and begins decreasing towards zero to the point of no movement. The point of no movement is a finite point of the strand that does not move when jacked and is defined as the location where internal strand forces are in equilibrium. For single-end post tensioning, the point of no movement is at the opposite anchorage from stressing. For two-end tensioning the location is where the movement in one direction is countered by movement from the other direction, and is generally near the middle of the frame.

Force coefficients are determined at each critical point along the girder. The product of the force coefficients and strand eccentricities (e) are called moment coefficients. The coefficients determined from the locked in moments at fixed supports are used to convert initial strand moment resistant capacities into capacities after losses, or final capacities.

3.2.2.5.1. Instantaneous Losses

There are two types of losses: instantaneous and long term. The instantaneous losses are due to anchor set, friction, and elastic shortening. Instantaneous losses are bridge specific, yet still broad enough to be estimated in user friendly equations. Therefore a lump sum value is not used and a bridge specific value is calculated. Given below are three different types of instantaneous losses.

3.2.2.5.2. Anchor Set Loss

Anchor Set is caused by the movement of the tendon prior to seating of the anchorage-gripping device. This loss occurs prior to force transfer between wedge (or jaws) and anchor block. Anchor set loss is the reduction in strand force through the loss in stretched length of the strand. Once a force is applied to the strands, the wedges move against the anchor block, until the wedges are "caught". Because of the elasticity of the strands, this movement will cause a loss in strain, stress, and force. This movement and the resulting loss of force prior to being "caught" is the anchor set loss. The force necessary to pull the movement out will not be captured as the effective force. Even though the size of the slip is small, it still manifests as a reduction in prestressing force. AASHTO 2005 suggests a common value for anchor set as 10mm.AASHTO 2005 puts the Anchor Set into a more familiar change in force and force coefficient form.

$$\Delta FC_{pA} = \frac{\Delta f_{pA}}{f_{ps}} = \frac{2(\Delta f_L)x_{pA}}{L(f_{ps})} \text{ --- } 3.23$$

$$x_{pA} = \sqrt{\frac{E_p(\Delta_{Aset})L}{12\Delta f_L}} \text{--} 3.24$$

Where:

FCpA = force coefficient for loss from anchor set

xpA = influence length of anchor set (m)

Ep = modulus of elasticity of prestressing

ΔAset = anchor set length (mm)

L = distance to a point of known stress loss (m)

ΔfL = friction loss at the point of known stress loss (MPa)

ΔfpA = jacking stress lost in the P/S steel due to anchor set (MPa)

3.2.2.5.3. Friction Loss

Friction loss is another type of instantaneous loss, which occurs when the prestressing tendons get physically caught on the ducts. This is a significant loss of force on non-linear prestressing paths because of the angle change of the ducts. Friction loss has two components: curvature and wobble frictional losses. Curvature loss occurs when some fraction of the jacking force is used to maneuver a tendon around an angle change in a duct. An example would be as a tendon is bending around a duct inflection point near a pier or bent, the bottom of the tendon is touching (and scraping) the bottom of the duct. This scraping of the duct is loss of force via friction.

$$FC_{pF} = \frac{\Delta f_{pF}}{f_{pj}} = e^{-(kx+\mu a)} \text{ ---} 3.25$$

Where:

e = e is the base of Napier an logarithms

FCpF = force coefficient for loss from friction

fpj = stress in the prestressing steel at jacking (MPa)

K = wobble friction coefficient (per m of tendon)

x = general distance along tendon (m)

kx+$\mu\varphi$ = total angular change of prestressing steel path from jacking end to a point under investigation (rad)

ΔfpF = change in stress due to friction loss

μ= coefficient of friction

3.2.2.5.4. Elastic Shortening

When the pre-stressing force is applied to a concrete section, an elastic shortening of the concrete takes place simultaneously with the application of the pre-stressing force to the pre-stressing steel. It is caused by the compressive force from the tendons pulling both anchors of the concrete towards the center of the frame. Therefore, the distance between restraints has been decreased. Because of the elastic nature of the strand decreasing the distance between restraints after the pre-stressing force has been applied, thus reducing the strain, stress, and force levels in the tendons.

The equations for elastic shortening in pre-tensioned (such as precast elements) members are shown in AASHTO 2005.

$$\Delta f_{pES} = \frac{E_p}{E_{ct}} f_{cgp} \quad \text{-----} \quad 3.26$$

Where:

f_{cgp} = the concrete at the center of center of gravity prestressing tendon

E_p = modulus of elasticity of prestessing steel

E_p = modulus of elasticity of concrete

The equations for elastic shortening in post-tensioned members other than slabs are (AASHTO, 2005).

$$\Delta f_{pES} = \frac{N-1}{2N} \frac{E_P}{E_{ci}} f_{cgp} \quad \text{-----} \quad 3.27$$

Where:

Ect = modulus of elasticity of concrete at transfer or time of load application

Ep = modulus of elasticity of prestressing tendons

N = number of identical prestressing tendons

fcgp = concrete stress at the center of gravity of prestressing tendons, that results from the prestressing force at either transfer or jacking and the self-weight of the member at sections maximum moment

ΔfpES = change in stress due to elastic shortening loss

3.2.2.5.5. Long Term Loss

Long term, time-dependent losses are the losses of presstress force in the tendon during the life of the structure. When using long-term losses on post-tensioned members it is acceptable to use a lump sum value in lieu of a detailed analysis (AASHTO, 2005). When completing a detailed analysis, long-term losses are the combination of the following three losses.

The first one is shrinkage of concrete which is produced due to the volume loss of concrete when the free water evaporation from concrete mix. The amount of shrinkage, and therefore the amount of loss caused by shrinkage, is dependent on the composition of the concrete and the curing process Empirical equations for calculating shrinkage have been developed which rely on concrete strength, and relative humidity of the region where the bridge will be placed (Department of Transportation, 2015).

Creep is, the second long term loss ,a phenomenon of gradual increase of deformation of concrete under sustained load. There are two types of creep, drying creep and basic creep. Drying creep is affected by moisture loss of the curing concrete and is similar to shrinkage, as it can be controlled by humidity during the curing process. Basic creep is the constant stress of the post-tensioning steel straining the concrete. Creep is determined by relative humidity at the bridge site, concrete strengths, gross area of concrete, area of prestressing steel, and initial prestressing steel (Department of Transportation, 2015).

The third one is the relaxation of steel, which is a phenomenon of gradual decrease of stress when the strain is held constant over time. As time goes by, force is decreasing in the elongated steel. Relaxation losses are dependent on how the steel was manufactured. The manufacturing processes used to create prestressing strands result in significant residual stresses in the strand. The steel can be manufactured to reduce relaxation as much as possible; this steel is called low relaxation (lo-lax). Lo-lax is generally the type of prestressing steel used in Caltrans post-tensioned girder bridges. A lo-lax strand goes through the production of high strength steel (patenting, cold drawing, stranding) and is then heated and cooled under tension. This process removes residual stresses and reduces the time dependant losses due to the relaxation of the strand (Department of Transportation, 2015).

3.2.2.6. Stress Limitation

3.2.2.6.1. Prestressing Tendons

Tensile stress is limited to a portion of the ultimate strength to provide a margin of safety against tendon fracture or end-anchorage failures. Stress limits are also used to avoid inelastic tendon deformation, and to limit relaxation losses.

3.2.2.6.1. Concrete

Stress in concrete varies at discrete stages within the life of an element. These discreet stages vary based on how the element is loaded, and how much pre-stress loss the element has experienced. The stages to be examined are the Initial Stage: Temporary Stresses before Losses, and the Final Stage: Service Limit State after Losses, as defined by AASHTO 2005. The prestress force is designed as the minimum force required to meet the stress limitations in the concrete as specified in (AASHTO, 2005).

During the time period right after stressing, the concrete in tension is especially susceptible to cracking. This is before losses occur when prestress force is the highest and the concrete is still young. At this point, the concrete has not completely gained strength. Caltrans project plans should show an initial strength of concrete that must be met before the stressing operation can begin. This is done to indicate strength required to resist the post tensioning during the concrete’s vulnerable state. During this initial temporary state, (AASHTO, 2005) allows for a higher tensile stress limit and the concrete is allowed to crack. The concrete is allowed to crack because as the losses reduce the high-tension stress and the young concrete strengthens, the crack widths will reduce. Then the high axial force from prestressing will pull the cracks closed (AASHTO, 2005).

3.2.2.7. Post Tensioning Anchor Design

The abrupt termination of high force strands within the girder generates a large stress ahead of the anchorage. Immediately ahead of the girder are bursting stresses, and surrounding the anchorages are spalling stresses. The code specifies that for ease of design, the anchorage zone shall consist of two zones (Figure 3.4). One a "Local Zone" consisting of high compression stresses which lead to spalling. In addition, there is a General Zone consisting of high tensile stresses that lead to bursting (AASHTO, 2005).

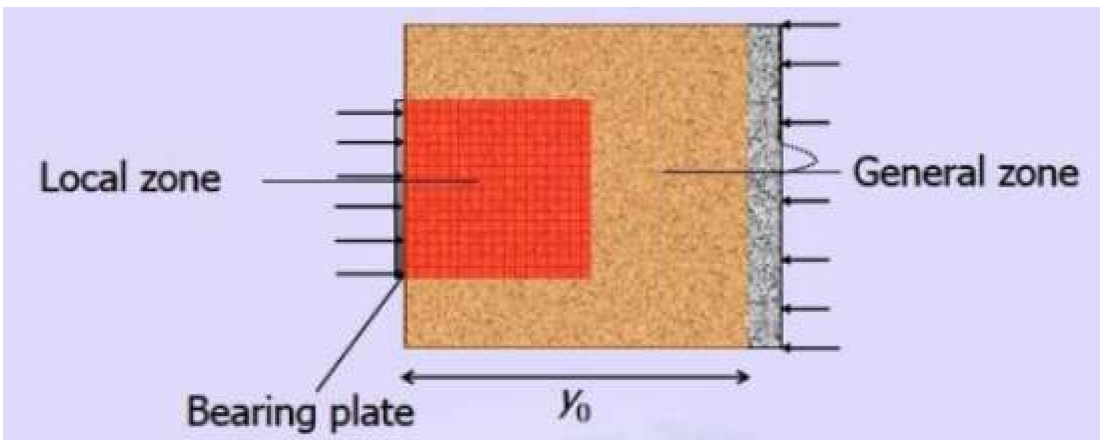


Figure 3.4 General and Local Anchorage Zone

The local zone of the anchorage system is dependent on the nearby crushing demand. Compression reinforcement is used within the local zone to keep concrete from spalling and eventually crushing. The local zone is more influenced by the characteristics of the anchorage device and its anchorage characteristics than by loading and geometry. Anchorage reinforcement is usually designed by the prestressing contractor and reviewed/approved by the design engineer during the shop drawing process.

The general zone is defined by tensile stresses due to spreading of the tendon force into the structure. These areas of large tension stresses occur just ahead of the anchorage and slowly dissipate from there. Tension reinforcement is used in the general zone as a means to manage cracking and bursting.

The specifications permit the general anchorage zone to be designed using: the Finite Element Method, the Approximate Method contained in the specifications and the Strut and Tie method, which is the preferred method

3.2.3. Steel Plate Bridges Analysis and Design

3.2.3.1. General

Steel Plate Girder Bridges are structurally the simplest and the most commonly used on short to medium span bridges. A plate girder is a beam built up from plate elements to achieve a more efficient arrangement of material than is possible with rolled beams. Plate girders are economical where spans are long enough to permit saving in cost by proportioning for the particular requirements. They are used as flexural members to carry extremely large lateral loads. In addition, they are typically used as long-span floor girders in buildings, as bridge girders, and as crane girders in industrial structures. They are constructed by welding steel plates together to form I sections.

3.2.3.2. Structural Materials

3.2.3.2.1. Structural Steel

ASTM A 709 or AASHTO M 270 (Grades 36, 50, 50S, 50W, HPS 50W, HPS 70W and 100/100W) structural steels are commonly used for bridge structures.

3.2.3.2.2. Concrete

Concrete with 28-day compressive strength of 28MPa is commonly used in concrete deck slab construction. The transformed area of concrete is used to calculate the composite section properties. For normal weight concrete of 28MPA, the ratio of the modulus of elasticity of steel to that of concrete, $n = E/Ec = 8$ is recommended by AASHTO 2005.

3.2.3.3. Span and Framing Arrangement

3.2.3.3.1. Span Configuration

Span configuration plays an important role in the efficient and cost-effective use of steel. For cases where pier locations are flexible, designers should optimize the span arrangement. Two-span continuous girders/beams are not the most efficient system because of high negative moments. Three- and four-span continuous girders are preferable, but may not always be possible. For multi-span continuous girders, a good span arrangement is to have the end span lengths approximately 70 to 80 percent of the interior span lengths. Equal interior span arrangements are also relatively economical. A span configuration with uplift due to live load plus impact should be avoided (Department of Transportation, 2015).

The use of simply supported girders under construction load and continuous girders through steel reinforcement for live load can be an economical framing method .This type of framing presents possible advantages over continuous beam designs by eliminating costly splices and heavy lifts during girder erection. The potential drawbacks are that more section depth may be required and the weight of steel per unit deck area may be higher. This framing method needs to be investigated on a case-by-case basis to determine whether it can be economically advantageous. When simply supported span configurations are used, special attention should be given to seismic performance detailing (Department of Transportation, 2015).

3.2.3.3.1. Girder Spacing

As a general rule, the most economical superstructure design can be achieved using girder spacing within an 3.0m to 3.65m range. For spans less than 40m, 3.0m to 3.65m spacing is preferred. For spans greater than 40 m, 3.2m to 4.26m spacing is recommended. The use of metal deck form panels will limit the spacing to about 16 ft. Girder spacings over 4.8m. may require a transversely (Department of Transportation, 2015).

3.2.3.3.2. Spacing

Arbitrary 7.62m spacing limit for diaphragms and cross frames was specified in the AASHTO Standard Design Specifications (AASHTO, 2002). The AASHTO LRFD Bridge Design Specifications (AASHTO, 2005), however, no longer specify a limit on the cross frame spacing, but instead require rational analysis to investigate needs for all stages of assumed construction procedures and the final conditions. Spacing should be compatible with the transverse stiffeners.

3.2.3.3.3. Connections

Cross frames are typically connected to transverse stiffeners. The stiffeners shall have a positive connection to the girder flange and may either be bolted or welded, although welding is preferred. For bridges built in stages or with larger skew angles, differential deflections between girders due to slab placement can be significant. If differential deflections are significant, slotted holes and hand tight erection bolts with jamb nuts shall be provided during concrete placement, and permanent bolts fully tensioned or field welded connections shall be installed after the barriers are placed. The bolt holes can be field drilled to insure proper fit. Intermediate cross frames between stages shall be eliminated if possible.

3.2.3.4. Section Proportion

3.2.3.4.1. Depth

Overall girder depth, h, will usually be in the range $L_o/12$ to $L_o/8$, where L_o is the length between points of zero moment. However, for plate girder bridges the range will extend to approximately $L_o/20$.

3.2.3.4.2. Flange breadth

The breadth, b, will usually be in the range h/5 to h/3, b being in multiples of 25mm. 'Wide flats' may be used unless the flange is very wide.

3.2.3.4.3. Flange thickness

The flange thickness, t_f, will usually at least satisfy the requirements for Class 3 (semi-compact) sections, i.e. $c/t_f < 13\varepsilon$. The thickness will usually be chosen from the standard plate thicknesses.

3.2.3.4.4. Web thickness

Web thickness, t_w, will determine the exact basis for web design, depending on whether the web is classified with regard to shear buckling as "thick" or "thin". Thin webs will often require stiffening; this may take the form of transverse stiffeners, longitudinal stiffeners or a combination. Longitudinally stiffened girders are more likely to be found in large bridge construction where high d/t_w ratios are appropriate, e.g. $200 < d/t_w < 500$, due to the need to minimize self-weight. Since the deeper the girder is made, the smaller the flange plates required.

Clearly, depending on the particular loading pattern, and on depth and breadth restrictions, one can expect wide variations within all the above limits which should be regarded as indicative only.

3.2.3.5. Stiffeners

Intermediate transverse stiffeners together with the web are used to provide postelastic shear buckling resistance by the tension field action and are usually placed near the supports and large concentrated loads. Stiffeners without connecting cross frames/diaphragms are typically welded to the girder web and shall be welded to the compression flange and fitted tightly to the tension flange. Stiffener plates are preferred to have even inch widths from the flat bar stock sizes. Bearing stiffeners are required at all bearing locations. Bearing stiffeners shall be welded or bolted to both sides of the web. Bearing stiffeners should be thick enough to preclude the need for multiple pairs of bearing stiffeners to avoid multiple-stiffener fabrication difficulties. AASHTO 2005 requires that the stiffeners shall extend the full depth of the web and as close as practical to the edge of the flanges. Longitudinal stiffeners are required to increase flexure resistance of the web by controlling lateral web deflection and preventing the web bending buckling. They are, therefore, attached to the compression portion of the web. It is recommended that sufficient web thickness be used to eliminate the need for longitudinal stiffeners as they can cause difficulty in fabrication and create fatigue-prone details.

