SOFTWARE DEVELOPMENT FOR DESIGN OF SLAB AND T-GIRDER REINFORCED CONCRETE BRIDGES

TEWODROS TESFAYE

A thesis submitted as a fulfillment of requirements for the award of degree of Master of Science (structure)

Faculty of Engineering
Addis Ababa University

December, 2009

Acknowledgement

I want to thank the Almighty God for allowing every thing to happen His way. Next my great acknowledgement goes to my advisor, Dr. Shifferaw Taye. I am grateful to him for being my advisor, help me improve my programming skills in previous courses and finally shape me well to accomplish this work with encouragement from the very beginning.

I extend my gratitude towards the following people from Core Consulting Engineers PLC: Engineer Dubale Demeke, Engineer Betelehem Woldemeskel for consulting on technical matters. I also want to acknowledge Engineer Abdulaziz Kassahun for his help concerning the programming part

Last but not least I would like to thank friends who in one way or the other helped me in accomplishing this paper.

Table of contents

Title **page**

List of figures……………………………………………………………….……….……….v

List of tables………………………………………………………………………………..vii

Abstract…………………………………………………………………………………….1

1. Introduction……………………………………………………………………………2
   1.1. background………………………………………………………………...….2
   1.2. objectives of the study……………………………………………………………2
   1.3. Methodology…………………………………………………………………...…3
   1.4. Scopes ……………..…………………………………………………………...…3
2. Literature review……………………………………………………………………….4
   2.1. Reinforced Concrete Bridges………………………………………….……………4
      2.1.1. Introduction ……………………..……………………………..………………4
      2.1.2. Materials ………..……………….……………………….……………………5
         2.1.2.1.Concrete ……..………………………..………………………..……………5
            2.1.2.1.1. Compressive Strength ……..……………………..……………5
            2.1.2.1.2. Characteristic Tensile Strength…….….………..……………7
            2.1.2.1.3. Shrinkage and Creep……….……………….…..……………8
         2.1.2.2.Reinforcement …..………………………………………………….9
            2.1.2.2.1. General ……………………………………………….……..9
            2.1.2.2.2. Stress–strain curve ………………………………………10
   2.2. Bridge Types ………………………………………………………….……..…..11
      2.2.1. Slab Bridges ……………..……………………………………………11
      2.2.2. T-Beam Bridges ……………………………………………………......12
   2.3. Loading ……………………………………………………………….………...13
      2.3.1. Dead Loads …………………………………………………………....13
      2.3.2. Live Loads ……………………………………………………………...13
   2.4. Design limit states ……..…………………………………………...……...16
      2.4.1. Service limit state ………………….…………..………………...17
      2.4.2. Fatigue limit state …………………………………………………....18

2.4.3. Strength limit state ……………………….…………………….……...18
2.5. Structural analysis ……………………………………….….…………..18
2.5.1. Linear Methods of Analysis ……………………….……………….....19
2.5.2. Design Philosophy ………………………………………………..…...19
2.5.3. Reinforcement detailing …..……………………………………......20
3.Flowcharts ………………………………………………………………………21
3.1. Girder bridge………………………………………………………………21
3.2. Slab Bridge…………………………………………………………………24
4.Design Steps……………………………………………………………………27
4.1. Girder bridge………………………………………………………………27
4.2. Slab Bridge…………………………………………………………………28
5.Numerical Experience and Discussion…………………………………………29
5.1. Girder bridge………………………………………………………………30
5.2. Bridge……………………………………………………………………48
6.The Graphical User Interface…………………………………………………59
6.1. Detailed procedure for Slab Bridge…………………………….……………60
6.2. Detailed procedure for T-girder Bridge……………………………….………69
7. Conclusions And Recommendations…………………………………………..76
7.1. Conclusions………………………………………………………………76
7.2. Recommendations…………………………………………………………77
Reference………………………………………………………………………...78

LIST OF FIGURES

Page

Figure2.1 Typical stress–strain curves for concrete
under uniaxial compression loading………………………………………….6
Figure 2.2Factor k_c for Volume to Surface Ratio………………………………………9
Figure 2.3 stress strain curve…………………………………………………………11
Figure 2.4 Sections of Voided (Hollowed) Slab and
Ribbed Slab Bridge Decks……………………………………………….…11
Figure 2.5 Characteristics of the Design Truck………………………………………14
Figure 2.6 Design Tandem Load………….…………………………………………15
Figure 6.1 The BRAD Screen……………………………………………..……59
Figure 6.2 The file menu…………………………………………………...…60
Figure 6.3 Template of bridge types (slab bridge) ……………………..………………60
Figure 6.4 Design data for slab bridge…………………………………………………61
Figure 6.5 Slab dimension input ……………………………………………….…62
Figure 6.6 Material properties for slab bridge……………………………..……………62
Figure 6.7 Guard rail for slab bridge……………………………………………………63
Figure 6.8 Limit state for slab bridge……………………………………………………63
Figure 6.9 The run window for slab bridge…………………………..………………64
Figure 6.10 completion of analysis for slab bridge………………………………………64
Figure 6.11 Slab bridge output…………………………………………………...…65
Figure 6.12 Influence line for slab bridge…………………………………..………66
Figure 6.13 Shear force output for slab bridge……………………………..…………66
Figure 6.14 Bending moment for slab bridge……………………………………………67
Figure 6.15 Display output in excel path……………………………………..……67
Figure 6.16 Excel output……………………………………………………...…68
Figure 6.17 General information…………………………………………..………68
Figure 6.18 Report for slab bridge design…………………………………..………69
Figure 6.19 The file menu………………………………………………….……69

Figure 6.20 Template of bridge types (t-girder bridge) …………………………………70
Figure 6.21 Design data for girder bridge……………………………………..……70
Figure 6.22 T-girder input data…………………………………………………..71
Figure 6.23 Material properties for girder bridge………………………………..…71
Figure 6.24 The run window for girder bridge…………………………………..…72
Figure 6.25 Completion of analysis for girder bridge……………………………………72
Figure 6.26 Girder bridge output…………………………………………………...73
Figure 6.27 Influence line for girder bridge…………………………………..………73
Figure 6.28 Shear force diagram for girder bridge………………………………………74
Figure 6.29 Bending moment diagram for girder bridge……………………..………74
Figure 6.30 Calculator……………………………………………………………..…75
Figure 6.31 About BRAD……………………………………………….…………75

LIST OF TABLES

Page

Table 2.1 Grades of Concrete and Characteristic
Cylinder and Cube Compressive Strength, f_{ck}……………………….………..….7
Table 2.2 Grades and Classes of Concrete……………………………………………….7
Table2.3 Grades of Concrete and Values of f_{ctk} and f_{ctm}……………..…..………………8
Table 2.4 Tensile Requirements for Reinforcement Bars…………………..……………10
Table 2.5 Multiple Presence Factors…………………………………………………..…14
Table 2.5 Dynamic Load Allowance, IM…………………………………..…………16

I. ABSTRACT

In bridge design, engineers strive to plan an economical structure that will safely transmit loads to the ground without collapsing or deforming excessively. Since it is difficult to predict the exact loading and circumstances that a bridge must withstand, all bridge designs include a substantial margin of safety. Design standards vary throughout the world, but all aim at ensuring that new bridges will provide many years of service and will maintain an adequate margin of safety against failure.

Bridge design involves a number of design steps which involves tidious calculations due to the presence of moving loads and needs choice of parameters and decision. So due to the complexity and time consumeness of the design we will be better off if we use bridge design programs to get better and accurate results in a short time. But the problem is these programs are too expensive to buy and use. Using pyrated softwares is illegal and immoral.And also using excel written programs has its own problems.

This project appreciates the application of home made (self made) programs to make life easy and give a highlight on the procedure behind commercial softwares. This thesis is concerned with developing Software for design of slab and T-girder reinforced concrete bridges. The software is produced using Visual basic 6.0. The design is based on the standards on ERA 2002 Bridge design manual. The program analyzes and designs only Simple span slab and girder bridges and outputs in different forms are available. The user manual and the video tutorials will show how to use the software simply. Finally, conclusions and recommendations are made based on the produced software.

CHAPTER ONE – INTRODUCTION

1.1 Background

Concrete slab and t-girder bridge have been a dominant bridge type in Ethiopia for a long time. Especially in the recent years a lot of road construction has been done, some are under construction and in the future a number of road projects are planned. As the projects are getting vast, we have to improve and make efficient our design approach everyday.

The design process is usually subdivided into several steps, beginning with conceptual design. Compiling the requirements for the new bridge and any important characteristics of its planned site forms the base for any design. The further design process will comprise many drafts and revisions until a feasible design has been produced. Constructability issues need to be included from a very early stage to ensure that the bridge can be built in a safe and economical manner. In the beginning the dimensions of structural members will be chosen mostly based on the designer's experience, in later stages engineering software is then employed to compare alternatives and optimize member dimensions. Finally, complete analytical calculations for all important construction stages and detailed shop drawings will be produced.

Technical factors such as bridge type and erection method, labor-related factors, and the particular needs of the owner need to be considered by the designer. All the mentioned factors should be considered in designing the bridge before structural analysis is begun. Analysis of the structural system generally makes use of a variety of simplifying assumptions. An adequate factor of safety should be incorporated to account for any uncertainties on the load and resistance sides of structural equations.

Designing with redundancy against structural failure increases the overall safety of the bridge. Any numerical results produced by engineering software need to be checked for consistency and accuracy of results to capture errors or omissions that might have been incurred during the modeling process. Finally, the results need to be interpreted by the structural engineer to apply them to the real structure.

1.2 Objectives of the Study

This thesis research has the following objectives:

- To make the manually computed routine calculations as simple as possible.
- To write a computer program which analyze and design slab and T-girder reinforced concrete bridges for different load types and cases.
- To provide manual for using the software properly.

1.3 Methodology

The methodology for carrying out the research work was focusing on reviewing different journals from the Internet in addition to the locally available books and journals that are related to the research work.

The study included Critical assessment of the different analysis methods, writing an interactive computer program illustrating the application of the computer program, sample problems is presented.

1.4 Scopes and Limitations of the Study

The design software has been limited to design of superstructure of reinforced concrete slab and T-girder bridge. Moreover, since skewness of bridges is not considered only non skew bridges can be designed using this software.

CHAPTER TWO - LITERATURE REVIEW

2.1 Reinforced Concrete Bridges

2.1.1 Introduction

An efficient design of bridge superstructure is essential to achieve overall economy in the whole bridge structure in that the superstructure dead weight may form a significant portion of the gravity load the bridge must sustain and transmit to the foundation. A light superstructure is economical not only in material requirements but also requires smaller size for substructure and foundations. A clear understanding of structural behavior under loads is essential for efficient design.

Reinforced concrete is used extensively in highway bridges because of its economy in short and medium spans, durability, low maintenance costs, and easy adaptability to horizontal and vertical curvature. The principal types of cast-in-place supporting elements are the longitudinally reinforced slab, T beam or girder, and cellular or box girder [6] .

The raw materials of concrete, consisting of water, fine aggregate, coarse aggregate, and cement, can be found in most areas of the world and can be mixed to form a variety of structural shapes. The great availability and flexibility of concrete material and reinforcing bars than steel sections have made the reinforced concrete bridge a very competitive alternative. Since in Ethiopia there is shortage of steel and also importing has its own problems, reinforced concrete is still of better choice.

Cast-in-place concrete structures are often constructed monolithically and continuously.They usually provide a relatively low maintenance cost and better earthquake-resistance [7].

Comparing the economics of different bridge types, the construction cost and maintenance cost should be considered in parallel. A general rule is that the bridge with minimum number of spans, fewest deck joints and widest spacing of girders will be the most economical [3]. By reducing the number of spans, the construction cost of one pier is eliminated. Deck joints are a high maintenance cost item, so minimizing their number will reduce the life cycle cost of the bridge. Generally, concrete structures require less maintenance than steel structures

Reinforced concrete bridges possess several advantages over steel bridges.

- adaptability of concrete wide variety of structural shapes
- Low maintenance cost
- Long life and better resistance to temporary overloads and dynamic loads than steel bridges.
- Cast-in-place Reinforced concrete structures are continuous and monolithic, attributes, which translate into easy construction, low cost and good seismic resistance. They can also be given the desired aesthetic appearance.

The disadvantage

- large dead weight
- difficulty to widen
- longer construction time
- requires formwork and false work

A bridge controls the capacity of the transportation system. For instance: If the strength of the bridge is unable to carry heavy trucks, loads limits will be posted and heavy trucks will be rerouted. Bridges are expensive structures. The cost per meter of a bridge is high in comparison to the road. If the bridge fails, the transportation system will not be in a position to give function. Therefore, bridge designer has control over the capacity, cost and Safety.

2.1.2 Materials

2.1.2.1 Concrete

2.1.2.1.1 Compressive Strength

In these Design Specifications, the compressive strength of concrete, f'c, is determined from tests on 150 mm cylinders at the age of 28 days in accordance with the Ethiopian Standards. It is common practice that the specified strength be attained 28 days after placement. Other maturity ages shall be assumed for design and specified for components, which will receive loads at times appreciably different than 28 days after placement.

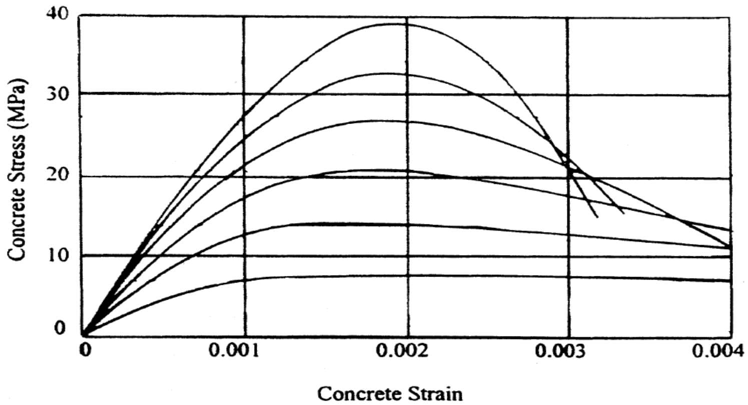


Figure2.1 Typical stress–strain curves for concrete under uniaxial compression loading.

Figure shows typical stress–strain curves from unconfined concrete cylinders under uniaxial compression loading. The strain at the peak compression stress is approximately 0.002 and maximum usablestrain is about 0.003.

Recommended grade of concrete and corresponding specified strengths are shown in Table 2.1 for both cylinder and cube strengths. Classes of concrete corresponding to these grades are shown in Table 2.2.

Grades of Concrete	C25	C30	C40	C50	C60
f_{ck} (150 mm cylinders, MPa)	20	24	32	40	48
f_{ck} (200 mm cubes, MPa)	21	25	34	42	50
f_{ck} (150 mm cubes, MPa)	25	30	40	50	60

Table 2.1 Grades of Concrete and Characteristic Cylinder and Cube Compressive Strength, f_{ck}

Class	Permissible Grades of Concrete					
I	(C20)	C25	C30	C40	C50	C60
II	(C20)	-	-	-	-	-

Table 2.2 Grades and Classes of Concrete

2.1.2.1.2 Characteristic Tensile Strength

The Characteristic Tensile Strength refers to the axial tensile strength as determined by tests in accordance with standards issued or approved by the Quality and Standardization Authority of Ethiopia. It shall be determined by either using the Ethiopian Standards, "Standard Test Method for Pullout Strength of Hardened Concrete", or the split tensile strength method in accordance with [1] "Standard Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.