3.2.3.6. Design Methodology

This design is based on Load and Resistance Factor Design (LRFD), as presented in the AASHTO LRFD Bridge Design Specifications. The following is a general comparison between the primary design methodologies: Service Load Design (SLD) or Allowable Stress Design (ASD) generally treats each load on the structure as equal from the viewpoint of statistical variability. The safety margin is primarily built into the capacity or resistance of a member rather than the loads. Load Factor Design (LFD) recognizes that certain design loads, such as live load, are more highly variable than other loads, such as dead load. Therefore, different multipliers are used for each load type. The resistance, based primarily on the estimated peak resistance of a member, must exceed the combined load.

Load and Resistance Factor Design (LRFD) takes into account both the statistical mean resistance and the statistical mean loads. The fundamental LRFD equation includes a load modifier (η), load factors (γ), force effects (Q), a resistance factor (φ), a nominal resistance (Rn), and a factored resistance ($Rr = \varphi Rn$). LRFD provides a uniform level of safety throughout the entire bridge, in which the measure of safety is a function of the variability of the loads and the resistance.

The first set of design factors applies to all force effects and is AASHTO 2005 represented by the Greek letter η (eta) in the Specifications. These factors are related to the ductility, redundancy, and operational importance of the structure. A single, combined eta is required for every structure. When a maximum load factor from AASHTO 2005 is used, the factored load is multiplied by eta, and when a minimum load factor is used, the factored load is divided by eta. All other loads, factored in accordance with AASHTO 2005, are multiplied by eta if a maximum force effect is desired and are divided by eta if a minimum force effect is desired. In this design example, it is assumed that all eta factors are equal to 1.0.

$\eta D = 1.0 \quad \eta R = 1.0 \quad \eta I = 1.0$

For loads for which the maximum value of γi is appropriate

$\eta = \eta D \cdot \eta R \cdot \eta I$ and $\eta \geq 0.95$

For loads for which the minimum value of γi is appropriate:

$$\eta = \frac{1}{\eta D * \eta R * \eta I} \text{ and } \eta \leq 1.00$$

3.2.3.7. Design Limit States

Steel Girder Bridges shall be designed to meet the requirements for all applicable limit states specified by AASHTO 2005 such as Strength I, Strength II, Service II, Fatigue I and II, and extreme events.

4. Program Development

4.1. General

Programming means designing a set of instructions to instruct the computer to carry out certain jobs in such a way that are very much faster than human beings can do. The earliest programming language is called machine language that uses binary codes comprises 0 and 1 to communicate with the computer. Machine language is extremely difficult to learn. Fortunately, scientists have invented high level programming languages that are much easier to master. Some of the high levels programming languages are Java, JavaScript, C, C++, c# and Visual Basic.

This paper focuses for the development of software program of CIPPTBGB and SPGB using Visual Studio 2012 software. Visual Basic is a third-generation event-driven programming language and integrated development environment (IDE) from Microsoft for its Component Object Model (COM) programming model first released in 1991 and declared legacy in 2008. Microsoft intended Visual Basic to be relatively easy to learn and use. Visual Basic was derived from BASIC, a user-friendly programming language designed for beginners, and it enables the rapid application development (RAD) of graphical user interface (GUI) applications, access to databases using Data Access Objects, Remote Data Objects, or ActiveX Data Objects, and creation of ActiveX controls and objects (Microsoft Corporation, 2012).

The main design outputs of the developed program are deck slab and overhang slab thickness, reinforcement area and area of prestressing steel, post anchorage zone reinforcement, steel plate cross section and stiffener cross section.

4.2. Programming Development Process

All programming involves creating something that solves a problem. Here there are four steps that are followed during the development of the program:

i. Identify the Problem
ii. Design a Solution
iii. Write the Program
iv. Check the Solution

4.3. Flowcharts

4.3.1. Flowchart for Deck slab Design

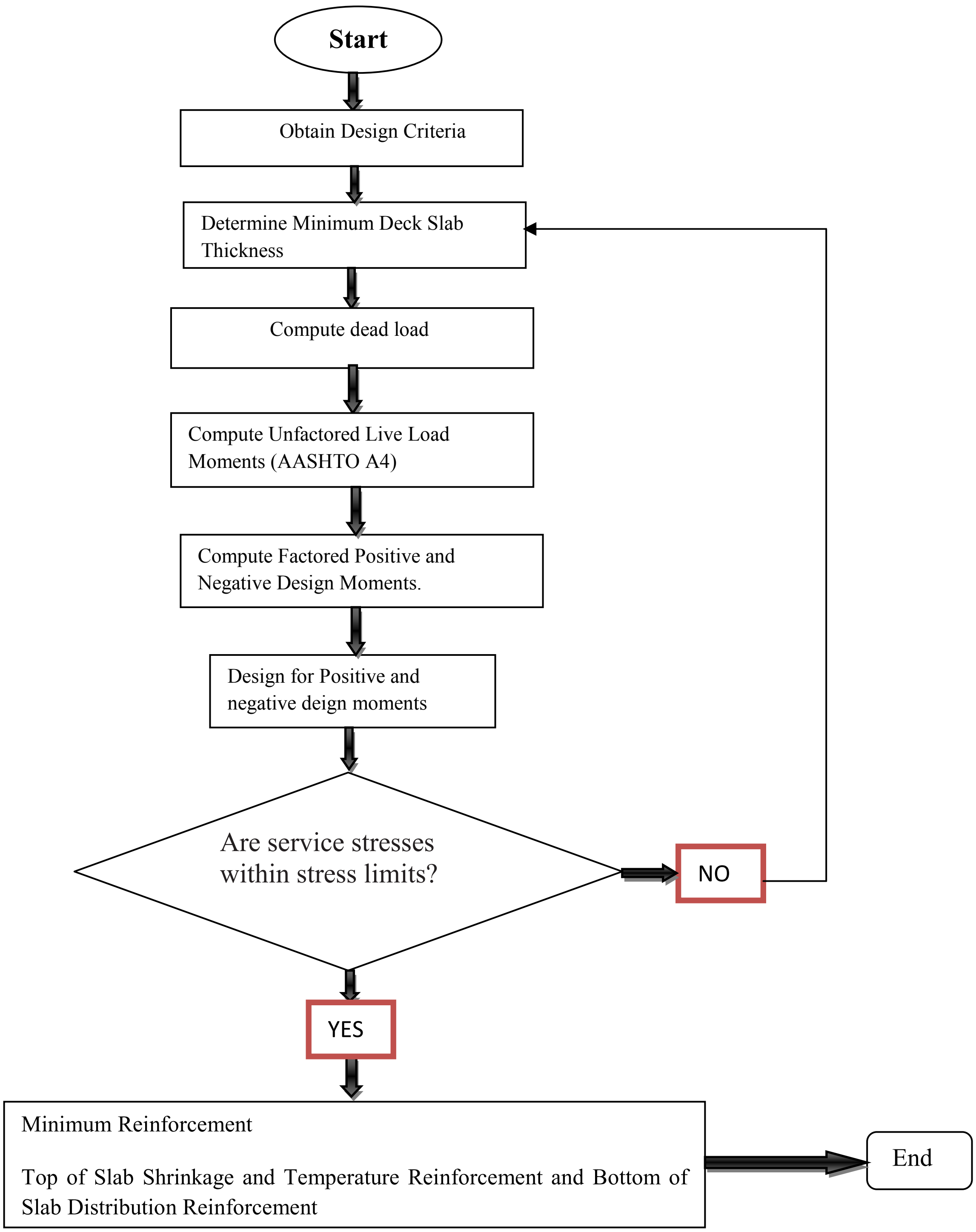


Figure 4.31 Flowchart for Deck slab Design

4.3.2. Flowchart for Overhang Design

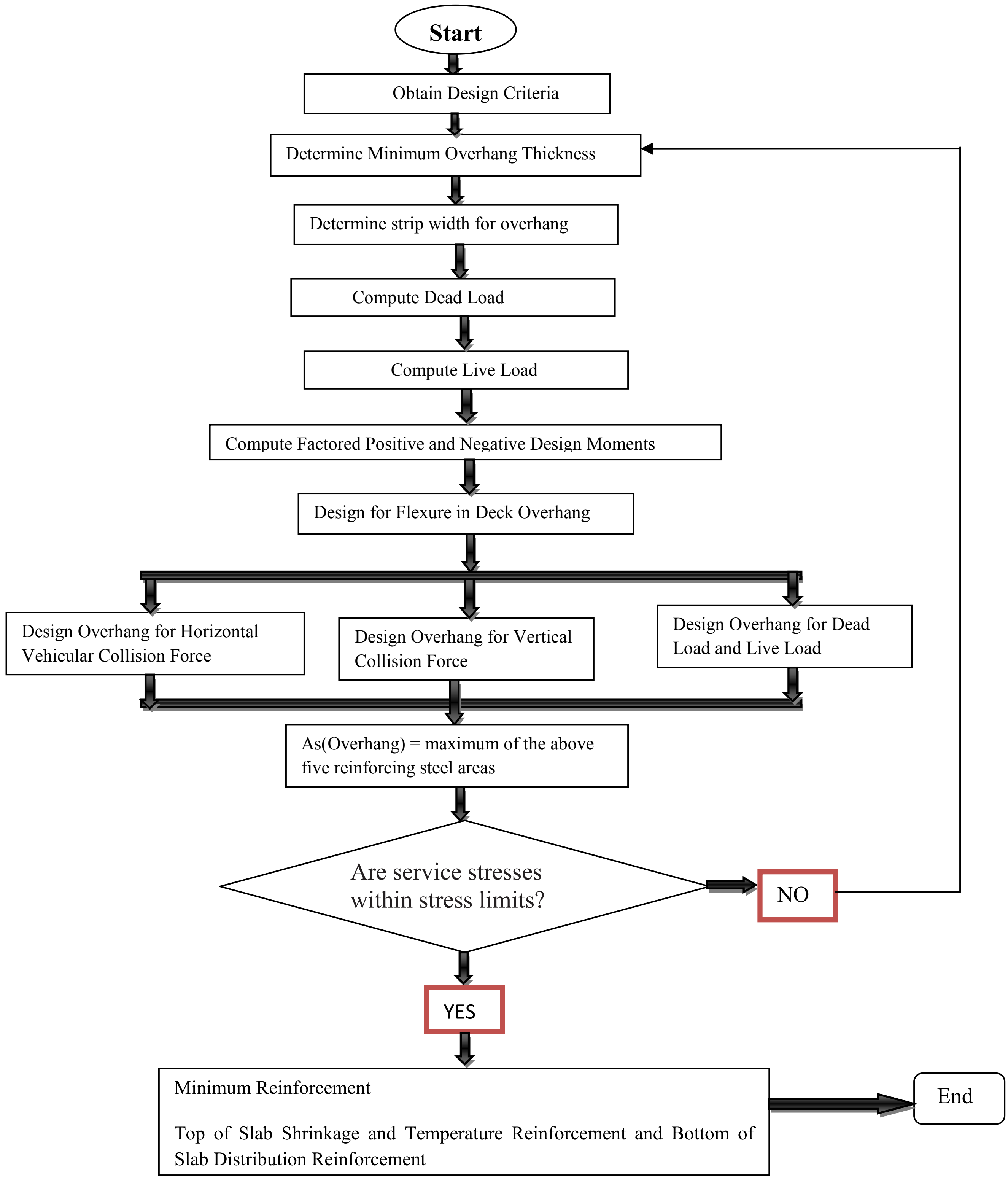


Figure 4.32 Flowchart for Overhang Design

4.3.3. CIPPTBGB Superstructure design Flow chart

Start

Span Lengths and bridge widths are determined by need, existing surroundings

Span Lengths (L)
Bridge Width (W)

Material properties

- **Reinforcing Steel**

Yield Strength fy = 420MPa Modulus of Elasticity Es = 200000 MPa

Structural Steel

Tensile Strength fu = 345MPa Yield Strength fy = 450MPa

Concrete

The final and release concrete strengths are specified below: Superstructure f'c = 28MPa

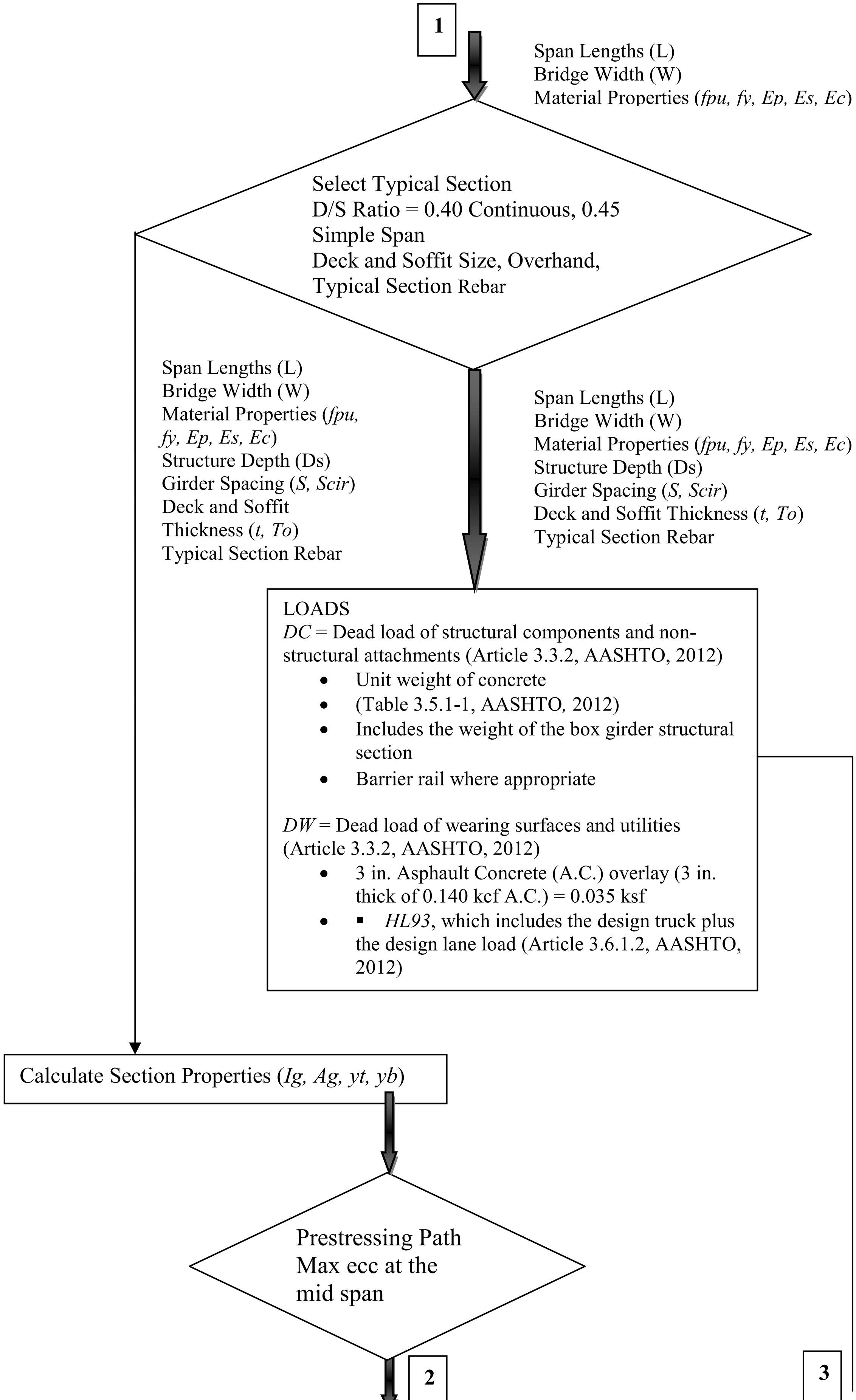
Unit weight for normal weight concrete is listed below: Unit weight for computing Ec = 2400kg/m3

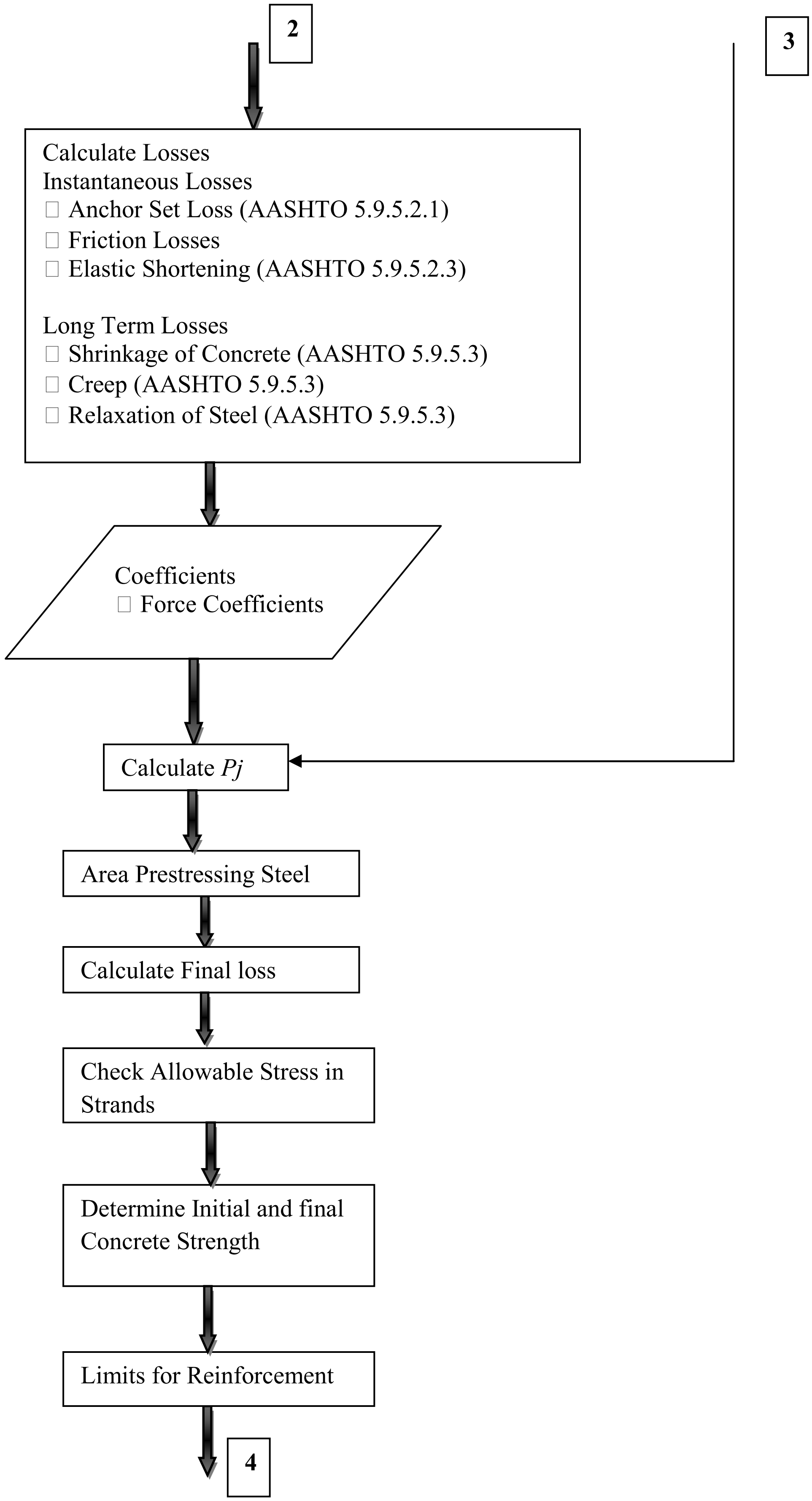
Prestressing Strand

Low relaxation prestressing strands , 16mm diameter strand Aps = 200.96mm^2 Tensile Strength fpu = 1860MPa

Yield Strength fpy = 1674MPa Modulus Elasticity Ep = 197000MPa

1


1
Span Lengths (L)
Bridge Width (W)
Material Properties (*fpu, fy, Ep, Es, Ec*)
Select Typical Section
D/S Ratio = 0.40 Continuous, 0.45
Simple Span
Deck and Soffit Size, Overhand,
Typical Section Rebar
Span Lengths (L)
Bridge Width (W)
Material Properties (*fpu, fy, Ep, Es, Ec*)
Structure Depth (Ds)
Girder Spacing (*S, Scir*)
Deck and Soffit Thickness (*t, To*)
Typical Section Rebar
Span Lengths (L)
Bridge Width (W)
Material Properties (*fpu, fy, Ep, Es, Ec*)
Structure Depth (Ds)
Girder Spacing (*S, Scir*)
Deck and Soffit Thickness (*t, To*)
Typical Section Rebar
LOADS
DC = Dead load of structural components and non-structural attachments (Article 3.3.2, AASHTO, 2012)
• Unit weight of concrete
• (Table 3.5.1-1, AASHTO, 2012)
• Includes the weight of the box girder structural section
• Barrier rail where appropriate
DW = Dead load of wearing surfaces and utilities (Article 3.3.2, AASHTO, 2012)
• 3 in. Asphault Concrete (A.C.) overlay (3 in. thick of 0.140 kcf A.C.) = 0.035 ksf
• ▪ *HL93*, which includes the design truck plus the design lane load (Article 3.6.1.2, AASHTO, 2012)
Calculate Section Properties (*Ig, Ag, yt, yb*)
Prestressing Path
Max ecc at the
mid span
2
3


2
3
Calculate Losses
Instantaneous Losses
Anchor Set Loss (AASHTO 5.9.5.2.1)
Friction Losses
Elastic Shortening (AASHTO 5.9.5.2.3)
Long Term Losses
Shrinkage of Concrete (AASHTO 5.9.5.3)
Creep (AASHTO 5.9.5.3)
Relaxation of Steel (AASHTO 5.9.5.3)
Coefficients
Force Coefficients
Calculate *Pj*
Area Prestressing Steel
Calculate Final loss
Check Allowable Stress in Strands
Determine Initial and final Concrete Strength
Limits for Reinforcement
4

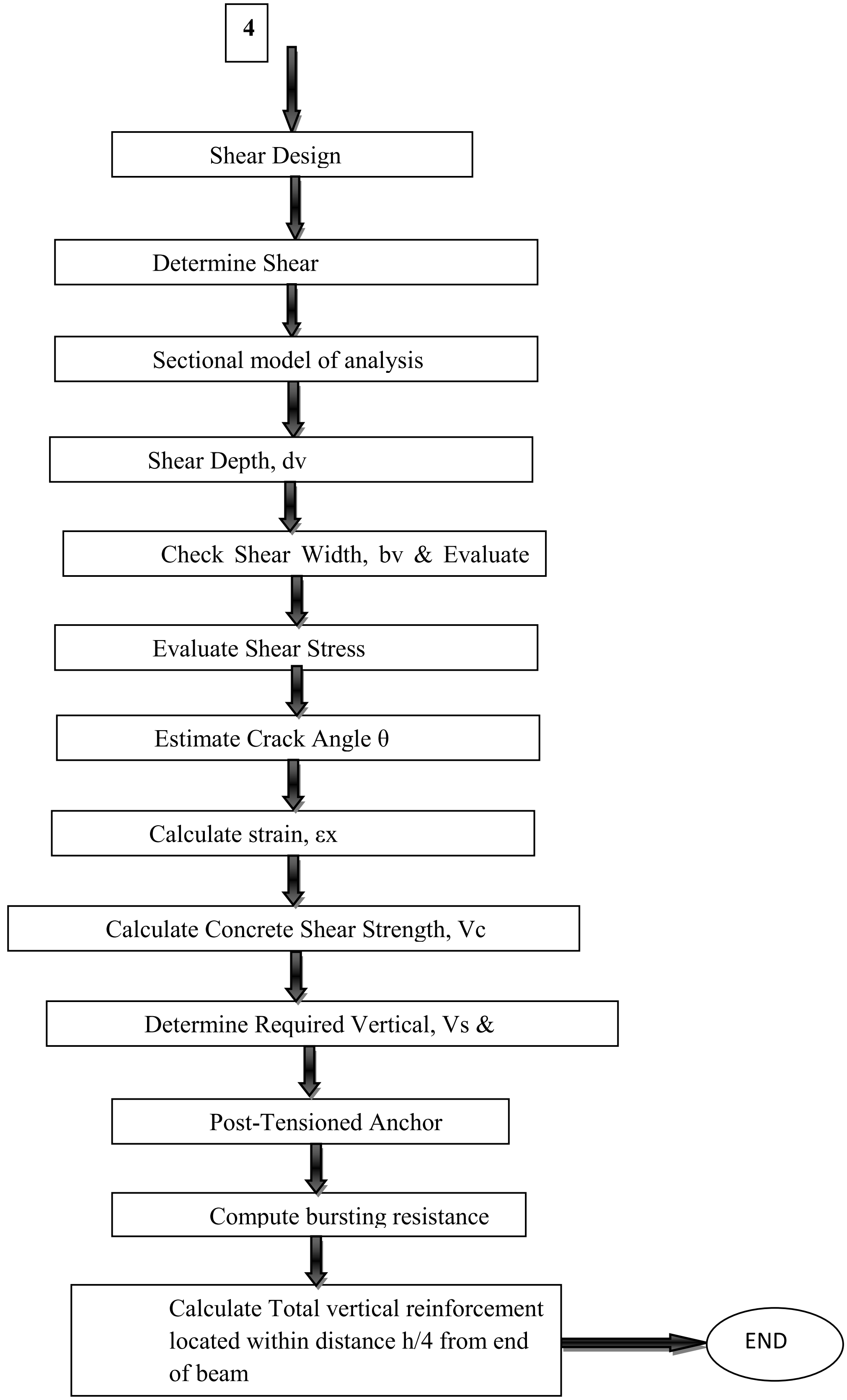
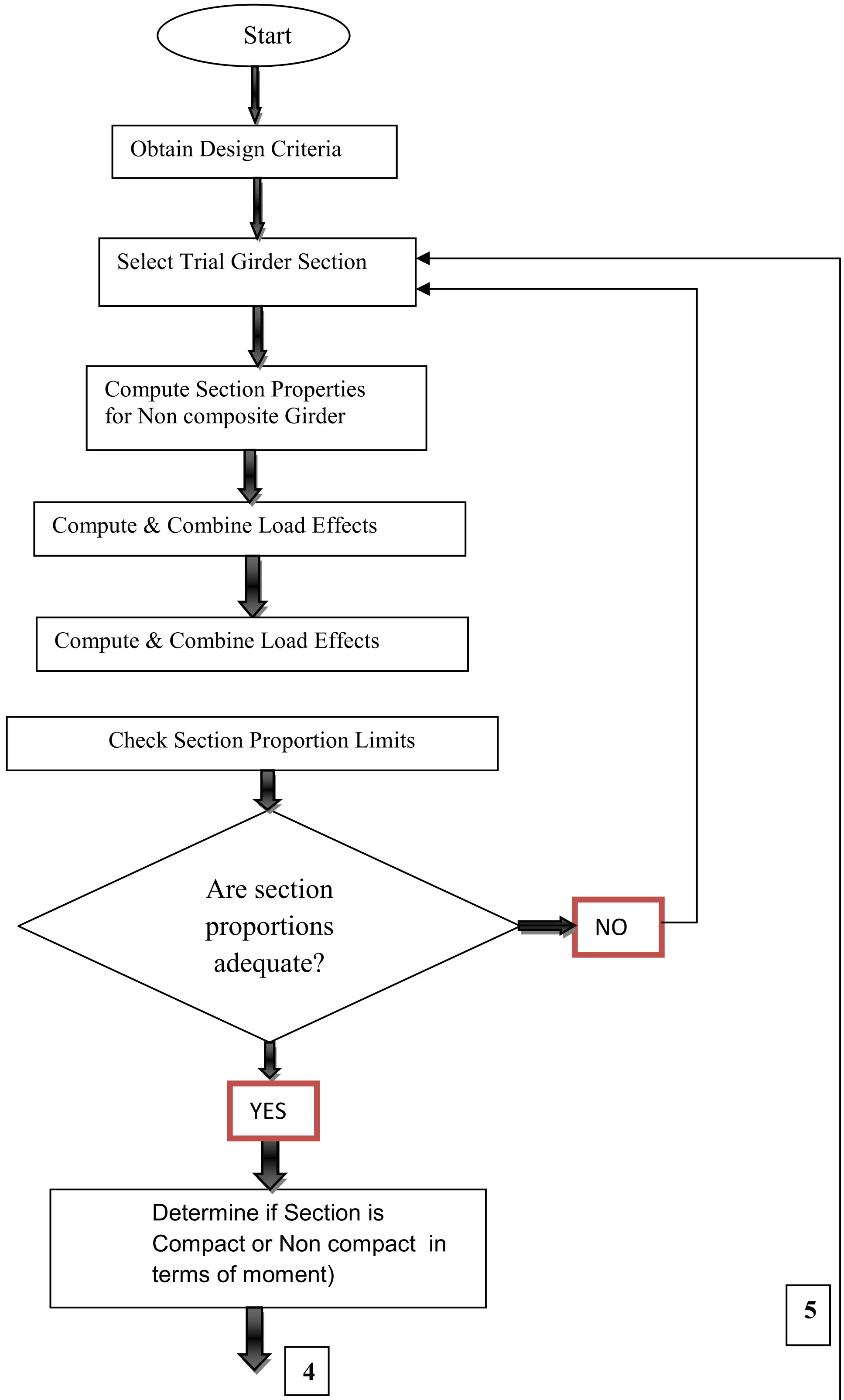


Figure 4.3 CIPPTBGB Superstructure design Flow chart

4.3.4. Steel Girder Design Flowchart



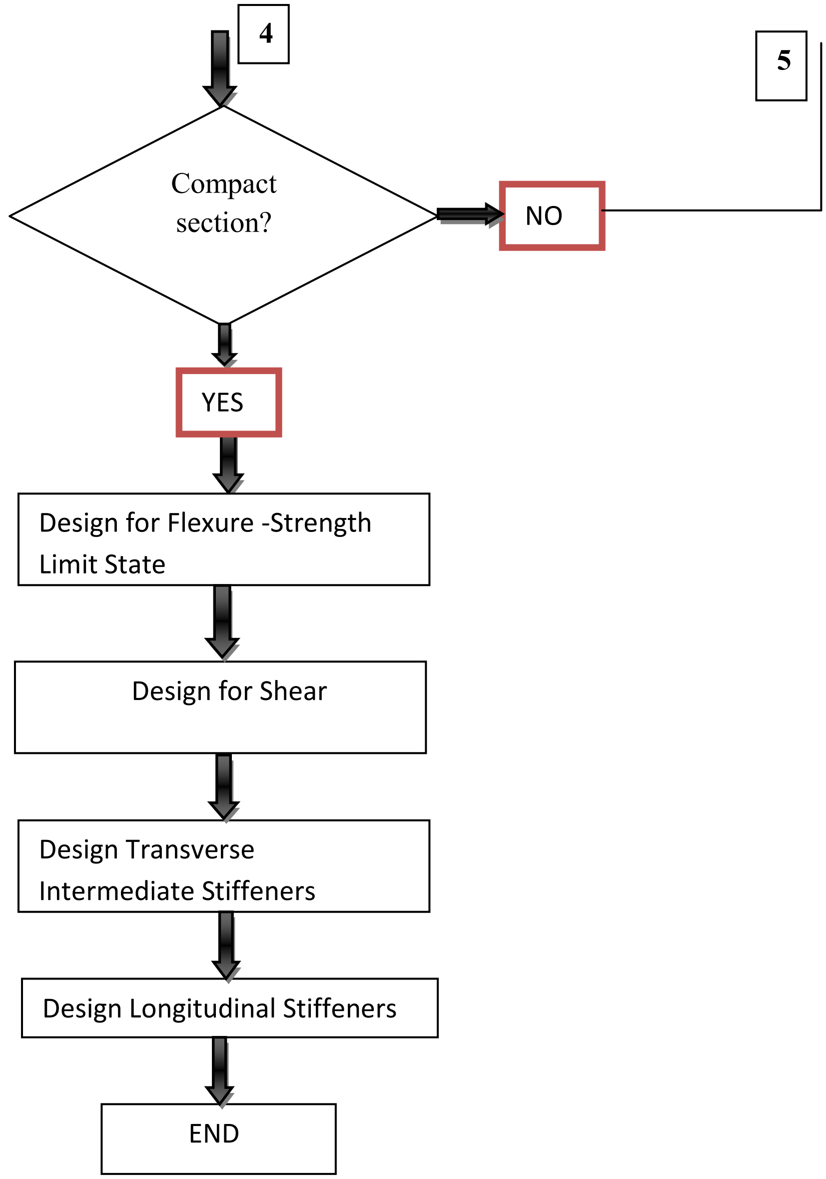


Figure 4.3 Steel Girder Design Flowchart

5. Design Example

5.1. Design Outputs

The summary of necessary outputs obtained from the design program for a span range of 40m to 120mm in place post tensioned box girder bridge and steel plate Bridges are provided in Table 4.1 and Table 4.2, respectively. To show the whole process of computation involved in the program, the detailed Input-Output of a 40m in place post tensioned box girder bridge and steel plate Bridges are attached in Annex 1.