The Characteristic Tensile Strength may also be determined from the characteristic cylinder compressive strength as:

fctk =0.7* fctm …………………………………………..(2.1)

where fctm =0.3*fck*2/3 (see Table 2.3 below)

Grades of Concrete	C20	C25	C30	C40	C50	C60
f_{ctm}	1.9	2.2	2.5	3.0	3.5	4.0
f_{ctk}	1.3	1.5	1.7	2.1	2.5	2.8

Table2.3 Grades of Concrete and Values of f_{ctk} and f_{ctm}

2.1.2.1.3 Shrinkage and Creep

Values of shrinkage and creep, specified herein, shall be used to determine the effects of shrinkage and creep on the loss of prestressing force in bridges other than segmentally constructed ones. These values in conjunction with the Moment of Inertia shall be used to determine the effects of shrinkage and creep on deflections.

The shrinkage coefficients shall be assumed to be 0.0002 after 28 days and 0.0005 after one year of drying.

Shrinkage of concrete can vary over a wide range from nearly nil if continually immersed in water to in excess of 0.0008 for either thin sections made with high shrinkage aggregates or for sections which are not property cured.

Creep is influenced by the same factors as shrinkage, and also by magnitude and duration of the stress, maturity of the concrete at the time of loading, and temperature of concrete.

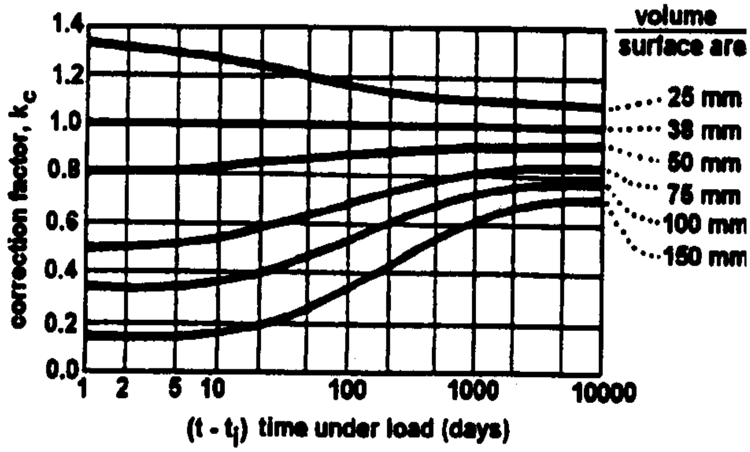


Figure 2.2 Factor k_c for Volume to Surface Ratio

Creep shortening of concrete under permanent loads is generally in the range of 1.5 to 4.0 times the initial elastic shortening, depending primarily on concrete maturity at the time of loading.

2.1.2.2 Reinforcement

2.1.2.2.1 General

Reinforcing bars, deformed wire, cold-drawn wire, welded plain wire fabric and welded deformed wire fabric shall conform to the materials standards as specified herein.

Reinforcement shall be deformed, except that plain bars or plain wire may be used for spirals, hoops and wire fabric. Bars < Ø 10 mm should not be used for cast-in-place structures.

The nominal yield strength shall be the minimum as specified for the grade of steel selected, except that yield strengths in excess of 520 MPa shall not be used for design purposes. Bars with yield strengths less than 270 MPa shall be used only with the approval of ERA. Tensile requirements are as indicated in Table 2.4.

AASHTO M31 M Grade	Grade 300	Grade 420	Grade 520
Equiv. European bars	B500B	Ks60	
(Old AASHTO M31 Grade)	(40)	(60)	(75)
Tensile strength, min. mPa	500	620	690
Yield strength, min. mPa	300	420	520

Table 2.4 Tensile Requirements for Reinforcement Bars

Where ductility is to be assured or where welding is required low alloy steel deformed bars for concrete reinforcement, or similar weldable european steel, should be specified.

Reinforcement shall be deformed, except that plain bars or plain wire shall be used for spirals, hoops and wire fabric. Bars < ∅10 mm should not be used for cast-in-place structures.

The Ethiopian Iron and Steel Foundry in Akaki and Zuquala Steel Rolling Mill Enterprises in Debre Zeit manufacture up to 400 MPa deformed bars with diameters ∅6 - ∅32 mm.

2.1.2.2.2 Stress–strain curve

The behavior of steel reinforcement is usually characterized by the stress–strain curve under uniaxial tension loading. Typical stress–strain curves for steel Grade 300 and 420 are shown in Figure below. The curves exhibit an initial linear elastic portion with a slope calculated as the modulus of elasticity of steel reinforcement Es= 200,000 MPa; a yield plateau in which the strain increases (from εy to εh) with little or no increase in yield stress(fy); a strain-hardening range in which stress again increases with strain until the maximum stress (fu) at a strain (fu) is reached; and finally a rangein which the stress drops off until fracture occurs at a breaking strain of εb.

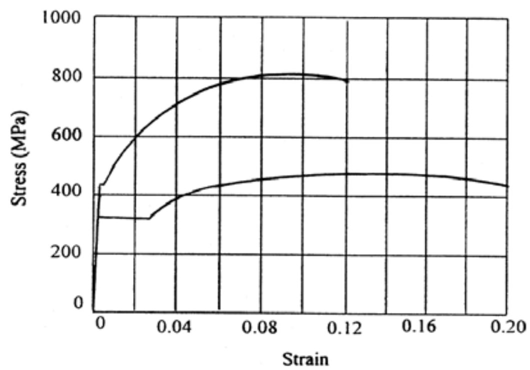


Figure 2.3 stress strain curve

2.2 Bridge Types

2.2.1 Slab Bridges

Single span slab bridges are perhaps the most common bridges in Ethiopia. They can be economical for spans up to 18 m. Above 15 m they should preferably be ribbed as shown in Figure 2.4 below

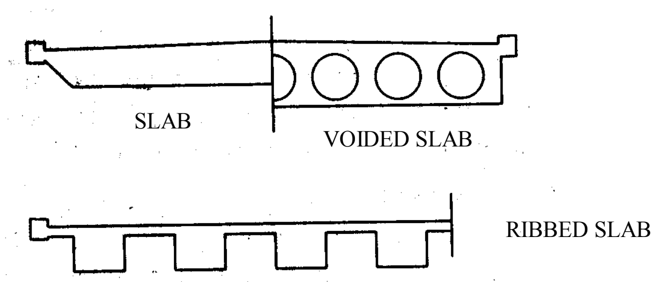


Figure 2.4 Sections of Voided (Hollowed) Slab and Ribbed Slab Bridge Decks

Concrete slab bridges, longitudinally reinforced, may be simply supported on piers and/or abutments, monolithic with wall supports, or continuous over intermediate supports[6]. Longitudinally reinforced slab bridges have the simplest superstructure configuration and the neatest appearance. They generally require more reinforcing steel and structural concrete than do girder-type bridges of the same span. However, the design details and formworks are easier and less expensive[7].

Normally the slab is made with a uniform depth over the whole bridge. The required design depth is usually 5.5 - 6 % of the span length, due to the width of the cracks. If stressed reinforced concrete is used, the design depth shall be reduced to 4.5 % of the span length. The abutments at single or double span slab bridges should preferably be placed perpendicular to the bridge in order to avoid a skew in earth pressure, which may cause skew in the abutment front wall .

Hydraulically, slab spans are better than box culverts. Economically, however, they have never been desirable. Substructure costs are excessive due to the limited distance between supports. With open railing, slab spans can become a nice solution for low headroom stream crossings where occasional flood inundation is expected. Deterioration has not been a significant problem because slab spans are thicker and are located predominantly in rural areas which are not salted.

2.2.2. T-Beam Bridges

The T-beam construction consists of a transversely reinforced slab deck which spans across to the longitudinal support girders. These require a more-complicated formwork, particularly for skewed ridges, compared to the other superstructure forms. T-beam bridges are generally more economical or spans of 12 to 18 m. The girder stem thickness usually varies from 35 to 55 cm and is controlled by the required horizontal spacing of the positive moment reinforcement. Optimum lateradl spacing of longitudinal girders is typically between 1.8 and 3.0 m for a minimum cost of formwork and structural materials. However, where vertical supports for the formwork are difficult and expensive, girder spacing can be increased accordingly[7]

A girder bridge is usually used for a single span bridge, or non-continuous girders for a multi-span bridge, in earthquake areas. They shall be used for span lengths between 12 – 20 m. Outside of earthquake zones, continuous girder bridges are preferred. In this case the exterior span length should be approximately 0.8 times the interior span. The LRFD design method usually minimizes materials used if the number of girders/beams is minimized. The cantilever should preferably not exceed 40 % of the spacing of the girders, or 2.8 m for a two-lane bridge.

The design depth of a normal girder bridge may vary between 7-10% of the span length depending on the number of beams used. If possible, a high stem of beam is preferred to a certain extent, both technically and economically. For construction reasons however, the height should be minimized. Esthetically a short bridge with a high superstructure close to the water surface should be avoided. Here a slender structure (slab) is more appealing. Regarding endwalls, the same restraints mentioned for slab bridges applies to girder bridges, as long as the total length of the continuous superstructure does not exceed 70-90 m

2.3 Loading

2.3.1 Dead Loads

Dead load shall include the weight of all components of the structure, appurtenances and utilities attached thereto, earth cover, wearing surface, future overlays, and planned widening.

2.3.2Live Loads

Number of Design Lanes: Generally, the number of design lanes should be determined by taking the integer part of the ratio w/3600, where w is the clear roadway width in mm between curbs and/or barriers.

Trucks will be present in adjacent lanes on roadways with multiple design lanes but this is unlikely that all adjacent lanes will be loaded simultaneously. This will be considered by the multiple presence factors.

Number of Loaded Lanes	1	2	3	>3
Multiple Presence Factors "m"	1.20	1.0	0.85	0.65

Table 2.5 Multiple Presence Factors

When the loading condition includes the pedestrian loads combined with one or more lanes of the vehicular live load, the pedestrian loads shall be taken to be one loaded lane.

Vehicular live loading on the roadways of bridges structures, designated HL-93, and shall consist of a combination of the:

- Design truck or design tandem, and
- Design lane load

Design truck: The weights and spacing of axles and wheels for the design truck shall be as specified in Figure below.

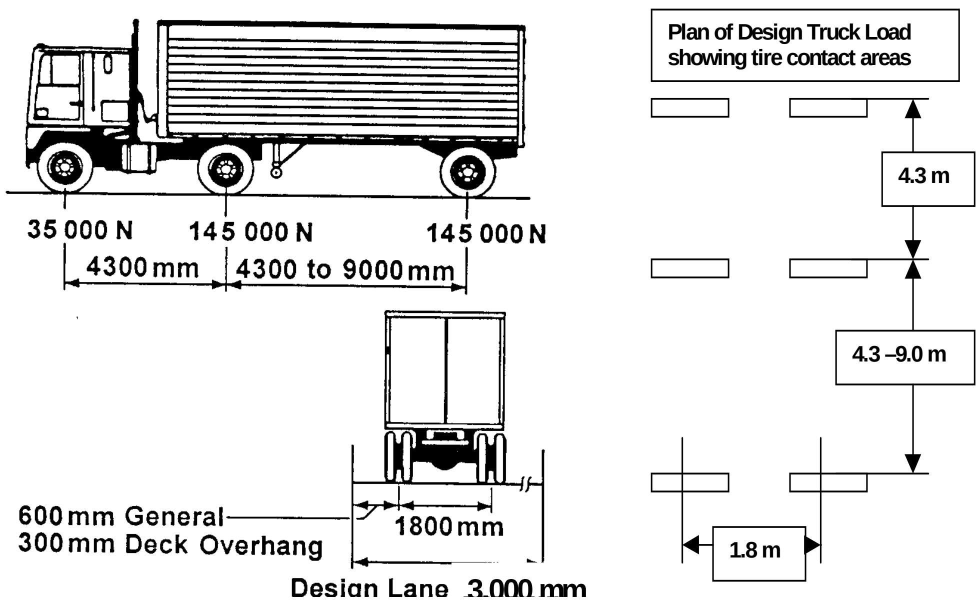


Figure 2.5 Characteristics of the Design Truck

Design Tandem: The design tandem used for Strategic Bridges shall consist of a pair of 110 kN axles spaced 1.2 m apart. The transverse spacing of wheels shall be taken as 1.8 m. See below.

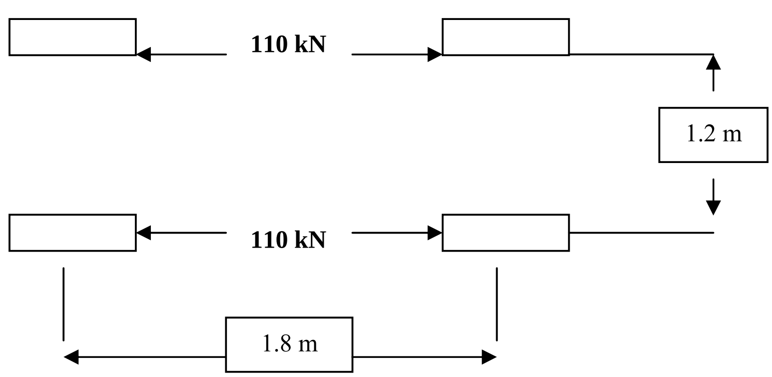


Figure 2.6 Design Tandem Load

Design Lane Load: The design lane load shall consist of a load of 9.3 kN/m, uniformly distributed in the longitudinal direction. Transversely, the design lane load shall be assumed to be uniformly distributed over a 3.0-m width. The force effects from the design lane load shall not be subject to a dynamic load allowance.

Dynamic Load Allowance (IM = Vehicular Dynamic Load Allowance): Dynamic effects due to moving vehicles shall be attributed to two sources:

1- Hammering effect is the dynamic response of the wheel assembly to riding surface discontinuities, such as deck joints, cracks, potholes, and delaminations, and

2- Dynamic response of the bridge as a whole to passing vehicles, which shall be due to long undulations in the roadway pavement, such as those caused by settlement of fill, or to resonant excitation as a result of similar frequencies of vibration between bridge and vehicle. The frequency of vibration of any bridge should not exceed 3 Hz.

Dynamic load allowance need not be applied to:

- Retaining walls not subject to vertical reactions from the superstructure, and
- Foundation components that are entirely below ground level.

The dynamic load allowance shall not be applied to pedestrian loads or to the design lane load.

The factor to be applied to the static load shall be taken as: (1 + IM/100).

Component	IM
Deck Joints – All Limit States	75%
All Other Components • Fatigue and Fracture Limit State • All Other Limit States	 15% 33%

Table 2.5 Dynamic Load Allowance, IM

The dynamic load allowance for culverts and other buried structures, in %, shall be taken as:

IM = 33 (1.0 - 4.l*10-4 DE) > 0%

Where:

DE = the minimum depth of earth cover above the structure (mm)

2.4 Design limit states

Structural components shall be proportioned to satisfy the requirements at all appropriate service, fatigue, strength and extreme event states.

Prestressed and partially prestressed concrete structural components shall be investigated for stresses and deformations for each stage that shall be critical during construction, stressing, handling, transportation, and erection, as well as during the service life of the structure of which they are part.

Stress concentrations due to prestressing or other loads, and restraints or imposed deformations shall be considered.

2.4.1 Service limit state

For concrete structures, service limit states correspond to the restrictions on cracking width and deformations under service conditions. They are intended to ensure that the bridge will behave and perform acceptably during its service life.