5.2. Summary on Outputs

5.2.1. Cost Analysis

The materials volume obtained from the output of the program and current material prices are used for the cost analysis in order to identify the economical span of the two types of bridges.

The cost of the main girders and cross-girders will be directly proportional to the span. The cost of substructure will be the cost of abutments, which will not vary, and cost of piers.
For cost analysis, recent values of construction costs including overhead cost are used here. Table 5.1 shows the cost for different items.

Table 5-1 Cast in Place Box Girder Bridge Design output

SPAN	WIDTH (m)	DECK slab THICKNESS (mm)	over hang thickness	Bottom Slab thickness	overhang length	bottom slab width	structural depth	web thickness	No of girders	deck slab reinforcement				Bottom slab rein.		Over hang reinfor. mm2 /mm	area of prestressing steel	number of ducts	number of strands	shear reinf.		anchorage zone reinforcement	
										Positive mm2 /mm	spacing mm	Negative mm2 /mm	spacing mm	para mm2/ mm	trans mm2 /mm					area	spacing	As1	As2
40	12	180	280	140	1200	9600	1800	300	5	1.59	120	2.2	90	0.72	0.9	1.55	23914.2	10	114	2009.6	450	10/450	10/450
45	12	205	305	140	1200	9600	2100	300	5	1.56	120	2.09	95	0.82	1.03	1.37	29139.2	10	140	2009.3	400	10/450	10/450
50	12	225	325	150	1200	9600	2250	300	5	1.46	135	1.9	105	0.9	1.13	1.25	35569.9	15	172	2009.6	365	10/450	10/450
55	12	250	350	170	1200	9600	2500	300	5	1.36	145	1.71	115	1	1.25	1.13	42402.6	15	206	2009.6	365	10/450	10/450
60	12	270	370	180	1200	9600	2700	300	5	1.29	155	1.6	120	1.08	1.35	1.05	49637.1	15	242	2009.6	335	10/450	10/450
65	12	300	400	200	1200	9600	3000	300	5	1.21	165	1.47	135	1.2	1.5	0.95	57474.6	20	281	2009.6	340	10/450	10/450
70	12	315	415	210	1200	9600	3150	300	5	1.17	170	1.41	140	1.26	1.58	0.91	66115.8	20	324	2009.6	315	10/450	10/450
75	12	340	440	225	1200	9600	3375	300	5	1.12	175	1.33	150	1.36	1.7	0.85	75960	20	370	2009.6	295	10/450	10/450
80	12	360	460	240	1200	9600	3600	300	5	1.09	180	1.28	155	1.44	1.8	0.8	85006.1	25	418	2009.6	300	10/450	10/450
85	12	385	485	260	1200	9600	3825	300	5	1.05	190	1.23	160	1.54	1.93	0.75	95657	25	471	2009.6	280	10/450	10/450
90	12	410	510	270	1200	9600	4100	300	5	1.02	195	1.18	170	1.64	2.05	0.71	105705	30	521	2009.6	285	10/450	10/450
95	12	430	530	285	1200	9600	4275	300	5	1	200	1.14	175	1.72	2.15	0.68	117562	30	580	2009.6	270	10/450	10/450
100	12	450	550	300	1200	9600	4500	300	5	0.98	200	1.11	180	1.8	2.25	0.65	129619	35	640	2009.6	260	10/450	10/450
105	12	475	575	315	1200	9600	4725	300	5	0.95	210	1.08	180	1.9	2.38	0.62	142280	35	703	2009.3	245	10/450	10/450
110	12	495	595	330	1200	9600	4950	300	5	0.94	210	1.06	190	1.98	2.48	0.59	155342	40	768	2009.6	250	10/450	10/450
115	12	520	620	350	1200	9600	5175	300	5	0.92	215	1.03	195	2.08	2.6	0.57	169811	45	840	2009.6	235	10/450	10/450
120	12	540	640	360	1200	9600	5400	300	5	0.9	220	1.01	195	2.16	2.7	0.55	183476	45	908	2009.6	240	10/350	10/451

Table 5-2 Steel Plate Girder Bridge Design output

SPAN	WIDTH	DECK slab THICKNESS	overhang thickness	overhang length	deck slab reinforcement				Overhang rein. mm2/mm	number of girders	Steel Girder section					Stiffeners						Flange to web welds
					Positive mm2/mm	spacing mm	Negative mm2/mm	spacing mm			flange width bf	flange thickness tf	web height hw	stiffener spacing	web thickness tw	Inermediate Stiffeners	weld size	Load Carrying stiffeners	weld size	End-post design	weld size	
40	12	200	230	1200	1.12	175	1.05	190	3.877	5	850	35	1930	1800	20	90/15	5	120/14	6	350/50	8	5
45	12	200	230	1200	1.12	175	1.03	195	3.877	5	900	40	2170	2000	20	100/15	5	120/20	6	400/50	8	5
50	12	200	230	1200	1.12	175	0.98	205	3.877	5	1000	45	2410	2225	20	110/20	5	120/20	6	410/65	8	5
55	12	200	230	1200	1.12	175	0.93	215	3.877	5	1100	50	2650	2450	22	110/20	5	120/20	6	440/80	8	5
60	12	200	230	1200	1.12	175	0.88	225	3.877	5	1200	55	2890	2700	24	120/20	5	120/20	6	470/100	8	5
65	12	200	230	1200	1.12	175	0.87	230	3.877	5	1300	55	3140	2880	26	120/20	6	120/20	8	510/120	8	5
70	12	200	230	1200	1.12	175	0.86	230	3.877	5	1400	60	3380	3100	28	130/20	8	120/20	8	560/160	8	5
75	12	200	230	1200	1.12	175	0.85	235	3.877	5	1500	65	3620	3320	30	130/20	8	130/30	8	560/160	8	5
80	12	200	230	1200	1.12	175	0.84	235	3.877	5	1600	70	3860	3550	32	150/20	8	140/30	10	560/160	8	5
85	12	200	230	1200	1.12	175	0.83	240	3.877	5	1700	75	4100	3770	34	150/20	8	150/30	10	560/170	8	5
90	12	200	230	1200	1.12	175	0.82	240	3.877	5	1800	80	4340	4000	36	150/20	10	150/40	10	560/180	8	5
95	12	200	230	1200	1.12	175	0.82	245	3.877	5	1900	85	4580	4210	38	150/25	10	150/40	12	590/200	8	5
100	12	200	230	1200	1.12	175	0.82	245	3.877	5	2000	85	4830	4430	40	155/25	12	160/40	12	610/210	8	5
105	12	200	230	1200	1.12	175	0.8	250	3.877	5	2100	90	5070	4650	42	165/30	12	160/50	12	620/220	8	5
110	12	200	230	1200	1.12	175	0.79	255	3.877	5	2200	95	5310	4870	44	165/30	12	160/60	14	630/230	8	5
115	12	200	230	1200	1.12	175	0.78	255	3.877	5	2300	100	5550	5100	46	165/30	12	160/70	14	660/250	8	5
120	12	200	230	1200	1.12	175	0.77	260	3.877	5	2400	110	5780	5310	48	190/35	14	180/70	14	660/250	8	5

Table 5-3 Unit price for materials

No	Material	Unit	Unit price(Bir)
1	Reinforcing bars	Kg	40.00
2	Concrete	m^3	2,500.00
3	Formwork	m^2	400.00
6	Prestressing strand	m	40.00
7	Duct	m	500.00

Table 5-4 Total costs for different span lengths.

span (m)	CIPPTBGB (Birr)	SPGB (Birr)
40	3,110,463.03	3,810,746.93
45	3,629,366.80	4,260,657.97
50	4,146,586.62	4,687,692.34
55	4,711,943.25	5,117,098.40
60	5,302,844.79	5,547,796.01
65	5,927,375.37	6,006,454.38
70	6,585,223.56	6,498,539.99
75	7,310,072.44	6,962,576.69
80	8,015,282.50	7,467,082.30
85	8,791,878.75	7,942,200.15
90	9,561,092.72	8,461,227.55
95	10,393,492.34	8,957,348.35
100	11,262,654.45	9,470,636.55
105	12,162,803.71	9,972,551.27
110	13,079,945.81	10,490,544.24
115	14,069,910.34	11,044,157.51
120	15,038,501.84	11,613,260.84

Relationship between span length and total cost of a superstructure for bridge span length of ranging from 40 to 120 m is shown in Figure 5.1.

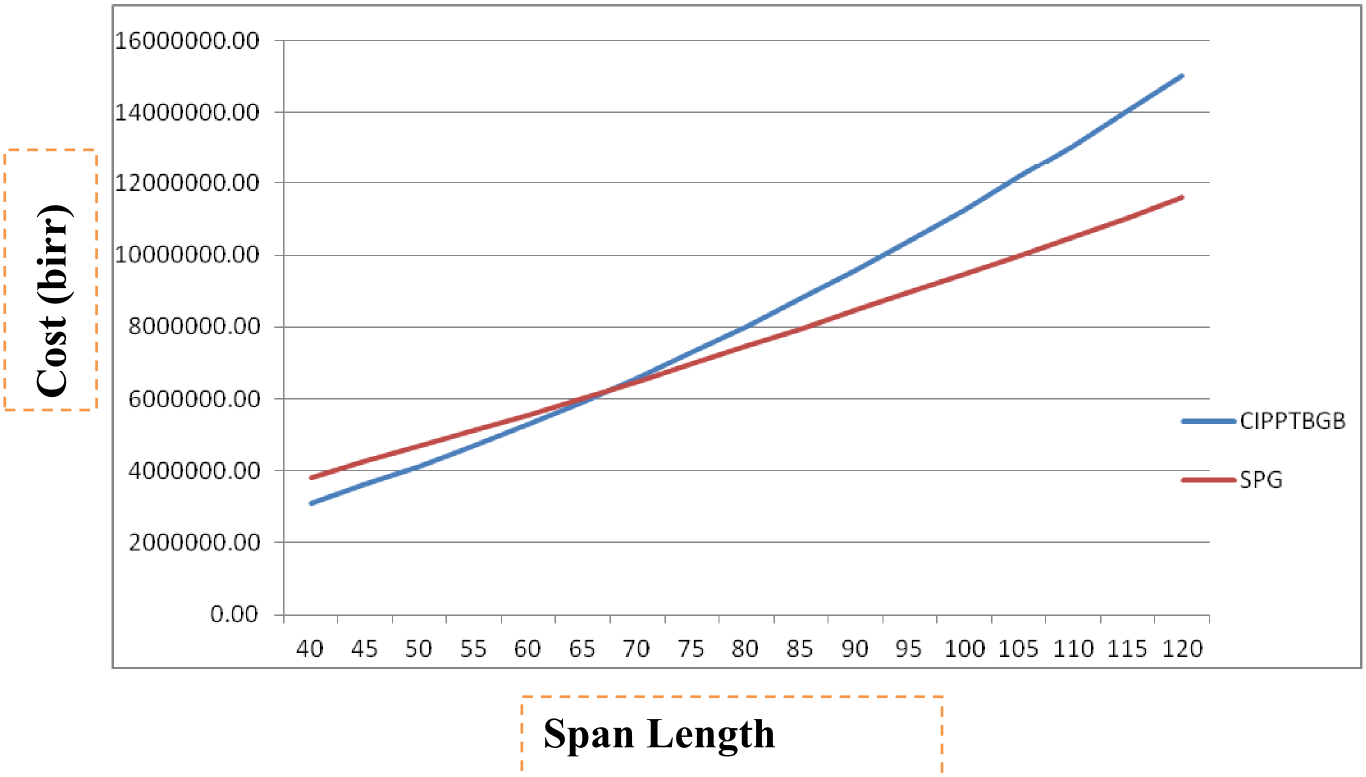


Figure 5.21 Span Length Verse Cost graph

6. Conclusions and Recommendation

6.1. Conclusions

This study has attempted to deal with the selection problem of cast in place box girder and Steel Plate Girder Bridges. From the observation of the result of Figure 5.1 cost comparison for superstructure of the two types of bridges based on the current cost, it is found that span seventy meters is the demarcation span for selecting Cast in Place Post Tension Box Girder or Steel Plate Girder Bridge. Therefore, up to 70m Cast in Place Post Tension Box Girder Bridges are economical. Beyond this length, Steel Plate Girder Bridges are economical.

6.2. Recommendations

From the study that has carried out, the followings are the recommendations drawn from the result:

1. Cast in Place Post Tensioned Box Girder Bridge is economical up to 70m.
2. Steel Plate Bridge is economical beyond 70m.
3. As the developed program is easy to apply, consulting firms can make use of the program for analysis and design of Cast in Place Post Tensioned Box Girder Bridge and Steel Plate Bridge.

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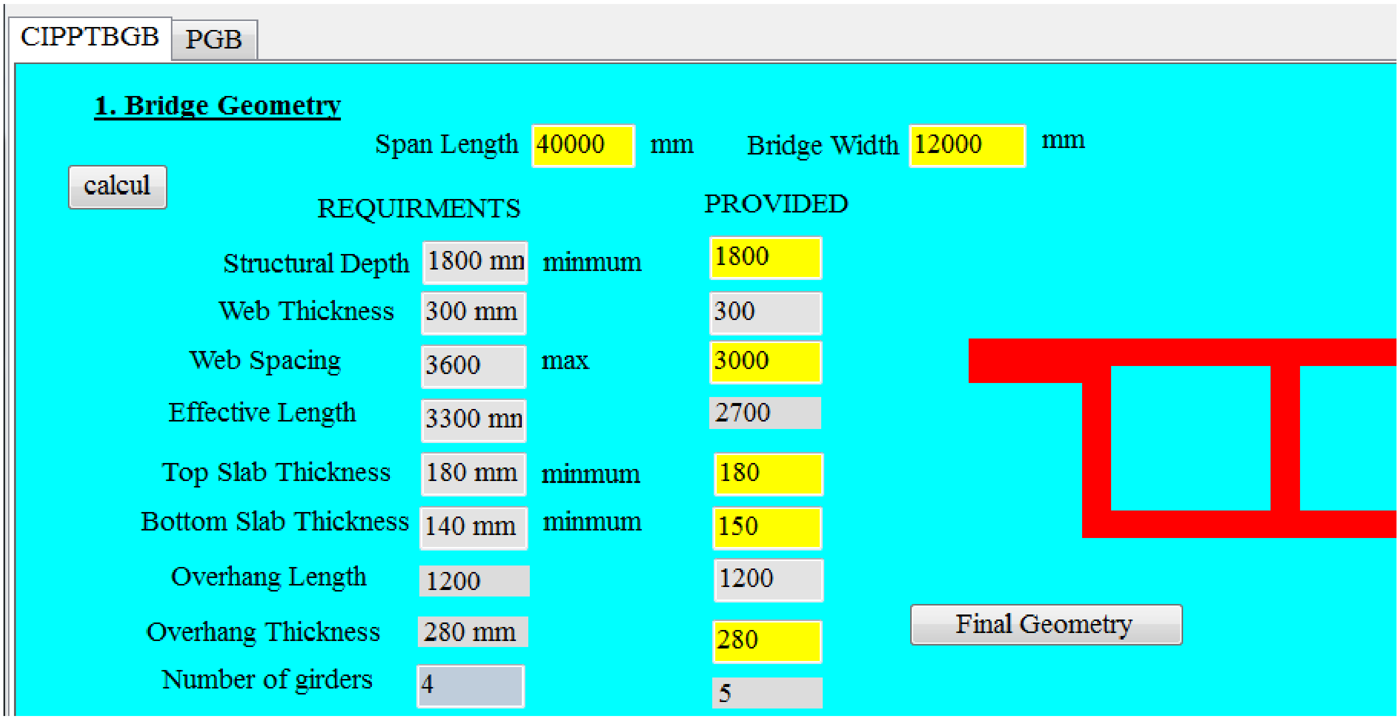
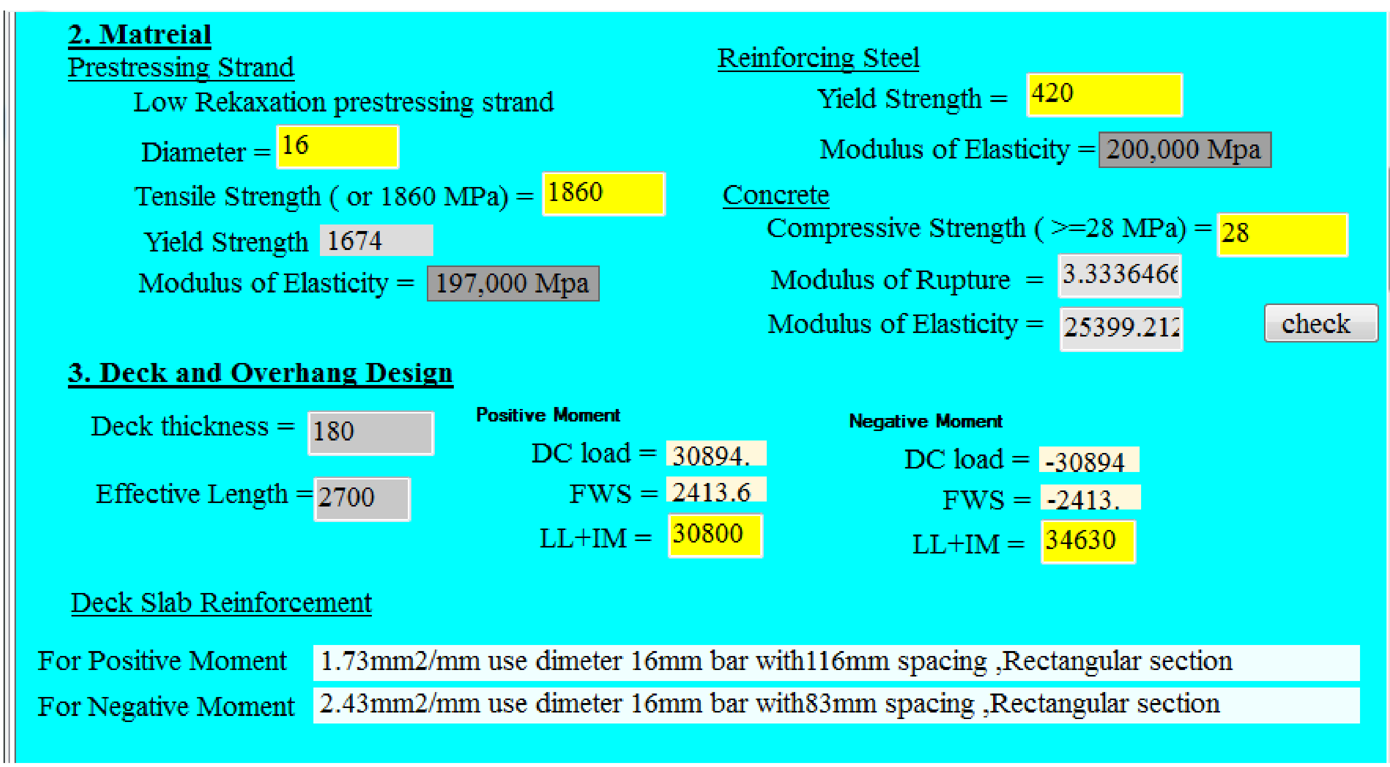
ANNEXES 1 Design Example





Bottom Slab Reinforcement

Parallel to span = 0.72 mm2/mm Transverse to span = 0.90 mm2/mm

Deck Overhang Design

Design Case 1: Transverse forces specified in Article A13.2
Extreme Event Limit Combination II Limit State

Overhang Thickiness = 280 mm

The required area of reinforcement= 1.55 mm2/mm

check

. Superstructur Design

:tion Properties Area = 6540000.00 Inertia = 1992871207887.73 Yb= 932.85 Yt = 867.1

Dead Loads and Midspan Moments

;uperstructure =	153977.76N/m	30795552.00Nm
Barrier =	7740.09N/m	1548018.00Nm
FWS =	3310.88N/m	662175.00Nm

Live Load Midspan Moments

Design Truck =	2864.20Nm
Design Lane Load =	1860.00Nm
Design Tandem =	2134.00Nm
LL+IM =	9820.23

Prestressing Steel = 24919.04

umber of Strands = 119

Use 2 tendons per web. This requires that each duct holds a maximum of 22 strands.

Shear Design

Dead Loads Max. shear

Superstructure = 2880000023.04

Barrier = 144770643.36

FWS = 61926606.00

Live Load Max. shear

Design Truck = 162.51

Design Lane Load = 2011.18

Design Tandem = 110.00

LL+IM =

Lab

Lab

bv= 1362.5 dv= 1296 Vu= 3873870.43 Vp= 2431.22 Vn= 2738617

2.44

vu/f'c = 0.09 εx= -0.352 θ = 26.8 β = 2.44

Required Vertical Reinforcement = 2009.6 Spacing = 450 OK;;;

TBGB PGB

Design Criteria

Governing specifications:- AASHTO LRFD Bridge Design Specifications

Deck width: 12000

Bridge length: 40000

Structural steel yield : 345

Structural steel tensile : 450

ncrete 28-day compressive strength: 28

Reinforcement strength: 420

Steel density: 77 KN/m

Concrete density: 24 KN/m

Parapet weight (each): 7.75 KN/

Future wearing surface: 22.5 KN/

Future wearing surface thickness: 63.5mm

Superstructure Cross Section

Girder Spacing: 3000 Overhang Length: 1200 Number of Girders : 4

Concrete Deck Design

Deck properties:

Deck Slab Thickness (>=175mm): 200

Overhang Thickness (>=200mm): 230

Deck Bottom Cover : 60mm

Deck Top Cover : 25mm

Parapet properties:

Width at base: 438mm

Moment capacity at base*: 125478 Nmm/mm

Parapet height: 1067mm

Critical length of yield line failure pattern*: Lc = 3600mm

Total transverse resistance of the parapet*: Rw = 522.22kN

Positive Moment

DC load = 4320 FWS = 1285.8

LL+IM = 30800

Negative Moment

DC load = -4320 FWS = -1285.

LL+IM = 23120

Deck Slab Reinforcement

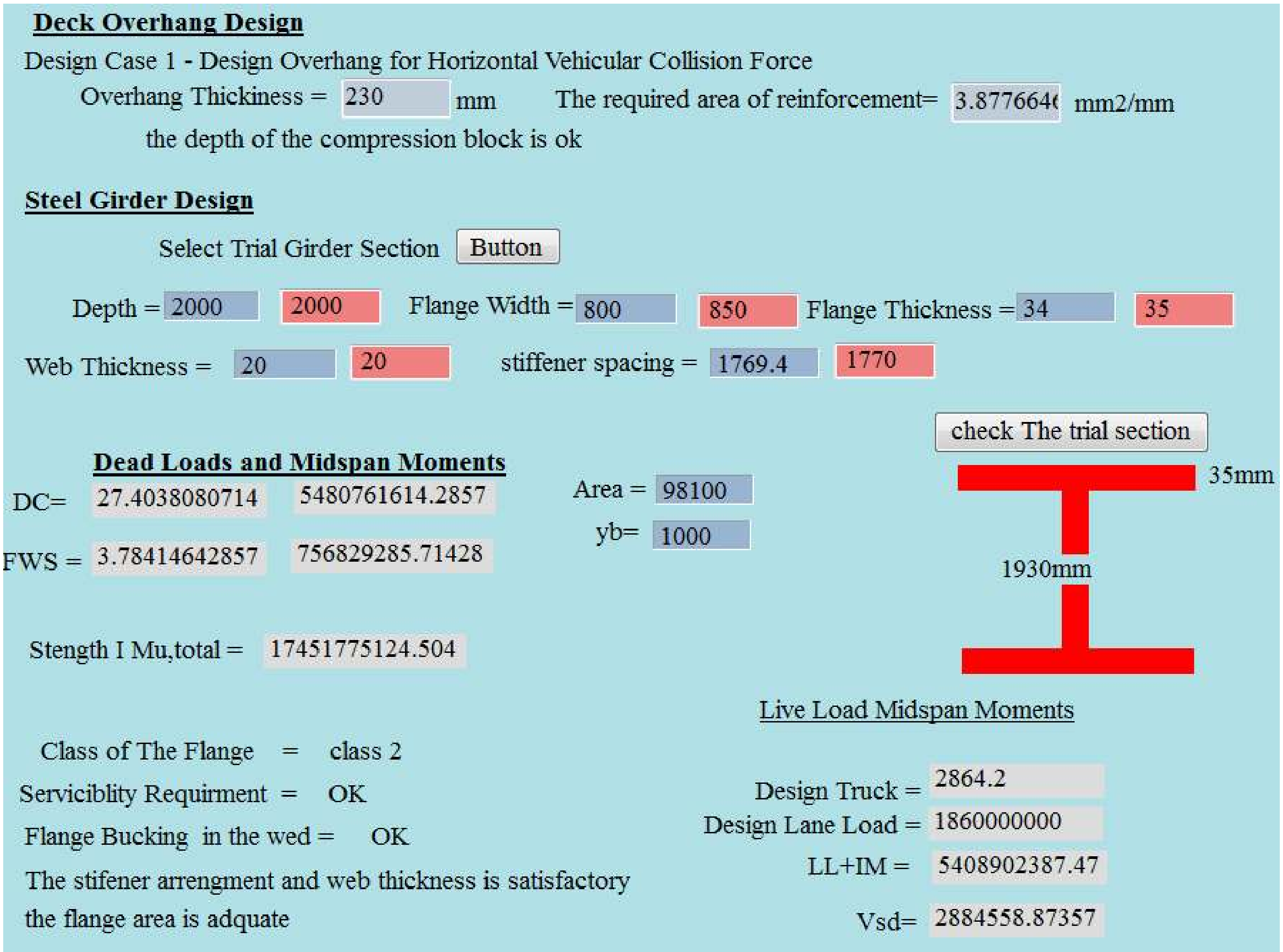
Design 1

For Positive Moment

required amount of reinforcing steel is 1.12 mm2/mm use dimeter 16mm bar with 179 bar spacing

For Negative Moment

required amount of reinforcing steel is 1.03 mm2/mm use dimeter 16mm bar with 195 bar spacing



Deck Overhang Design
Design Case 1 - Design Overhang for Horizontal Vehicular Collision Force
Overhang Thickness = 230 mm
The required area of reinforcement= 3.877664(mm2/mm
the depth of the compression block is ok
Steel Girder Design
Select Trial Girder Section
Button
Depth = 2000 2000
Flange Width = 800 850
Flange Thickness = 34 35
Web Thickness = 20 20
stiffener spacing = 1769.4 1770
check The trial section
Dead Loads and Midspan Moments
DC= 27.4038080714 5480761614.2857
FWS = 3.78414642857 756829285.71428
Area = 98100
yb= 1000
35mm
1930mm
Stength I Mu,total = 17451775124.504
Live Load Midspan Moments
Class of The Flange = class 2
Servicibltiy Requirment = OK
Flange Bucking in the wed = OK
The stifener arrengment and web thickness is satisfactory
the flange area is adquate
Design Truck = 2864.2
Design Lane Load = 1860000000
LL+IM = 5408902387.47
Vsd= 2884558.87357

Design of Stiffeners

a). Inermediate Stiffeners

- Trial stiffeners section bs= 70 ts = 20 check

the stiffener area is sufficent with respect to stiffenesuse.use ts=20

The outstand is less then 13ts .use bs=107.292097578986..........OK

107.292 20

- Buckling Resistance Stiffeners L= 0.48846 X= 0.8973

Buckling Resistance is OK

- Connection between web and stiffeners Check

Weld Size = 8

use 8mm fillet welds

b). Load Carrying stiffeners

- Trial stiffeners section bs= 120 ts = 10

**

**

120 10 Button

- Buckling Resistance Stiffeners L= 1.72650 X= 0.2577

Buckling Resistance is OK

-Bearing Resistance

Bearing Resistance is OK

- Connection between web and stiffeners

Weld Size = 10

use 10mm fillet welds

Check

c). End-post design Button

- Trial stiffeners section bs= 350 ts = 60

**

350 60

- Buckling Resistance Stiffeners L= 0.29063 X= 0.94

Buckling Resistance is OK

-Bearing Resistance

Bearing Resistance is OK

- Connection between web and stiffeners

Weld Size = 12

use 12mm fillet welds

ANNEXES 2 Programming code

Programming code

Cast in place post tension prestressed box girder bridge design

```
Public Class comparative

    Private Sub Form1_Load(sender As Object, e As EventArgs) Handles MyBase.Load
    End Sub
    Private Sub Button4_Click(sender As Object, e As EventArgs) Handles Button4.Click
        'CIPPTBFB
        Dim spanlength As Double
        Dim bridgewidth As Double
        Dim structuraldepth As Double
        Dim webthickness As Double
        Dim webspacing As Double
        Dim effectivelength As Double
        Dim topslabthickness As Double
        Dim topslabthick As Double
        Dim bottomslabthickness As Double
        Dim bottomslabthick As Double
        Dim overhanglength As Double
        Dim overhangthickness As Double
        Dim numberofgirders As Integer
        spanlength = spanlength1.Text
        bridgewidth = bridgewidth1.Text
        structuraldepth = 0.045 * spanlength
        structuraldepth1.Text = structuraldepth & " mm"
        webthickness = 300
        webthickness1.Text = 300 & " mm"
        webspacing = 2 * structuraldepth
        webspacing1.Text = webspacing
        effectivelength = webspacing - webthickness
        effectivelength1.Text = effectivelength & " mm"
        topslabthick = webspacing * 0.05
        If topslabthick > 175 Then
```

```
            topslabthickness = topslabthick
            topslabthickness1.Text = topslabthickness & " mm"
        Else
            topslabthickness = 175
            topslabthickness1.Text = 175 & " mm"
        End If
        bottomslabthick = webspacing * 0.0333
        If bottomslabthick > 140 Then
            bottomslabthickness = bottomslabthick
            bottomslabthickness1.Text = bottomslabthickness & " mm"
        Else
            bottomslabthickness = 140
            bottomslabthickness1.Text = 140 & " mm"
        End If
        overhanglength = 1200
        overhanglength1.Text = 1200 & " mm"
        overhangthickness = topslabthickness + 100
        overhangthickness1.Text = overhangthickness & " mm"
        numberofgirders = (((bridgewidth - (2 * overhanglength)) / webspacing) + 1)
        numberofgirder1.Text = numberofgirders
    End Sub

    Private Sub numberofgirder1_TextChanged(sender As Object, e As EventArgs) Handles
numberofgirder1.TextChanged

    End Sub
    Private Sub Button3_Click(sender As Object, e As EventArgs) Handles Button3.Click
        Dim bridgewidth As Double
        Dim pstructuraldepth As Double
        Dim pwebthickness As Double
        Dim pwebspacing As Double
        Dim peffectivelength As Double
        Dim ptopslabthickness As Double
        Dim pbottomslabthickness As Double
        Dim poverhanglength As Double
        Dim poverhangthickiness As Double
        Dim pnumberofgirders As Integer
        bridgewidth = bridgewidth1.Text
        pstructuraldepth = structuraldepth2.Text
```

```
        pwebthickness = 300
        webthickness2.Text = pwebthickness
        pwebspacing = webspacing2.Text
        peffectivelength = pwebspacing - pwebthickness
        effectivelength2.Text = peffectivelength
        ptopslabthickness = topslabthickness2.Text
        pbottomslabthickness = bottomslabthickness2.Text
        overhanglength2.Text = 1200
        poverhangthickiness = overhangthickness2.Text
        pnumberofgirders = (((bridgewidth - (2 * poverhanglength)) / pwebspacing) + 1)
        numberofgirder2.Text = pnumberofgirders
    End Sub

    Private Sub CIPPTBGB_Click(sender As Object, e As EventArgs) Handles CIPPTBGB.Click
    End Sub
    Private Sub Button5_Click(sender As Object, e As EventArgs) Handles Button5.Click
```