Actions to be considered for concrete at the service limit state shall be cracking (if the tension exceeds $0.5\sqrt{f^1{}_c}$) deformations, and concrete stresses.

The cracking stress shall be taken as the modulus of rupture .

1. Control of Cracking

All reinforced concrete members are subject to cracking under any load condition, including thermal effects and restraint of deformations, which produces tension in the gross section in excess of the cracking strength of the concrete. Locations particularly vulnerable to cracking include those where there is an abrupt change in section and intermediate post-tensioning anchorage zones.

Provisions specified, herein, are used for the distribution of tension reinforcement to control flexural cracking in beams.

From the standpoint of appearance, many fine cracks are preferable to a few wide cracks. The best crack control is obtained when the steel reinforcement is well distributed over the zone of maximum concrete tension. Several bars at moderate spacing are more effective in controlling cracking than one or two larger bars of equivalent area.

2. Control of Deformations

Service-load deformations in bridge elements need to be limited to avoid the structural behavior which differs from the assumed design conditions and to ease the psychological effects on motorists. Service-load deformations may not be a potential source of collapse mechanisms but usually cause some undesirable effects, such as the deterioration of wearing surfaces and local cracking in concrete slab which could impair serviceability and durability. [1] provides two alternative criteria for controlling the deflections:

Limiting Computed Deflections:

Vehicular load, general Span length/800

Vehicular and/or pedestrian loads Span length/1000

Vehicular load on cantilever arms Span length/300

Vehicular and/or pedestrian loads on cantilever arms Span length/1000

2.4.2 Fatigue limit state

Fatigue need not be investigated for concrete deck slabs in multi-girder applications. In regions of compressive stress due to permanent loads and prestress, fatigue shall be considered only if this compressive stress is less than twice the maximum tensile live load stress resulting from the fatigue load combination as specified in [2].

2.4.3 Strength limit state

The strength limit state issues to be considered shall be those of strength and stability. Factored resistance shall be the product of nominal resistance and the resistance factor in [2].

2.5 Structural analysis

Linear, non-linear or full range and plastic methods of analysis can all contribute to an assessment of bridge. However, it should be emphasised that the predictions of linear and non-linear methods of analysis must be regarded as approximate. Although these methods can provide enormous quantities of detailed data, their inherent assumptions regarding the structural response are based on the behaviour of idealised materials, idealised boundary conditions and a known construction sequence. Movement of supports, a failed bearing, the effects of cracking during construction and under environmental loading, for example, can all lead to considerable stress redistribution.

2.5.1 Linear Methods of Analysis

Linear methods of analysis can provide reasonable estimates of moment and shear force distributions under working loads. Predictions of linear analyses using loads factored for the ultimate limit state are often used in design. The most reliable linear analytical techniques for slab bridges are the grillage analogy and the finite element method. Both of these approaches can treat plan-forms of any shape, varying depth, and both column and line supports. When suitable stiffness parameters are provided, they can also be used to analyse pseudo-slab bridges of most commonly encountered cross-sections. Both methods are readily available in computer packages and can deal easily with a large number of load cases.

2.5.2 Design Philosophy

In engineering design the general principle is that the resistance of a cross section has to exceed the effects come from the applied loads. That is

$$\text{Resistance} \geq \text{Effect of Loads}$$

When a particular loading condition reaches and just exceeds the resistance capacity of the provided section failure is the result. Such a condition is referred to as a Limit State. A limit state is a condition beyond which a bridge system or bridge component ceases to full fill the function for which it is designed. Preventing a limit state from being reached is the central goal of design of bridges. In addition to this function, appearance and economy must get due attention. Safety is achieved by using reasonable margin of safety factors. These factors are results of collective experience and judgment of qualified group of engineers and officials. In Highway Bridge design [1]provision is used for bridge design. The resistance side of the inequality of Equation above is multiplied by a statistically based resistance factor, whose value is usually less than one, and the load side is multiplied by a statistically based load factor, whose value is usually greater than one. The load effect at a particular limit state involves a combination of a different load types that have different degrees of predictability [2].

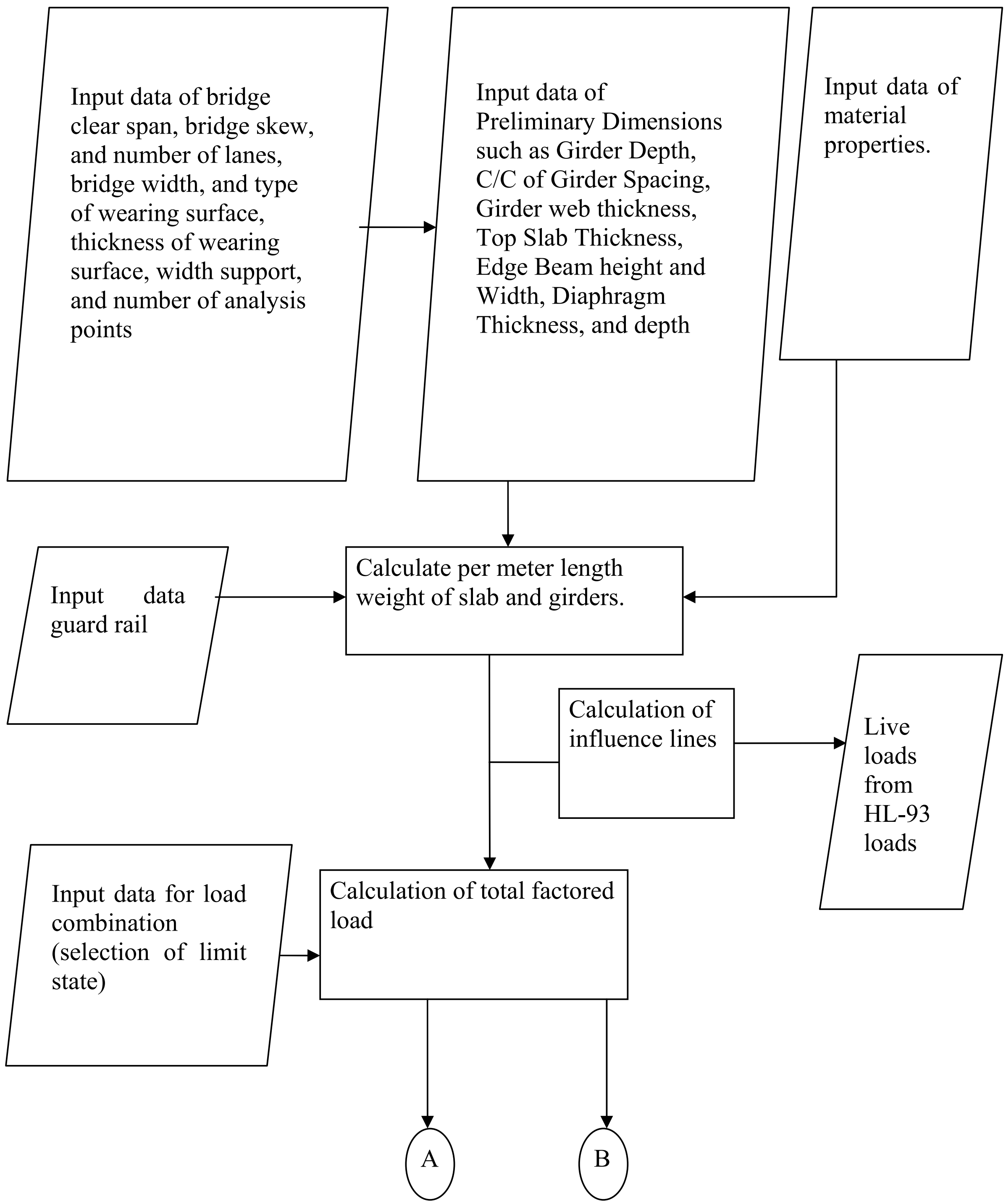
2.5.3 Reinforcement detailing

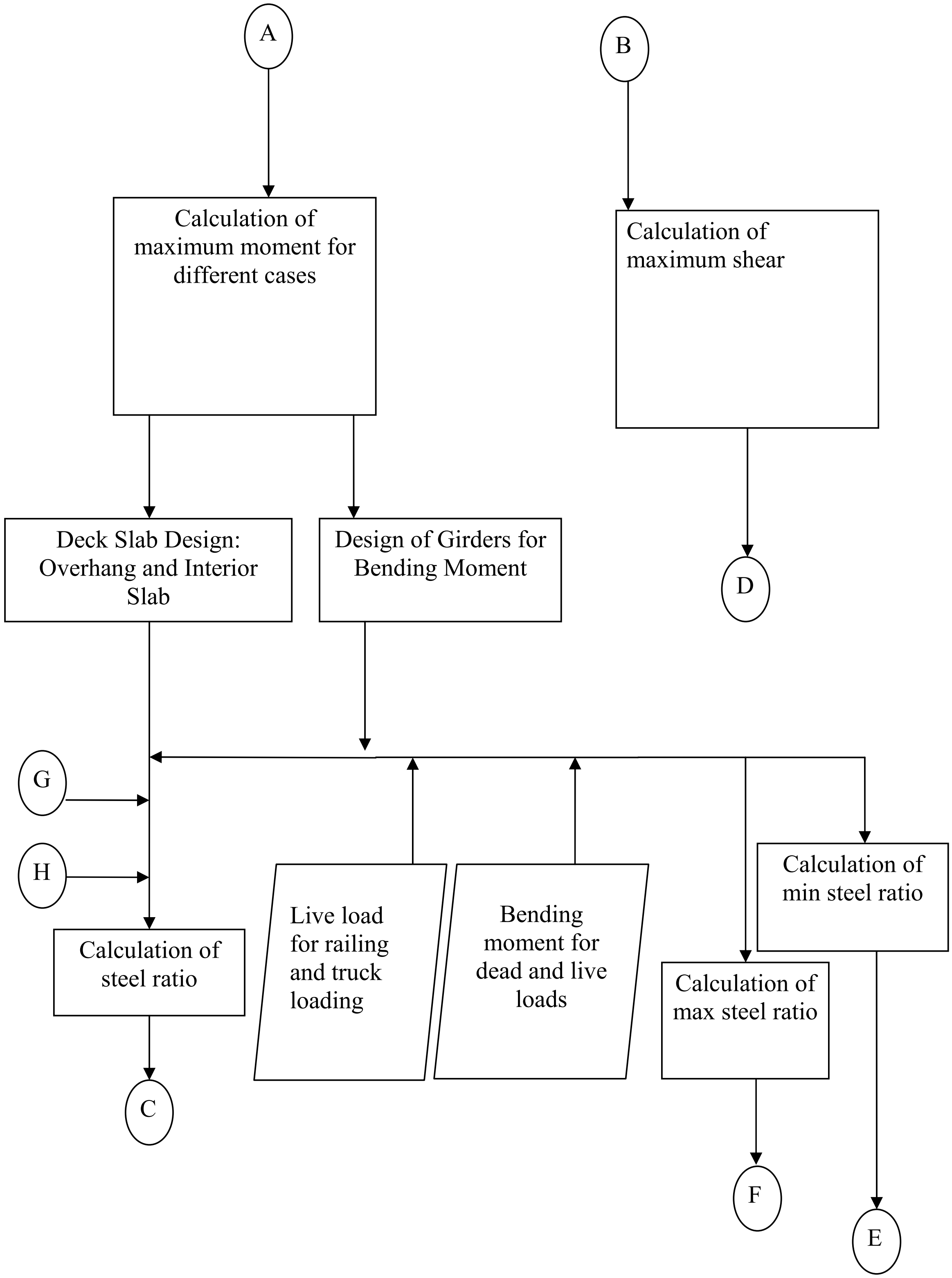
When reinforcement is finally positioned within the confines of a shutter it will be because the designer has considered factors other than those pertaining just to the reinforcement itself. These will include specification, reinforcement type and scheduling, wastage, storage on site, laps, protection and the placing and vibrating of concrete around it[4].

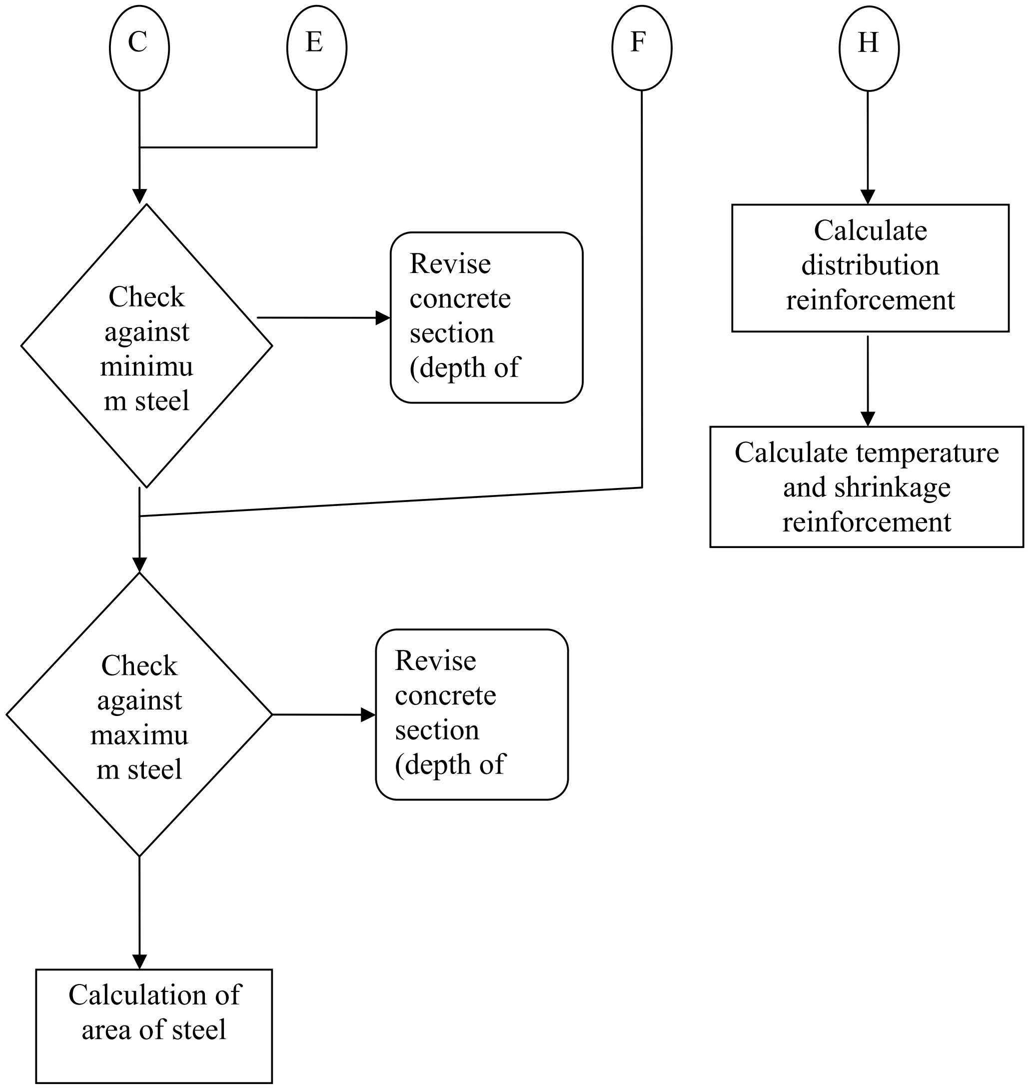
To summarize, the importance of conceptual analysis in bridge-designing problems cannot be emphasized strongly enough. The designer must first visualize and imagine the bridge in order to determine its fundamental function and performance. Without question, the factors of safety and economy shape the bridge designer’s thought in a very significant way. The values of technical and economic analysis are indisputable, but they do not cover the whole design process. Bridge design is a complex engineering problem. The superstructure design process includes consideration of other important factors, such as choice of bridge system, materials, dimensions and aesthetics.