Deck design

```
        Dim deckthickness As Double
        Dim effectivelength4 As Double
        Dim Apara As Double
        Dim Atra As Double
        Dim overhangthicknesss As Double
        Dim mco As Double
        Dim mdcdeck As Double
        Dim mdcpra As Double
        Dim mutotal As Double
        Dim tensile As Double
        Dim de As Double
        Dim Rn As Double
        Dim p As Double
        Dim fc As Double
        Dim fy As Double
        Dim ass As Double
        Dim ta As Double
        Dim c As Double
        Dim a As Double
        Dim mn As Double
```

```
Dim mdc As Double
Dim mfws As Double
Dim LLIM As Double
Dim LLIMN As Double
Dim mup As Double
Dim mun As Double
Dim dep As Double
Dim den As Double
Dim zp As Double
Dim asdp As Double
Dim zn As Double
Dim asdn As Double
Dim barspacingn As Integer
Dim barspacingp As Integer
Dim webthickness As Double
Dim ar As Double
Dim at As Double
Dim aspf1 As Double
Dim mu1 As Double
Dim mu2 As Double
Dim aspw1 As Double
Dim ast As Double
Dim barspacingt As Double
Dim arn As Double
Dim aspfn1 As Double
Dim mun1 As Double
Dim mun2 As Double
Dim aspwn1 As Double
Dim astn As Double
Dim barspacingtn As Double
Dim atn As Double

webthickness = webthickness2.Text
fc = compstrength.Text
fy = yildstr.Text
overhangthicknesss = overhangthickness2.Text
overthi.Text = overhangthicknesss
effectivelength4 = effectivelength2.Text
deckthickness = topslabthickness2.Text
```

```
        effectivelength3.Text = effectivelength4
        deckthickness1.Text = deckthickness

        Apara = 0.004 * deckthickness
        Atra = 0.005 * deckthickness
        Apara1.Text = Apara.ToString("0.00") & " mm2/m"
        Atra1.Text = Atra.ToString("0.00")
        mco = 125478
        mdcdeck = 2.823 * overhangthicknesss
        mdcpra = 2723
        mutotal = mco + mdcdeck + mdcpra
        tensile = 91
        de = overhangthicknesss - 68
        Rn = mutotal / (de * de)

        p = (0.85 * (fc / fy)) * (1 - ((1 - ((2 * Rn) / (0.85 * fc))) ^ 0.5))
        ass = p * de
        AS1.Text = ass.ToString("0.00")
        ta = fy * ass
        c = ta - tensile
        a = c / (0.85 * fc)
        mn = (ta * (de - (a / 2))) - (tensile * ((de / 2) - (a / 2)))
        If mn > mutotal Then
            Label76.Text = "the depth of the compression block is adequate "
        Else
            Label76.Text = "the depth of the compression block not adequate"
        End If
        mdc = (deckthickness * 2400 * effectivelength4 * effectivelength4 * 9.81) /
1000000000
        DC.Text = mdc
        mfws = (9.81 * 15 * 2250 * effectivelength4 * effectivelength4) / 1000000000
        FWS.Text = mfws
        fwsn.Text = -mfws
        dcn.Text = -mdc
        LLIM = LLIMMm.Text
        LLIMN = llimmn.Text
        mup = (1.25 * mdc) + (1.5 * mfws) + (1.75 * LLIM)
        mun = (1.25 * mdc) + (1.5 * mfws) + (1.75 * LLIMN)
```

```
        dep = deckthickness - 25 - 8
        zp = (1.7 * fc * 1000 * dep) / fy
        asdp = (zp / 2) * (1 - ((1 - ((4 * mup) / (0.9 * fy * dep * zp))) ^ 0.5))
        ar = (asdp * fy) / (0.85 * fc * 1000)
        barspacingp = 200.96 / asdp
        aspf1 = (fc * deckthickness * 1000 * (1000 - webthickness)) / fy
        mu1 = aspf1 * fy * (dep - (0.5 * webthickness))
        mu2 = mup - mu1
        at = dep - (((dep * dep) - ((2 * mu2) / (fc * webthickness))) ^ 0.5)
        aspw1 = fc * webthickness * at / fy
        ast = aspf1 + aspw1
        barspacingt = 200.96 / ast
        If ar <= (deckthickness * 0.5) Then
            Label120.Text = asdp.ToString("0.00") & "mm2/mm use dimeter 16mm bar with" &
barspacingp & "mm spacing ,Rectangular section"
        Else
            Label120.Text = ast.ToString("0.00") & "mm2/mm use dimeter 16mm bar with" &
barspacingt & "mm spacing ,T section "
        End If
        den = deckthickness - 60 - 8
        zn = (1.7 * fc * 1000 * den) / fy
        asdn = (zn / 2) * (1 - ((1 - ((4 * mun) / (0.9 * fy * den * zn))) ^ 0.5))
        arn = (asdn * fy) / (0.85 * fc * 1000)
        barspacingn = 200.96 / asdn
        aspfn1 = (fc * deckthickness * 1000 * (1000 - webthickness)) / fy
        mun1 = aspf1 * fy * (den - (0.5 * webthickness))
        mun2 = mun - mun1
        atn = den - (((den * den) - ((2 * mun2) / (fc * webthickness))) ^ 0.5)
        aspwn1 = fc * webthickness * atn / fy
        astn = aspfn1 + aspwn1
        barspacingtn = 200.96 / astn
        If arn <= (deckthickness * 0.5) Then
            Label119.Text = asdn.ToString("0.00") & "mm2/mm use dimeter 16mm bar with" &
barspacingn & "mm spacing ,Rectangular section"
        Else
            Label119.Text = astn.ToString("0.00") & "mm2/mm use dimeter 16mm bar with" &
barspacingtn & "mm spacing ,T section "
        End If
    End Sub
```

```
    Private Sub Button6_Click(sender As Object, e As EventArgs) Handles Button6.Click
        Dim dimeter As Integer
        Dim yieldstrength As Double
        Dim tensilestrength As Double
        Dim yieldstrengthr As Double
        Dim compressivestre As Double
        Dim modulusofrup As Double
        Dim Moduelascon As Double
        dimeter = diameterprstrand.Text
        tensilestrength = Fs.Text
        yieldstrength = 0.9 * tensilestrength
        Fy.Text = yieldstrength
        yieldstrengthr = yildstr.Text
        compressivestre = compstrength.Text
        modulusofrup = 0.63 * (compressivestre ^ 0.5)
        modurup.Text = modulusofrup
        Moduelascon = 4800 * ((compressivestre) ^ 0.5)
        Epc.Text = Moduelascon
    End Sub
    Private Sub overhangthickness2_TextChanged(sender As Object, e As EventArgs) Handles
overhangthickness2.TextChanged
    End Sub
```

Superstructure design

```
    Private Sub Button7_Click(sender As Object, e As EventArgs) Handles Button7.Click
        Dim yb As Double
        Dim yt As Double
        Dim I As Double
        Dim tdacks As Double
        Dim tbottoms As Double
        Dim s As Double
        Dim h As Double
        Dim NG As Double
        Dim ovlength As Double
        Dim ovthickiness As Double
        Dim A As Double
        Dim tweb As Double
        Dim I1A As Double
        Dim I2A As Double
```

```
Dim I3A As Double
Dim I1B As Double
Dim I2B As Double
Dim I3B As Double
Dim bridgewidth As Double
Dim wdc As Double
Dim wbrr As Double
Dim wfws As Double
Dim Mdc As Double
Dim Mbr As Double
Dim Mfws As Double
Dim Se As Double
Dim designlane As Double
Dim designtruck As Double
Dim designtendon As Double
Dim L As Double
Dim LLDis1 As Double
Dim LLDis2 As Double
Dim LLdis As Double
Dim LLIMs As Double
Dim Must As Double
Dim Muse As Double
Dim Ms As Double
Dim emax As Double
Dim k As Double
Dim u As Double
Dim angle As Double
Dim fpj As Double
Dim fpu As Double
Dim fpFnojackingend As Double
Dim ex As Double
Dim dfpfnj As Double
Dim fpFmidspan As Double
Dim dfpFms As Double
Dim anchorsetlength As Double
Dim Ep As Double
Dim ΔfpA As Double
Dim dfpAend As Double
Dim dfpAmid As Double
```

```
Dim fpAend As Double
Dim fpAmid As Double
Dim JackingEnd As Double
Dim Midspan As Double
Dim EndSeating As Double
Dim NonJackingEnd As Double
Dim elasticshorteningloss As Double
Dim timedependentlosses As Double
Dim FCf As Double
Dim AllowableTension As Double
Dim fc As Double
Dim Pjs As Double
Dim Pjd As Double
Dim pj As Double
Dim Aps As Double
Dim NumberofStrands As Integer
Dim Apsp As Double
Dim diameter As Double
Dim asp As Double
Dim numberofducts As Integer
Dim Epp As Double
Dim cgducts As Double
Dim cgstrands As Double
Dim AllowableCompression As Double
Dim peff As Double
Dim ficb As Double
Dim fict As Double
Dim ds As Double
Dim B1 As Double
Dim c1 As Double
Dim c2 As Double
Dim c As Double
Dim aa As Double
Dim et As Double
Dim fps As Double
Dim Mnr As Double
Dim Mnt As Double
Dim Mn As Double
Dim fr As Double
```

```
        Dim Sc As Double
        Dim pf As Double
        Dim fcpe As Double
        Dim Mcr As Double
        Dim mm As Double
        Dim nn As Double
        Dim fic As Double
        Dim Ec As Double
        Dim fy As Double
        Dim tt As Double

        fy = yildstr.Text
        Ec = Epc.Text
        fr = modurup.Text
        Epp = Epc.Text
        fc = compstrength.Text
        fpu = Fs.Text
        L = spanlength1.Text / 1000
        bridgewidth = bridgewidth1.Text
        tdacks = topslabthickness2.Text
        tbottoms = bottomslabthickness2.Text
        s = effectivelength2.Text
        tweb = webthickness2.Text
        h = structuraldepth2.Text
        ovthickiness = overhangthickness2.Text
        ovlength = overhanglength2.Text
        NG = numberofgirder2.Text
        A = (2 * ovlength * ovthickiness) + (2 * tweb * h) + (2 * ((0.5 * s) - (tweb *
0.5)) * tbottoms) + (2 * ((0.5 * s) - (tweb * 0.5)) * tdacks) + ((NG - 2) * ((tdacks * s)
+ (tbottoms * s) + ((h - tbottoms - tdacks) * tweb)))
        ae.Text = A.ToString("0.00")
        yb = ((2 * ovlength * ovthickiness * (h - (ovlength * 0.5))) + (2 * tweb * h * h
* 0.5) + (2 * ((0.5 * s) - (tweb * 0.5)) * tbottoms * tbottoms * 0.5) + (2 * ((0.5 * s) -
(tweb * 0.5)) * tdacks * (h - (tdacks * 0.5))) + ((NG - 2) * ((tdacks * s * (h - (tdacks
* 0.5))) + (tbottoms * tbottoms * 0.5 * s) + ((h - tbottoms - tdacks) * tweb * ((h -
tbottoms - tdacks) * 0.5) + tbottoms)))) / A
        yt = h - yb
        ybb.Text = yb.ToString("0.00")
        ytt.Text = yt.ToString("0.00")
```

```
        I1A = ((((tbottoms ^ 3) * ((s * 0.5) + (tweb * 0.5))) / 12) + (((s * 0.5) + (tweb * 0.5) * tbottoms) * ((yb - ((s * 0.5) + (tweb * 0.5))) ^ 2)))
        I2A = ((((h - tdacks - tbottoms) ^ 3) * tweb) / 12) + (((h - tdacks - tbottoms) * tweb) * ((yb - (((h - tdacks - tbottoms) / 2) + tbottoms) ^ 2)))
        I3A = (((tdacks ^ 3) * (ovlength + (s / 2))) / 12) + ((ovlength + (s / 2)) * tdacks * ((yb - (h - (tdacks / 2))) ^ 2))
        I1B = (((tbottoms ^ 3) * s) / 12) + ((s * tbottoms) * ((yb - (tbottoms / 2)) ^ 2))
        I2B = (((tweb ^ 3) * (h - tbottoms - tdacks)) / 12) + ((tweb * (h - tdacks - tbottoms) * ((yb - ((h - tdacks - tbottoms) / 2) + tbottoms) ^ 2)))
        I3B = (((tdacks ^ 3) * s) / 12) + ((tdacks * s) * ((yb - (h - (tdacks / 2))) ^ 2))
        I = (2 * (I1A + I2A + I3A)) + ((NG - 2) * (I1B + I2B + I3B))
        Ii.Text = I.ToString("0.00")
        wdc = (A / 1000000) * 2400 * 9.81
        wbrr = 789 * 9.81
        wfws = 0.15 * 2250 * 9.81
        Wdcc.Text = wdc.ToString("0.00") & "N/m"
        Wbdc.Text = wbrr.ToString("0.00") & "N/m"
        wfwss.Text = wfws.ToString("0.00") & "N/m"
        Se = s / 1000
        Mdc = (wdc * L * L) / 8
        Mbr = (wbrr * L * L) / 8
        Mfws = (wfws * L * L) / 8
        mdcc.Text = Mdc.ToString("0.00") & "Nm "
        mbrr.Text = Mbr.ToString("0.00") & "Nm "
        mfwss.Text = Mfws.ToString("0.00") & "Nm "
        designlane = 1.1625 * L * L
        designtruck = (81.28 * L) - 387
        designtendon = (55 * L) - 66
        dgntru.Text = designtruck.ToString("0.00") & "Nm "
        dsgnlan.Text = designlane.ToString("0.00") & "Nm "
        desigten.Text = designtendon.ToString("0.00") & "Nm "
        LLDis1 = (1.75 + (s / 1100)) * ((300 / (L * 1000)) ^ 0.35) * ((1 / NG) ^ 0.45)
        LLDis2 = ((13 / NG) ^ 0.3) * (s / 430) * ((1 / (L * 1000)) ^ 0.25)

        If LLDis1 > LLDis2 Then
            LLdis = (LLDis1 * NG)
        Else
```

```
    LLdis = (LLDis2 * NG)
End If

LLIMs = (designlane + (1.33 * designtruck)) * LLdis
llimm.Text = LLIMs.ToString("0.00") & "Nm"
'load combination
'strength I
Must = 1.25 * (Mdc + Mbr) + 1.5 * (Mfws) + 1.75 * (LLIMs)
'SERVICE I
Muse = 1.0 * (Mdc + Mbr + Mfws) + 1.0 * (LLIMs)
'SERVICE III
Ms = 1.0 * (Mdc + Mbr + Mfws) + 0.8 * (LLIMs)
'Prestress Design
'Friction Losses
emax = yb - 25 - 8
k = 0.0002
u = 0.25
angle = 2 * emax / (L * 500)
fpj = 0.74 * fpu
ex = 2.718282
fpFnojackingend = fpj * (1 - (ex ^ (-((k * L) + (u * angle)))))
dfpfnj = (1 - (ex ^ (-((k * L) + (u * angle)))))
fpFmidspan = fpj * (1 - (ex ^ (-((k * L * 0.5) + (u * angle)))))
dfpFms = (1 - (ex ^ (-((k * L * 0.5) + (u * angle)))))
'Anchor Set Losses
Ep = 197000
anchorsetlength = ((197000 * 10 * L) / (1000 * fpFnojackingend)) ^ 0.5
ΔfpA = (2 * fpFnojackingend * anchorsetlength) / L
'Anchor Set Loss At End:
fpAend = ΔfpA
dfpAend = ΔfpA / fpj
'Anchor Set Loss At Midspan:
fpAmid = ΔfpA * ((anchorsetlength - (0.5 * L)) / anchorsetlength)
dfpAmid = fpAmid / fpj
'force coefficient
JackingEnd = 1 - dfpAend
Midspan = 1 - dfpFms - dfpAmid
EndSeating = 1 - (dfpAend * 0.5)
NonJackingEnd = 1 - dfpfnj
```

```
        elasticshorteningloss = 0.0219 * fpj
        timedependentlosses = 0.1248 * fpj
        'final force coefficient at midspan
        FCf = Midspan - 0.0219 - 0.1248
        'Area Prestressing Steel
        AllowableTension = 0.0948 * ((fc) ^ 0.5)
        Pjs = (((Ms * 1000 * yb) / I) - AllowableTension) / ((FCf / A) + ((emax * FCf *
yb) / I))
        'Zero Tension under Effective Prestress and Dead Load
        Pjd = ((((Mdc + Mbr + Mfws) * 1000 * yb) / I) - AllowableTension) / ((FCf / A) +
((emax * FCf * yb) / I))
        If Pjs > Pjd Then
            pj = Pjs
        Else
            pj = Pjd
        End If
        diameter = diameterprstrand.Text
        asp = 3.14 * diameter * diameter * 0.25
        Aps = pj / fpj
        NumberofStrands = Aps / asp
        Apsp = (NumberofStrands + 5) * asp
        nost.Text = NumberofStrands
        Apss.Text = Apsp
        numberofducts = (NumberofStrands / (22 * NG)) + 1
        Label85.Text = "Use " & numberofducts & " tendons per web. This requires that
each duct holds a maximum of 22 strands."
        'Verify Cable Path at Midspan
        cgducts = 50 + (3 * 16) + (0.5 * ((numberofducts * 110) + ((numberofducts - 1) *
25)))
        cgstrands = cgducts + 25
        ' Determine Initial Concrete Strength
        AllowableCompression = 0.6 * fc
        peff = fpj * (1 - dfpFms - dfpAmid - 0.0219)
        'Bottom fiber at midspan
        ficb = (peff * ((1 / A) + ((emax * yb) / I))) - ((Muse * 1000 * yb) / I)
        'Top fiber at midspan
        fict = (peff * ((1 / A) - ((emax * yt) / I))) + ((Muse * 1000 * yt) / I)
        If ficb > fict Then
            fic = ficb
```

```
        Else
            fic = fict
        End If
        If fic <= AllowableCompression Then
            Label94.Text = "The initial concrete stresses are less than the allowable
compressive stress.Therefore fci =" & fc & "MPa is acceptable."
        Else
            Label94.Text = fc & "Mpa not acceptabel"
        End If
        'Flexural Resistance
        ds = h - 15 - cgstrands
        B1 = 0.85 - (0.05 * ((fc - 28) / 7))
        c1 = (Apsp * fpu) / ((0.85 * B1 * fc * bridgewidth) + (0.28 * Apsp * (fpu / ds)))
        c2 = ((Apsp * fpu) - (0.85 * fc * (bridgewidth - (NG * tweb)))) / ((0.85 * B1 *
fc * (bridgewidth - (NG * tweb))) + (0.28 * Apsp * (fpu / ds)))
        If c1 < tdacks Then
            c = c1
            Label99.Text = "Rectangular section"
        Else
            c = c2
            Label99.Text = "T- section"
        End If
        aa = c * B1
        et = 0.003 * ((ds / c) - 1)
        If et > 0.005 Then
            Label96.Text = "the member is tension controlled"
        Else
            Label96.Text = "the member isNOT tension controlled"
        End If

        fps = fpu * (1 - (0.28 * (c / ds)))
        Mnr = (Apsp * fps * (ds - (aa / 2)))
        Mnt = (Apsp * fps * (ds - (aa / 2))) + (0.85 * fc * (bridgewidth - (NG * tweb)) *
tdacks * ((aa / 2) - (tdacks / 2)))
        If c1 < tdacks Then
            Mn = Mnr
        Else
            Mn = Mnt
        End If
```

```
If 0.95 * Mn > Must Then
    Label97.Text = " Section is adequate."
Else
    Label97.Text = " Section isNOT adequate."
End If
Sc = I / yb
pf = fpj * (1 - dfpFms - dfpAmid - 0.0219 - 0.1248)
fcpe = pf * ((1 / A) + ((emax * yb) / I))
Mcr = Sc * (fr + fcpe)
If 1.2 * Mcr < 1.33 * Must * 1000 Then
    mm = 1.2 * Mcr
    nn = 1.33 * Must * 1000
Else
    mm = 1.33 * Must * 1000
    nn = 1.2 * Mcr
End If
If 0.95 * Mn > mm Then
    Label98.Text = "The minimum reinforcement limit is satisfied."
Else
    Label98.Text = " The minimum reinforcement limit isNOT satisfied."
End If
```

'shear design

```
Dim vdc As Double
Dim vbar As Double
Dim vfws As Double
Dim vtu As Double
Dim vten As Double
Dim vlane As Double
Dim dv As Double
Dim dv1 As Double
Dim dv2 As Double
Dim dv3 As Double
Dim lldi As Double
Dim LL As Double
Dim vu As Double
Dim vp As Double
```

```
Dim bvu As Double
Dim bvg As Double
Dim bvua As Double
Dim bvga As Double
Dim yeq As Double
Dim dp As Double
Dim ax As Double
Dim fpss As Double
Dim mnss As Double
Dim dvv As Double
Dim bv As Double
Dim bv1 As Double
Dim bv2 As Double
Dim bv3 As Double
Dim vuu As Double
Dim rr As Double
Dim mu As Double
Dim ac As Double
Dim exp As Double
Dim exn As Double
Dim exx As Double
Dim θ As Double
Dim β As Double
Dim fpo As Double
Dim vc As Double
Dim av As Double
Dim sp As Integer
Dim spp As Integer
Dim sp1 As Double
Dim sp2 As Double
Dim sppp As Double
Dim vs As Double
Dim vn1 As Double
Dim vn2 As Double
Dim vn As Double
Dim spppp As Double
'shear depth

dv1 = 0.72 * h
```

```
        yeq = 350 + ((yb - 350) * ((((L * 1000 * 0.5) - dv1) / (L * 1000 * 0.5)) ^ 2))
        dp = h - yeq
        dv2 = 0.9 * dp
        c2 = ((Apsp * fpu) - (0.85 * fc * (bridgewidth - (NG * tweb)))) / ((0.85 * B1 *
fc * (bridgewidth - (NG * tweb))) + (0.28 * Apsp * (fpu / dp)))
        ax = c2 * B1
        fpss = fpu * (1 - (0.28 * (c2 / dp)))
        Mnss = (Apsp * fps * (dp - (ax / 2))) + (0.85 * fc * (bridgewidth - (NG * tweb))
* tdacks * ((ax / 2) - (tdacks / 2)))
        dv3 = mnss / (Apsp * fpss)
        If dv1 >= dv2 Then
            dvv = dv1
        Else
            dvv = dv2
        End If
        If dvv >= dv3 Then
            dv = dvv
        Else
            dv = dv3
        End If
        'critical shear
        vdc = wdc * ((0.5 * L * 1000) - dv)
        vbar = wbrr * ((0.5 * L * 1000) - dv)
        vfws = wfws * ((0.5 * L * 1000) - dv)
        vtu = ((162.5 * L * 1000) + 473) / (L * 1000)
        vten = ((110 * L * 1000) + 132) / (L * 1000)
        vlane = 0.0502796 * L * 1000
        shsuper.Text = vdc.ToString("0.00")
        shbar.Text = vbar.ToString("0.00")
        shfws.Text = vfws.ToString("0.00")
        shdetu.Text = vtu.ToString("0.00")
        shdela.Text = vlane.ToString("0.00")
        shdeta.Text = vten.ToString("0.00")
        lldi = ((s / 2200) ^ 0.9) * ((h / (L * 1000)) ^ 0.1)
        LL = (vlane + (1.33 * vtu)) * lldi * NG
        llimm.Text = LL.ToString("0.00")
        'strength I
        vu = ((1.25 * (vdc + vbar)) + (1.5 * vfws) + (1.75 * LL)) / 1000
        'Calculate, Vp
```

```
vp = (0.74 * fpu * Apsp * (JackingEnd - 0.0219 - 0.1248) * angle) / 1000
'Check Shear Width, bv
'For ungrouted ducts under DC dead load
bvu = (((1.25 * (vdc + vbar)) / 0.9) - vp) / (0.25 * dv * fc)
'For grouted ducts under full load:
bvg = ((vu / 0.9) - vp) / (0.25 * dv * fc)
bvua = (5 * tweb) - (0.5 * 110 * NG)
bvga = (5 * tweb) - (0.25 * 110 * NG)
If bvu >= bvg Then
    bv1 = bvu
Else
    bv1 = bvg
End If
If bv1 > bvua Then
    bv2 = bv1
Else
    bv2 = bvua
End If
If bv3 > bvga Then
    bv = bv3
Else
    bv = bvga
End If
Label295.Text = bv
Label297.Text = dv
'Evaluate Shear Stress
vuu = (vu - (0.9 * vp)) / (0.9 * bv * dv)
rr = vuu / fc
Label282.Text = rr.ToString("0.00")
mu = vu * dv
ac = (bridgewidth - (2 * ovlength)) + (((h * 0.5) - tbottoms) * NG * tweb)
β = TextBita.Text
θ = Textteta.Text
tt = (θ * 2) / 21.6
fpo = 0.7 * fpu

exp = ((mu / dv) + (0.5 * tt * (vu - vp)) - (Apsp * fpo)) / (2 * Ep * Apsp)
exn = ((mu / dv) + (0.5 * tt * (vu - vp)) - (Apsp * fpo)) / (2 * ((Ec * ac) + (Ep
* Apsp)))
```

```
Label299.Text = vuu.ToString("0.00")
Label300.Text = vu.ToString("0.00")
Label301.Text = vp.ToString("0.00")
If exp > 0 Then
    exx = exp
Else
    exx = exn
End If
Label292.Text = (exx * 1000).ToString("0.000")
'Calculate Concrete Shear Strength, Vc

vc = ((0.83 * β * ((fc) ^ 0.5) * bv * dv)) / 1000
av = 3.14 * 64 * 2 * NG
sp = (av * fy * dv * tt) / ((vu / 0.9) - vc - vp)
If sp > (av * fy) / (0.083 * (fc ^ 0.5) * bv) Then
    spp = (av * fy) / (0.083 * (fc ^ 0.5) * bv)
Else
    spp = sp
End If
If vu < 0.125 * fc Then
    sp1 = 0.8 * dv

ElseIf vu >= 0.125 * fc Then
    sp1 = 0.4 * dv

End If

If sp1 > 450 Then
    sppp = 450
Else
    sppp = sp2

End If
If spp > sppp Then
    spppp = sppp
Else
    spppp = spp
End If
Label287.Text = av
```

```vb
        Label288.Text = spppp

        vs = av * fy * dv * tt * 0.001 / spppp
        vn1 = vc + vs + vp
        vn2 = (0.25 * fc * bv * dv) + vp
        If vn1 > vn2 Then
            vn = vn2
        Else
            vn = vn1
        End If
        Label305.Text = vn * 1000
        If vn * 1000 > vu Then
            Label290.Text = " OK;;; "
        Else
            Label290.Text = " NOT OK;;; "
        End If
        ' Longitudinal Reinforcement
        If Apsp * fpss >= ((mu / (dv * 0.95)) + ((((vu / 0.9) - vp) - (0.5 * vs)) * tt))
Then
            Label291.Text = "The prestressing strands are adequate for longitudinal
reinforcement without additional mild reinforcing."
        Else
            Label291.Text = "The prestressing strands are NOT adequate for longitudinal
reinforcement "
        End If

        'Post-Tensioned  Anchor(Zone)
        Label308.Text = h
        Dim td As Double
        td = 0.3 * h
        Label309.Text = td
        Dim pjg As Double
        pjg = pj / (NG * 1000)
        Dim as1 As Double
        Dim as2 As Double
        as1 = (1.33 * pjg * (h - (pjg / 1200))) / (300 * h)
        as2 = (0.67 * pjg * (h - (pjg / 1200))) / (300 * h)
        Label312.Text = pjg.ToString("0.00")
        Label314.Text = as1.ToString("0.00")
```

```
    Label316.Text = as2.ToString("0.00")
    Dim ss As Integer
    Dim ss1 As Integer
    ss = (1000 * 3.14 * 25) / as1
    ss1 = (1000 * 3.14 * 25) / as2
    Dim sss As Double
    Dim sss1 As Double
    If ss > 450 Then
        sss = 450
    Else
        sss = ss
    End If
    If ss1 > 450 Then
        sss1 = 450
    Else
        sss1 = ss1
    End If
    Label317.Text = "spacing " & sss & " mm"
    Label318.Text = "spacing " & sss1 & " mm"
End Sub

Private Sub Button1_Click(sender As Object, e As EventArgs) Handles Button1.Click
```