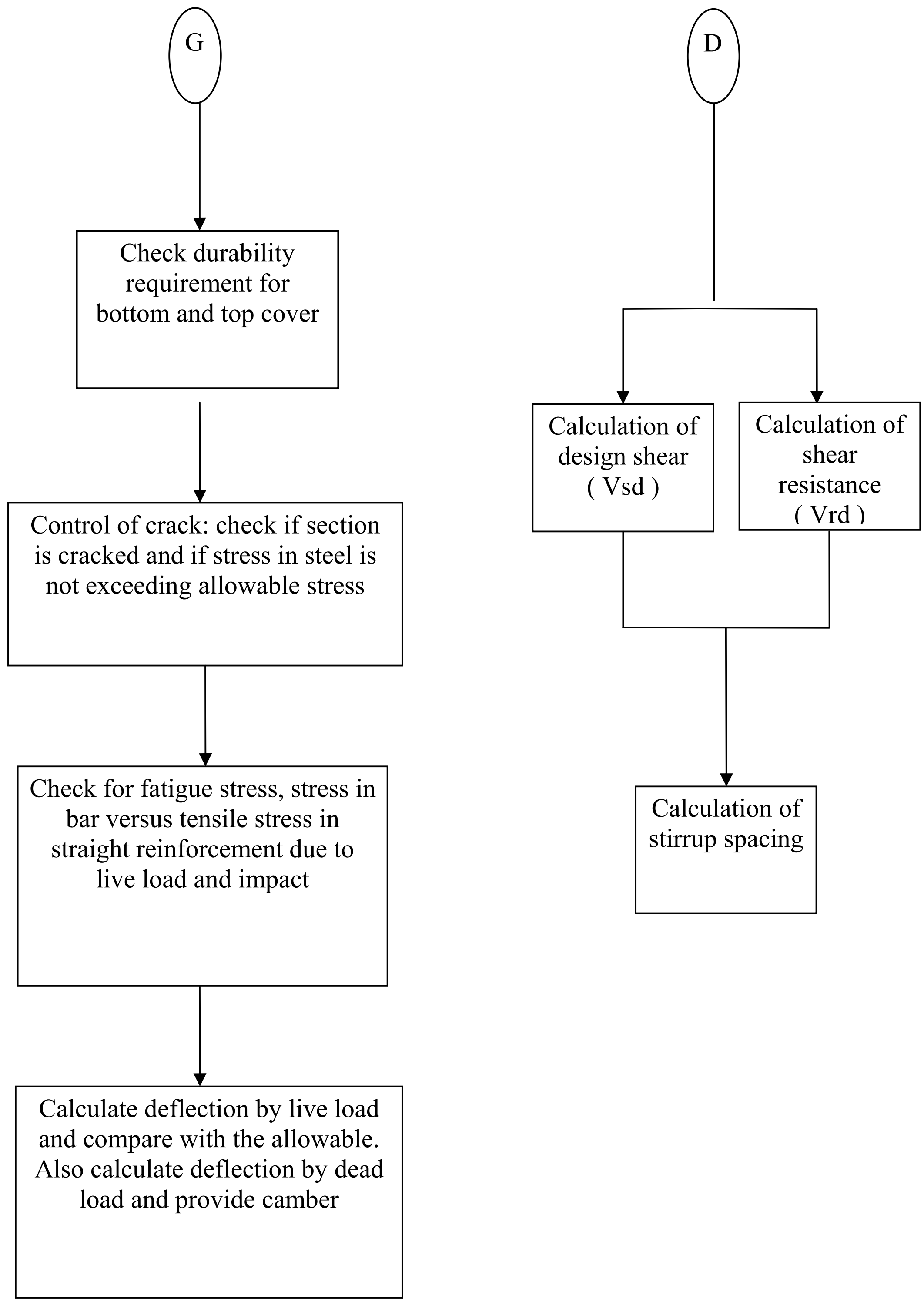
CHAPTER THREE – FLOWCHARTS

3.1 Girder Bridge

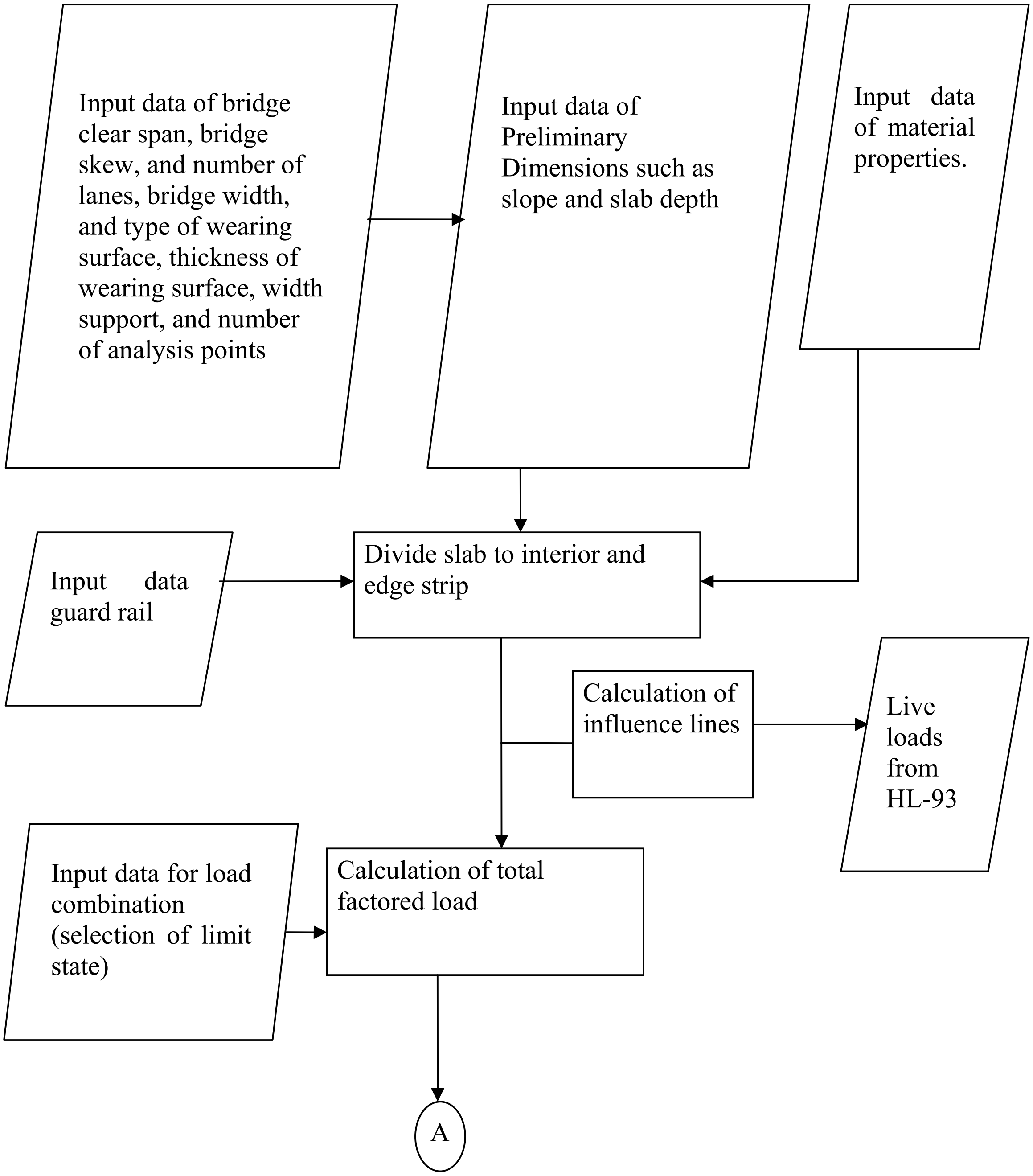


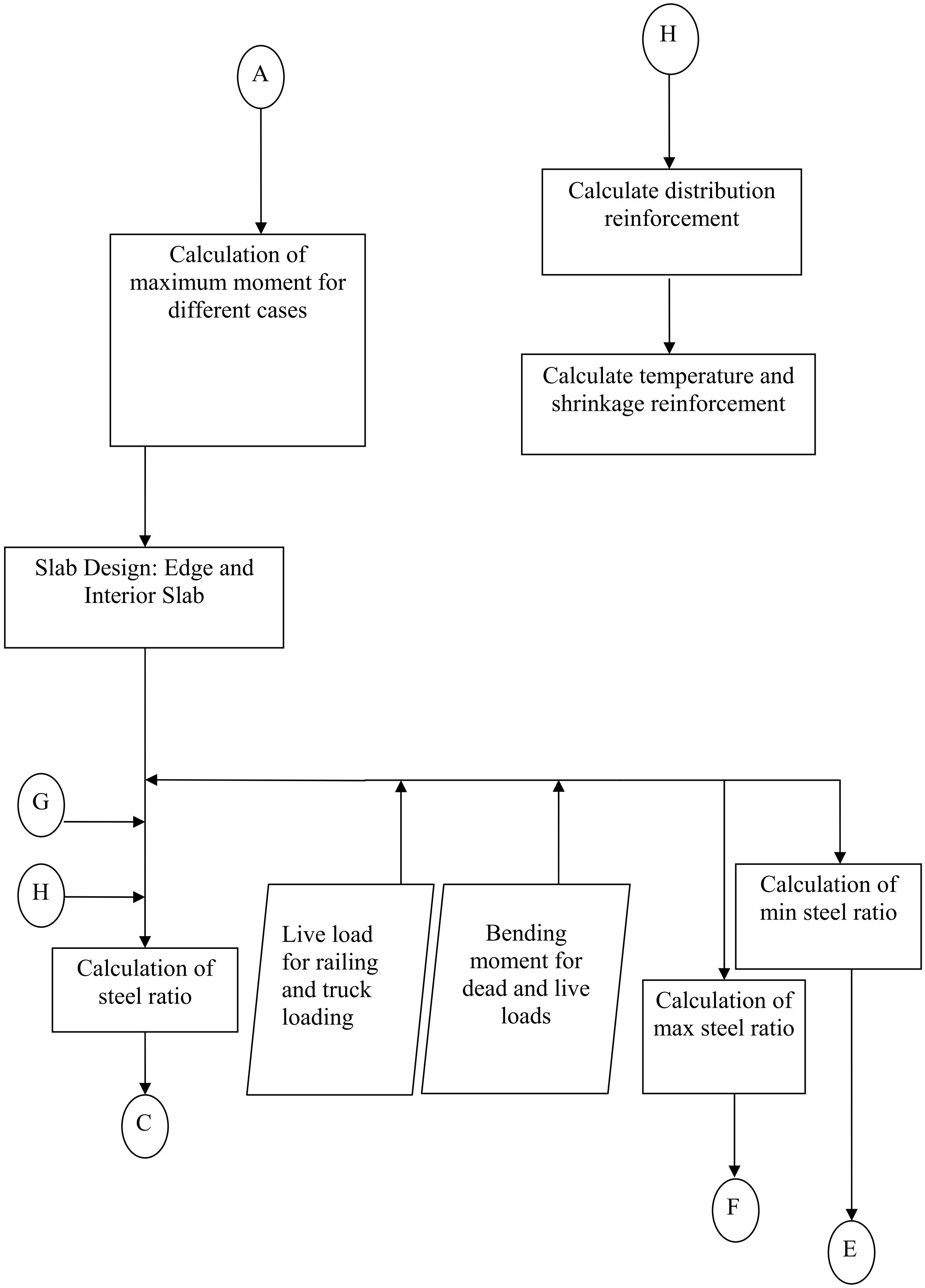

A
B
Calculation of maximum moment for different cases
Calculation of maximum shear
Deck Slab Design: Overhang and Interior Slab
Design of Girders for Bending Moment
D
G
H
Calculation of steel ratio
Live load for railing and truck loading
Bending moment for dead and live loads
Calculation of min steel ratio
Calculation of max steel ratio
C
F
E

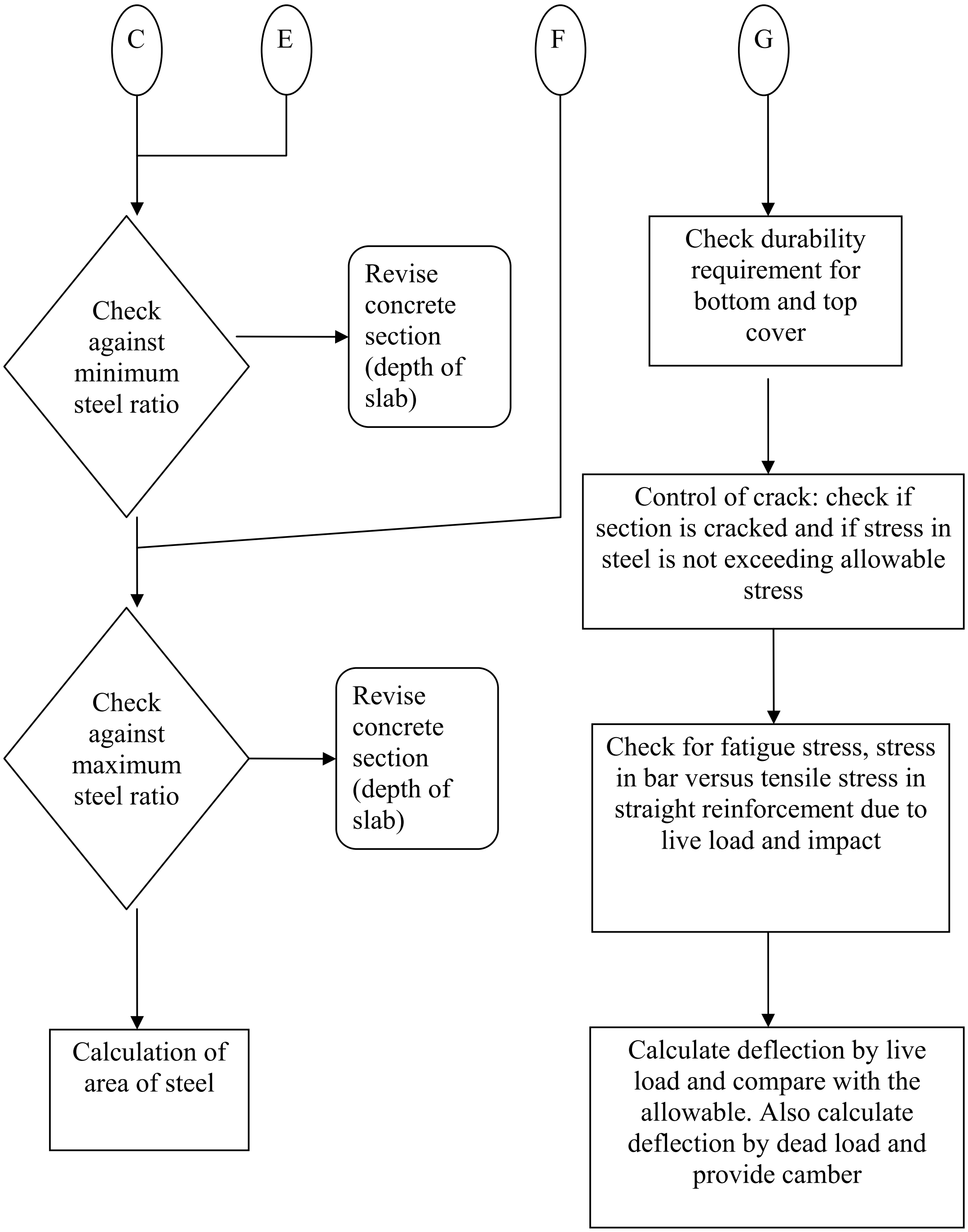

C
E
F
H
Check against minimum steel
Revise concrete section (depth of
Calculate distribution reinforcement
Calculate temperature and shrinkage reinforcement
Check against maximum steel
Revise concrete section (depth of
Calculation of area of steel


G
Check durability requirement for bottom and top cover
Control of crack: check if section is cracked and if stress in steel is not exceeding allowable stress
Check for fatigue stress, stress in bar versus tensile stress in straight reinforcement due to live load and impact
Calculate deflection by live load and compare with the allowable. Also calculate deflection by dead load and provide camber
D
Calculation of design shear (Vsd)
Calculation of shear resistance (Vrd)
Calculation of stirrup spacing

3.2 SLAB BRIDGE




A
Calculation of maximum moment for different cases
Slab Design: Edge and Interior Slab
G
H
Calculation of steel ratio
C
Live load for railing and truck loading
Bending moment for dead and live loads
Calculation of max steel ratio
Calculation of min steel ratio
F
E
H
Calculate distribution reinforcement
Calculate temperature and shrinkage reinforcement


C
E
F
G
Check against minimum steel ratio
Revise concrete section (depth of slab)
Check durability requirement for bottom and top cover
Control of crack: check if section is cracked and if stress in steel is not exceeding allowable stress
Check against maximum steel ratio
Revise concrete section (depth of slab)
Check for fatigue stress, stress in bar versus tensile stress in straight reinforcement due to live load and impact
Calculation of area of steel
Calculate deflection by live load and compare with the allowable. Also calculate deflection by dead load and provide camber

CHAPTER FOUR - DESIGN STEPS

4.1 Girder Bridge

Girder Superstructure Design

1. Develop General Section
    - Roadway Width (Highway-Specified)
    - Span Arrangements
    - Select Bridge Type
2. Develop Typical Section CIP T- Girders
    - Top Flange
    - Bottom Flange
    - Webs
    - Structure Depth
    - Reinforcement
        - Minimum Reinforcement
        - Temperature and Shrinkage Reinforcement
    - Strut-and-Tie Areas, if Any
    - Effective Flange Widths
3. Design Conventionally Reinforced Concrete Deck
    - Deck Slabs
    - Minimum Depth
    - Empirical Design
    - Traditional Design
    - Strip Method
    - Live Load Application
    - Distribution Reinforcement
    - Overhang Design
4. Select Resistance Factors
5. Select Load Modifiers, Strength Limit State (Conventional)
    - Ductility
    - Redundancy
    - Operational Importance
6. Select Applicable Load Combinations and Load Factors
7. Calculate Live Load Force Effects
    - Live Loads and Number of Lanes
    - Multiple Presence
    - Dynamic Load Allowance
    - Distribution Factor for Moment
        - Interior Beams with Concrete Decks
        - Exterior Beams
        - Skewed Bridges
    - Distribution Factor for Shear
        - Interior Beams
        - Exterior Beams
        - Skewed Bridges
    - Reactions to Substructure
8. Calculate Force Effects from Other Loads as Required
9. Investigate Service Limit State

  - Durability
  - Crack Control
  - Fatigue, if Applicable
  - Deflection and Camber

10. Investigate Strength Limit State
    - Flexure
      - Flexural Resistance
      - Limits for Reinforcement
    - Shear (Assuming No Torsional Moment)
      - General Requirements
      - Sectional Design Model
        - Nominal Shear Resistance
        - Determination of ß and 8
        - Longitudinal Reinforcement
        - Transverse Reinforcement
        - Horizontal Shear
11. Check Details
    - Cover Requirements
    - Development Length-Reinforcing Steel
    - Development Length-Prestressing Steel
    - Reinforcement Spacing Limits
    - Transverse Reinforcement
    - Beam Ledges

4.2 Slab Bridge

Generally, the design approach for slab bridges is similar to beam and girder bridges with some exceptions, as noted below.

1. Check Minimum Recommended Depth
2. Determine Live Load Strip Width
3. Determine Applicability of Live Load for Decks and Deck Systems
4. Investigate Shear
5. Investigate Distribution Reinforcement

CHAPTER FIVE - NUMERICAL EXPERIENCE AND DISCUSSION

To show some numerical experience using the written Program, BRAD, two design examples are provided. The first one is a 20 m span girder bridge is designed using BRAD and the pdf output from the program is provided on page 30 .And also another design example of a 10 slab bridge is provided on page 48. Note that the results are presented as they are i.e not edited.

CHAPTER SIX - THE GRAPHICAL USER INTERFACE

The BRAD graphical user interface is used to model, analyze, design, and display output results. This chapter introduces you to some of the basic concepts of the BRAD graphical user interface and the detailed steps of analyzing and designing reinforced concrete slab and t-girder Bridge.

The BRAD Screen

Go to the startup menu & Click on it, then in the all programs menu point out your cursor, thereafter search for the program BRAD and open it.

The BRAD graphical user interface appears on your screen and looks similar to the following:

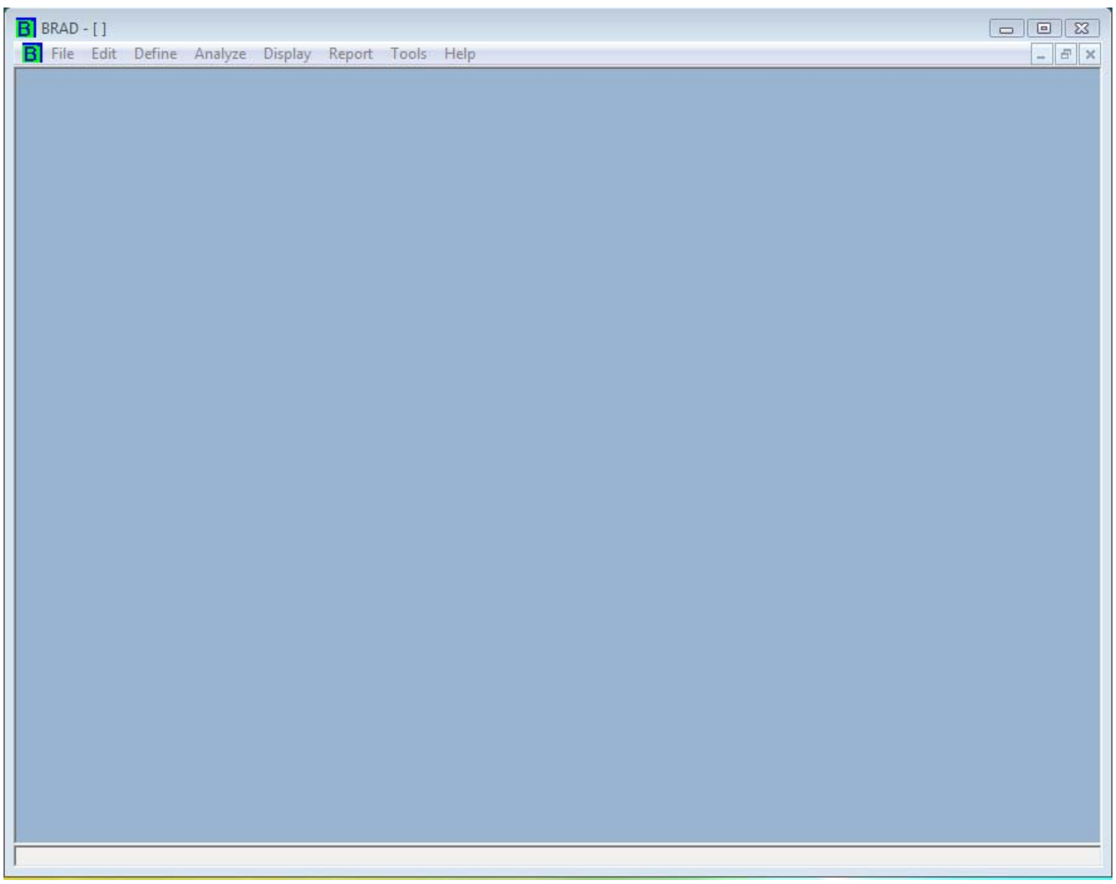


Figure 6.1 The BRAD Screen

6.1 Detailed procedure for Slab Bridge

Step1. In the File menu if you click, it will display the submenus which are seen below, and make your selection on new model (Ctrl+N shortcut) to continue.

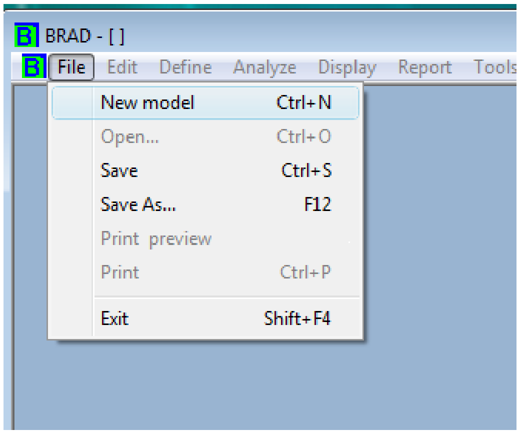


Figure 6.2 The file menu

Step 2.user is expected to select one from the options and to go for detail design and output. The templates are shown below:

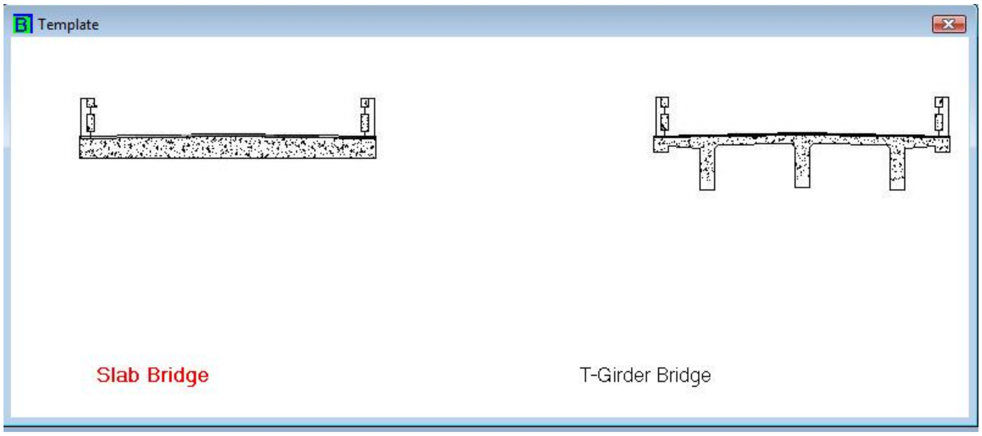


Figure 6.3 Template of bridge types (slab bridge)

Step3. For the analysis & design of Slab Bridge, on the template Click the template saying Slab Bridge & you will be provided with form design data.

Input as follows:

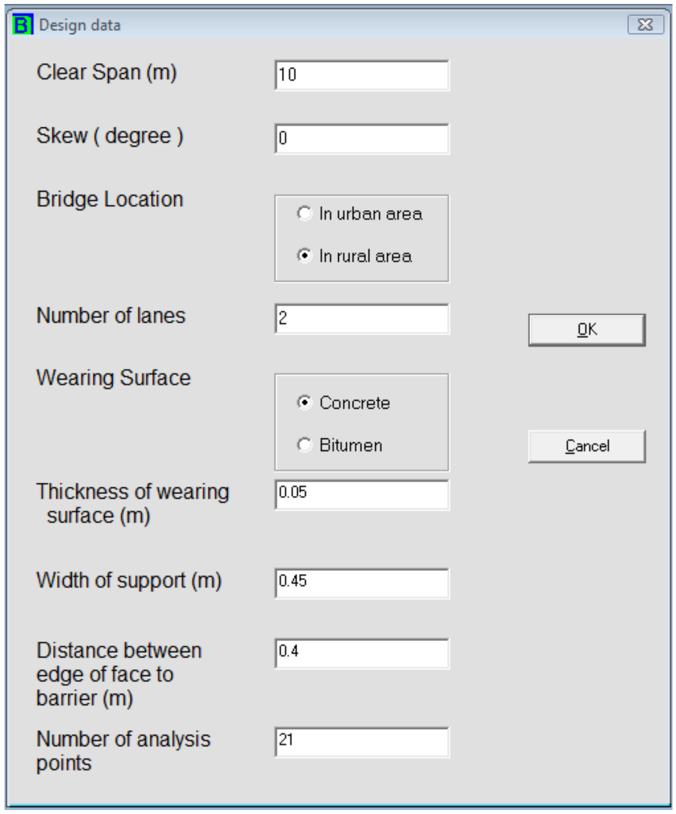


Figure 6.4 Design data for slab bridge

Step4. After filling the design data click the ok button to accept the design data values. Then a form slab input to adjust depth of slab is provided.

Input as follows:

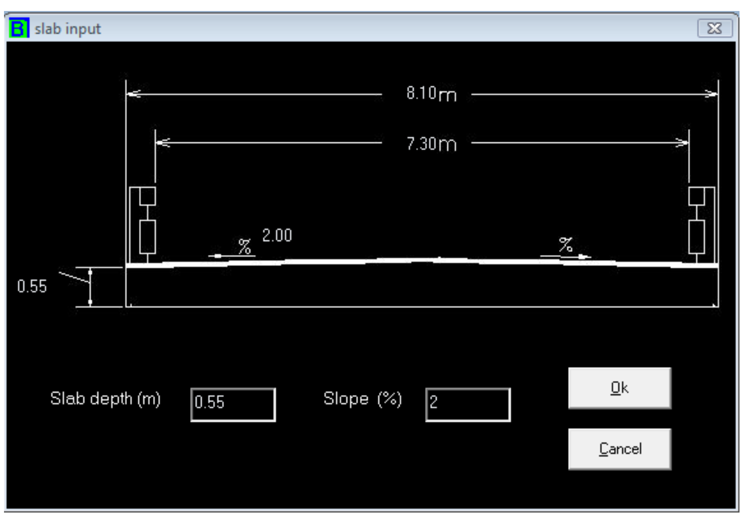


Figure 6.5 Slab dimension input

Step5. Click the define Menu and select the material property Submenu to select the material property. Then choose the material data on which you want to work with. The following picture displays the form with material property.

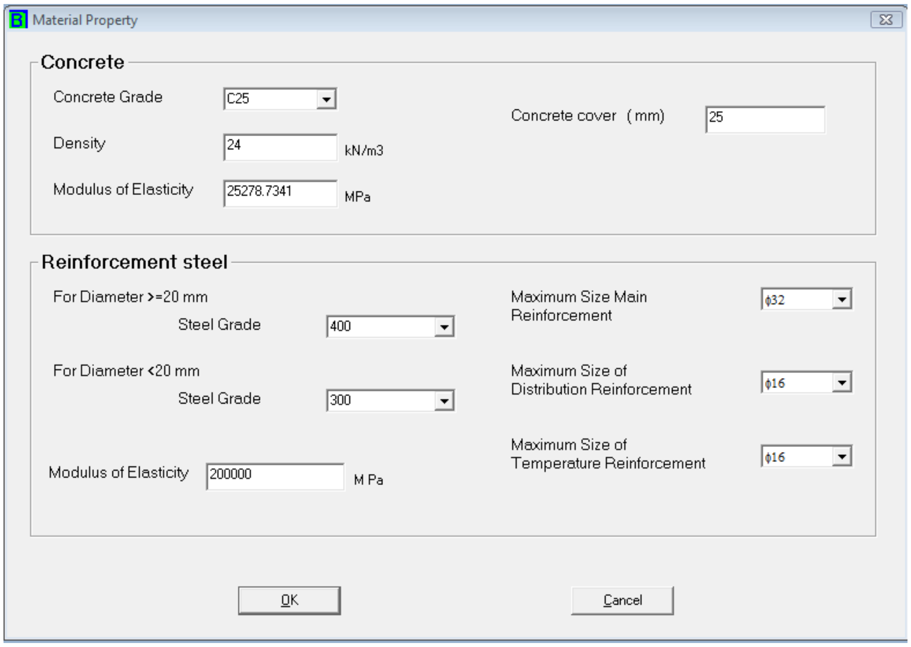


Figure 6.6 Material properties for slab bridge

Step6. In the Define Menu select the guard rail Submenu to supply your input data with the appropriate selection of input.

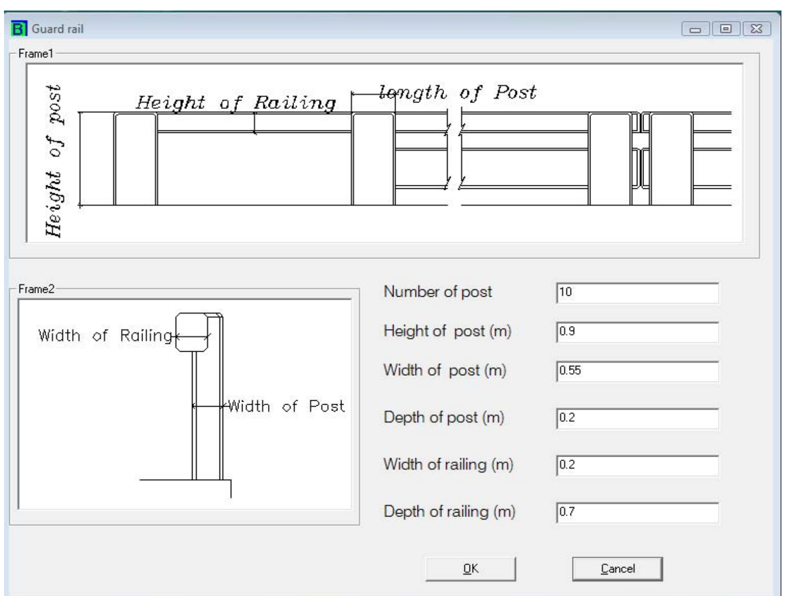


Figure 6.7 Guard rail for slab bridge

Step7. Again in the Define Menu select the limit state Submenu to supply your input data with the appropriate selection of input.

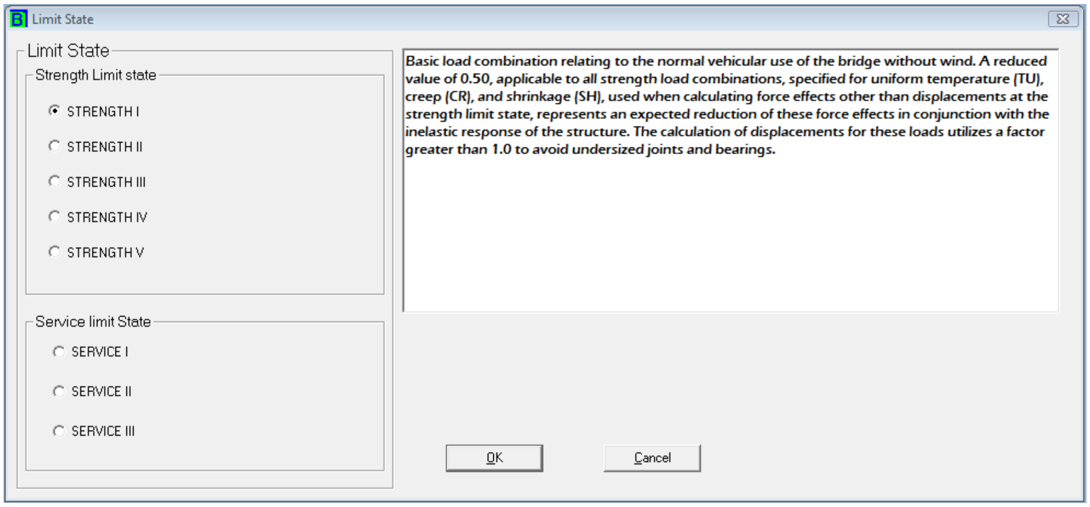


Figure 6.8 Limit state for slab bridge

Step8. Go to the Analysis Menu or press F5 to run.

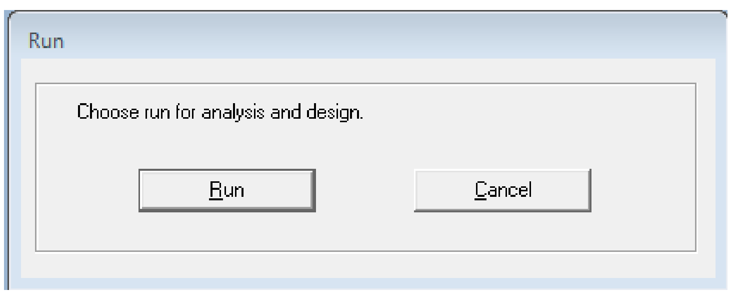


Figure 6.9 The run window for slab bridge

Step9. To run the analysis click run and automatically it will display the completion of analysis

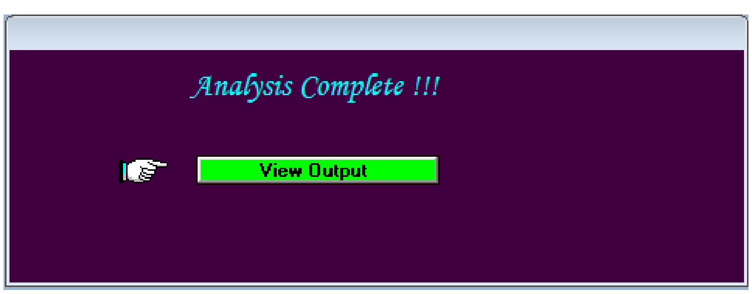


Figure 6.10 completion of analysis for slab bridge

Step10. To view the output click the view output button and automatically it will display the output.

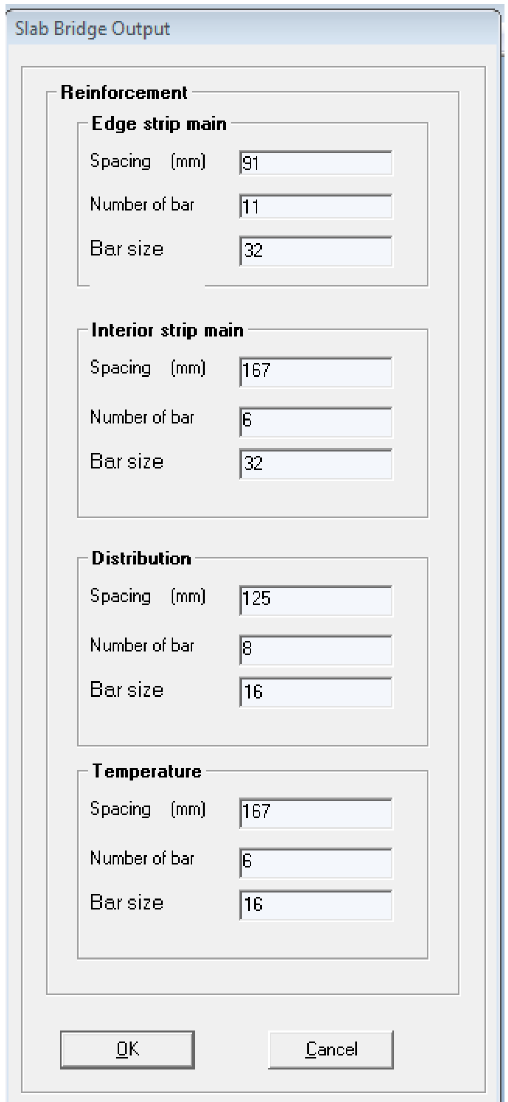


Figure 6.11 Slab bridge output

Step11. In the display Menu you will be displayed with the different options of outputs. You may choose to see the influence line, bending moment and shear force forms as follows.

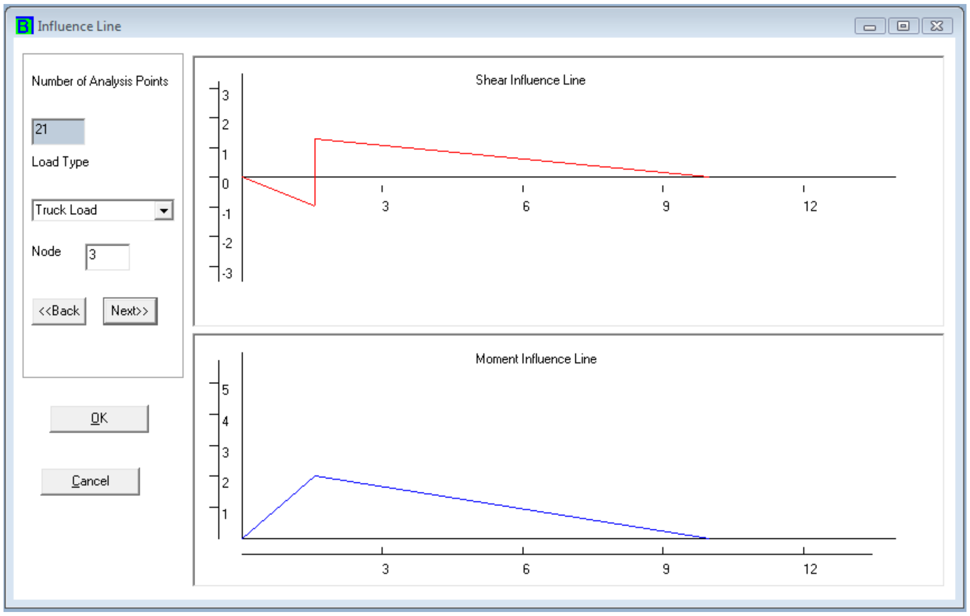


Figure 6.12 Influence line for slab bridge

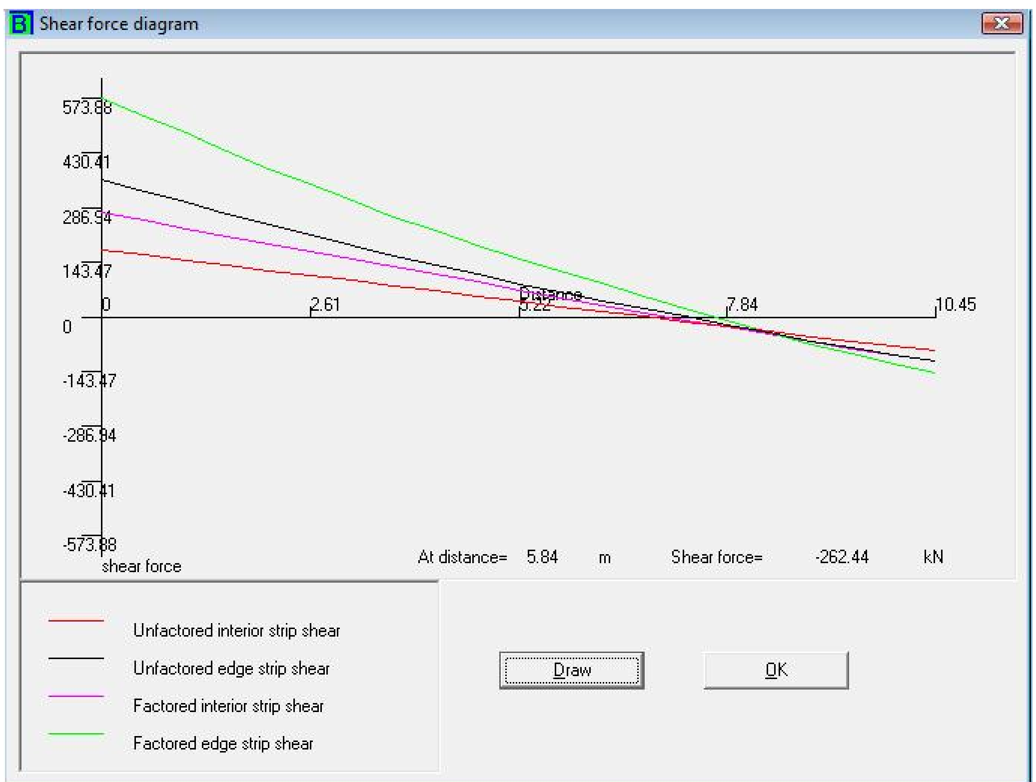


Figure 6.13 Shear force output for slab bridge

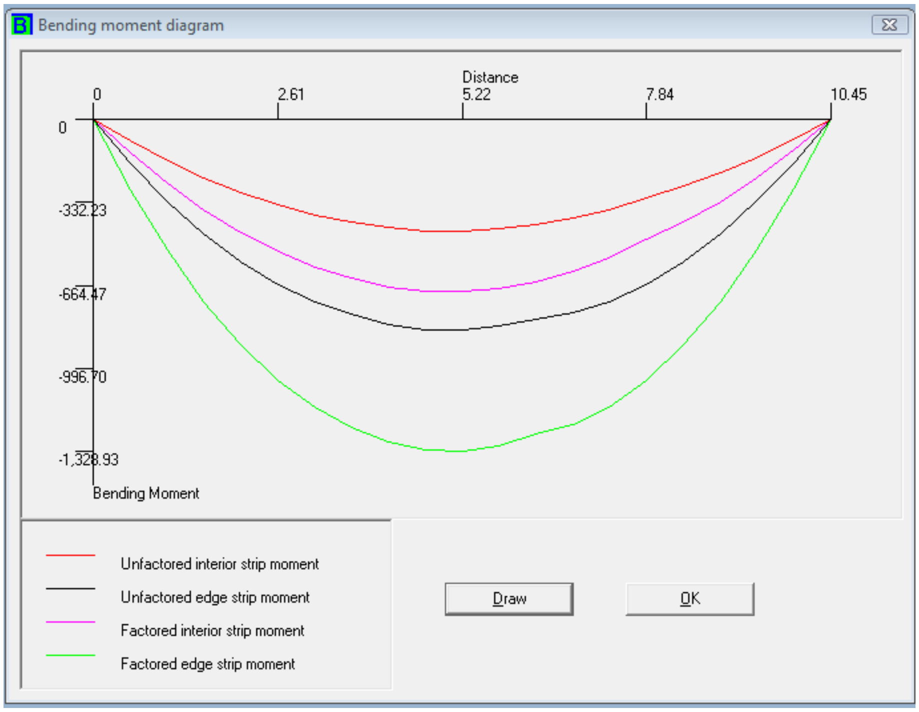


Figure 6.14 Bending moment for slab bridge

Step12. And also in the display Menu you will be displayed detailed output in excel. You may choose to see the output as follows.

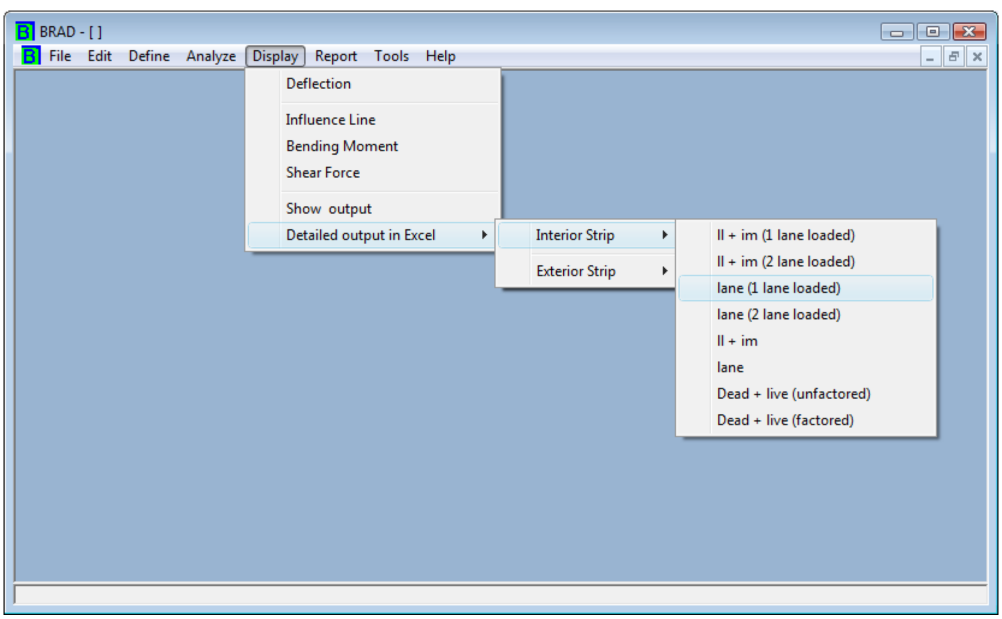


Figure 6.15 Display output in excel path

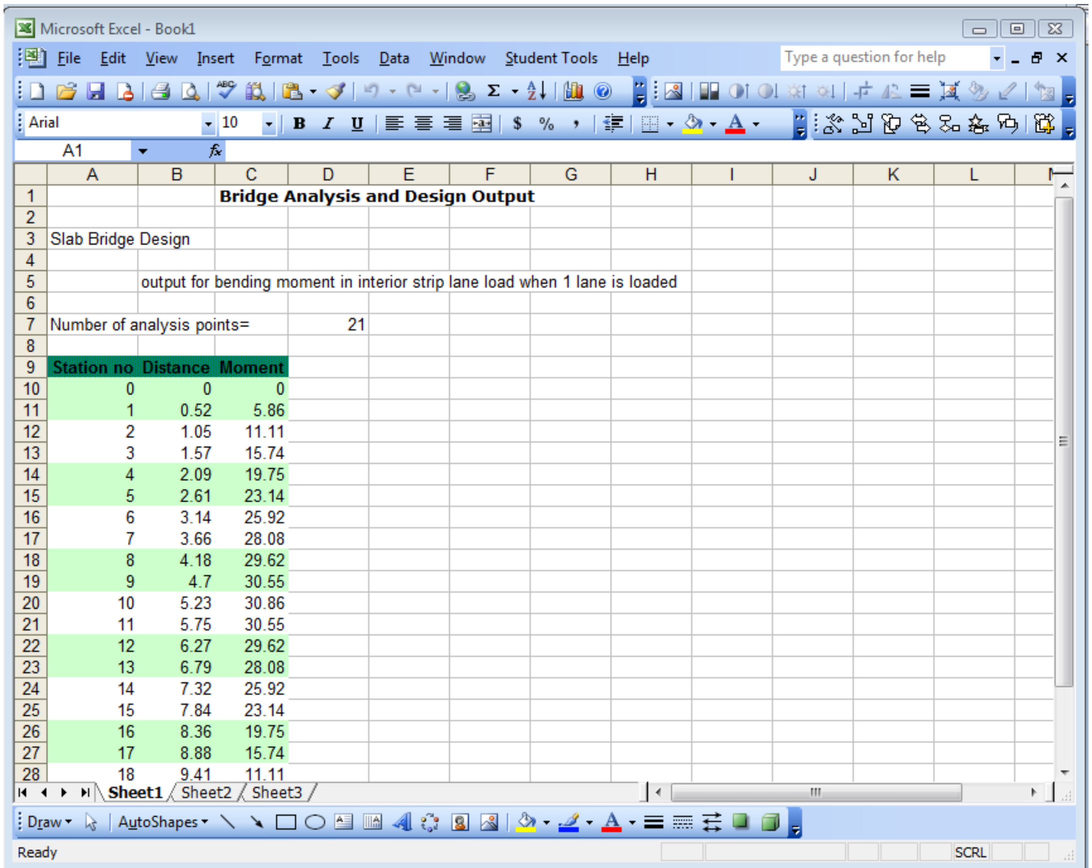


Figure 6.16 Excel output

Step13. In the report Menu fill design information and you can have a design report output as follows.

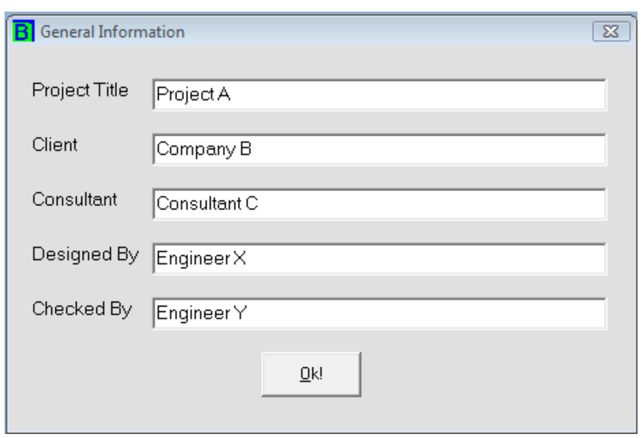


Figure 6.17 General information

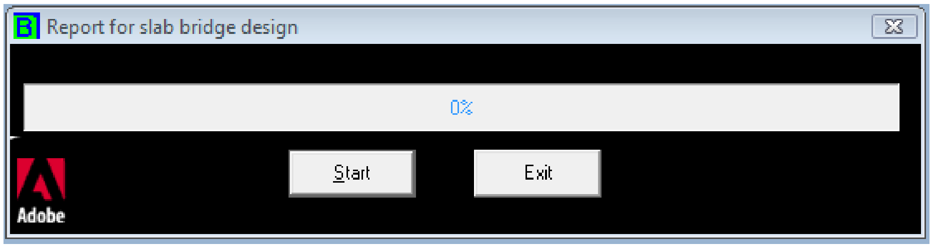


Figure 6.18 Report for slab bridge design

6.2 Detailed procedure for T-girder Bridge

Step1. In the File menu if you click, it will display the submenus which are seen below, and make your selection on new model (Ctrl+N shortcut) to continue.

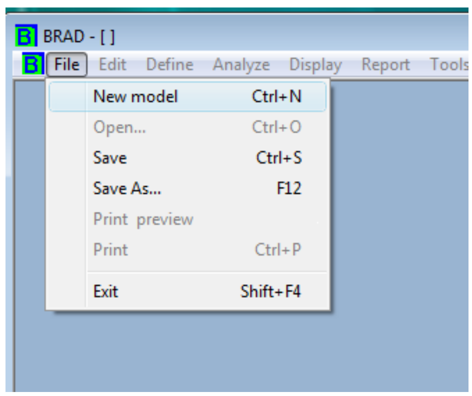


Figure 6.19 The file menu

Step 2.user is expected to select one from the options and to go for detail design and output. The templates are shown below:

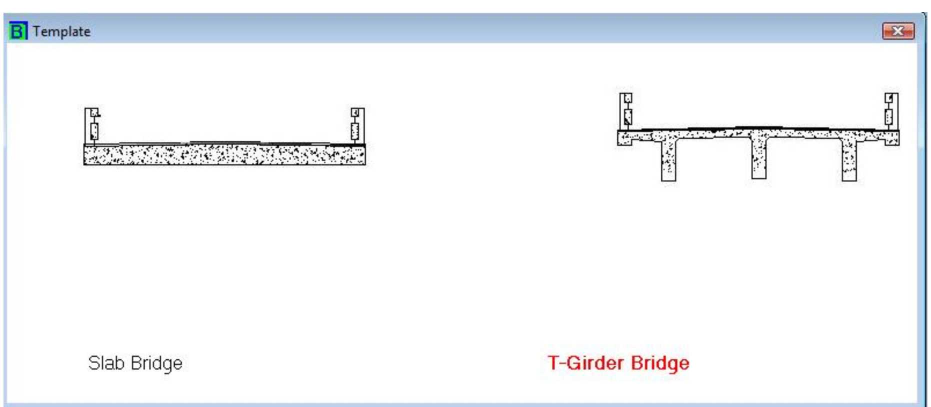


Figure 6.20 Template of bridge types (t-girder bridge)

Step3. For the analysis & design of t-girder bridge, on the template Click the template saying t-girder Bridge & you will be provided with form design data.

Input as follows:

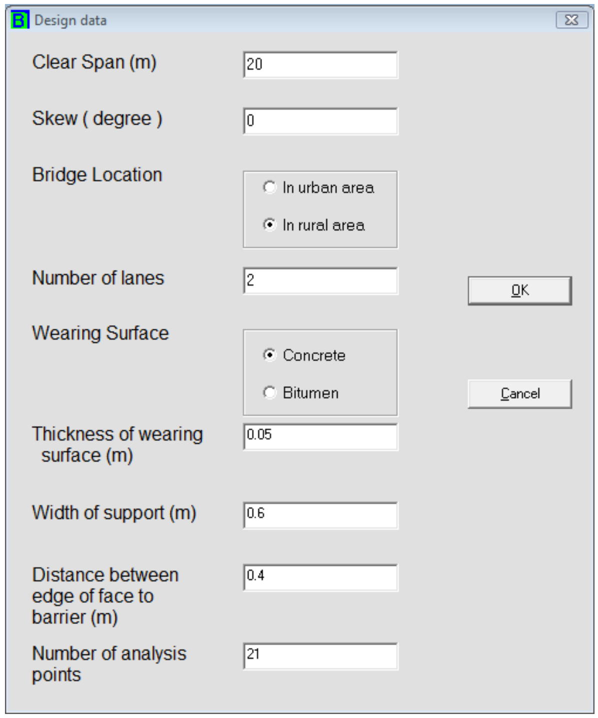


Figure 6.21 Design data for girder bridge

Step4. After filling the design data click the ok button to accept the design data values. Then a form slab input to adjust depth of slab is provided. Input as follows:

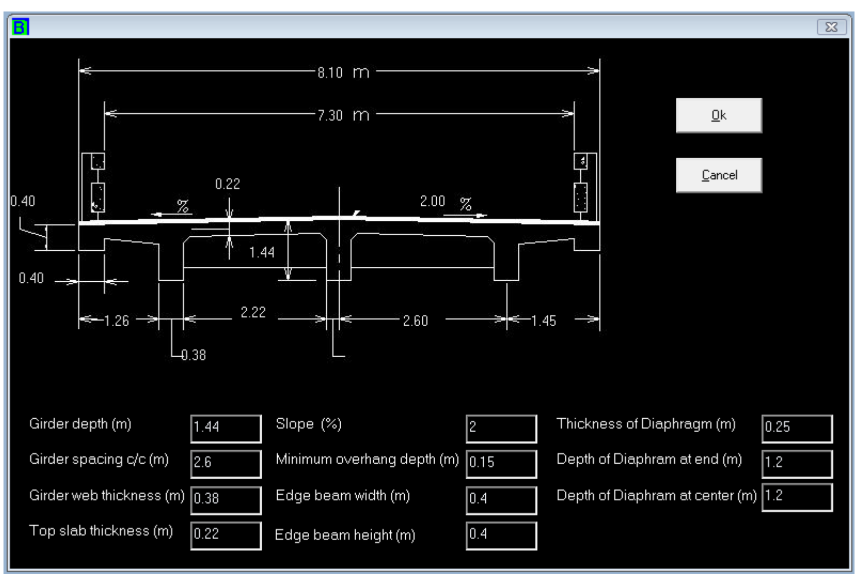


Figure 6.22 T-girder input data

Step5. Click the define Menu and select the material property Submenu to select the material property. Then choose the material data on which you want to work with. The following picture displays the form with material property.

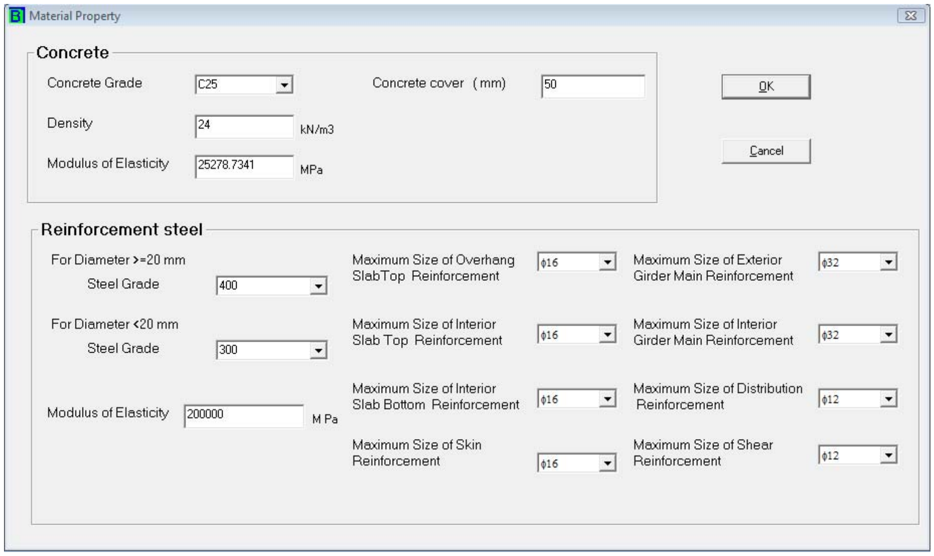


Figure 6.23 Material properties for girder bridge

Step6. In the Define Menu select the guard rail and limit state Submenu to supply your input data with the appropriate selection of input.

Step7. Go to the Analysis Menu or press F5 to run.

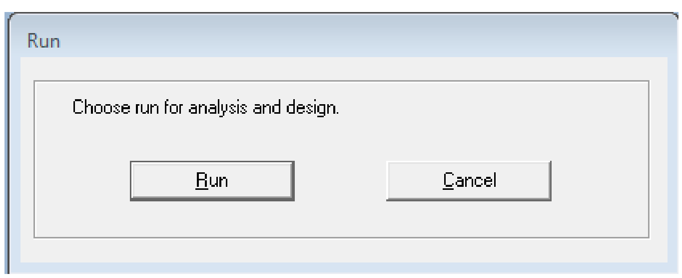


Figure 6.24 The run window for girder bridge

Step8. To run the analysis click run and automatically it will display the completion of analysis

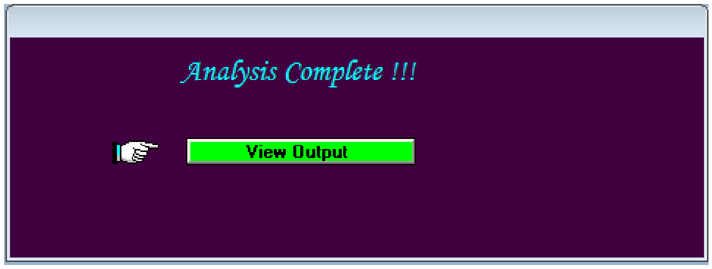


Figure 6.25 Completion of analysis for girder bridge

Step9. To view the output click the view output button and automatically it will display the output.

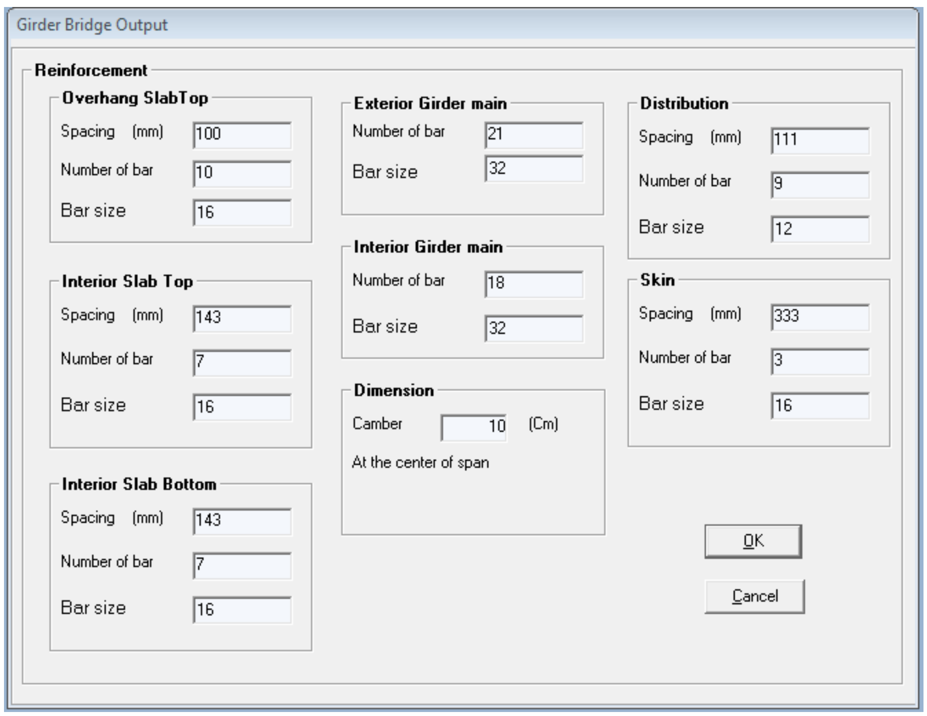


Figure 6.26 Girder bridge output

Step10. In the display Menu you will be displayed with the different options of out puts.

You may choose to see the influence line, bending moment and shear force forms as follows.

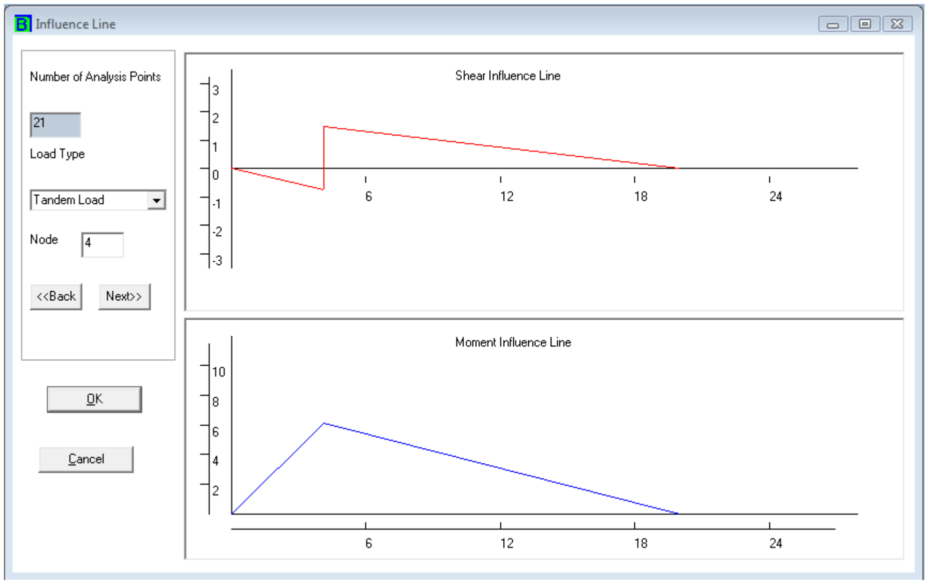


Figure 6.27 Influence line for girder bridge

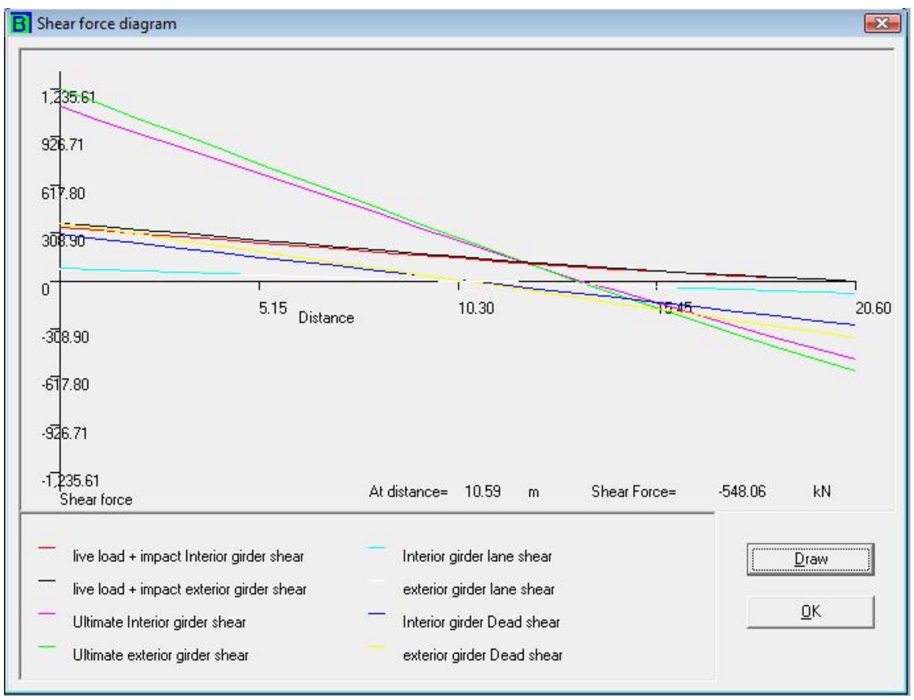


Figure 6.28 Shear force diagram for girder bridge

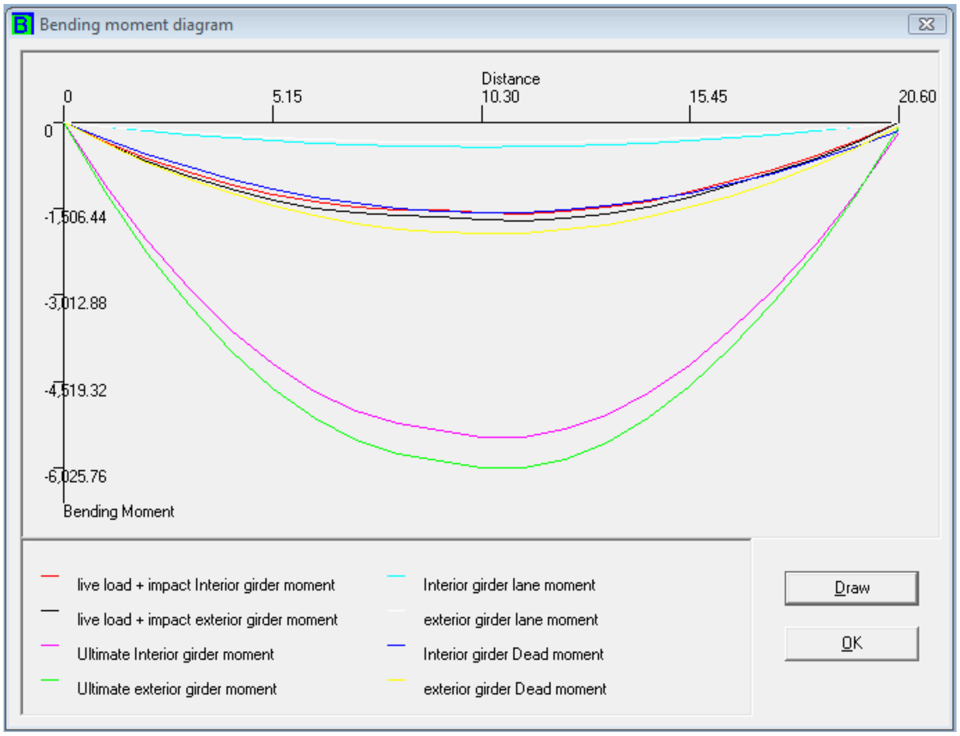


Figure 6.29 Bending moment diagram for girder bridge

Step11. As that of the slab bridge, follow steps 12 to13 display detailed output in excel and to have a design report in PDF.

In the tools menu Brad also provides a quick calculator.

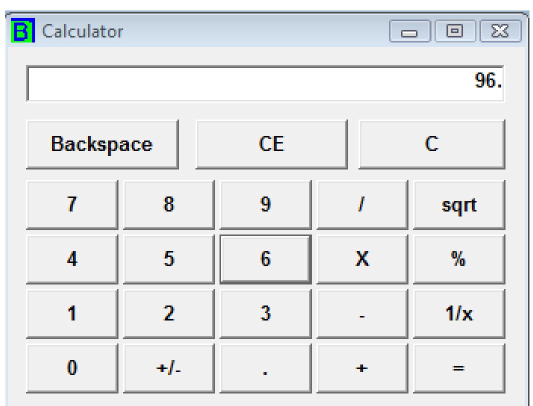


Figure 6.30 Calculator

Finally to know about the software, in the help menu if you click on about BRAD, it will display the following window.

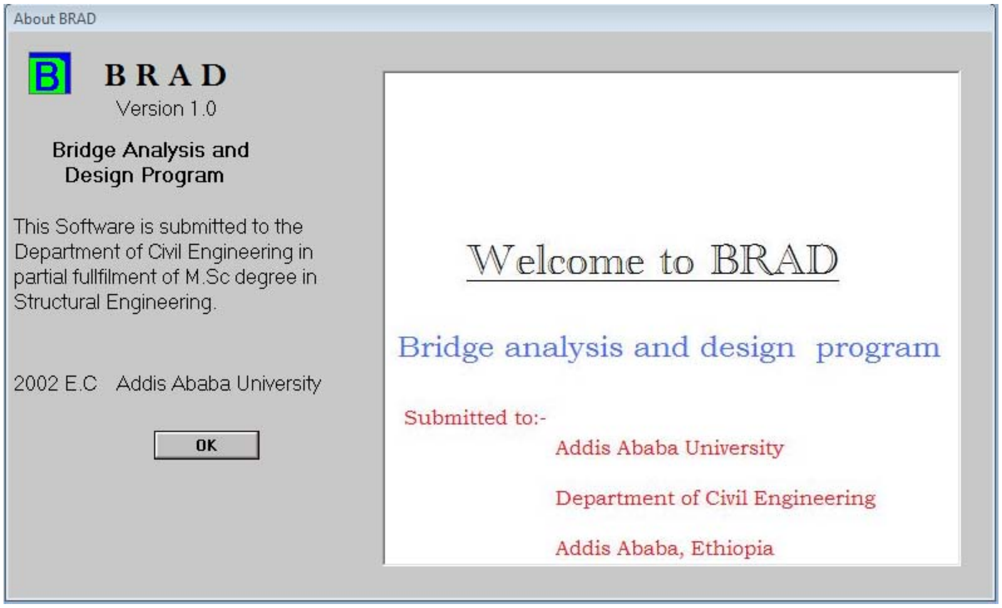


Figure 6.31 About BRAD

CHAPTER SIX - CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The thesis has shown it is possible to produce our own software to facilitate our daily design works. Since there are potentials for preparing such software not only in the bridge but also in the building industry in the country, this research work will contribute a little for the designers and consultants by showing how to produce our own user friendly programs with little programming concept.

The following points have been summarized as conclusions for the research work.

1. Since traditional methods for the analysis and design of bridge is tedious and time consuming, Providing computer program for bridge design that offers accuracy and flexibility that cannot be matched with traditional hand calculations or Microsoft excel written programs.
2. In times when buying original software is difficult, such projects appreciate the application of homemade (self made) programs to make life easy in analysis and design of any structure.
3. Also, this program is particularly useful to those who have very little experience in bridge analysis and design. Hence, design office and bridge engineers will benefit a lot from the result of this project. For example, getting quick results of dimension and reinforcement detail from the output of this product, one can do economic comparison between different types and spans of bridges. The package could also serve as a good educational aid for related courses

6.2 Recommendations

This study has mainly dealt with design of superstructure of reinforced concrete slab and girder bridge. In the future I hope that this work is to be developed into potential software which incorporates design of continuous spans and also design of substructures with a more features by providing drawings and other important outputs. Future research could include other bridge types, such as box girder bridge. Providing a collection of several different design methods, each illustrated with real-life examples would be a valuable source of information in teaching future bridge engineers.

The following points have been summarized as recommendations for the research work.

1. It would be possible to better compare various design methods and thus generate a more broad view of bridge engineering. Linking currently existing design procedures with new structural concepts would contribute to the body of knowledge in that current methods are assessed and possibly adjusted to future challenges in bridge engineering.
2. It would be better if civil engineers especially who have the interest in programming area participate in developing programs that will make different design processes simple and efficient around the construction industry.
3. The university should appreciate such projects in order to increase the productivity of students and of course the engineers to contribute something valuable for our country

REFERENCE

1. American Association of State Highway and Transportation Officials (AASHTO) (2004)," Load Resistance Factored Design (LRFD) Bridge Design Specification", Third Ed. Washington, DC.

2. Federal Democratic Republic of Ethiopia (2002) "Ethiopian Roads Authority: Bridge Design Manual" Addis Ababa

3. R.J.Cope (2004) "Concrete Bridge Engineering" , Performance and Advances, Elsevier Applied Science Publishers Ltd., London

4. Soubry, M A(2001) "Bridge detailing guide", Construction Industry Research and Information Association, London

5. Texas Department of Transportation(2001) "Bridge Design Manual" , Texas

6. Thomas A. Ostrom and Steven L. Mellon(2004) "Standard Handbook for Civil Engineers", The McGraw-Hill Companies, USA

7. Wai-Fah Chen and Lian Duan (2000) "Bridge Engineering Handbook", CRC Press, Boca Raton London New York Washington, D. C.

DECLARATION

I, the undersigned declare that this thesis is my work and that all sources of material used for this thesis have been duly acknowledged.

NAME: TEWODROS TESFAYE GASHAW

SIGNATURE: ________________________

PLACE: FACULTY OF TECHNOLOGY, ADDIS ABABA UNIVERSITY

DATE OF SUBMISSION: JANUARY 2010