'Steel plate Girder bridge design Bridge

```
    Dim densityofconcrete As Double
    Dim dackthickness As Double
    Dim girderspacing As Double
    Dim Mdc As Double
    Dim densityoffws As Double
    Dim fwsthickness As Double
    Dim Mdw As Double
```

```
        Dim llimp As Double
        Dim llimn As Double
        Dim mup As Double
        Dim mun As Double
        Dim de As Double
        Dim Rn As Double
        Dim p As Double
        Dim fc As Double
        Dim fy As Double
        Dim Asp As Double
        Dim barspacingP As Integer
        Dim barspacingn As Integer
        Dim de2 As Double
        Dim Rn2 As Double
        Dim p2 As Double
        Dim asn As Double

        fc = compressivestrengthpg.Text
        fy = reinforcementstrengthpg.Text
        llimp = llimpp.Text
        llimn = llimnn.Text

        fwsthickness = 63.5
        densityofconcrete = 24000
        dackthickness = daackthicknesspg.Text
        girderspacing = girderspacingpg.Text
        densityoffws = 22500
        Mdc = (densityofconcrete * dackthickness * girderspacing * girderspacing) /
10000000000
        Mdw = (fwsthickness * densityoffws * girderspacing * girderspacing) / 10000000000
        dcloadp.Text = Mdc
        dcloadn.Text = -Mdc
        fwsp.Text = Mdw
        fwwsn.Text = -Mdw
        mup = (1.25 * Mdc) + (1.5 * Mdw) + (1.75 * llimp)
        mun = (1.25 * Mdc) + (1.5 * Mdw) + (1.75 * llimn)
        de = dackthickness - 25 - 8 - 13
        Rn = mup / (0.9 * de * de)
        p = 0.85 * (fc / fy) * (1 - ((1 - ((Rn * 2) / (0.85 * fc))) ^ 0.5))
```

```
        Asp = p * de
        barspacingP = 200.96 / Asp
        Label147.Text = "required amount of reinforcing steel is " & Asp.ToString("0.00")
& " mm2/mm use dimeter 16mm bar with " & barspacingP & " bar spacing"
        de2 = dackthickness - 60 - 8
        Rn2 = mun / (0.9 * de2 * de2)
        p2 = 0.85 * (fc / fy) * (1 - ((1 - ((Rn2 * 2) / (0.85 * fc))) ^ 0.5))
        asn = p2 * de2
        barspacingn = 200.96 / asn
        Label146.Text = "required amount of reinforcing steel is " & asn.ToString("0.00")
& " mm2/mm use dimeter 16mm bar with " & barspacingn & " bar spacing"
        Dim mco As Double
        Dim mdcdack As Double
        Dim mdcpar As Double
        Dim mutotal As Double
        Dim T As Double
        Dim tover As Double
        Dim deo As Double
        Dim rno As Double
        Dim po As Double
        Dim aso As Double
        Dim ta As Double
        Dim c As Double
        Dim a As Double
        Dim mn As Double

        tover = overhangthicknesspg.Text
        mco = 125478
        mdcdack = (1.25 * tover * densityofconcrete * girderspacing * girderspacing) /
2000000000
        mdcpar = (1.25 * 7750 * (438 - 156.5)) / 1000
        mutotal = mco + mdcdack + mdcpar
        T = 91
        deo = dackthickness - 68
        rno = mutotal / (deo * deo)
        po = 0.85 * (fc / fy) * (1 - ((1 - ((rno * 2) / (0.85 * fc))) ^ 0.5))
        aso = po * deo
        ta = aso * fy
        c = ta - T
```

```
    a = c / (0.85 * fc)
    mn = (ta * (deo - (a / 2))) - (T * ((deo / 2) - (a / 2)))
    If mn >= mutotal Then
        Label168.Text = "the depth of the compression block is ok"
    Else
        Label168.Text = "the depth of the compression block is NOT ok"
    End If
    asoo.Text = aso
    tov.Text = overhangthicknesspg.Text
End Sub
Private Sub Button2_Click(sender As Object, e As EventArgs) Handles Button2.Click
    Dim hi As Integer
    Dim l As Integer
    Dim bi As Integer
    Dim cc As Double
    Dim tfi As Integer
    Dim twi As Integer
    Dim ee As Double
    Dim nig As Integer
    Dim bridgewidth As Double
    Dim ovle As Double
    Dim fy As Double
    Dim girderspacing As Double
    Dim doo As Double
    Dim stiffnerspai As Double
    Dim ttt As Double

    fy = steelyield.Text
    ovle = overhanglengthpg.Text
    bridgewidth = deckwidthpg.Text
    girderspacing = girderspacingpg.Text

    nig = ((bridgewidth - (2 * ovle)) / girderspacing) + 1
    numberofgirderspg.Text = nig
    l = bridgelengthpg.Text
    hi = l / 20
    bi = 0.4 * hi
    ttt = hi / 125
    If ttt >= 20 Then
```

```
            twi = ttt
        Else
            twi = 20
        End If

        cc = (bi - twi) * 0.5
        ee = (235 / fy) ^ 0.5
        tfi = cc / (14 * ee)
        depthpg.Text = hi
        flangewidthpg.Text = bi
        flangethicknesspg.Text = tfi
        Label174.Text = twi

        doo = hi - (tfi)
        stiffnerspai = 0.9 * doo
        Label217.Text = stiffnerspai
    End Sub
    Private Sub Button9_Click(sender As Object, e As EventArgs) Handles Button9.Click
        Dim DLdack As Double
        Dim DLmis As Double
        Dim DLpara As Double
        Dim DLdackform As Double
        Dim DLfws As Double
        Dim DLsteel As Double
        Dim DL As Double
        Dim densityofconcrete As Double
        Dim girderspacing As Double
        Dim dackthickness As Double
        Dim bridgewidth As Double
        Dim nig As Double
        Dim ovle As Double
        Dim area As Double
        Dim b As Double
        Dim tf As Double
        Dim tw As Double
        Dim h As Double
        Dim l As Double
        Dim cc As Double
        Dim fy As Double
```

```
Dim ybb As Double
Dim stiffnerspa As Double


fy = steelyield.Text
l = bridgelengthpg.Text
h = Textdepth.Text
b = Textflangewidth.Text
tf = Textflangethick.Text
tw = Textwebthic.Text
dackthickness = daackthicknesspg.Text
girderspacing = girderspacingpg.Text
stiffnerspa = Textstifsp.Text
area = (2 * tf * b) + (tw * (h - (2 * tf)))
Label190.Text = area
ybb = ((b * tf * tf * 0.5) + (b * tf * (h - (tf * 0.5))) + ((((h - (2 * tf)) *
0.5) + tf) * (h - (2 * tf)) * tw)) / area
Label192.Text = ybb
cc = (b - tw) * 0.5
ovle = overhanglengthpg.Text
bridgewidth = deckwidthpg.Text
nig = ((bridgewidth - (2 * ovle)) / girderspacing) + 1

densityofconcrete = 24000
DLdack = (densityofconcrete * girderspacing * dackthickness) / 1000000000
DLmis = 0.22
DLpara = 9.81 * 0.79 * 2 / nig
DLdackform = (9.81 * 73 * (girderspacing - b)) / 1000000
DLfws = (22500 * 63.5 * (bridgewidth - (2 * 438))) / (nig * 1000000000)
DLsteel = 77000 * area / 1000000000
DL = (DLdack + DLmis + DLpara + DLdackform + DLsteel)
Label207.Text = DL
Label208.Text = DLfws
Dim lldispg1 As Double
Dim lldispg2 As Double
Dim LLdispg As Double
Dim LLIMSPG As Double
Dim designlane As Double
Dim designtruck As Double
```

```
        Dim mdcpg As Double
        Dim mfwspg As Double
        Dim Mustpg As Double
        Dim doo As Double
        Dim ee As Double
        Dim a As Double

        ee = (235 / fy) ^ 0.5
        mdcpg = ((DL * l * l) / 8)
        mfwspg = ((DLfws * l * l) / 8)
        Label204.Text = mdcpg
        Label205.Text = mfwspg
        designlane = (1.1625 * l * l)
        designtruck = (81.28 * (l / 1000)) - 387
        Label197.Text = designtruck
        Label196.Text = designlane
        lldispg1 = (1.75 + (girderspacing / 1100)) * ((300 / (l)) ^ 0.35) * ((1 / nig) ^
0.45)
        lldispg2 = ((13 / nig) ^ 0.3) * (girderspacing / 430) * ((1 / (l)) ^ 0.25)

        If lldispg1 > lldispg2 Then
            LLdispg = (lldispg1 * nig)
        Else
            LLdispg = (lldispg2 * nig)
        End If
        LLIMSPG = (designlane + (1.33 * designtruck)) * LLdispg
        Label198.Text = LLIMSPG

        'strength I
        Mustpg = (1.25 * mdcpg) + 1.5 * (mfwspg) + 1.75 * (LLIMSPG)
        Label200.Text = Mustpg
        'class of the flange
        If cc / tf <= (8.5 * ee) Then
            Label206.Text = "class 1 "
        ElseIf 8.5 < cc / tf <= (9.5 * ee) Then
            Label206.Text = "class 2 "
        ElseIf 9.5 < cc / tf <= (15 * ee) Then
            Label206.Text = "class 3 "
        End If
```

```
        doo = h - tf

        'serviciblity requirment
        If tf >= (doo / 250) * ((a / doo) ^ 0.5) Then
            Label213.Text = "OK"
        Else
            Label213.Text = "NOT OK"
        End If

        'flange bucking in the web

        If tf >= (doo / 250) * ((Fy / 455) ^ 0.5) Then
            Label215.Text = "OK"
        Else
            Label215.Text = "NOT OK"
        End If
        Dim vdc As Double
        Dim vdw As Double
        Dim vlane As Double
        Dim vtru As Double
        Dim vllim As Double
        Dim Vsd As Double
        Dim Vba As Double
        Dim shearba As Double

        vdc = DL * l * 0.5
        vdw = DLfws * l * 0.5
        vlane = 9.3 * l * 0.5
        vtru = 162500 + (437000 / l)
        vllim = (vtru + (vlane * 1.33)) * LLdispg
        Vsd = 1.25 * (vdc) + 1.5 * (vdw) + 1.75 * (vllim)
        Label235.Text = Vsd
        shearba = Fy / ((3) ^ 0.5)
        Vba = (doo * tw * shearba) / 1.1
        If Vba > Vsd Then
            Label216.Text = "The stifener arrengment and web thickness is satisfactory"
        Else
            Label216.Text = "The stifener arrengment and web thickness isNOT
satisfactory"
```

```
    End If
    If (b * tf) >= (((Mustpg * 1.1)) / (doo * fy)) Then

        Label219.Text = "the flange area is adquate"
    Else
        Label219.Text = "the flange area is not adquate"
    End If
    Label179.Text = (doo - tf).ToString("0") & "mm"
    Label180.Text = b & "mm"
    Label181.Text = tf & "mm”
End Sub

Private Sub PGB_Click(sender As Object, e As EventArgs) Handles PGB.Click
End Sub
Private Sub Button10_Click(sender As Object, e As EventArgs) Handles Button10.Click
    'intermidate stifener
    Dim tsi As Double
    Dim isi As Double
    Dim I As Double
    Dim bsi As Double
    Dim ee As Double
    Dim tw As Double
    Dim bs As Double
    Dim ts As Double
    Dim iss As Double
    Dim fy As Double
    Dim d As Double
    Dim h As Double
    Dim tf As Double
    Dim stiffnerspa As Double
    Dim lamda As Double
    Dim lamdabar As Double
    Dim Kl As Double
    Dim lamda1 As Double
    Dim ass As Double
    Dim r As Double
    tsi = Texttsi.Text
    bsi = Textbsi.Text
    stiffnerspa = Textstifsp.Text
```

```
        tf = Textflangethick.Text
        h = Textdepth.Text
        tw = Textwebthic.Text
        d = h - tf
        tw = Textwebthic.Text
        fy = steelyield.Text
        ee = (235 / fy) ^ 0.5
        If (stiffnerspa / d) >= ((2) ^ 0.5) Then
            isi = 0.75 * d * tw * tw * tw
        Else
            isi = 1.5 * ((d / stiffnerspa) ^ 2) * d * tw * tw * tw
        End If
        I = (tsi * bsi * bsi * bsi) / 12

        If isi >= I Then
            ts = tsi
            Label225.Text = "the stiffener area is sufficent with respect to
stiffenesuse.use ts=" & ts
        Else

            ts = (I / (bsi * bsi * bsi)) * 12
            Label225.Text = "the stiffener area is not sufficent with respect to
stiffenes.use ts=" & ts
        End If
        'bs
        If (2 * bsi) < (13 * ts * ee) Then
            bs = 13 * ts * ee * 0.5
            Label226.Text = "The outstand is less then 13ts .use bs=" & bs &
"..........OK"

        ElseIf (19 * ts * ee) < (2 * bsi) Then
            bs = 19 * ts * ee * 0.5
            Label226.Text = "The outstand is greater then 19ts .use bs=" & bs &
"..........OK"
        ElseIf (13 * ts * ee) <= (2 * bsi) <= (19 * ts * ee) Then
            bs = bsi
            Label226.Text = "The outstand is between 13ts and 19ts, use bs=" & bs &
"..........OK"
        End If
```

```
        ass = (2 * bs * ts) + (30 * tw * tw * ee)
        iss = (ts * (((2 * bs) + tw) ^ 3)) / 12
        r = (iss / ass) ^ 0.5
        Kl = 0.75 * d
        lamda1 = 93.9 * ee
        lamda = Kl / r
        lamdabar = lamda / lamda1
        Label230.Text = lamdabar
        Label231.Text = bs
        Label232.Text = ts
    End Sub
    Private Sub Button11_Click(sender As Object, e As EventArgs) Handles Button11.Click
        Dim x As Double
        Dim ass As Double
        Dim fy As Double
        Dim bs As Double
        Dim ts As Double
        Dim tw As Double
        Dim ee As Double
        Dim Px As Double
        Dim vsd As Double
        Dim weldsize As Double
        Dim m As Double
        Dim n As Double
        Dim q As Double

        fy = steelyield.Text
        ee = (235 / fy) ^ 0.5
        bs = Label231.Text
        ts = Label232.Text
        x = Textx.Text
        tw = Textwebthic.Text
        ass = (2 * bs * ts) + (30 * tw * tw * ee)
        Px = (x * ass * fy) / 1.1
        vsd = Label235.Text
        If Px > vsd Then
            Label233.Text = "Buckling Resistance is OK"
        Else
            Label233.Text = "Buckling Resistance is not OK"
```

```
        End If
        weldsize = Textws.Text
        m = (0.63 * fy) / 1.25
        n = m * 0.707 * weldsize * 0.001
        q = (tw * tw) / (8 * bs)
        If n > q Then
            Label239.Text = "use " & weldsize & "mm fillet welds"
        Else
            Label239.Text = "it is not adqute "
        End If
    End Sub
    Private Sub Button12_Click(sender As Object, e As EventArgs) Handles Button12.Click
        'load carying stiffener
        Dim tsi As Double
        Dim I As Double
        Dim bsi As Double
        Dim ee As Double
        Dim tw As Double
        Dim fy As Double
        Dim d As Double
        Dim h As Double
        Dim tf As Double
        Dim stiffnerspa As Double
        Dim lamda As Double
        Dim lamdabar As Double
        Dim Kl As Double
        Dim lamda1 As Double
        Dim ass As Double
        Dim r As Double

        tsi = Texttslc.Text
        bsi = Textbslc.Text
        stiffnerspa = Textstifsp.Text
        tf = Textflangethick.Text
        h = Textdepth.Text
        tw = Textwebthic.Text
        d = h - (2 * tf)
        tw = Textwebthic.Text
        fy = steelyield.Text
```

```
        ee = (235 / fy) ^ 0.5
        I = (tsi * bsi * bsi * bsi) / 12
        Label242.Text = bsi
        Label241.Text = tsi
        ass = (2 * bsi * tsi) + (30 * tw * tw * ee)
        r = (I / ass) ^ 0.5
        Kl = 0.75 * d
        lamda1 = 93.9 * ee
        lamda = Kl / r
        lamdabar = lamda / lamda1
        Label250.Text = lamdabar
    End Sub
    Private Sub Button13_Click(sender As Object, e As EventArgs) Handles Button13.Click
        Dim x As Double
        Dim ass As Double
        Dim fy As Double
        Dim bs As Double
        Dim ts As Double
        Dim tw As Double
        Dim ee As Double
        Dim Px As Double
        Dim weldsize As Double
        Dim m As Double
        Dim n As Double
        Dim pap As Double
        Dim ps As Double
        Dim w As Double
        Dim h As Double
        Dim d As Double
        Dim tf As Double
        pap = 325
        fy = steelyield.Text
        ee = (235 / fy) ^ 0.5
        bs = Label242.Text
        ts = Label241.Text
        x = Textxlc.Text
        tw = Textwebthic.Text
        ass = (2 * bs * ts) + (30 * tw * tw * ee)
        Px = (x * ass * fy) / 1.1
```

```
        If Px > pap Then
            Label249.Text = "Buckling Resistance is OK"
        Else
            Label249.Text = "Buckling Resistance is not OK"
        End If
        h = Textdepth.Text
        tw = Textwebthic.Text
        tf = Textflangethick.Text
        d = h - (2 * tf)
        w = (pap / (2 * d)) + ((tw * tw) / (8 * bs))
        weldsize = Textwslc.Text
        m = (0.63 * fy) / 1.25
        n = m * 0.707 * weldsize * 0.001

        If n > w Then
            Label255.Text = "use " & weldsize & "mm fillet welds"
        Else
            Label255.Text = "it is not adqute "
        End If
        'Bearing Resistance
        ps = (ass * fy) / 1.1
        If ps > pap Then
            Label258.Text = "Bearing Resistance is OK"
        Else
            Label258.Text = "Bearing Resistance is not OK"
        End If
    End Sub
    Private Sub Button15_Click(sender As Object, e As EventArgs) Handles Button15.Click
        'end post
        Dim tsi As Double
        Dim I As Double
        Dim bsi As Double
        Dim ee As Double
        Dim tw As Double
        Dim fy As Double
        Dim d As Double
        Dim h As Double
        Dim tf As Double
```

```vb
        Dim stiffnerspa As Double
        Dim lamda As Double
        Dim lamdabar As Double
        Dim Kl As Double
        Dim lamda1 As Double
        Dim ass As Double
        Dim r As Double

        tsi = Texttsep.Text
        bsi = Textbsep.Text
        stiffnerspa = Textstifsp.Text
        tf = Textflangethick.Text
        h = Textdepth.Text
        tw = Textwebthic.Text
        d = h - (2 * tf)
        tw = Textwebthic.Text
        fy = steelyield.Text
        ee = (235 / fy) ^ 0.5

        I = (tsi * bsi * bsi * bsi) / 12
        Label260.Text = bsi
        Label259.Text = tsi
        ass = (2 * bsi * tsi) + (30 * tw * tw * ee)
        r = (I / ass) ^ 0.5
        Kl = 0.75 * d
        lamda1 = 93.9 * ee
        lamda = Kl / r
        lamdabar = lamda / lamda1
        Label263.Text = lamdabar
    End Sub

    Private Sub Button14_Click(sender As Object, e As EventArgs) Handles Button14.Click
        Dim x As Double
        Dim ass As Double
        Dim fy As Double
        Dim bs As Double
        Dim ts As Double
        Dim tw As Double
        Dim ee As Double
```

```
Dim Px As Double
Dim weldsize As Double
Dim m As Double
Dim n As Double
Dim vsd As Double
Dim ps As Double
Dim w As Double
Dim h As Double
Dim d As Double
Dim tf As Double
vsd = Label235.Text
fy = steelyield.Text
ee = (235 / fy) ^ 0.5
bs = Label260.Text
ts = Label259.Text
x = Textxlc.Text
tw = Textwebthic.Text
ass = (2 * (bs - 50) * ts)
Px = (x * ass * fy) / 1.1

If Px > vsd Then
    Label262.Text = "Buckling Resistance is OK"
Else
    Label262.Text = "Buckling Resistance is not OK"
End If
```

'connection

```
h = Textdepth.Text
tw = Textwebthic.Text
tf = Textflangethick.Text
d = h - (2 * tf)
w = vsd / (2 * d * 1000)
weldsize = Textwsep.Text
m = (0.63 * fy) / 1.25
n = m * 0.707 * weldsize * 0.001
If n > w Then
    Label273.Text = "use " & weldsize & "mm fillet welds"
Else
    Label273.Text = "it is not adqute "
End If
```

```
        'Bearing Resistance
        ps = (ass * fy) / 1.1
        If ps > vsd Then
            Label272.Text = "Bearing Resistance is OK"
        Else
            Label272.Text = "Bearing Resistance is not OK"
        End If
    End Sub

    Private Sub Button16_Click(sender As Object, e As EventArgs) Handles Button16.Click
        Dim Ix As Double
        Dim A As Double
        Dim y As Double
        Dim b As Double
        Dim h As Double
        Dim tf As Double
        Dim tw As Double
        Dim F As Double
        Dim j As Double
        Dim fy As Double
        Dim weldsize As Double
        Dim m As Double
        Dim n As Double

        weldsize = Textfw.Text
        fy = 330
        F = Label235.Text
        tf = Textflangethick.Text
        h = Textdepth.Text
        tw = Textwebthic.Text
        b = Textflangewidth.Text
        y = (0.5 * h) - (tf * 0.5)
        A = tf * b
        Ix = 2 * ((b * tf * tf * tf) / 12) + ((b * tf) * ((h - (tf * 0.5)) ^ 2)) + ((tw *
((h - (2 * tf)) ^ 3)) / 12) + ((tw * (h - (2 * tf))) * ((h * 0.5) ^ 2))
        j = (F * A * y) / (2 * Ix * 1000)
        m = (0.63 * Fy) / 1.25
        n = m * 0.707 * weldsize * 0.001
```

```
        If n > j Then
            Label279.Text = "use " & weldsize & "mm fillet welds"
        Else
            Label279.Text = "it is not adqute "
        End If
    End Sub

End Class
```

Declaration

I hereby declare that the work presented in this thesis, which is entitled "**COMPUTER PROGRAM FOR COMAPRATIVE STUDY OF THE ANALASIS AND DESIGN OF PRESTRESSED CONCRETE BOX GIRDER AND PLATE GIRDER HIGHWAY BRIDGES**" is my original work and has not been presented in any other University and that all sources of material used for the thesis have been properly acknowledged.

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Signature: