Load Distribution in Concrete Solid Slab Bridges

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ABSTRACT

Canadian Highway Bridge Design Code (CHBDC) specifies empirical equations for the moment and shear distribution factors for selected bridge configurations. These empirical equations were based on the orthotropic plate theory with equivalent slab bending and torsional rigidity. Also, they were based on analysis procedure and CHBDC truck loading condition slightly different from those specified in the current CHBDC code of 2006. In this study, a parametric study was conducted, using the finite-element modeling to determine the moment and shear distribution factors for solid slab bridges subjected to CHBDC truck loading. Shell elements were used to model the bridge deck slab supported over bearings on each side of the bridge at 1.2 m spacing. The results from the parametric study were correlated to those available in the CHBDC code. Results show considerable difference in FEA results and CHBDC equations, especially for shear distribution factors. This project provides research results that can be used further to develop more reliable expressions for moment and shear distribution factors for solid slab bridges.

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DEDICATED

TO MY FAMILY

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NOTATIONS

A	Bridge width
B	The clear spacing between girders
Be	Effective concrete slab width
E	Modulus of Elasticity
F	Width dimension factor
Fm	Moment distribution factor
Fv	Shear distribution factor
Fd	Deflection distribution factor
I_t	The moment of inertia of the composite girder
L	Centre line span of a simply supported bridge
M_{DL}	The mid-span moment for a straight simply supported girder due to a single girder dead load
M_T	The mid-span moment for a straight simply supported girder due to a single CHBDC truck loading
V_T	The Max. shear force for a straight simply supported girder due to a single CHBDC truck loading
D_T	The Max. Deflection for a straight simply supported girder due to a single CHBDC truck loading
n	Number of design lanes
N	Number of girders
[P]	Applied loads vector at the nodes
R	Radius of curvature of the centre span of the curved bridge
R_L	Multi-lane factor based on the number of the design lanes
R_L'	Multi-lane factor based on the number of the loaded lanes
S	Girders spacing
[U]	Displacement vector at the nodes
W_c	Deck width
W_e	Width of design lane
Y_b	The distance from the neutral axis to the bottom flange
$(R_{straight})_{DL}$	Maximum shear forces calculated for straight simply supported beam due to Dead Load
$(R_{straight})_{truck}$,	Maximum shear forces calculated for straight simply supported beam due to truck loading
$(R_{FE.})_{DL}$	The greater reaction at the girder supports found from the finite-element analysis due to dead load
$(R_{FE.})_{FL}$	The greater reaction at the girder supports found from the finite-element analysis due to Fully loaded lanes
$(R_{FE.})_{PL}$	The greater reaction at the girder supports found from the finite-element analysis due to partially loaded lanes
$(R_{FE.ext})_{Fat}$	The greater reaction at the exterior girder supports found from the finite-element analysis due to Fatigue loading

$(R_{FE.mid})_{Fat}$	The greater reaction at the middle girder supports found from the finite-element analysis due to Fatigue loading
$(SDF)_{DL}$	Shear distribution factor for the girder due to Deal Load
$(SDF)_{FL}$	Shear distribution factor for the girder due to Fully Loaded lanes
$(SDF)_{PL}$	Shear distribution factor for the girder due to Partially Loaded lanes
$(SDF)_{Fat\ ext}$	Shear distribution factor for the exterior girder due to Fatigue Loading
$(SDF)_{Fat\ int}$	Shear distribution factor for the interior girder due to Fatigue Loading
$(\sigma_{straight})_{DL}$	Maximum flexural stresses in bottom flange fibers, for the straight simply supported beam due to Deal Load
$(\sigma_{straight})_{truck}$	Maximum flexural stresses in bottom flange fibers, for the straight simply supported beam due to CHBDC truck loading
$(\sigma_{FE.})_{FL}$	The bigger flexural stresses of r girder due to Fully loaded lanes case
$(\sigma_{FE.})_{PL}$	The bigger flexural stresses of e girder due to Partially loaded lanes case
$(\sigma_{FE.})_{Fat}$	The bigger flexural stresses of girder due to Fatigue loading case
$(MDF)_{DL}$	Moment distribution factor of girder for dead load case
$(MDF)_{FL}$	Moment distribution factor of girder for full load case
$(MDF)_{PL}$	Moment distribution factor of girder for partial load case
$(MDF)_{Fat.ext}$	Moment distribution factor of exterior girder for fatigue case
$(MDF)_{Fat.int}$	Moment distribution factor of interior girder for fatigue case
$(\Delta_{imple})_{DL}$	Mid-span deflection in bottom flange fibers, for a straight simply supported girder subject to dead load
$(\Delta_{simple})_{truck}$	Mid-span deflection in bottom flange fibers, for a straight simply supported girder subject to CHBDC truck loading
$(\Delta_{FE\ ext})_{DL}$	Mid-span deflection in bottom flange fibers at point 2 of exterior girder, for the dead load case, obtained from finite-element analysis
$(\Delta_{FE})_{FL}$	Mid-span deflection in bottom flange fibers of girder, for the full lane loading case, obtained from finite-element analysis
$(\Delta_{FE})_{PL}$	Mid-span deflection in bottom flange fibers of girder, for the partial lane loading case, obtained from finite-element analysis
$(\Delta_{FE\ ext})_{Fat}$	Mid-span deflection in bottom flange fibers at exterior girder, for the fatigue case, obtained from finite-element analysis
$(DDF)_{DL}$	Deflection distribution factor of exterior girder for dead load case
$(DDF)_{FL}$	Deflection distribution factor of exterior girder for full load case
$(DDF)_{PL}$	Deflection distribution factor of exterior girder for partial load case
$(DDF)_{Fat.ext}$	Deflection distribution factor of exterior girder for fatigue case

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CHAPTER I

INTRODUCTION

1.1 General

Solid slab or voided-slab bridges can be used for bridge spans ranging from 5 to 32 m, representing the range for short spans and lower range of the medium span bridges. In the analysis and design of bridges, the calculation of structural response of a bridge to live loads is a complicated and lengthy task. The design values for bending moment, shear or deflection for solid slab bridges depend on the location and the number of moving trucks on the bridge, boundary conditions and the cross section properties of bridge components. These values vary with the change in slab thickness, span, width of bridge, and load cases. In order to calculate the live load carried by slab in case of a straight bridge, lateral load distribution factor is a key element and important in analyzing existing bridges and designing new ones. To simplify the design process, the Canadian Highway Bridge Design Code (CHBDC, 2006) specified imperial expressions for moment and shear distribution factors which are basically the ratio between them maximum structural quantities in a bridge cross-section resulting from different scenarios of truck loading conditions to the average value obtained from simple beam analysis. As such, the load distribution factors takes into account the two- and three-dimensional behaviour of the bridge superstructure when treating the bridge as one-dimensional structural (i.e. simple beam) to simplify the design process.

1.2 The Problem

The Canadian Highway Bridge Design Code (CHBDC, 2006) specifies empirical equations for the moment, shear and deflection distribution factors for selected bridge configurations, including slab-on-girders, multiples-spine bridges, cellular or voided slab bridge and solid slab bridges (Fig. 1.1). These empirical equations were based on the orthotropic plate theory with equivalent slab bending and torsional rigidity, in case of slab bridges, shown in Fig. 1.2. Also, there were based on analysis procedure and CHBDC truck loading condition slightly different from those specified in the current CHBDC code of 2006. Despite the general availability of computers and computer software programs for the bridge analysis, bridge designers strongly prefer simplified methods of analysis to reduce the time spent in the design that would be reflected in a considerable reduction in design cost. In addition, most engineers are not familiar with the finite-element modeling and are reluctant to use this technique, especially in the preliminary designs because of its time consuming in terms of modeling assumptions and verifications and results interpretation. In this study, a parametric study was conducted to investigate the level of confidence of CHBDC simplified analysis method specified in CHBDC for solid slab bridge. This simplified analysis method was aimed at determining the most critical load effect by accounting for the transverse distribution of wheel loads through empirical factors. With this method, load effects were computed considering the bridge structures as an equivalent beam. The load sharing between longitudinal members was then determined using simple relationships that constitute the specificity of the method. In this study, the 3D finite element modelling, using SAP2000 software (Computers and Structures, 2009) was conducted on wide range of solid slabs to obtain their moment and shear distribution factors when subjected to CHBDC truck loading conditions. Then, the obtained results were correlated between the FEA results and CHBDC equations for solid slab bridges.

1.3 Objectives

The objectives of this study are:

1. Conduct a parametric study, using the three-dimensional finite-element method (FEA), on selected solid slab bridges, to determine the maximum flexural stresses, support reaction forces and deflection to provide database for the evaluation of their moment, shear and deflection distribution factors.
2. Correlate the FEA results with CHBDC moment and shear distribution factors so that recommendations can be made on the use of such expression in design new bridges and evaluating existing ones.

1.4 Scope

The scope of this study includes the following:

1. A literature review of previous research, textbooks, and design codes of practice related to the study.
2. Conduct a practical-design-oriented study to investigate the key parameters affecting the load distribution in slab bridges. The range of studied parameters include: (i) span of the bridge; (ii) total width of bridge; (iii) number of design lanes; and (v) truck loading conditions. The parametric study was performed using the commercially-available Finite-Element Software "SAP2000" on 54 solid slab bridges subjected to CHBDC truck loading, leading to more than 2000 loading cases.

3. Preparation of database that can be correlated with the available CHBDC simplified method of analysis.
4. Made recommendations on the use of CHBDC load distribution factors on the design of slab bridges.

1.5 Contents and Arrangement of this study

Chapter II: Contains the literature review which is a thorough explanation of lateral load distribution factor concept and review of previous work.

Chapter III: Describes the finite-element method and "SAP2000" software used in the analysis, modeling, bridge configurations, loading cases, and the methodology to calculate the load distribution factors.

Chapter IV: Presents the outcome of the parametric study performed on the bridge prototypes, and the developed empirical equations for load distribution factors.

Chapter V: Includes the summary and conclusions drawn from this study.

CHAPTER II

LITERATURE REVIEW

2.1 Concept of Lateral Load Distribution Factor

In the analysis and designing of bridge, the calculation of structural response of a bridge to live loads is a complicated and lengthy task. The design values for bending moment, shear or deflection force for solid slab depend on the location and the number of moving trucks on the bridge, boundary conditions and the cross section properties of bridge components. These values vary with the change in slab thickness, span, width of bridge, and load cases.

In order to calculate the live load carried by slab in case of a straight bridge, lateral load distribution factor is a key element and important in analyzing existing bridges and designing new ones. To simplify the design process, North American bridge codes, such as CAN/CSA-S6-06 (CHBDC, 2006), AASHTO-LRFD Bridge Design Specification (AASHTO, 2007, 2004 and 2000), and AASHTO Standard Specifications (AASHTO, 1996), treat the longitudinal and transverse effects of wheel loads as uncoupled phenomena. Based on these codes, to obtain the design moment, deflection and shear force, we calculate the maximum moment, deflection, and shear force caused by a single truck live load per meter of width of the bridge. Then the values are to be amplified by a factor, which is usually referred to as the live load distribution factor. The literature survey conducted in this study includes previous research work on the simplified methods of analysis of bridges.

2.2 Bridge Types

Bridge is not a construction but it is a concept, the concept of crossing over large spans of land or huge masses of water. The idea behind a bridge is to connect two far-off points eventually reducing the distance between them. Apart from this poetic aspect of 'bridges', there is a technical aspect to them that classifies bridges on the basis of the techniques of their construction. Bridges can be constructed entirely from reinforced concrete, pre-stressed, post-tensioned concrete, steel, wood or composite concrete deck-steel girders. These bridges may be comprised of a wood deck, concrete slab or steel deck on wood, concrete or steel girders. The box girder bridge can be used in such a way the top flanges of the precast box girders form the bridge deck surface. Many types of bridges have been used significantly on highway and road to facilitate the traffic flow. The bridge types covered by the simplified methods of analysis in the CHBDC are as follows:

(a) Reinforced / post-tensioned solid slab

(b) Post-tensioned circular / trapezoidal voided deck

(c) Deck-on-girders, including concrete slab-on-girder, steel grid deck on girder and wood deck on girder

(d) Truss and arch

(e) Rigid frame and integral abutment types

(f) Bridges incorporating wood beams

(g) Multi-cell and multi-spine

(h) Cable Stayed

(i) Suspension

2.3 Slab Bridges

Slab bridges are easiest to construct and are frequently used for comparatively smaller span. The form is very efficient at distributing point loads because of it two way spanning ability and high torsional strength. It is relatively easy to construct and this reflected in its construction cost. The principal disadvantages are its high self weight which can be counteracted to some extent, by providing suitable variation in thickness or by providing voids. It may be of reinforced concrete or of prestressed concrete. Solid reinforced concrete slab of constant depth is normally used for span up to 10 m. For larger span say up to 15 m, hunching or variable depth is adopted to reduce the dead load. A solid slab of uniform depth is preferred in highly skewed crossing, particularly if significant curvature and variation in width of deck is involved.

2.4 Review of Previous Research on Load Distribution

2.4.1 Review of Study on Distribution Factors for Straight Bridges

This section summarizes previous research work pertained to load distribution in bridges. According to the level of bridge lateral rigidity, different methodologies are implemented in practice, including hinged joint method, fixed joint method, orthotropic plate analogy, AASHTO Standard, AASHTO-LRFD and CHBDC simplified method.

2.4.1.1 Concept of orthotropic plate

In 1979, Bakht et al. used the concept of orthotropic plate to develop a simplified method for calculating the design live load longitudinal moments. In their research, they conducted extensive parametric studies, which led them to find out that the distribution factor of bridges is related to a torsional parameter α and a flexural parameter θ, which are functions of geometry and material properties of the bridge. These parameters are given by:

$$\alpha = \frac{D_{xy} + D_{yx} + D_1 + D_2}{2(D_x D_y)^{0.5}} \tag{2.1}$$

$$\theta = \frac{b}{2L}\left(\frac{D_x}{D_y}\right)^{0.25} \tag{2.2}$$

Where b is the bridge width, L is the span length of the bridge and the various rigidities are given by:

$$D_x = \frac{E_G\, I_G}{S} + \frac{E_c t^3}{12} \tag{2.3}$$

$$D_y = \frac{E_c\, t^3}{12(1 - v_c^2)} \tag{2.4}$$

$$D_{xy} = \frac{G_G\, J_G}{S} + \frac{G_c\, t^3}{6} \tag{2.5}$$

$$D_{yx} = \frac{G_c\, t^3}{6} \tag{2.6}$$

$$D_1 = D_2 = v_c D_y \tag{2.7}$$

Which E_c, G_c and v_c are the Young's modulus, the shear modulus and the Poisson's ratio, respectively, t is the concrete slab thickness, S is the girder spacing, I_G and J_G are the flexural and torsional moment of inertia of the girder cross section, respectively. The subscript G refers to girder and c refers to the concrete slab. This method gives better results than the AASHTO recommendations that assume the girder spacing S is the only parameter that affects load distribution in slab-on-girder bridges. This method formed the basis of the 1991 version of the OHBDC as well as the CHBDC provisions.

Jaeger and Bakht (1982) used the grillage analogy method for the idealization of slab and beam bridges. In grillage analogy method, the longitudinal members were positioned to coincide with the actual girders centerlines and were given the properties of the composite section. The transverse members were considered as beams replacing the strips of the top slab. The moment of inertia, I_y, of the transverse beam is considered as follows:

$$I_y = \frac{L_x t^3}{12} I_x \tag{2.8}$$

And the torsional inertia, J_x, is given by the relationship:

$$G_c J_x = E_c I_y \tag{2.9}$$

In which results to:

$$J_x = \left(\frac{E_c}{G_c}\right)\left(\frac{L_x t^3}{12}\right) \tag{2.10}$$

Where L_x is the length of the strip in the longitudinal direction, t is the thickness of the strip, E_c and G_c are the concrete material modulus of elasticity and the shear modulus respectively. Details of simplified methods of analysis, which are also applicable for AASHTO loading, are given by Bakht and Jaeger (1985).

2.4.1.2 Orthotropic Plate Analogy (*Guyon-Massonnet or G-M Method*)

For concrete bridges with continuous slab and intermediate diaphragms and with the bridge width to span length ratio B/L greater than 0.5, grillage system may be used to simulate the bridge system. Or, the bridge may be analogized to a rectangular thin plate, which is called orthotropic plate analogy or Guyon-Massonnet (G-M) method (Yao, 1990). Orthotropic plate is referred to as a plate with the elastic properties different in x and y directions. Figure 2.10a shows the longitudinal and transverse configuration of a bridge structure. In this case, the girder spacing is considered as S, girder moment of inertia and torsional inertia are I_x and I_{Tx}, respectively, diaphragm spacing is S_c, and diaphragm moment of inertia and torsional inertia are I_y and I_{Ty} respectively. For very small values of S and S_c compared to the bridge width and span length, and for fully composite action, we can distribute girder moment of inertia and torsional inertia I_x and I_{Tx} to the distance S and distribute diaphragm moment of inertia and torsional inertia I_y and I_{Ty} to the distance S_c. Thus, the real grid system (Fig. 2.1a) is analogized to an imaginary plate (Fig. 2.1b). In Fig. 2.1b, the thickness in the x direction is shown in dashed line, which indicates that, the equivalent thickness in the x and y direction is different for the analogized plate. The moment of inertia and torsional inertia per unit width in the x and y directions for the analogized plate are considered as follows:

$$J_x = \frac{I_x}{S},\ J_{Tx} = \frac{I_{Tx}}{S},\ J_y = \frac{I_y}{S_c},\ J_{Ty} = \frac{I_{Ty}}{S_c} \tag{2.11}$$

For beam and slab concrete bridges and prestressed concrete bridges, Poisson's ratio v can be neglected for simplicity. In that case, the bridge can be analogized to an orthotropic plate with rigidity per unit width E_xJ_x, $G_x J_{Tx}$, $E_x J_y$, and $G_x J_{Ty}$. The analogized orthotropic (in configuration) plate differential equilibrium with E_x=E_y=E and v_x=v_y=v *is:*

$$EJ_x \frac{\partial^4 w}{\partial x^4} + G(J_{Tx} + J_{Ty}) \frac{\partial^4 w}{\partial x^2 \partial y^2} + EJ_y \frac{\partial^4 w}{\partial y^4} = p(x,y) \tag{2.12}$$

Let $D_x = EJ_x$, $D_y = EJ_y$ and $H = G\,(J_{Tx} + J_{Ty})/\,2E$, Equation 2.9 becomes:

$$D_x \frac{\partial^4 w}{\partial x^4} + 2H \frac{\partial^4 w}{\partial x^2 \partial y^2} + D_y \frac{\partial^4 w}{\partial y^4} = p(x,y) \tag{2.13}$$

which is identical to the differential equation for orthotropic plate (in material elastic properties). This means that analogized orthotropic (in configuration) plate can be solved the same way as orthotropic (in material properties) plate, except that that the stiffness constants contained in the equations are different.

The internal forces can be obtained by solving this equation for displacement w under applied load. Directly solving the partial differential equation is difficult. For convenience, Guyon and Massonnet had developed solution charts, which can be found in *Bridge Engineering* (Yao 1990) and can be used to easily obtain the transverse influence line. Once the transverse influence line is obtained, the distribution factors can be obtained by arranging the trucks transversely on the bridge.

2.4.1.3 Grillage Method

In 2000, Zokaie (Zokaie, 2000) carried out extensive analysis using grillage and finite element analysis to verify and evaluate the formulas, developed earlier in 1991. In the finite element model, shell element was used to represent the deck slab and frame element to represent the precast girders. In his study, Zokaie calibrated the developed formulas for moment and shear distribution factors to the interior and the exterior girders for bridges designed for one traffic lane and for bridges designed for two or more traffic lanes. According to this study, the distribution factor of longitudinal bending moment for slab-on-girder bridges for interior girders was given by the following equations:

For one traffic lane:

$$D_f = 0.1 + \left(\frac{S}{4f}\right)^{0.4} \left(\frac{S}{L}\right)^{0.3} \left[\frac{K_g}{Lt_s^3}\right]^{0.1} \tag{2.14}$$

For two or more traffic lanes:

$$D_f = 0.15 + \left(\frac{S}{3f}\right)^{0.6} \left(\frac{S}{L}\right)^{0.2} \left[\frac{K_g}{Lt_s^3}\right]^{0.1} \tag{2.15}$$

The distribution factor of the longitudinal shear for slab-on-girder bridges for interior was given by the following equations:

For one traffic lane:

$$D_f = 0.6 + \left(\frac{S}{15f}\right) \tag{2.16}$$

For two or more traffic lanes:

$$D_f = 0.4 + \left(\frac{S}{6f}\right) - \left(\frac{S}{25f}\right)^2 \tag{2.17}$$

Where: S, L, K_g and t_s are the spacing between girders, the span length, the longitudinal stiffness parameter, and the slab thickness, respectively. The factor f is a conversion factor between metric and imperial systems which equal to 304.8 mm and 1.0 ft. For exterior girders for one traffic lane, the factor 1.0 was provided for moment and shear related to the single beam distribution. For exterior girders for two or more traffic lanes, multiplication factors to the factors provided for interior girders are given as follows:

For bending moment for two or more traffic lanes:

$$e = \frac{7f + d_e}{9.1f} \geq 1.0 \qquad (2.18)$$

For shear for two or more traffic lanes:

$$e = \frac{6f + d_e}{10f} \qquad (2.19)$$

Where: d_e is the edge distance. The factor f is a conversion factor between metric and imperial systems which equal to 304.8 mm. Zokaie concluded that the results from the formulas previously provided in 1991 were within 5% of the results from the finite element analysis that he performed in his study in the year 2000.

2.4.1.4 The Finite-Element Method (Logan 2002)

This is the most famous and widely used method in many engineering applications. The principal of this numerical method is discretizing the structure into small divisions, or elements, where each element is defined by specific number of nodes (hence this process of modeling a body by dividing it into an equivalent system of smaller bodies or units called finite elements). The finite-element method is a numerical acceptable solution, it formulation of the problem results in a system of simultaneous algebraic equations for solution, rather than requiring analytical solutions (solutions of ordinary or differential equations), which because of the complicated geometries, loadings, and material properties, are not usually obtainable. The behavior of each element, and ultimately the structure, is assumed to be a function of its nodal quantities (displacements and/or stresses), which considered as the primary unknown of its nodal quantities. The modern development of the finite-element method began by Hrennikoff in the 1941 and McHenry in 1943 using (one-dimensional) elements (bars and beams) in the field of structural engineering. In 1947, Levy developed the flexibility or force method, and in 1953 he suggested that another method (the stiffness or displacement method) could be a promising alternative for use in analyzing statically redundant aircraft structures. However his equations were cumbersome to solve by hand, and hence it only became popular after the advent of the high speed computers. Turner et al. was the first who introduced the treatment of two-dimensional elements in 1956, they derived stiffness matrices for truss elements, beam elements, and two-dimensional triangular and rectangular elements in plane stress. The finite-element method extended to cover three-dimensional problems only after the development of tetrahedral stiffness matrix which was done by Martin in 1961.

2.4.1.5 AASHTO Methods

AASHTO introduced empirical methods which are more convenient to use as compared with the theoretical methods mentioned above. AASHTO defines the distribution factor as the ratio of the moment or shear obtained from the bridge system to the moment or shear obtained from a single girder loaded by one truck wheel line (*AASHTO Standard* 1996) or the axle loads (*AASHTO-LRFD* 2004). It should be noted that AASHTO Standard Specifications and AASHTO LRFD Specifications define the live load differently. The live load in the Standard specifications consists of an HS 20 truck or a lane load. While, the live load in the LRFD specifications consists of an HS 20 truck in conjunction with a lane load.

2.4.1.5.1 AASHTO Standard Method (1996)

AASHTO Standard specifications contain simple procedures used in the analysis and design of highway bridges. AASHTO adopted the simplified formulas for distribution factors based on the work done in the 1940s by Newmark (1948). AASHTO typical procedure is used to calculate the maximum bending moment based on a single line of wheel loads from the HS20 design truck or lane loading. This calculated bending moment is then multiplied by the load distribution factor (S/5.5) or in the format of *(S/D)*, where *S* is the girder spacing in feet and *D* is a constant based on the bridge type to obtain the moment in an individual girder. This method is applicable to straight and right (non-skewed) bridges only. It was proved to be accurate when girder spacing was near 1.8m and span length was about 18 m (Zokaie, 2000). For relatively medium or long bridges, these formulas would lose accuracy.

2.4.1.5.2 AASHTO LRFD Method

The specifications outlined in Load and Resistance Factor Design, LRFD Design specifications were adopted (AASHTO, 2004). This code introduced another load distribution factors based on a comprehensive research project, National Cooperation Highway Research Program (NCHRP) 12-26 which was entitled "Distribution of Live Loads on Highway Bridges" and initiated in 1985, consequently the guide specification for Distribution of Loads for Highway Bridges (AASHTO, 1994) was found. This guide recommends the use of simplified formulas, simplified computer analysis, and/or detailed finite-element analysis (FEA) in calculating the actual distribution of loads in highway bridges. It was noted that those new formulas were generally more complicated than those recommended by the Standard Specifications for Highway Bridges (AASHTO 1996), but their use is associated with a greater degree of accuracy (Munir, 1997). For example the lateral load distribution factor for bending moment in interior girders of concrete slab on steel girder bridge superstructure is:

$$g = 0.15 + (S/3)^{0.6} (S/L)^{0.2} (Kg/12Lt^3_s)^{0.1} \tag{2.20}$$

Where g = wheel load distribution factor; S = girder spacing in feet, ($3.5 < S < 16$ ft); L = span length of the beam in feet ($20 < L < 200$ ft); t_s = concrete slab thickness in inches ($4.5 < t < 12$ inch); Kg = longitudinal stiffness parameter = $n(I + Ae^2_g)$; n = modular ratio between beam and deck material; I = moment of inertia of beam (in.^{4}); A = cross-sectional area of beam (in.^{2}) and e_g = distance between the center of gravity of the basic beam and deck (in.).

AASHTO LRFD Specifications have become highly attractive for bridge engineers because of its incentive permitting the better and more economical use of material. The rationality of LRFD and its many advantages over the Allowable Stress Design method, ASD, are indicative that the design philosophy will downgrade ASD to the background in the next few years (Salmon and Johnson, 1996). The research results were first adopted by AASHTO Standards in 1994 and were then officially adopted by AASHTO-LRFD in 1998. More parameters, such as girder spacing, bridge length, slab thickness, girder longitudinal stiffness, and skew effect are considered in the developed formulas which earned them sound accuracy. The AASHTO-LRFD formulas were evaluated by Shahawy and Huang (2001), their evaluation showed a good agreement with test results for bridges with two or more loaded design lanes, provided that girder spacing and overhang deck did not exceed

2.4 m and 0.9 m, respectively. Outside of these ranges, the error could be as much as up to 30%. For one loaded design lane, the relative error was less than 10% for interior girders and could be as high as 100% and as low as –30% for exterior girders. Shahawy and Huang presented modification factors for the AASHTO LRFD formulas and the results of the modified formulas showed good agreement with their test results (Shahawy and Huang, 2001).

2.4.1.6 Simplified Methods of Analysis (CHBDC 2006)

The Canadian Highway Bridge Design Code (CHBDC, 2006), as well as the 1991 version of the Ontario Highway Bridge Design Code (OHBDC, 1991)), specifies simplified method of analysis for live load using load distribution factors for slab-on-girder bridges. For OHBDC, the simplified method of analysis for the live load is based on considering the bridge as a rectangular orthotropic plate that was simply supported at two opposite ends on unyielding line supports which were continuous across the width of the plate and did not impose moment restraint. For CHBDC, the simplified method of analysis for the live load is based on the results from many bridge structures using grillage, semi-continuum and finite element methods for which the idealized structure was essentially an orthotropic plate. There are conditions and limitations for the use of simplified method of analysis, which are specified in the CHBDC. Conditions for applying simplified methods of analysis on straight bridges are as follows:

1. The bridge width is constant;
2. The support conditions are closely equivalent to line support;
3. The skew Parameter ($\varepsilon = S \tan \omega / L$) does not exceed 1/18 where "S" is the spacing between girders, "ω" is the skew angle and "L" is the span length;

4. There shall be at least three longitudinal girders that are of equal flexural rigidity and equally spaced or with variation from the mean of not more than 10% in each case; and
5. The overhang does not exceed 60% of the spacing between longitudinal girders and not more than 1.80 m.

These restrictions have been provided for the consistency between the methods of analysis in CHBDC and OHBDC. Shear-connected beam bridges are analyzed by the methods applicable to shallow superstructure provided that continuity of transverse flexural rigidity across the cross-section is present. If not, analysis for longitudinal moments and shears is by the same method as for multispine box girders.

When the skew angle "ω" of a bridge is less than 20°, it has usually been considered safe to ignore the skew angle and analyze the bridge as a right bridge whose span is equal to the skew span. The implication of this practice is that the angle of skew is considered to be the only necessary measure of the "skewness" of the bridge with respect to its load distribution characteristics. Extensive comparative analyses of skew and equivalent right bridges conducted by Jaeger and Bakht showed that the angle of skew of the bridge is not the only necessary measure of its skew ness, which is also affected by its span, width and girder spacing, if present. In particular, it has been shown that a dimensionless parameter characterizing the skewness of a slab-on-girder bridge is $S \tan \omega / L$. For permitting the analysis of a skew bridge as an equivalent right bridge, the Code has imposed the upper limits of 1/18 for this parameter to ensure that the shear values in particular are not in unsafe error by more than 5%. CHBDC noted that the force effects in skewed, slab-on-girder type bridges may be analyzed by the simplified methods presented, if the other conditions of the simplified method are met. The simplified method presented in the CODE enable the designer to calculate the increased shear effects that occur with increase in skewness.

CHBDC stated that the two limitations pertaining to an overhanging deck slab, noted in condition 5, relate to the need to have the structure remain such that the orthotropic plate approximation is closely applicable. For a slab-on-girder bridge with equally spaced girders a distance S apart, a cantilever overhang of S/2 on either side is the desired condition, since each longitudinal girder can then be associated in a width S/2 of deck on either side of its centreline; a uniformly distributed load over the entire deck area would then result in the girders sharing equally in accepting the total longitudinal responses. If the overhang is permitted to be a maximum of 0.6S, the outer girders then accept rather more bending moment and shear force than the interior ones, but the departure from uniformity is still acceptable. So far as the limitation on the deck overhang of 1.80 m is concerned, when due allowance is made for barrier walls, curbs, etc. this limitation means that when a vehicle is travelling as far over in the outside lane as possible, its centre of gravity will not be significantly outside the centreline of the outermost girder. This limitation is necessary if the orthotropic plate representation is to be realistic. The bridges selected for establishing analysis results for the simplified methods in this Code had the same limitations for the deck slab overhang, being equal to or less than 60% of the girder spacing, S, with a maximum overhang equal to 1.8 m.

The Canadian Highway Bridge Design Code (CHBDC, 2006) specifies equations for the simplified method of analysis to determine the longitudinal bending moments and vertical shear in slab-on-girder bridges due to live load for ultimate, serviceability and fatigue limit states using load distribution factors. The CHBDC distribution factor equations used for solid slab bridge are as follows:

For the longitudinal bending moment per meter of width, m, for ultimate and serviceability limit states:

$$m = F_m \, m_{avg} \tag{2.21}$$

Where m_{avg} the average moment per meter of width and F_m is an amplification factor for the transverse variation in maximum longitudinal moment intensity (Distribution Factor).

$$m_{avg} = \frac{nM_T R_L}{Be} \tag{2.22}$$

$$F_m = \frac{B}{F\left(1+\dfrac{\mu C_f}{100}\right)} \geq 1.05 \tag{2.23}$$

$$\mu = \frac{W_e - 3.3}{0.6} \leq 1.0 \tag{2.24}$$

Where M_T is the maximum moment per design lane, n is the number of design lanes, R_L is a modification factor for multilane loading, Be is the effective width of the bridge found by reducing the total width B for the effects of tapered edges, B is the total width of bridge, regardless of whether tapered edges are present in meter, W_e is the width of the design lane in meter, C_f is a correction factor obtained from tables and F is the width dimension that characterizes the load distribution for the bridge.

For the longitudinal bending moment per meter of width, M_g, for Fatigue Limit State:

$$m = F_m \, m_{avg} \tag{2.25}$$

Where: m_{avg} is the average moment per meter of width and F_m is an amplification factor for the transverse variation in maximum longitudinal moment intensity (Distribution Factor).

$$m_{avg} = \frac{M_T}{Be} \tag{2.26}$$

s(N) ? # of girder

$$F_m = \frac{B}{F\left(1+\frac{\mu C_f}{100}\right)} \geq 1.05 \tag{2.27}$$

with dimention fact from table

$$\mu = \frac{W_e - 3.3}{0.6} \leq 1.0 \tag{2.28}$$

Where M_T is the maximum moment per design lane, n is the number of design lanes, R_L is a modification factor for multilane loading, Be is the effective width of the bridge found by reducing the total width B for the effects of tapered edges, B is the total width of bridge, regardless of whether tapered edges are present in meter, W_e is the width of the design lane in meter, C_f is a correction factor obtained from tables, C_e is a correction factor for vehicle edge distance obtained from tables and F is the width dimension that characterizes the load distribution for the bridge.

For the longitudinal vertical shear per meter of width, V, for ultimate, serviceability and fatigue limit states:

$$V = F_v V_{avg} \tag{2.29}$$

Where V_{avg} the average is shear per meter of width and F_v is an amplification factor for the transverse variation in maximum longitudinal vertical shear intensity (Distribution Factor).

$$V_{avg} = \frac{nV_T R_L}{Be} \tag{2.30}$$

$$F_v = \frac{B}{F} \geq 1.05 \tag{2.31}$$

Where V_T is the maximum vertical shear per design lane, n is the number of design lanes, R_L is a modification factor for multilane loading, Be is the effective width of the bridge found by reducing the total width B for the effects of tapered edges, B is the total width of bridge, regardless of whether tapered edges are present in meter, W_e is the width of the design lane in meter and F is the width dimension that characterizes the load distribution for the bridge and can be obtained from provided tables.

CHAPTER III

FINITE-ELEMENT ANALYSIS

3.1 General

The advancement of computers in terms of hardware and software engineering let the structural engineering enter into a new era. More extensive and approximate numerical solutions to complicated engineering problems were initiated due to the wide use of the finite element method. The finite element method is considered the most powerful and versatile method of analysis available nowadays. In early 1980's, the grillage analogy method was extensively used and was very popular. Because of the recent development in the finite element method, and the large capacities of high-speed computers, it is possible to model a bridge in a very realistic manner and to provide a full description of its structural response due to different loading conditions. One of the most important advantages of the finite element method is the ability to deal with problems that have arbitrary arrangements of structural elements, material properties, and boundary conditions. Finite element analysis has proven to give reliable results when compared to experimental findings; this built up trust encouraged the designers and code writers to allow the implementation of the finite element method in the analysis and design of different engineering structures. The finite element analysis software "SAP2000" version 10 was used throughout this study to determine the structural behaviour of the prestressed concrete box girder bridges under truck loads. A general description of this software is presented further in this chapter. The developed finite element methods described herein were used to perform extensive parametric study on the structural response of slab bridges due to CHBDC truck loading conditions.

The Canadian Highway Bridge Design Code (CHBDC 2006), section 5.9, permits the use of six different refined methods of analysis for short and medium span bridges. The finite element method is one of the methods recognized by CHBDC. From all the six permitted methods, the finite element method is considered to be the most powerful, and versatile. In finite element method solutions can be find out without the use of governing differential equations, It permits the combination of various structural elements such as plates, beams, and shells, It is able to analyze structures having arbitrary geometries with any material variations thereof, and It is possible to automate every step involved in the method.

In this chapter a brief description of finite-element approach will be reviewed as well as descriptions of modeling the slab bridges. The available commercial finite-element program, SAP2000, was utilized through this study to determine the structural response of the modeled bridge prototypes. A general description of this software is presented later in this chapter. The procedure to perform an extensive parametric study on selected straight slab bridge prototypes to evaluate loads distribution characteristics is explained also in this chapter.

3.2 Finite-Element Approach

The finite-element method is a numerical method for solving problems of engineering and mathematical physics. In structural engineering problems, the solution is typically concerned with determining stresses and displacements and will yield approximate values of the unknowns at discrete number of points in a continuum. This numerical method of analysis starts by discretizing a model. This numerical method of analysis which begins by dividing a body into an equivalent system of smaller bodies or units (finite-elements) interconnected at points (nodes) common to two or more elements and/or boundary lines and/or surfaces is called discretization. Hence, instead of solving the problem for the entire body in one operation, it facilitates the formation of equations for each finite-element and at the end; it will combine them to obtain the solution of the whole body. For the purpose of simplifying the formulation of the above elements equations, matrix methods are implemented. Matrix methods are considered as an important tools used to structure the program of the finite-element methods to facilitate their computation process in high-speed computers.

In general there are two approaches associated with the finite-element; (1) force or flexibility method, and (2) displacement or stiffness method. It has been shown that for computational purposes, the latter method is more desirable because its formulation is simpler for most structural analysis problems; moreover a vast majority of general-purpose finite-element programs have incorporated the displacement formulation for solving structure problems. The finite-element method uses different types of elements; (1) one dimensional element or so called linear element; (2) two-dimensional element which can be in the forms of plane element or triangular and quadrilateral shape elements; and (3) three-dimensional solid shape elements.

Selecting the most appropriate element type should be to model the most closely to the actual physical behaviour. An equation is then formulated combining all the elements to obtain a solution for one whole body. Using a displacement formulation, the stiffness matrix of each element is derived and the global stiffness matrix of the entire structure can be formulated by the direct stiffness method. This global stiffness matrix, along with the given displacement boundary conditions and applied loads is then solved, thus that the displacements and stresses for the entire system are determined. The global stiffness matrix represents the nodal force-displacement relationships and is expressed in a matrix equation form as follows:

$$[P] = [K][U] \tag{3.1}$$

Where:

[P] = nodal load vector;

[K] = the global stiffness matrix;

[U] = the nodal displacement vector;

The steps for deriving the above equation can be summarized in the following basic relationships:

a) $$\upsilon(x,y) = [\phi(x,y)][\alpha] \tag{3.2}$$

Where:

$\upsilon(x,y)$ = the internal displacement vector of the element;

$[\phi(x,y)]$ = the displacement function matrix; and

$[\alpha]$ = the generalized coordinates matrix.

b) $[U] = [A][\alpha]$ then, $[\alpha] = [A]^{-1}[U]$ (3.3)

Where $[A]$ is the transformation matrix from local to global coordinates,

c) $$[\varepsilon(x,y)]=[B(x,y)][\alpha]=[B(x,y)][A]^{-1}[U] \tag{3.4}$$

Where:

$[B(x,y)]$ = The strain-displacement matrix; and

$[\varepsilon(x,y)]$ = The strain matrix.

d) $$[\sigma(x,y)]=[D][\varepsilon(x,y)]=[D][B(x,y)][A]^{-1}[U] \tag{3.5}$$

Where:

$[D]$ = the constitutive matrix or the elasticity matrix.

From the principle of minimization of the local potential energy, the total external work is equal to $\frac{1}{2}[U]^T[P]$, then

e) I - $$W_E=[U']^T\,[P] \tag{3.6}$$

II - $$W_I=\int_{vol}[\varepsilon]^T[\sigma]=[u']^T[A]^{-1}[k'][A]^{-1}[U] \tag{3.7}$$

$$[k']=\int_{vol}[B(x,y)]^T[D][B(x,y)] \tag{3.8}$$

Where:

W_E = the external virtual work;

W_I = the internal virtual work;

$[u']$ = the vector of virtual displacement; and

$[k']$ = the element stiffness matrix.

f) From the principle of virtual work, $W_E = W_I$. By taking one element of virtual nodal displacement vector $[u']$ equal to unity successfully, the solution becomes:

$$[P] = [K][U] \tag{3.9}$$

Where $[K] = \Sigma[k']$, so the global structural stiffness matrix is an assemblage of the element stiffness matrix $[k']$.

g) The solution of the resulting system of equations yields the values of nodal displacement $[U]$ and the internal forces for each element can be obtained from equation (3.4).

In the case of a linear (elastic) structural problem, loads are first applied on a model and the solution is obtained directly. In a non-linear case, the analysis follows a different numerical method to obtain a solution. However, such analysis is beyond the scope of this thesis and is not discussed.

3.3 SAP2000 Computer Program

The software "SAP2000" is a structural analysis program that employs the finite-element method in the analysis and designs of complicated structures. During the 1980's and 1990's SAP engineering software become a popular choice for finite element analysis. The program is used worldwide to estimate structural responses of structures due to various applied loads. This program has a range of capabilities depending on the version used. SAP2000 is also capable of analyzing structures in static and/or dynamic modes. Its finite-element library consists of six elements.

1. *FRAME Element*: The Frame element is a two-node three-dimensional element, which includes the effect of biaxial bending, tension, axial deformation, and biaxial shear deformation.

2. *Shell Element*: The Shell element is a three or four-node three-dimensional element, which combines separate membrane and plate-bending behaviour. The membrane behaviour includes translational in-plane stiffness components and rotational stiffness component in the direction normal to the plane of the element. The plate bending behaviour includes two-way, out of plane, plate rotational stiffness components and translational stiffness component in the direction normal to the plane of the element. The program allows using pure membrane, pure plate, or full shell behaviour.

3. *Plane Element*: The Plane element is a three- to nine-node two-dimensional element, which contributes stiffness only in the two translational degrees of freedom at each of its connected joints. Plane element is used for modeling thin plane stress structures and long plane strain structures.

4. *Solid* Element: The Solid element is an eight-node three-dimensional element, which includes nine optional incompatible bending modes. The solid element contributes stiffness in all three translational degrees of freedom at each of its connected joints.

5. *Asolid* Element: The Asolid element is a three- to nine-node two-dimensional element, which contributes stiffness only in the two translational degrees of freedom at each of its connected joints. Asolid element is used for modeling axisymmetric structures under axisymmetric loading.

6. *Nllink* Element: The Nllink element is a one joint grounded spring or two joint link which is composed of six separate springs, one of each of the six deformational degrees of freedom. The Nllink element is used for modeling linear or nonlinear structural behaviour. The nonlinear behaviour is used only for the time-history analysis.

In addition, subsets of these elements with varying degrees of freedom are available in the form of truss, frame, membrane, beam, strain, gap, and hook elements.

3.4 Finite Element Modeling of Solid Slab Bridges

A three dimensional finite element model was used to analyze the solid slab bridges in this study. A sensitivity study was conducted to choose the finite element mesh. The finite element mesh is usually chosen based on pilot runs and is a compromise between economy and accuracy.

3.4.1 Geometric Modeling

3.4.1.1 Modeling of Solid Slab Bridge

To analyze solid slab bridges and to determine their structural response, a three-dimensional finite-element model was adopted. From SAP2000 library, the four-node shell element was chosen to model all bridge components, see Fig. 3.1. Figure 2 and 3 shows views of the FEA model for a 16 m span bridge modeled using SAP2000 software. The four-node shell element has six degrees of freedom at each node that are three displacements (U1, U2, U3) and three rotations (Φ1, Φ2, Φ3). A varying width and thickness of slab was considered in this study. In the longitudinal direction of the bridge, number of elements are depends on the length of bridge.

A sensitivity study has been carried out to investigate the accuracy of the results from the finite element analysis. In this study, various numbers of elements, in the longitudinal, vertical and transverse directions of the bridge model, have been considered. The various number and types of boundary conditions were used to find the accurate results. The level of accuracy of the developed FEA model was examined against results from simple beam analysis for the following loading cases: (i) self-weight of the bridge superstructure; (ii) a uniform superimposed loading of 10 kN/m^2; and a line load at the mid-span section of total value of 100 kN. The straining actions considered for comparison were maximum bending stresses at mid-span location, maximum mid-span deflection and support reaction. The results from the sensitivity study are presented in Table A.1 through A.6 for a bridge prototype of 7.396 m bridge width. The analysis was conducted for different span lengths and associated slab thicknesses. The results shown in these tables indicate that the proposed finite-element models for this parametric study provides results very close to those obtained from simple-beam analysis in case of self-weight and uniform loading. However, this difference increases for maximum flexural stresses and deflections in case of point loads at the mid-span due to plate action.

3.4.1.2 Aspect Ratio

The aspect ratio is defined as the ratio of the longest dimension to the shortest dimension of a quadrilateral element. In many cases, as the aspect ratio increases, the inaccuracy of the solution increases (Logan, 2002). Logan presented a graph showing that as the aspect ratio rises above 4, the percentage of error from the exact solution increases greater than 15%. By maintaining the length of the shell elements in the direction of bridge as 500 mm, the maximum aspect ratio used in the modeling of elements in this study was 2.5.

3.4.1.3 Modeling of Moving Load Paths

SAP2000 software has the ability to run a moving load along a defined frame element path. The program shifts a group of loads, previously defined as static loads, certain interval along a defined path and provides the extreme straining actions at each node. Therefore, Frame elements are provided in the longitudinal direction at the top of the shell elements for the paths of the moving loads. These frame elements are modeled with a very small section dimensions so that they do not affect the finite element model of the structure. Static loads on frame elements were used to reduce the time of computer runs and placed to provide equivalent maximum bending moment, deflection and shear force resulted from SAP2000 moving loads runs.

3.4.2 Boundary Conditions

Nodal constraints were used in the analysis as boundary conditions to represent the supports of the bridge. The roller support condition at the node 1.22m apart of the bottom of the slab was provided at the one end of the bridge to restrain both vertical and lateral displacements. While, the hinged support condition at the node 1.22m apart of the bottom of the slab was provided at the other end of the bridge to restrain displacements in all directions.

3.4.3 Material Modeling

The material properties can highly affect the results of the analysis. Therefore, it is important that the material properties are defined so that SAP2000 software can provide suitable properties for elements. Material properties are considered linear elastic and isotropic for these structures. The required properties for SAP2000 software are the elastic modulus, Poisson's ratio, and the weight density. In SAP2000 software, the shear modulus is defined in terms of Young's modulus and Poisson's ratio as per the following equation:

$$G = \frac{E}{2(1+\upsilon)} \tag{3.10}$$

Where:

$G =$ the shear modulus;

$E =$ Young's modulus; and

$\upsilon =$ Poisson's ratio.

Materials and their properties are chosen based on the CHBDC and the common materials available in Ontario. The compressive strength of concrete (f'_c) is considered 35 MPa. As per CHBDC, the weight density (γ_c) for normal concrete is considered 24.0 kN/m^3. The modulus of elasticity of concrete (E_c) is calculated from the following equation:

$$E_c = \left(3000\sqrt{f'_c} + 6900\right)\left(\gamma_c / 2300\right)^{1.5} \tag{3.11}$$

$$E_c = 27{,}900.0 \text{ MPa} \tag{3.12}$$

Poisson's ratio for elastic strains of concrete is taken as 0.2.

Mass density for concrete is taken as 2500 kg/m^3.

3.5 CHBDC Design Loading

The design of Highways and Bridges in Canada has its own criteria in terms of the critical live loads selected in the design. Two types of live loads were specified in CHBDC; namely: truck loading and lane loading. Both above mentioned loads were investigated in this study. Figure 3.4 shows schematic diagram of the above-mentioned CHBDC live truck and lane loads namely; CL-W truck loading and the CL-W lane loading. The CL-W truck is an idealized five-axle truck, the number "W" indicates the gross load (625) of the CL-W truck in KN. Wheel and axle loads are shown in terms of W, and are also shown specifically for CL-625 truck. Whereas the CL-W lane loading consists of CL-W truck loading, with each axle load reduced to 80% of its original value, and superimposed within a uniformly distributed load of 9 KN/m over 3.0 m width. For the purpose of this study, the following different CHBDC truck loading configurations were considered.

Figure 3.5 presents a schematic diagram of truck axle load locations to produce maximum bending moment. By inspection, Level 2 loading was used in the analysis of the 16 m and 20 m span bridges, while Level 1 was used to analyze bridges of 24, 26, 30 and 32 m spans. Figure 3.6 presents a schematic diagram of truck axle load locations to produce maximum reaction force. By inspection, Level 2 loading was used in the analysis of the 16 m span bridges, while Level 1 was used to analyze bridges of 20, 24, 26, 30 and 32 m spans. In studying the moment, shear and deflection distributions, the loading on the bridge prototypes was applied in such a way to produce maximum reaction forces and longitudinal flexural stresses.

3.6 CHBDC Specifications for Truck Loading

The live load specified in CHBDC consists of CL-W Truck or CL-W Lane Load. CL-W Truck, provided for all other provinces, in the axle loads. The selection between the two different CHBDC types of live loads (CL-625 truck and CL-625 lane) depends on whichever gives the greatest design values. Dynamic load allowance is applied to both CL-W and CL-625-ONT Trucks. The CL-W Lane Load consists of 80% of the value given for each axle of the CL-W Truck superimposed within a uniformly distributed load of 9 kN/m and a space of 3.0 m wide (Figure 3.4). No dynamic load allowance is considered for both CL-W and CL-625-ONT Lane Loads. A sensitivity study was carried out in this regard showed that the CL-625 truck loading is governing the extreme design values for the box girder of 16, 20, 24, 26, 30 and 32 m span lengths. CL-625 truck loading giving higher values, accordingly the CL-625 lane loading was utilized in this study. CHBDC requires considering three limit states in bridge designs; namely:

a. The Ultimate Limit State (ULS), that involve failure, including rupture, overturning, sliding, and other instability,

b. The Serviceability Limit State (SLS), at which the effect of vibration, permanent deformation, and cracking on the usability or condition of the structure are considered,

c. The Fatigue Limit State (FLS), at which the effect of fatigue on the strength or condition of the structure are considered.

For fatigue analysis, an equivalent static load is specified in the CHBDC. Only one truck, either CL-W Truck or CL-625-ONT Truck, can be placed at the centre of one travelling lane. The lane load is not considered for the fatigue limit state. CHBDC states that for longitudinal bending moments and associated deflections for Fatigue Limit State and superstructure vibration, the vehicle edge distance (the distance from the centre of the outer wheel load to the edge of the bridge) shall not be greater than 3.0 m.

Different loading configurations were also considered in this study represented by: two-lane, three-lane and four-lane bridges. As a result, a total of 48 different load cases were employed of the above mentioned design requirements. Figures 3.7, 3.8 and 3.9 presents the loading cases considered in this study for two-, three-, and four-lane bridges, respectively.

3.7 Composite Bridge Configurations

A total of 54 solid slab bridge prototypes were considered for the finite-element analysis in this parametric study.

Below are the major parameters were considered:

a. Span length **(L)**: 16, 20, 24, 26, 30, and 32 m

b. Slab Thickness **(t)**: **L/25** m based on the span length of the bridge.

For the above-mentioned bridge configurations, the number of design lanes in a bridge cross-section was determined based on Table 3.1 (CHBDC, 2006).

3.8 Load Distribution Factor

3.8.1 Calculation of the Moment Distribution Factors

The longitudinal stresses (σ_{FE}) in concrete slab was determined in order to calculate the load distribution factor for longitudinal bending moment (F_m) due to truck loadings. The maximum flexural stresses $(\sigma_{straight})_{truck}$, were calculated for the straight simply-supported beam due to CHBDC truck loading.

$(\sigma_{straight})_{truck} = M_{T}(y_b) / I_t$ (3.13)

Where M_T = the mid-span moment for a straight simply supported per meter width due to a single CHBDC truck loading; y_b = the distance from the neutral axis to the bottom of slab; and I_t = the moment of inertia per meter width.

Also the results of the above equations were verified by SAP2000 program using the developed FEA model. The finite-element modeling was then used to calculate the maximum longitudinal flexural stresses along the bottom flange for fully-loaded lanes, partially loaded lanes, and fatigue loading conditions presented in Figs. 3.7 to 3.9. Consequently, the moment distribution factors (Fm,) due to truck loading conditions were calculated as follows:

- ($(F_m)_{FL} = (\sigma_{FE.})_{FL} \times B / ((\sigma_{straight})_{truck} \times n)$ (3.14)
- $(F_m)_{PL} = (\sigma_{FE.})_{PL} \times B \times R_L' / ((\sigma_{straight})_{truck} \times n \times R_L)$ (3.15)

Where:

B = total width of bridge

n = number of design lanes;

R_L = multi-lane factor based on the number of the design lanes; as shown in Table 3.2, considering Class A highway.

R_L' = multi-lane factor based on the number of the loaded lanes; as shown in Table 3.2,

$(\sigma_{FE.})_{PL}$ = the maximum average flexure stress, resulting from FEA bridge analysis, at the bottom surface of the concrete slab;

$(\sigma_{FE.})_{FL}$ = the maximum average flexure stress, resulting from FEA bridge analysis, at the bottom surface of the concrete slab due to fatigue Loadings;

3.8.2 Calculation of the Shear Distribution Factors

In determining the shear distribution factor (Fv) for slab bridges, the maximum shear forces, $(R_{straight})_{truck}$, were calculated for straight simply supported beam due to a single CHBDC truck loading. By using finite-element modeling, the maximum shear forces (R_{FE}) for different truck loading conditions were determined. Consequently, the shear distribution factors (F_v) were calculated as follows:

$$(F_v)_{FL} = (R_{FE.})_{FL} \times B / ((R_{straight})_{truck} \times n) \quad (3.16)$$

$$(F_v)_{PL} = (R_{FE.})_{PL} \times B \times R_L' / ((R_{straight})_{truck} \times n \times R_L) \quad (3.17)$$

$$(F_v)_{Fat} = (R_{FE.})_{Fat} \times B / (R_{straight})_{truck} \quad (3.18)$$

B = total width of bridge;

n = number of design lanes;

R_L = multi-lane factor based on the number of the design lanes; as shown in Table 3.2,

R_L' = multi-lane factor based on the number of the loaded lanes; as shown in Table 3.2,

$(R_{FE.})_{FL}$ = the maximum total reaction, resulting from bridge analysis, at the slab supports;

$(R_{FE.})_{FL}$ = the maximum total reaction, resulting from bridge analysis, at the slab supports due to fatigue Loadings;

3.8.3 Calculation of the Deflection Distribution Factors

In order to determine the load distribution factor for deflections (F_d) for the slab bridges, the deflection resulting from bridge analysis at the critical section (Δ_{FE}), due to truck loadings at fatigue load case was identified. Also, the maximum deflection resulting from the analysis at the corresponding critical section of the bridge $(\Delta_{straight})_{truck}$, due to single truck loading was identified. The distribution factors for deflections were calculated in accordance with CHBDC as follows:

For deflection at the bottom of slab for fatigue ($F_{f\delta}$):

$$(F_d)_{Fat.} = (\Delta_{FE})_{Fat} \times B / (\Delta_{straight})_{truck} \quad (3.19)$$

Where:

B = total width of bridge;

Δ_{FE} = the maximum deflection, resulting from bridge analysis, at the bottom surface of the slab due to fatigue.

CHAPTER IV

RESULTS FROM THE PARAMETRIC STUDY

4.1 General

A practical-design-oriented parametric study on 54 simply-supported straight, solid slab bridge prototypes was conducted to investigate the moment, shear and deflection distribution factors at the ultimate, serviceability and fatigue limit states. The bridges were analyzed to evaluate their structural responses when subjected to the Canadian Highway Bridge Design truck loading, CHBDC truck CL-625. The results generated from the parametric study were then correlated with the values obtained from the load distribution factor equations specified in CHBDC.

In this study the following major key parameters were considered: (i) bridge width **(B)**, (ii) bridge span length **(L)**, (iii) number of design lanes (***n***), and (vi) truck loading conditions. The following sections present the results from the parametric study as compared to the available equations in CHBDC and FEA for solid slab bridges.

4. 2 Effect of Span Length

To investigate the effect of span length on the structural response of studied bridges, 6 different span lengths were considered, namely: 16, 20, 24, 26, 30 and 32 m. The following subsections explain the effect of span length of the moment, shear and deflection distribution factors of the studied bridges.

4.2.1 Moment Distribution Factor

Figures 4.1 to 4.9 show the relationship between the change in span length and moment distribution factor, F_m, of selected bridge geometries. To explain the trend, Fig. 4.9 depicts the change in moment distribution factor with increase in span length of a four-lane bridge with constant width of 17.276 m. It can be observed that F_m changes from 1.15 to 1.04 when increasing span length from 16 to 32 m for ULS design. This considers a decrease of 9.6%. In the same sense, F_m decreases from 1.9 to 1.32 when increasing bridge span from 16 to 32 m (a decrease of 30.5%) for FLS design. Similar trend was observed in other Figures for 2-, and 3-lane bridge cross-sections.

4.2.2 Shear Distribution Factor

Figures 4.10 to 4.18 show the relationship between the span length and the shear distribution factor, F_v, for selected bridge geometries. To explain the trend, Figure 4.15 is considered here as an example. This figure shows the change in shear distribution factor with increase in span length from 16 to 32 m for a two-lane bridge of 13.571 m width. It can be observed that F_v changes from 1.73 to 2.4 when increasing bridge span from 16 to 32 m for ULS and FLS design, an increase of 28%. Also, F_v changes from 2.49 to 3.64 when increasing bridge span from 16 to 32 m for FLS design, an increase of 31.5%. Similar trend was observed in other Figures for 2-, and 4-lane bridge cross-sections.

4.2.3 Deflection Distribution Factor

Figures 4.19 through 4.27 depict the change in deflection distribution factor, F_d, with increase in bridge span length. As an example, Figure 4.25 depicts the change in deflection distribution factor with increase in bridge span of a four-lane bridge of 14.806 m width. It can be observed that F_d changes from 1.65 to 1.20 when increasing bridge span from 16 to 32 m, a decrease of 27.7%. Similar trend was observed in other Figures for 2-, and 3-lane bridge cross-sections.

4.3 Effect of Number of Design Lanes

As stated earlier, three different numbers of design lanes were considered in this study, namely, 2, 3 and 4. Bridge width is dependent on the lanes of bridge as given in CHBDC Table 3.1. It should be noted the simplified method of analysis specified in CHBDC provides sets of F and C_f parameters shown in Equation 2.23 for bridges made of one-design lane to more than four-design lanes. This effect directly includes the effect of change in bridge width, in addition to change in design lane width implied in the parameter μ in Equation 2.24.

4.3.1 Moment Distribution Factor

Figures 4.28 to 4.33 present the effect of the change in number of design lanes on the moment distribution factor of selected bridges. One may observe the general trend of insignificant effect of the change in number of design lanes on F_m values at the ULS design as compared to those at FLS design. As an example, Figure 4.29 depicts the change in F_m values with increase in number of design lanes for a 20-m span bridge. It can be observed that F_m changes from 1.19 to 1.57 (an increase of 24.2%) when changing the number of design lanes from 2 to 4 for FLS design. While the increase in F_m for ULS was 5.2% (i.e.

change from 1.09 to 1.15) when increasing the number of design lanes from 2 to 4. Similar trend was observed in other bridge geometries.

4.3.2 Shear Distribution Factor

The parametric study revealed that the shear distribution factors increase with increase in number of design lanes as depicted in Figs. 4.34 to 4.39. As an example, Figure 4.38 depicts the change in F_v values with increase in number of design lanes for a 30-m span bridge. It can be observed that F_v changes from 2.55 to 4.81 (an increase of 45%) when changing the number of design lanes from 2 to 4 for FLS design. While the increase in F_v for ULS was 32.6% (i.e. change from 1.88 to 2.79) when increasing the number of design lanes from 2 to 4.

4.3.3 Deflection Distribution Factor

Figures 4.40 through 4.45 depict the change in deflection distribution factor, F_d, with increase in number of design lanes. It can be observed that the deflection distribution factor increases with increase in number of design lanes. As an example, Figure 4.45 depicts the change in deflection distribution factor with increase in number of design lanes for 32-m span bridge. It can be observed that F_d changes from 1.06 to 1.27 when increasing the number of design lanes from 2 to 4, an increase of 16.5%.

4.4 Effect of Load Cases

Few loading cases for CHBDC truck loading were considered in the analysis to obtain the maximum effect on the studied slab bridges. These loading cases were presented in Chapter III and can be divided into two main groups; namely: bridges with fully loaded lanes and bridges with partially loaded lanes. Tables A.7 to A66 in Appendix A summarize the values of the moment; shear and deflection distribution factors obtained from the parametric study due to fully loaded lanes and partially loaded lanes. There is no specific trend to reach regarding which type of loading provides the maximum effect on slab. However, the greatest value of the distribution factors for each bridge geometric was considered for further analysis to developed new expressions for designers. It should be noted that the F_m, F_v and F_d determined in this study were determined as the greatest values calculated from a set of loading cases for each specific bridge geometry.

4.5 Correlation of Moment and Deflection Distribution Factors obtained from FEA analysis

CHBDC did not specify imperial expressions for deflection distribution factors. However, it specified that the deflection distribution factor can be taken as the moment distribution factors in structural design. Figures 4.46 through 4.54 show the change in both the moment distribution factors and deflection distribution factors for the studies slab bridges. It can be observed that the deflection distribution factors are always less that the corresponding moment distribution factors. As such, CHBDC provided conservative values for the deflection distribution factors by taking them as those calculated from the moment distribution factors.

4.6 Comparison between the FEA Results and Distribution factors specified in CHBDC for Slab Bridges

The Canadian Highway Bridge Design Code specifies equations for calculating the moment, shear and deflection distribution factors for straight slab bridges and voided slab bridges. It should be noted that CHBDC specifies the F_d values for such bridges can be taken as those for F_m values for simplicity. Figures 4.55 to 4.59 present correlations between the results from the current study and those obtained from the CHDBC simplified method for straight slab bridges. By inspection of these figures, it can be observed that the moment, shear and deflection distribution factors for the studied slab bridges scattered with no general trend except for Fv values for ULS, on which FEA provides values considerably greater that those specified in the CHBDC. This may be attributed to the assumption associated with the use of orthotropic plate theory in analyzing such bridges with equivalent torsional and bending stiffness with line supports rather than point supports. Due to these discrepancies in correlation, the author suggests extending this study to develop more reliable expressions for moment and shear distribution factors for slab bridges based on the data generated from this study.

CHAPTER V

CONCLUSIONS, AND RECOMMENDATIONS FOR FUTURE RESEARCH

5.1 General

A practical-design-oriented parametric study, using finite element method, was conducted to investigate the static response of simply-supported solid slab bridges. A literature review was provided in order to establish the basis of this study. The influence of few key parameters on the moment, deflection and shear distribution factors for ultimate, serviceability and fatigue limit states designs was investigated using commercially-available finite-element computer program "SAP2000". The key parameters considered in this study included span length, number of design lanes, and truck loading conditions.

5.2 Conclusions

Based on the results from the parametric study on slab bridges, the following conclusions are drawn:

1. Bridge span length and number of design lanes play a significant role on the values of the load distribution factors.
2. Deflection distribution factors are generally smaller than the corresponding moment distribution factors for a typical bridge configuration.
3. The correlation between FEA results for slab bridges and those obtained from CHBDC showed scattered trend. However, CHBDC showed underestimating the structural response of slab bridges in few bridge geometries.

4. The database generated from the parametric study can be further used to develop empirical expressions for moment, shear and deflection distribution factors for ULS, SLS2 and FLS designs. The proposed expressions can be used with confidence to design new bridges and evaluate existing bridges more economically and reliably.

5.3 Recommendations for Future Research

It is recommended that further research efforts be directed towards the following:

1- Based on the data generated from this study, imperial expressions can be developed for the moment and shear distribution factors for slab bridges.

2- Study the load distribution in skew slab bridges.

3- Study the load distribution in curved slab bridges.

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Table 3.1 Number of Design Lanes (CHDBC, 2006)

Wc	n
6.0 m or less	1
Over 6.0 m to 10.0 m incl.	2
Over 10.0 m to 13.5 m incl.	2 or 3
Over 13.5 m to 17.0 m incl.	4
Over 17.0 m to 20.5 m incl.	5
Over 20.5 m to 24.0 m incl.	6
Over 24.0 m to 27.5 m incl.	7
Over 27.5 m	8

Table 3.2 Modification Factors for Multilane Loading (CHDBC, 2006)

Number of Loaded Design Lanes	Modification Factor
1	1.00
2	0.90
3	0.80
4	0.70
5	0.60
6 or more	0.55

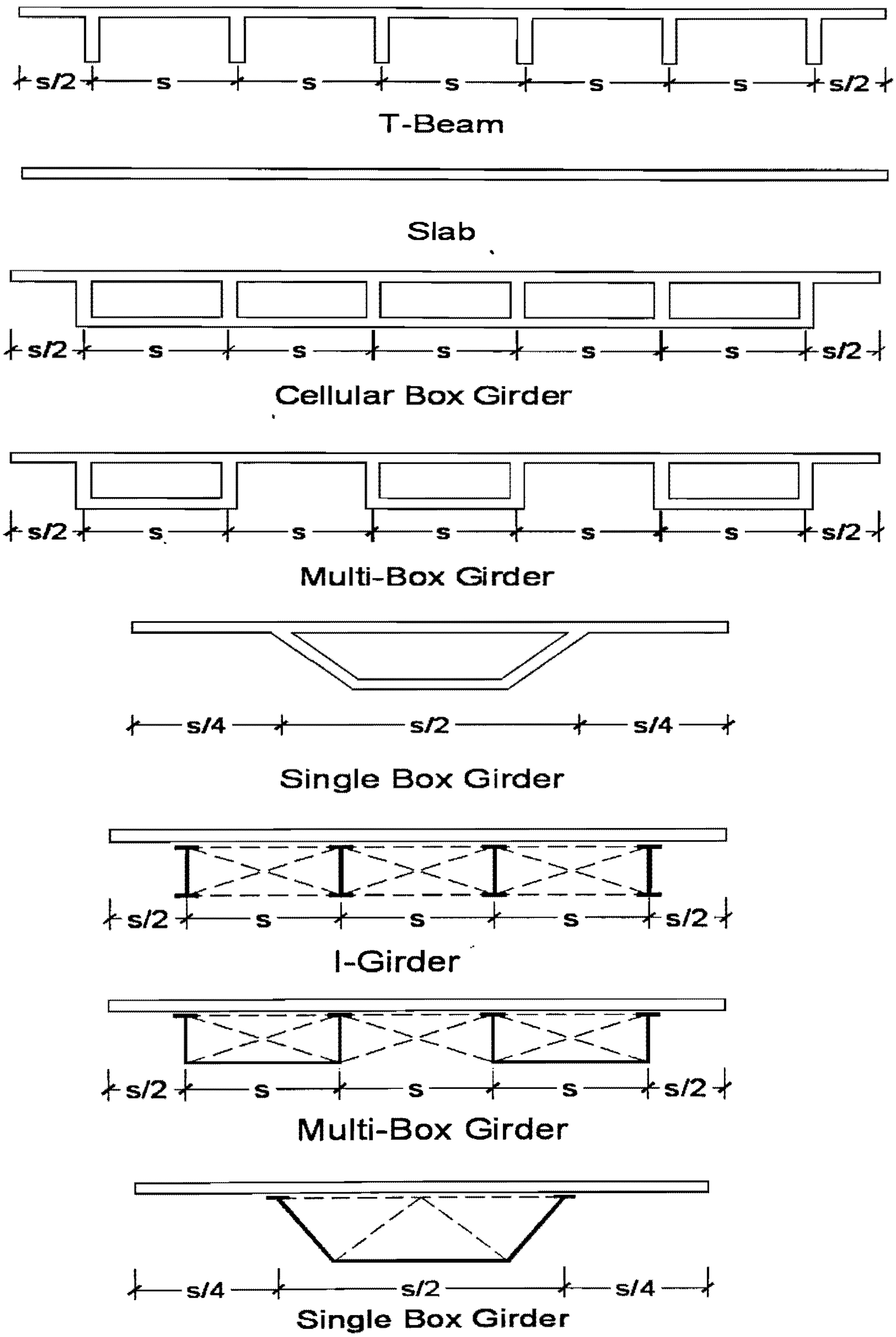


Figure 1.1 Views of Common Bridge Cross-Sections in CHBDC

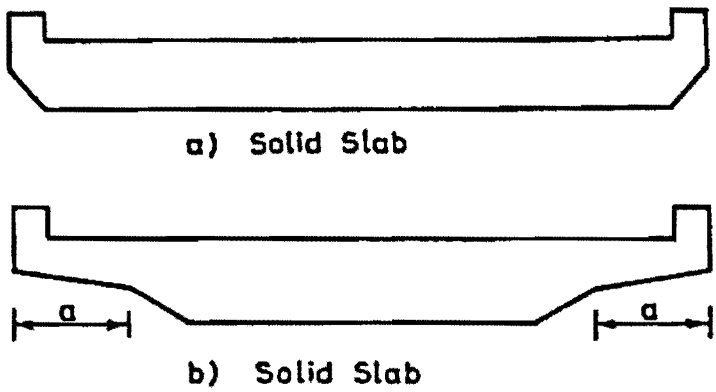
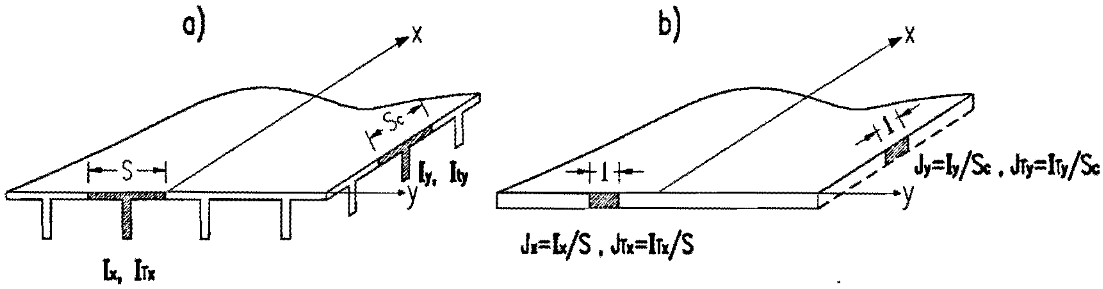


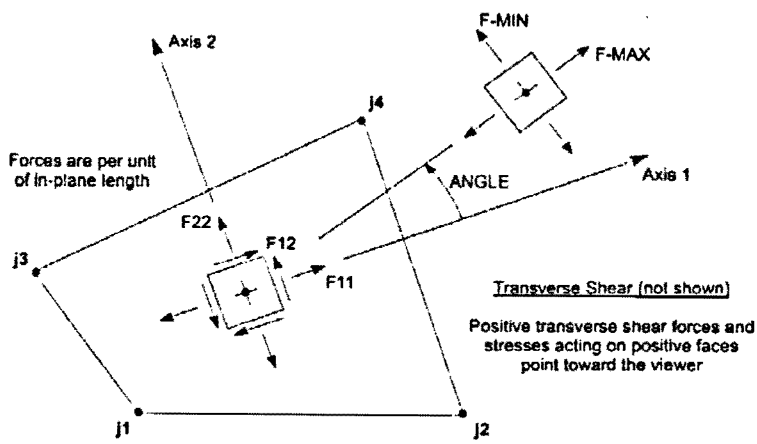
Figure 1.2 Schematic Diagrams of Solid Slab Bridges



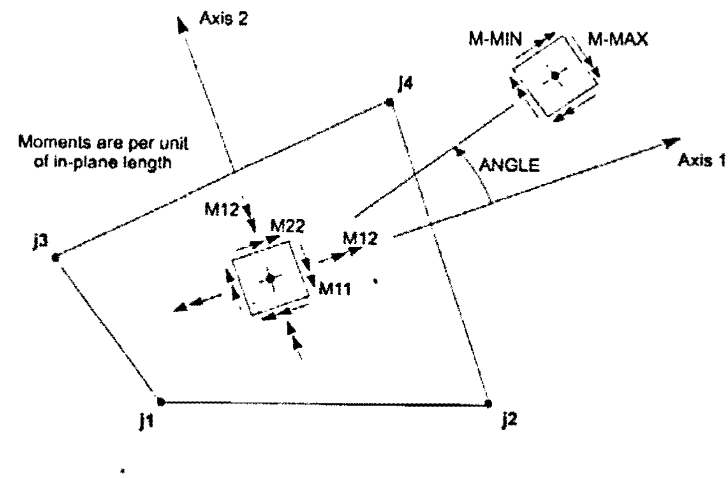
a) Real Structure

b) Analogized Equivalent Orthotropic Plate

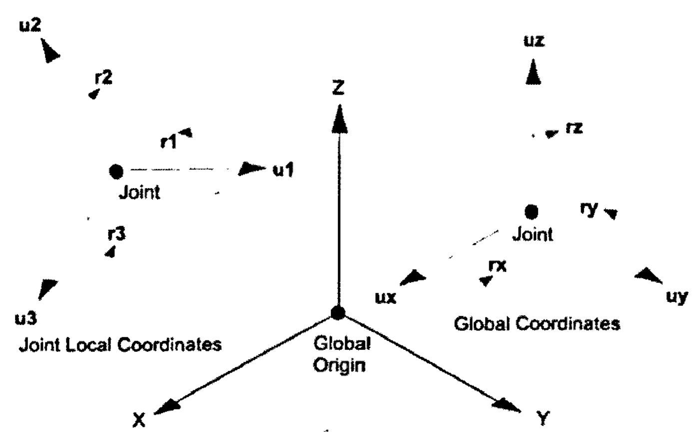
Figure 2.1 Real Structures and Orthotropic Plate Analogy



a) Stress and membrane forces



b) Plate bending moments



c) Global and local coordinates

Figure 3.1 Sketches of the four-node shell element used in the SAP2000 analysis

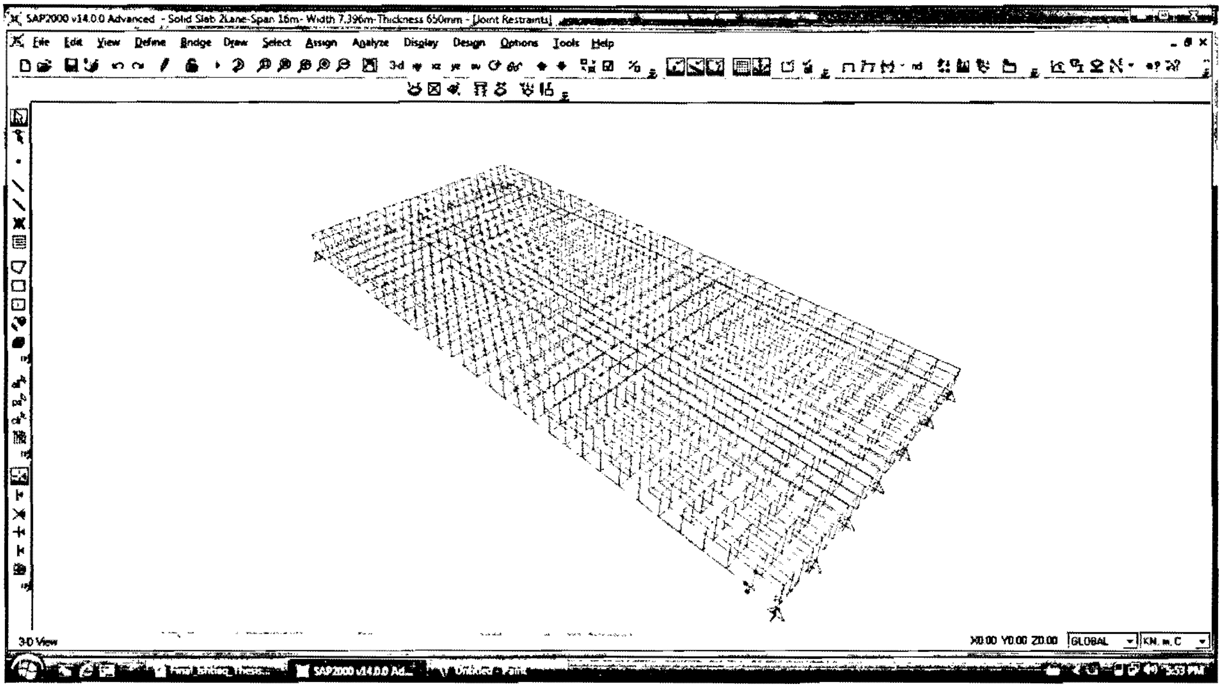


Figure 3.2 View of 3D Model of Solid Slab Bridge (7.396m Width and 16 m span)

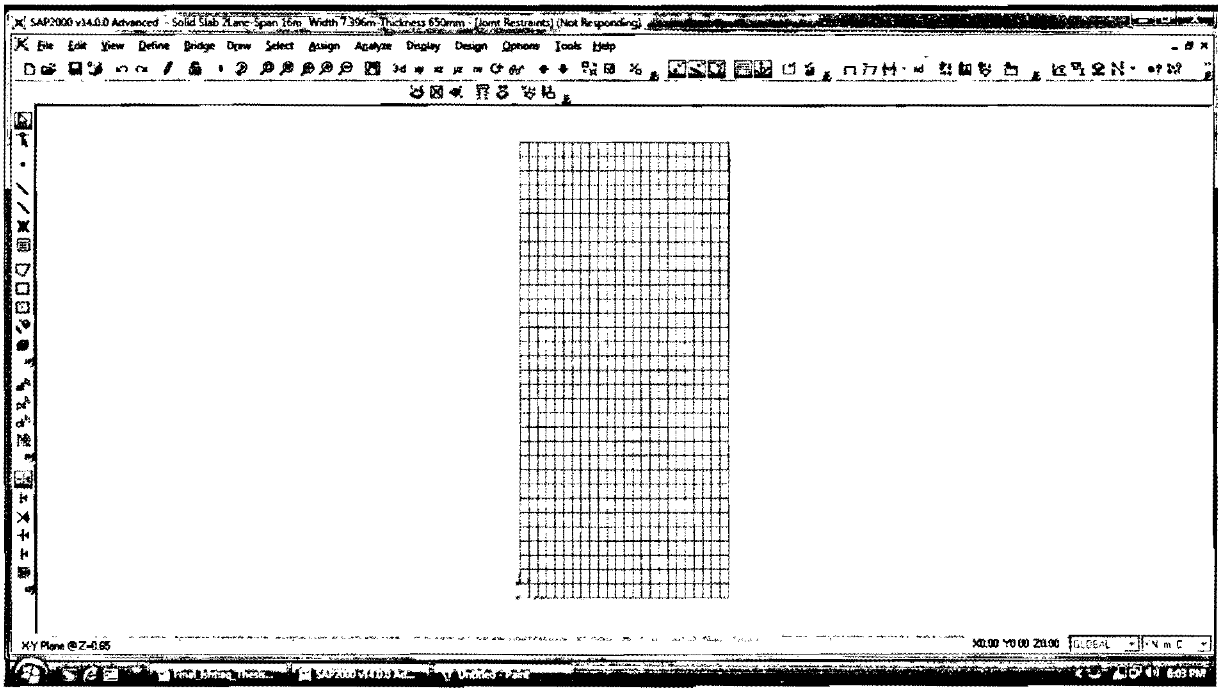


Figure 3.3 View of X-Y Plane of Solid Slab Bridge (7.396 m width and 16 m span)

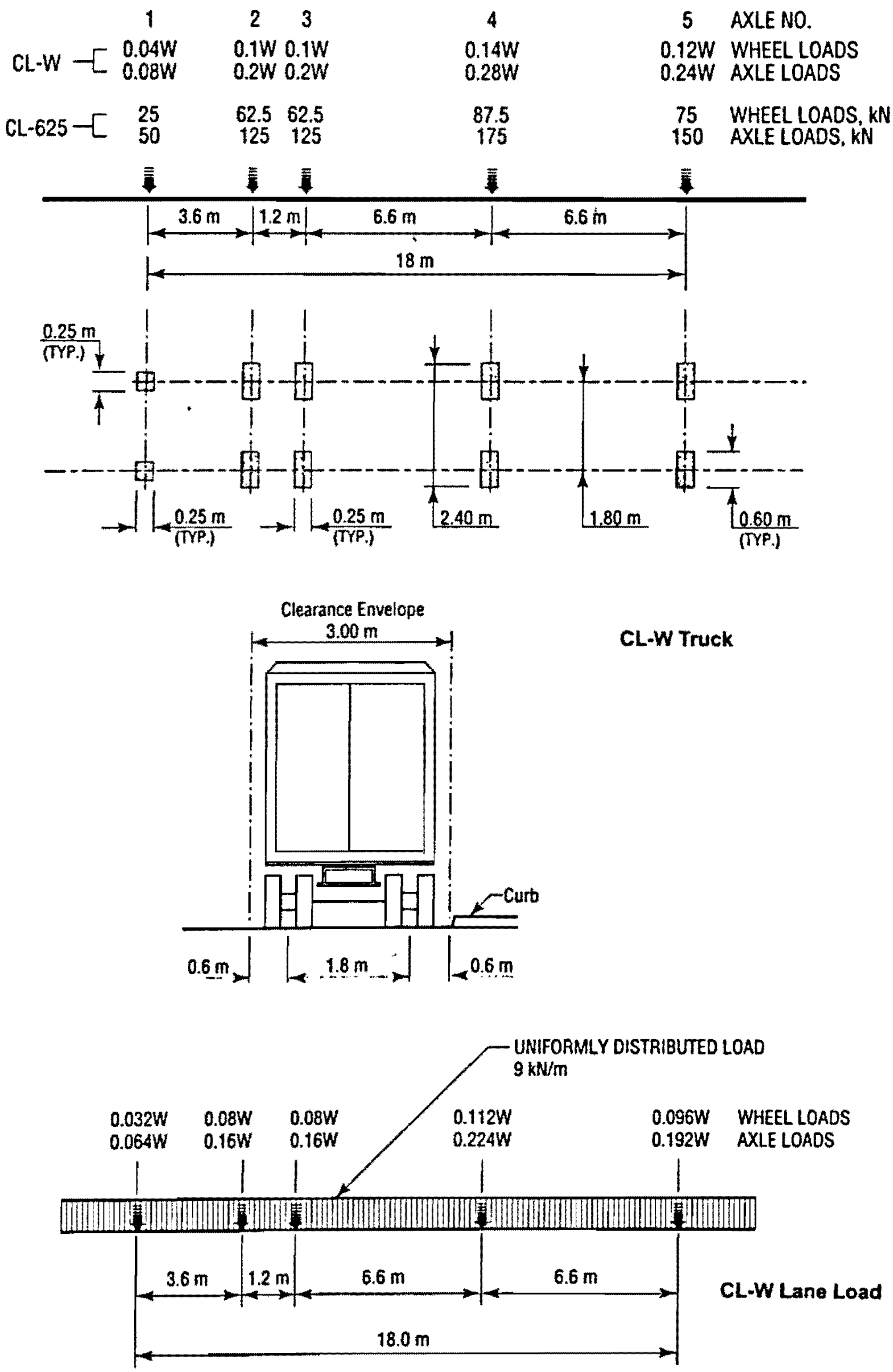


Figure 3.4 CL-W Truck and Lane Loading, CHBDC

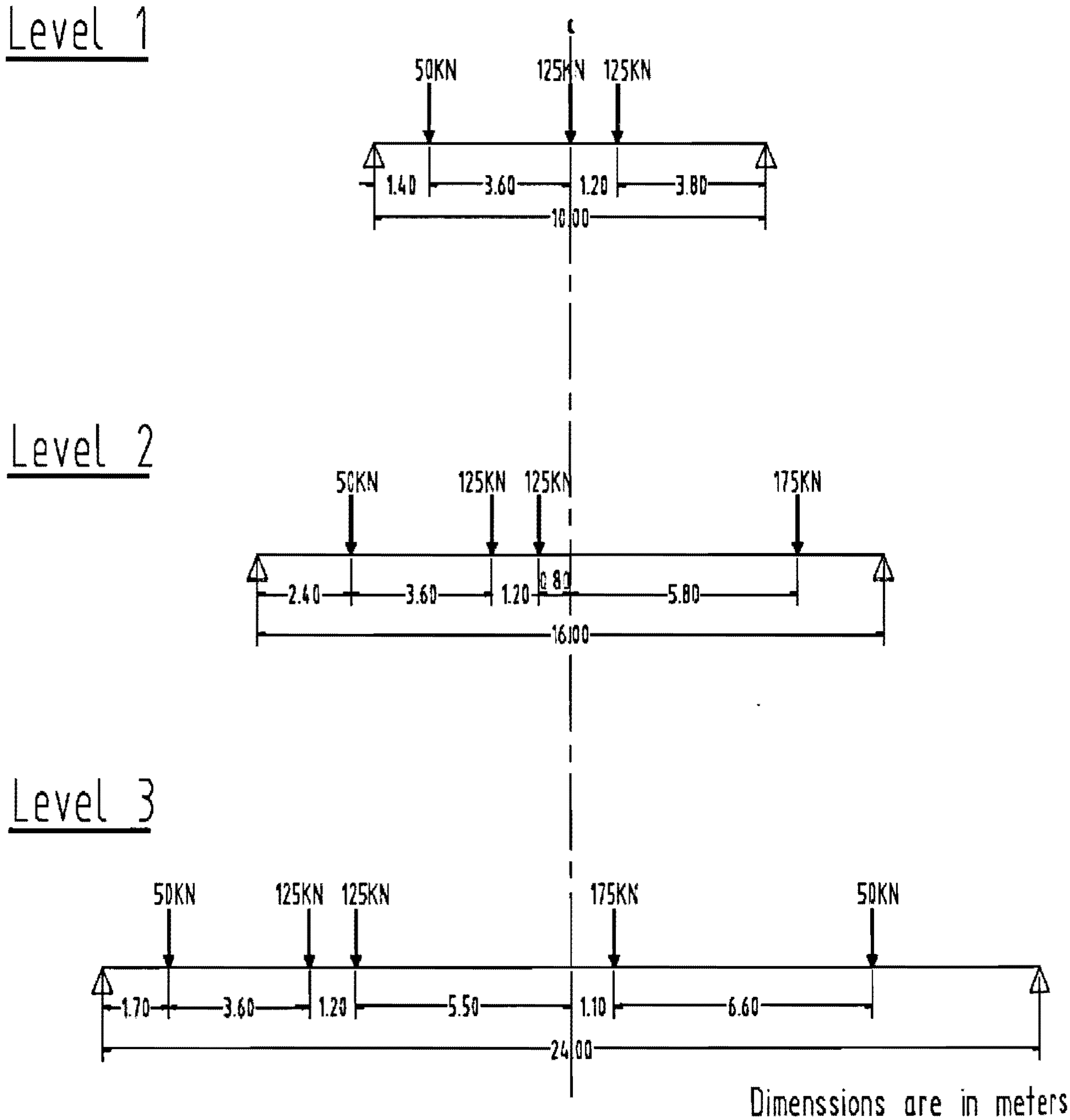


Figure 3.5 Maximum Moment Locations

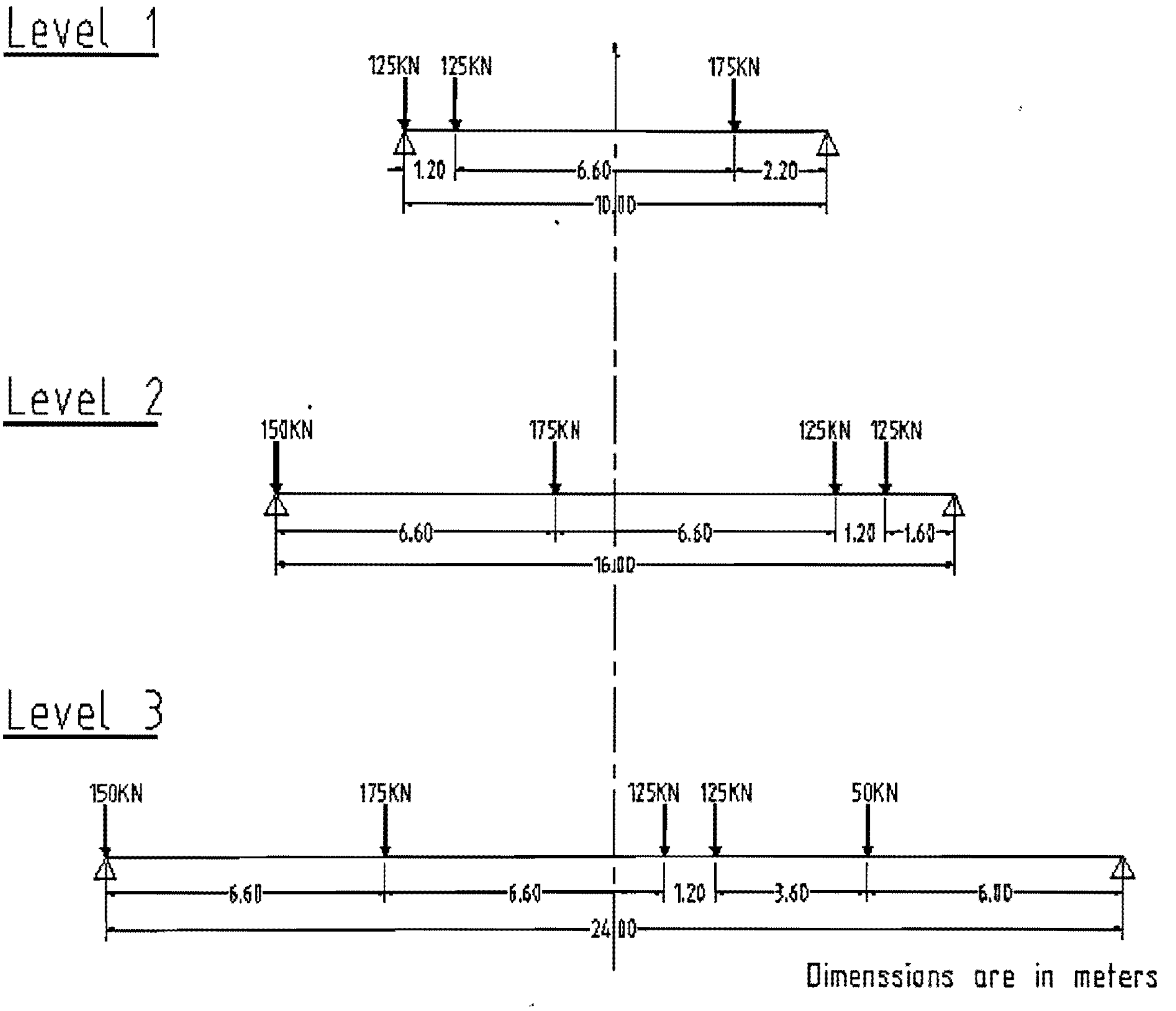
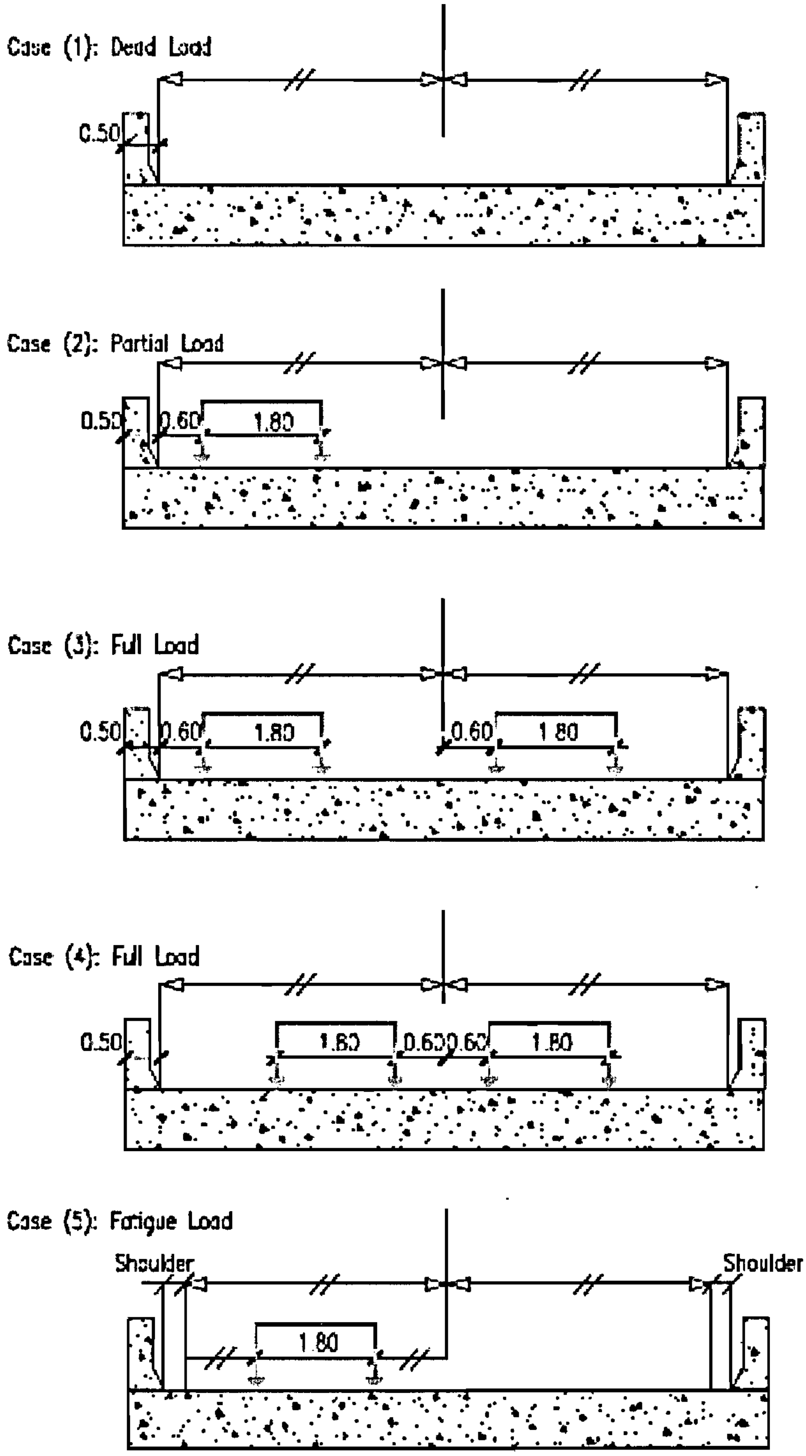
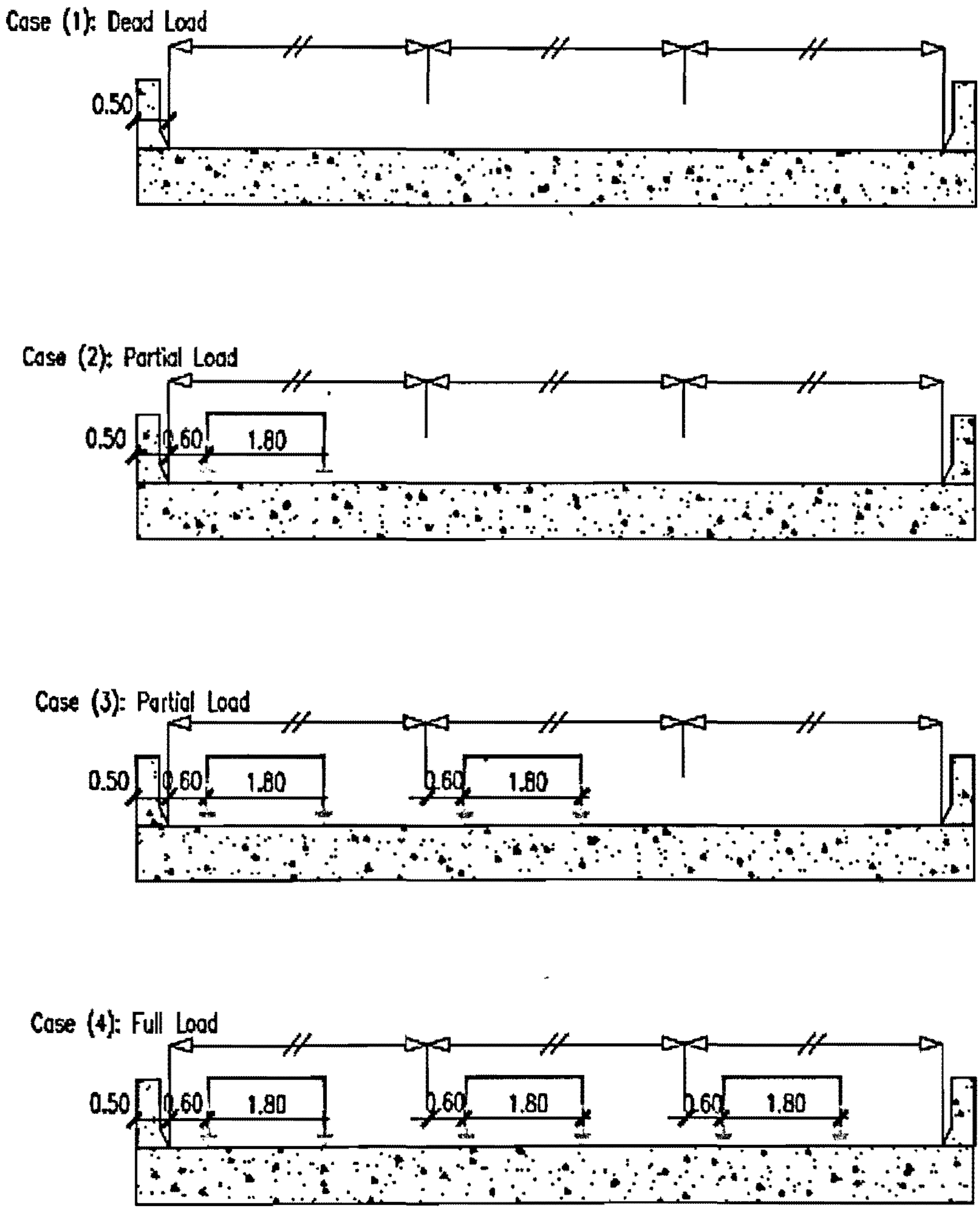


Figure 3.6 Maximum Shear Locations



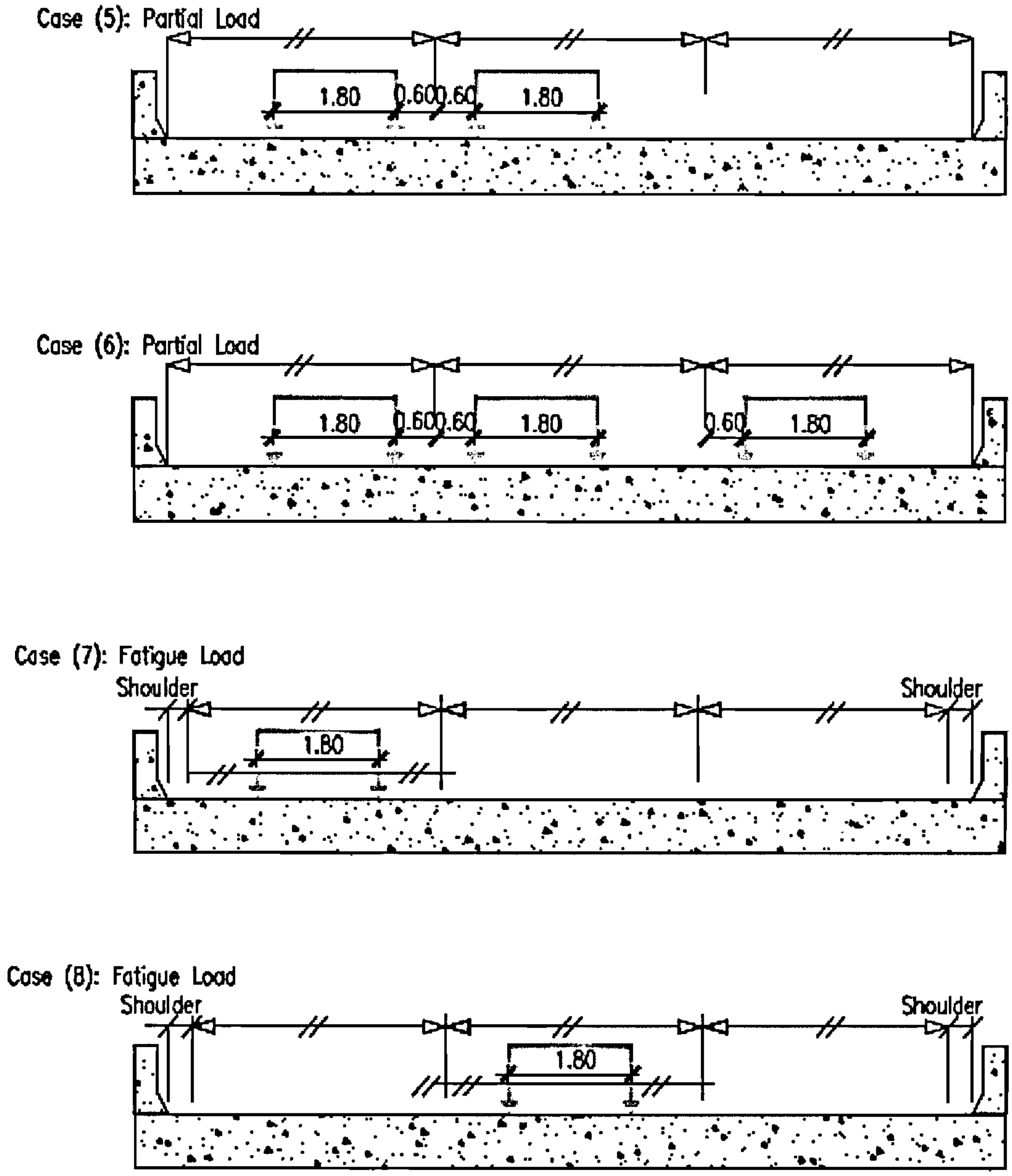
(Dimension is in meter)

Figure 3.7 Live Loading Cases for Two-Lane Bridges



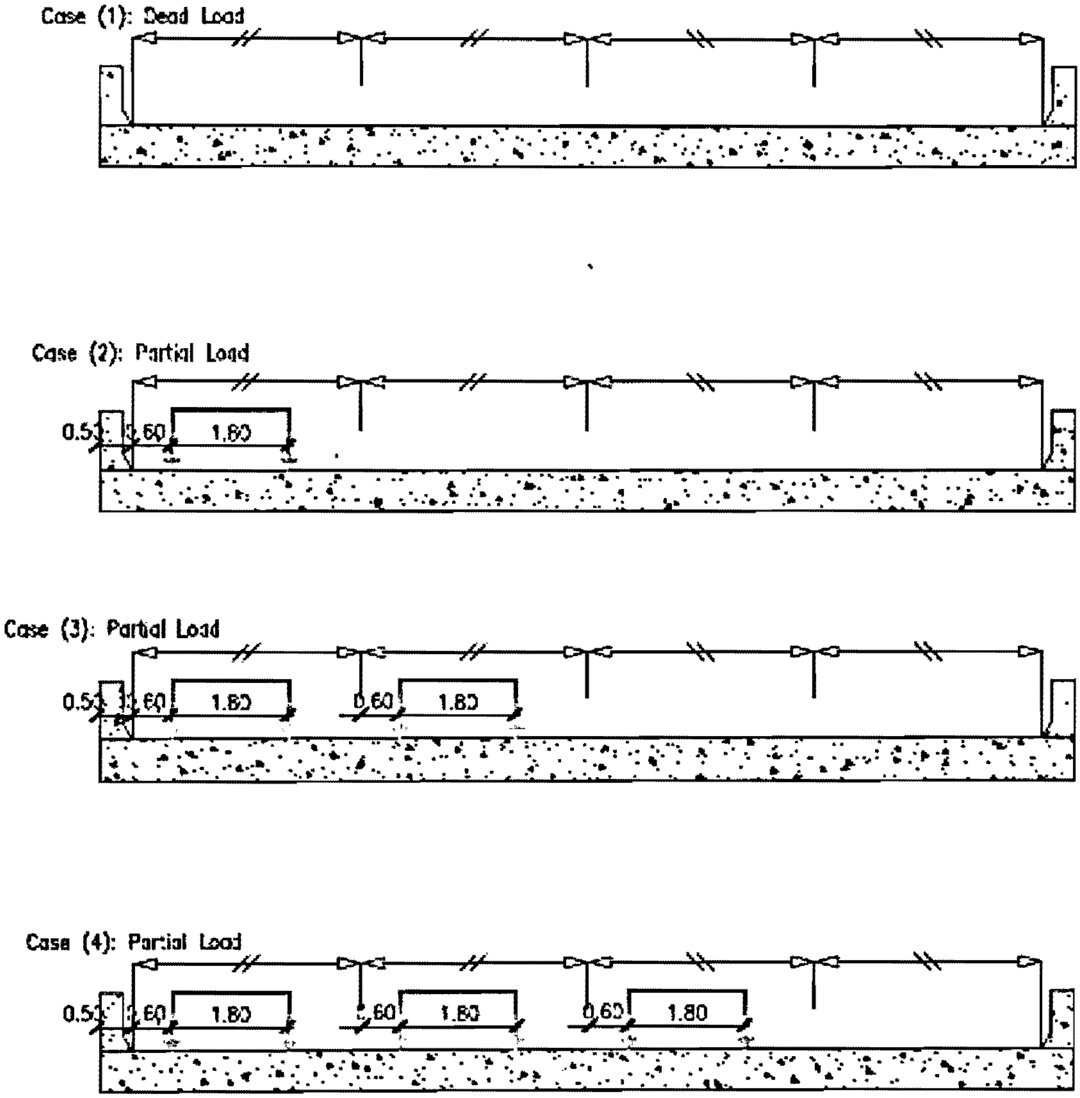
(Dimension is in meter)

Figure 3.8 Live Loading Cases for Three-Lane Bridges (Continue)



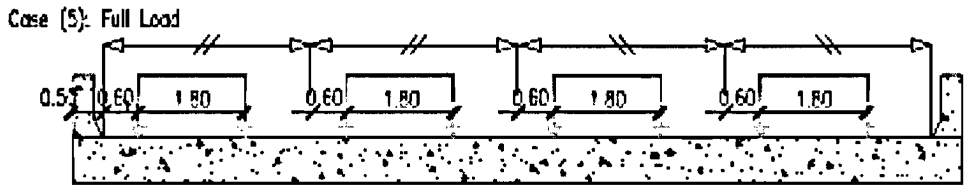
(Dimension is in meter)

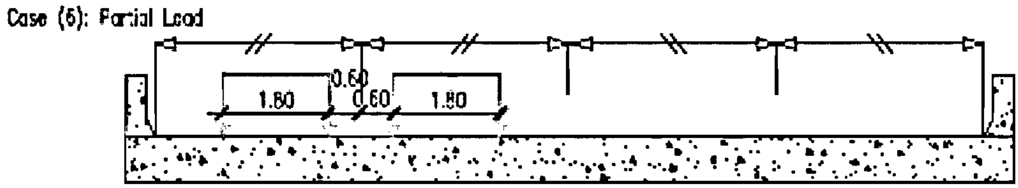
Figure 3.8 Live Loading Cases for Three-Lane Bridge

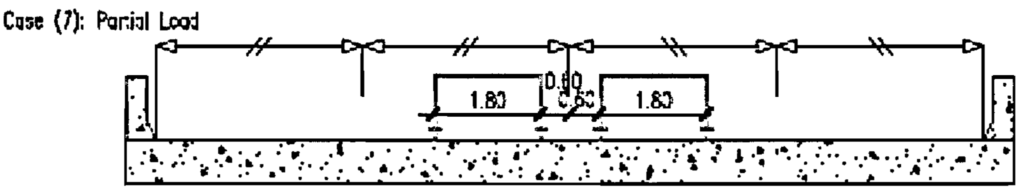


(Dimension is in meter)

Figure 3.9 Live Loading Cases for Four-Lane Bridge (Continue)



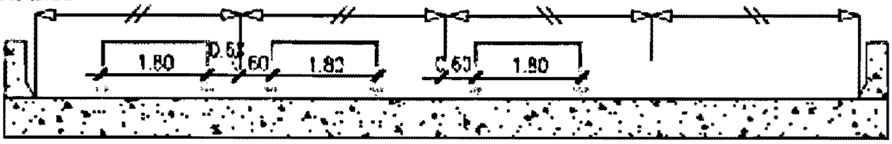




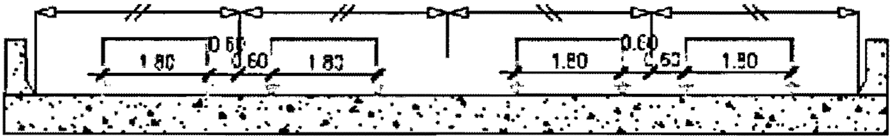
(Dimension is in meter)

Figure 3.9 Live Loading Cases for Four-Lane Bridge (Continue)

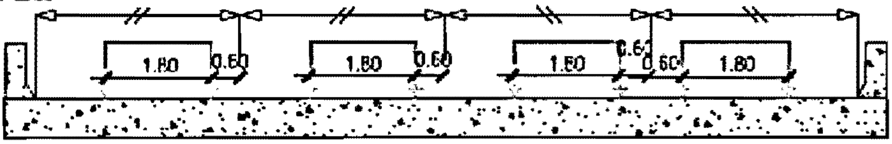
Case (8): Partial Load



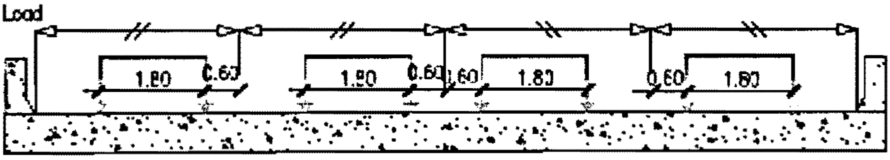
Case (9): Full Load



Case (10): Full Load

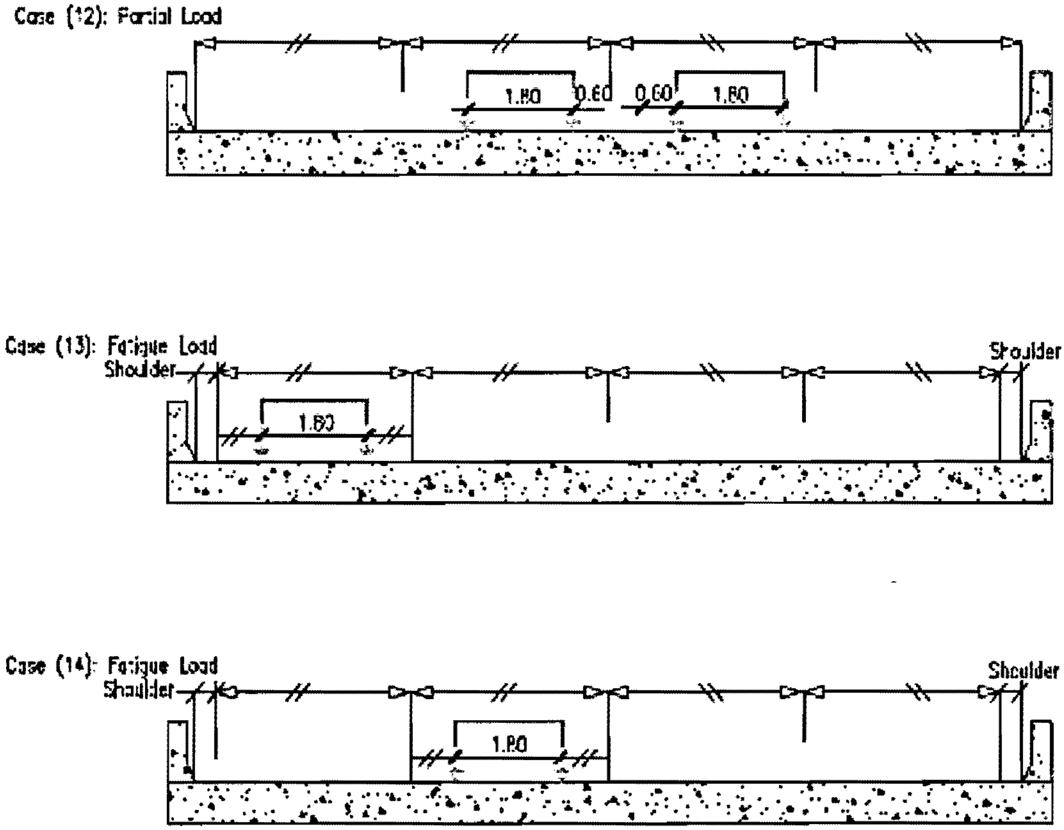


Case (11): Full Load



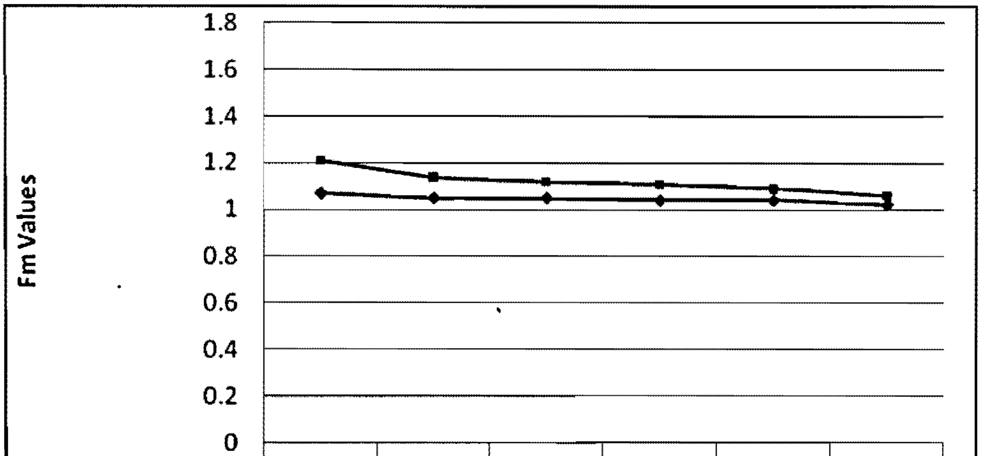
(Dimension is in meter)

Figure 3.9 Live Loading Cases for Four-Lane Bridge (Continue)



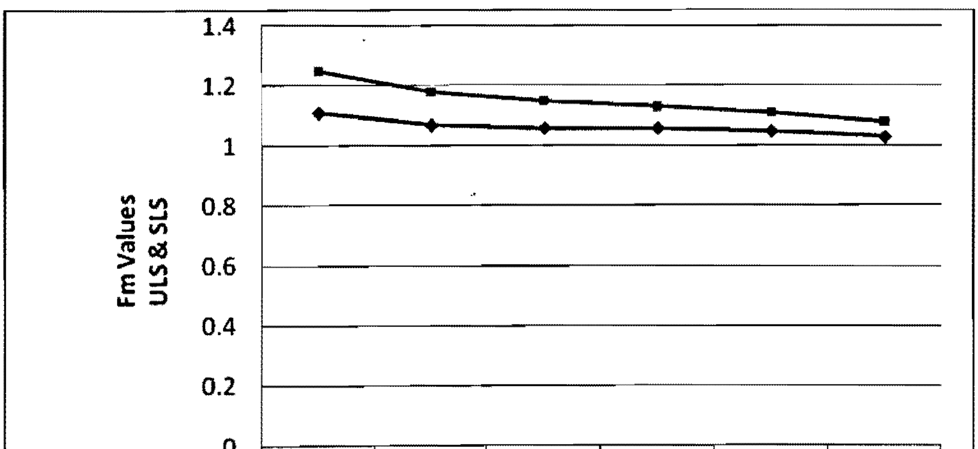
(Dimension is in meter)

Figure 3.9 Live Loading Cases for Four-Lane Bridge



	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.07	1.05	1.05	1.04	1.04	1.02
FLS	1.21	1.14	1.12	1.11	1.09	1.06

Figure 4.1 Effect of Span Length on the Moment Distribution Factor for 2-Lanes Bridge of 7.396 m width



	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.11	1.07	1.06	1.06	1.05	1.03
FLS	1.25	1.18	1.15	1.13	1.11	1.08

Figure 4.2 Effects of Span Length on the Moment Distribution Factor for 2-Lanes Bridge of 8.631 m Width

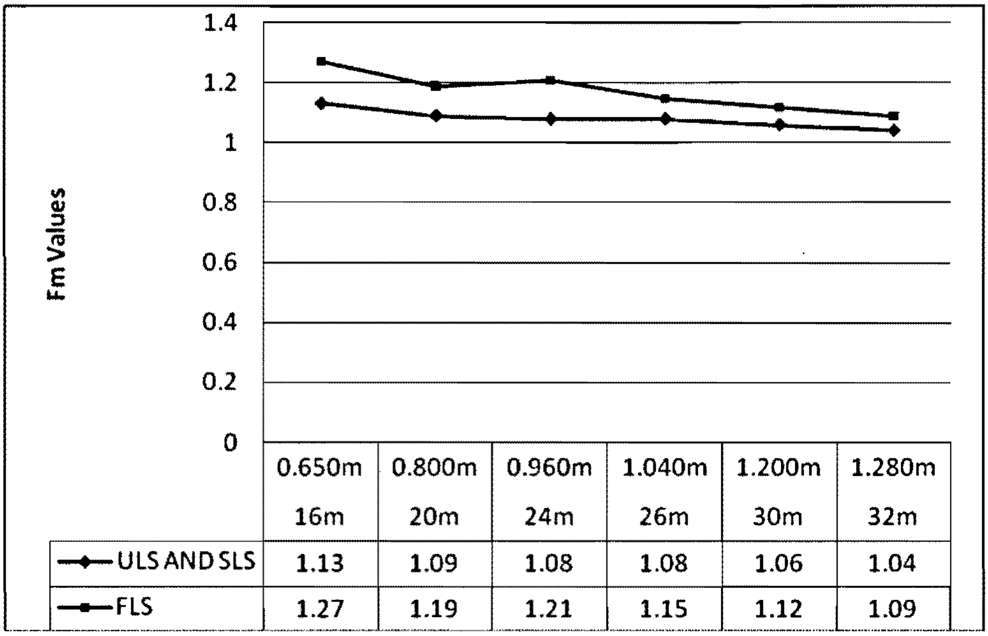


Figure 4.3 Effects of Span Length on the Moment Distribution Factor for 2-Lanes Bridge of 9.866 m Width

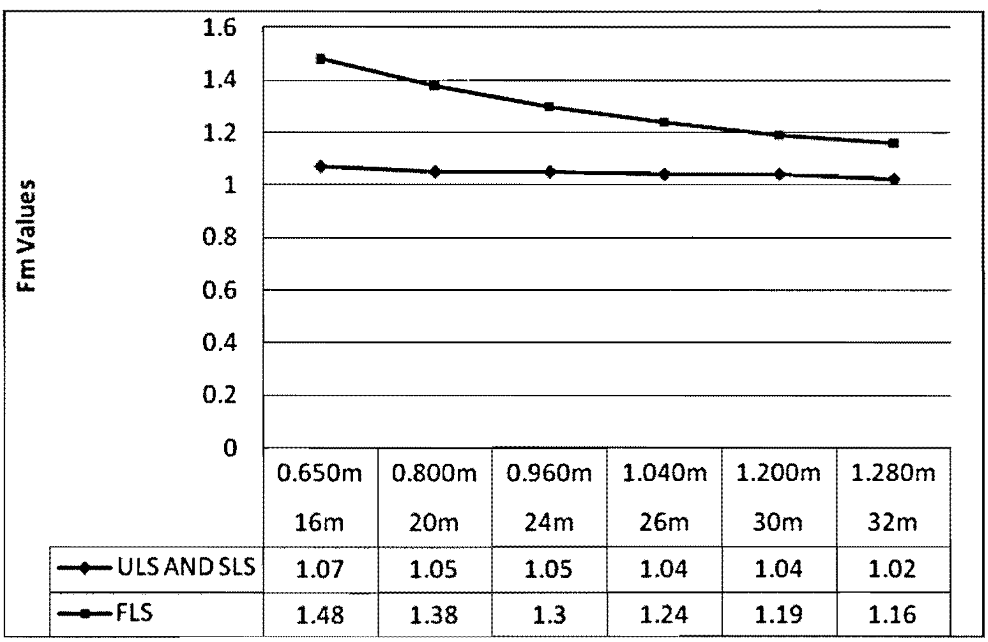
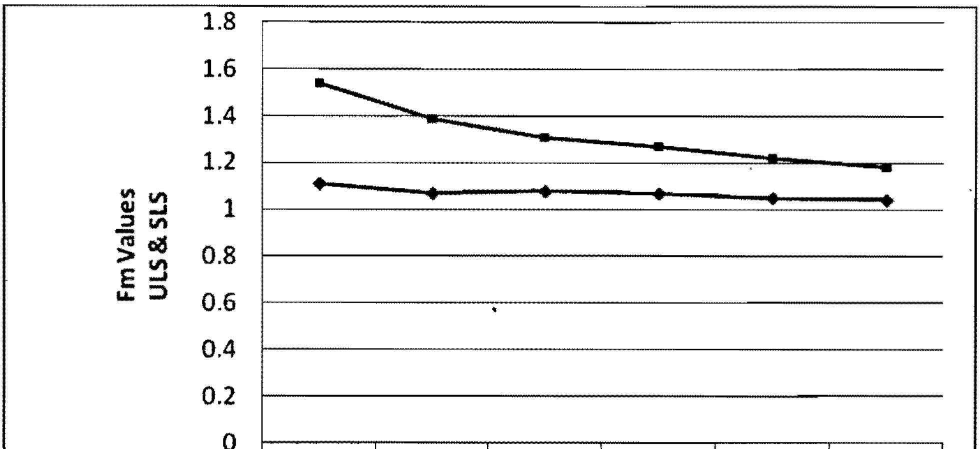
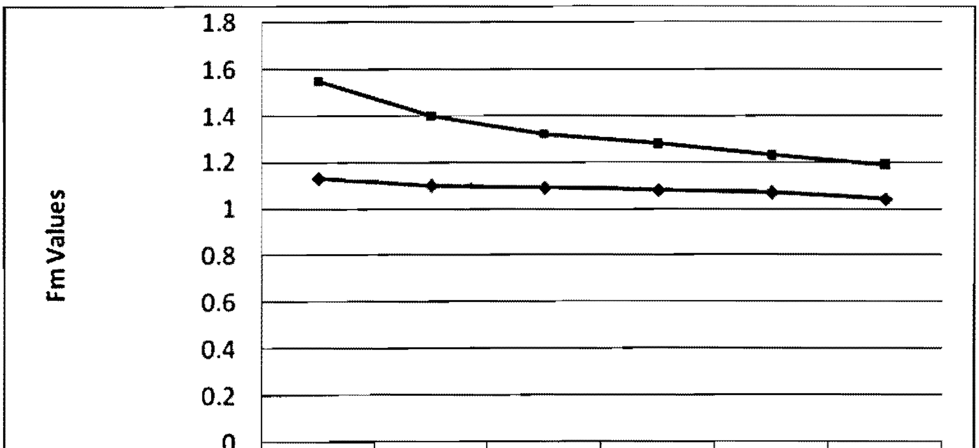


Figure 4.4 Effects of Span Length on the Moment Distribution Factor for 3-Lanes Bridge 11.101 m Width



	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.11	1.07	1.08	1.07	1.05	1.04
FLS	1.54	1.39	1.31	1.27	1.22	1.18

Figure 4.5 Effects of Span Length on the Moment Distribution Factor for 3-Lanes Bridge 12.336 m Width



	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.13	1.1	1.09	1.08	1.07	1.04
FLS	1.55	1.4	1.32	1.28	1.23	1.19

Figure 4.6 Effects of Span Length on the Moment Distribution Factor for 3-Lanes Bridge 13.571 m Width

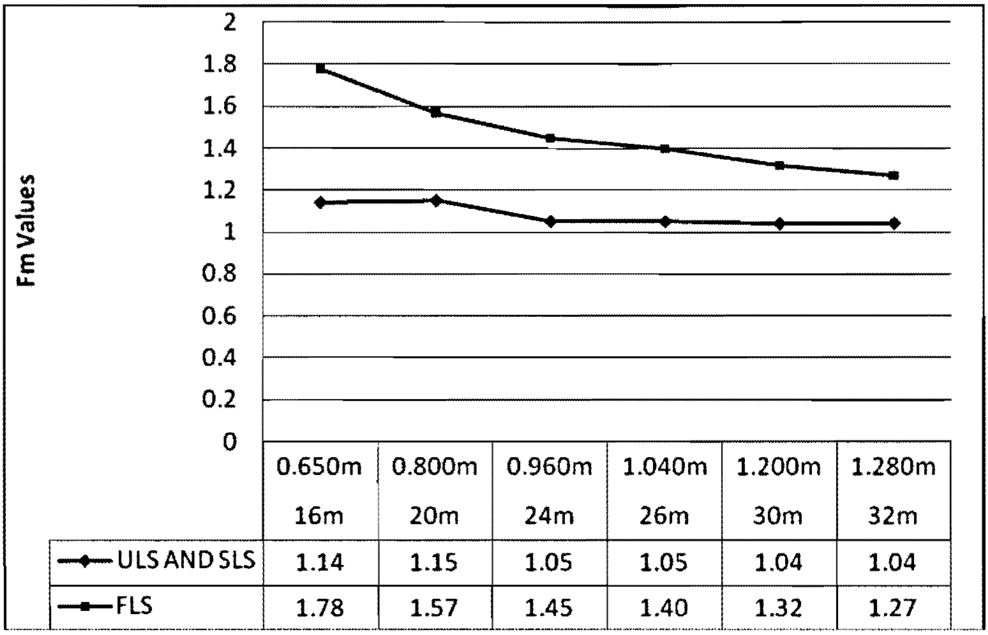


Figure 4.7 Effects of Span Length on the Moment Distribution Factor for 4-Lanes Bridge 14.806 m Width

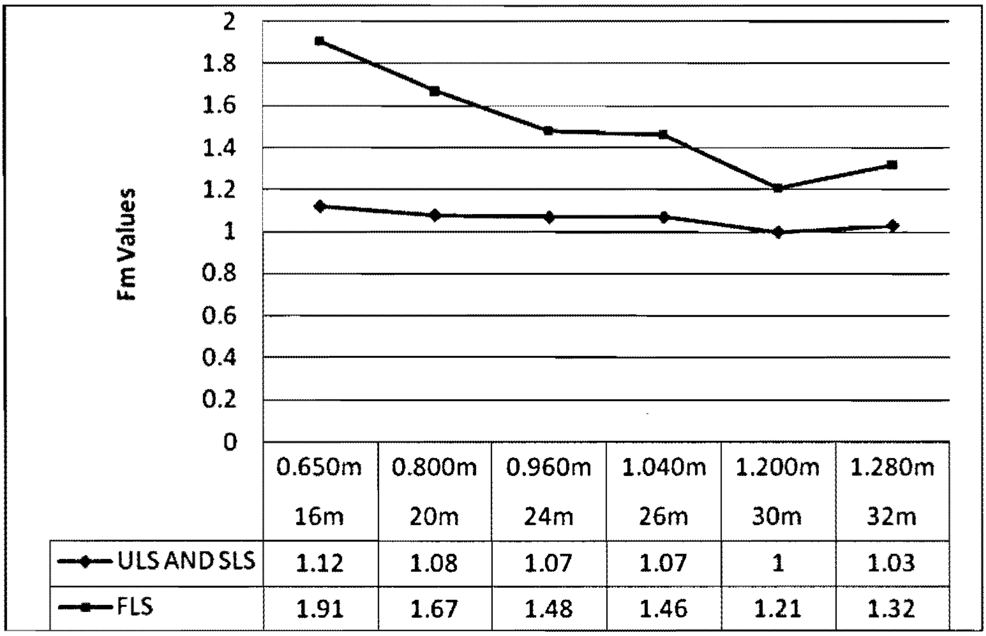
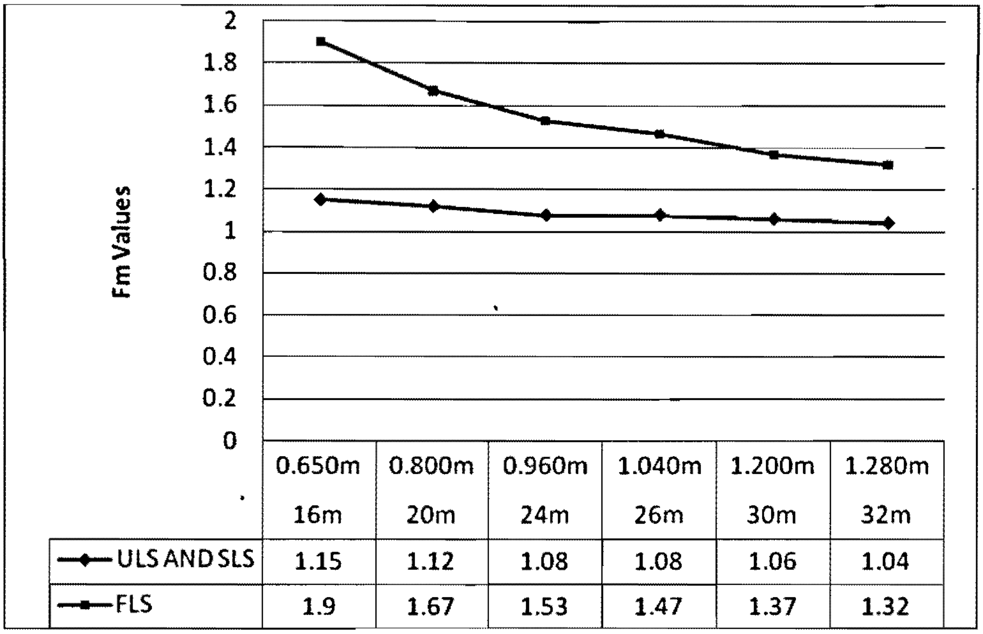
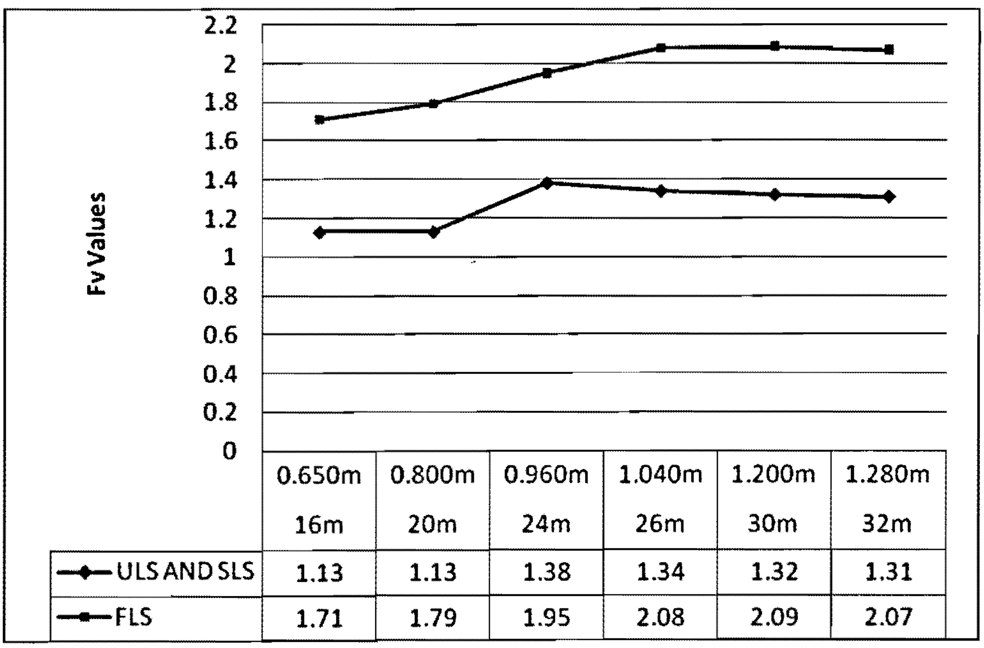


Figure 4.8 Effects of Span Length on the Moment Distribution Factor for 4-Lanes Bridge of 16.041 m Width



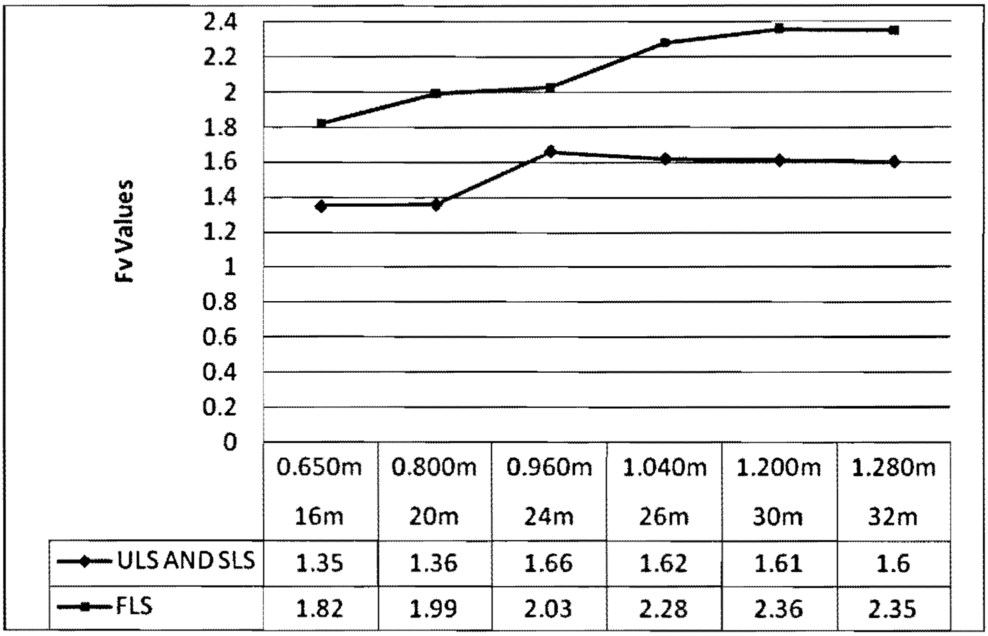
	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.15	1.12	1.08	1.08	1.06	1.04
FLS	1.9	1.67	1.53	1.47	1.37	1.32

Figure 4.9 Effects of Span Length on the Moment Distribution Factor for 4-Lanes Bridge of 17.276 m Width



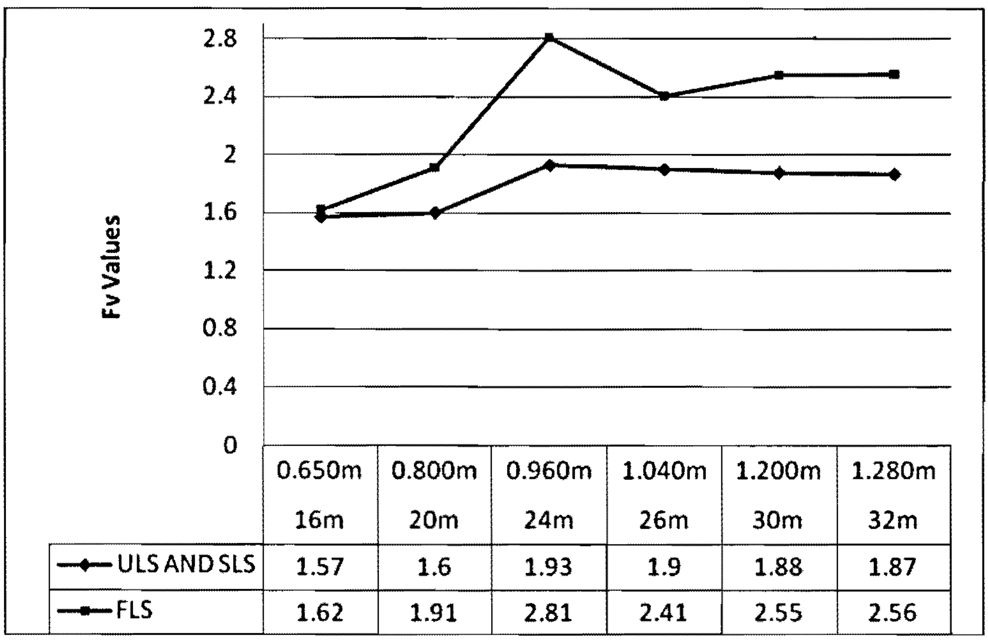
	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.13	1.13	1.38	1.34	1.32	1.31
FLS	1.71	1.79	1.95	2.08	2.09	2.07

Figure 4.10 Effects of Span Length on the Shear Distribution Factor for 2-Lanes Bridge of 7.396 m Width



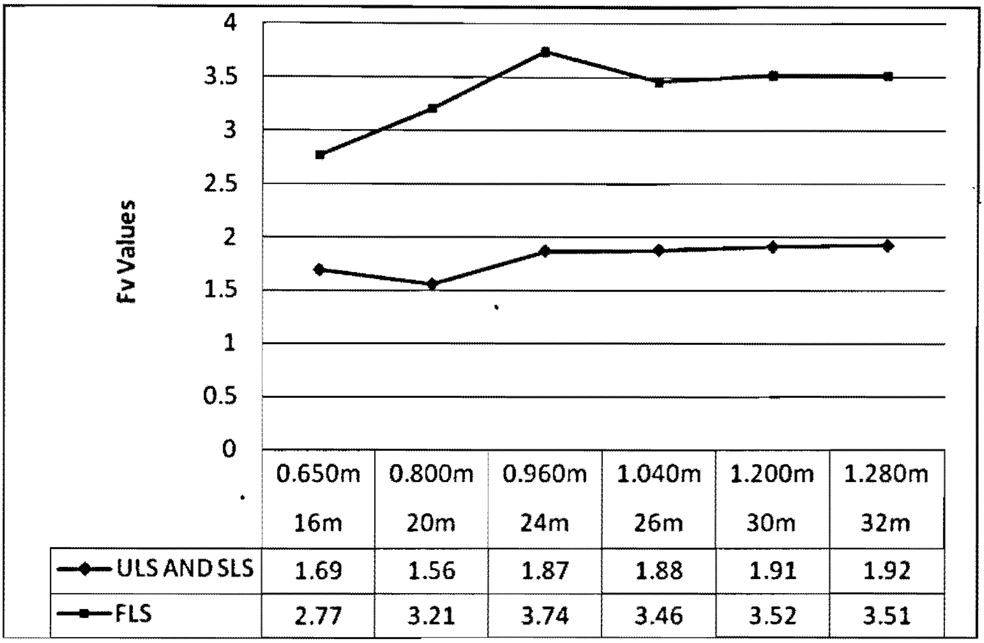
	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.35	1.36	1.66	1.62	1.61	1.6
FLS	1.82	1.99	2.03	2.28	2.36	2.35

Figure 4.11 Effects of Span Length on the Shear Distribution Factor for 2-Lanes Bridge of 8.631 m Width



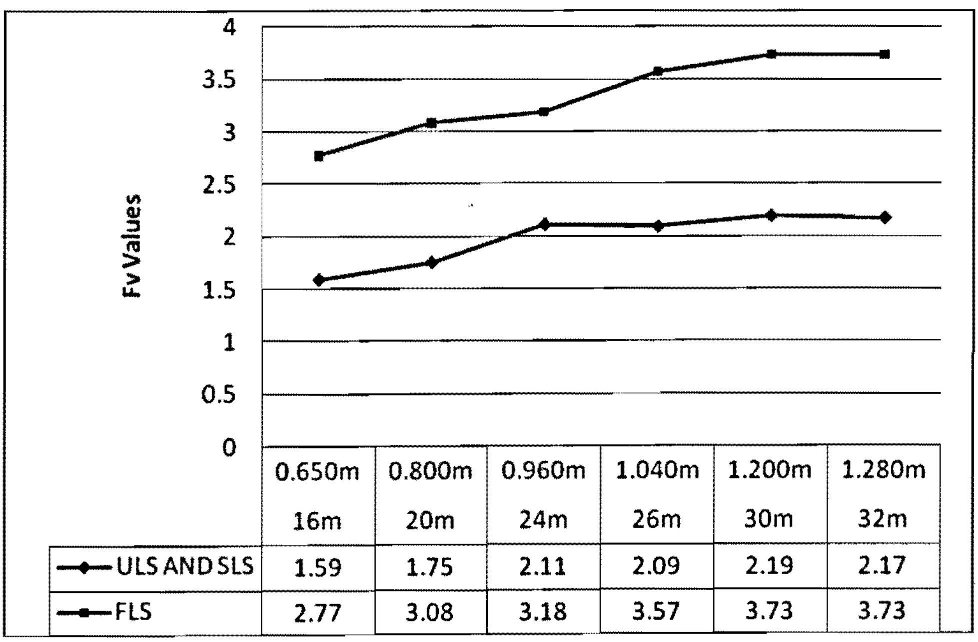
	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.57	1.6	1.93	1.9	1.88	1.87
FLS	1.62	1.91	2.81	2.41	2.55	2.56

Figure 4.12 Effects of Span Length on the Shear Distribution Factor for 2-Lanes Bridge of 9.866 m Width



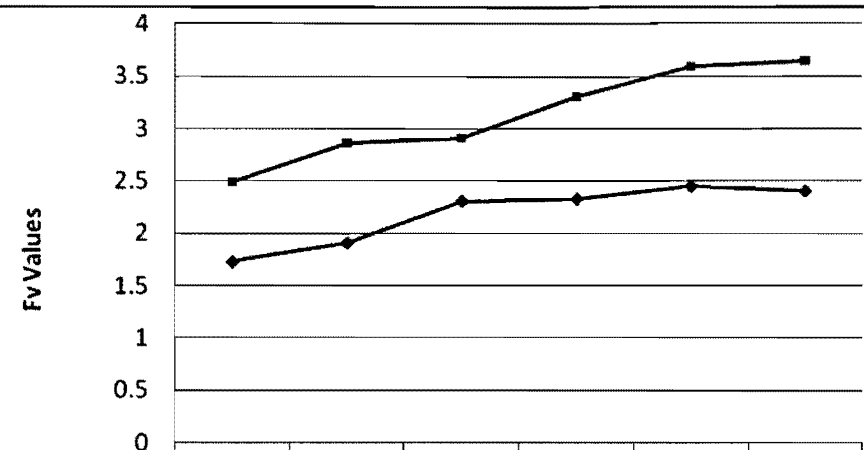
	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.69	1.56	1.87	1.88	1.91	1.92
FLS	2.77	3.21	3.74	3.46	3.52	3.51

Figure 4.13 Effects of Span Length on the Shear Distribution Factor for 3-Lanes Bridge of 11.101 m Width



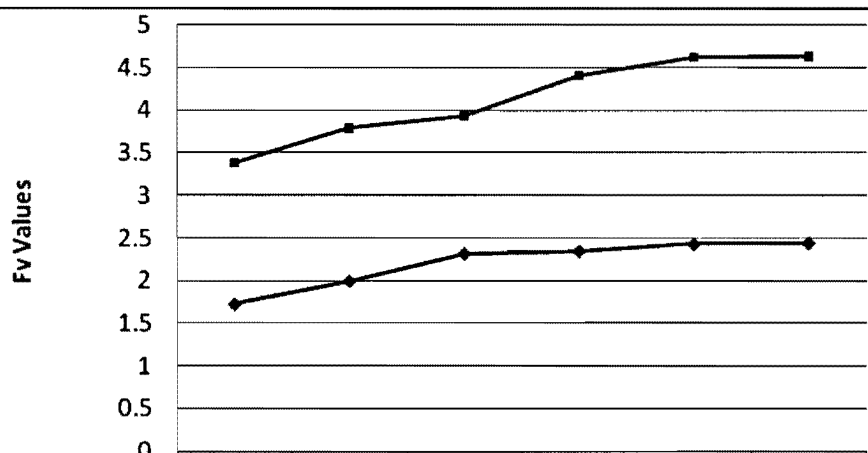
	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.59	1.75	2.11	2.09	2.19	2.17
FLS	2.77	3.08	3.18	3.57	3.73	3.73

Figure 4.14 Effects of Span Length on the Shear Distribution Factor for 3-Lanes Bridge of 12.336 m Width



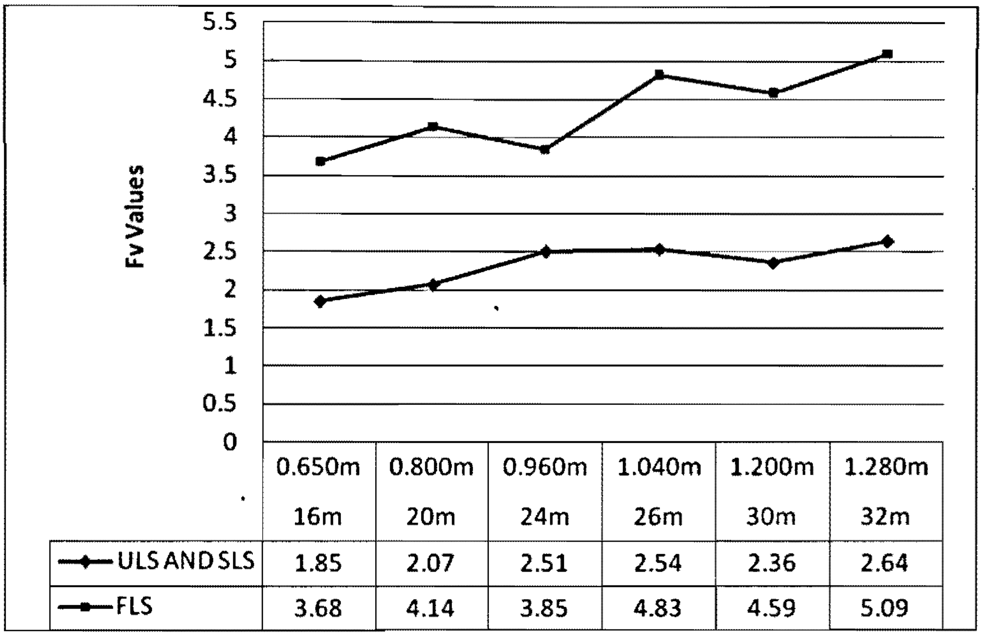
	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.73	1.91	2.31	2.33	2.45	2.4
FLS	2.49	2.86	2.91	3.31	3.59	3.64

Figure 4.15 Effects of Span Length on the Shear Distribution Factor for 3-Lanes Bridge of 3.571 m Width



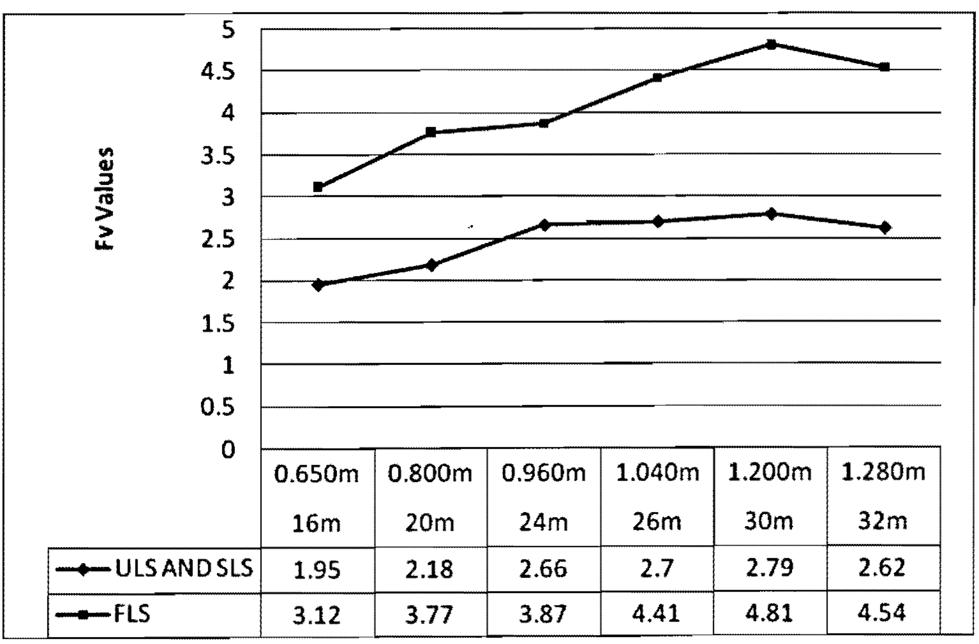
	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.73	2	2.32	2.35	2.43	2.44
FLS	3.38	3.79	3.94	4.41	4.62	4.63

Figure 4.16 Effects of Span Length on the Shear Distribution Factor for 4-Lanes Bridge of 14.806 m Width



	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.85	2.07	2.51	2.54	2.36	2.64
FLS	3.68	4.14	3.85	4.83	4.59	5.09

Figure 4.17 Effects of Span Length on the Shear Distribution Factor for 4-Lanes Bridge of 16.041 m Width



	0.650m 16m	0.800m 20m	0.960m 24m	1.040m 26m	1.200m 30m	1.280m 32m
ULS AND SLS	1.95	2.18	2.66	2.7	2.79	2.62
FLS	3.12	3.77	3.87	4.41	4.81	4.54

Figure 4.18 Effects of Span Length on the Shear Distribution Factor for 4-Lanes Bridge of 17.276 m Width

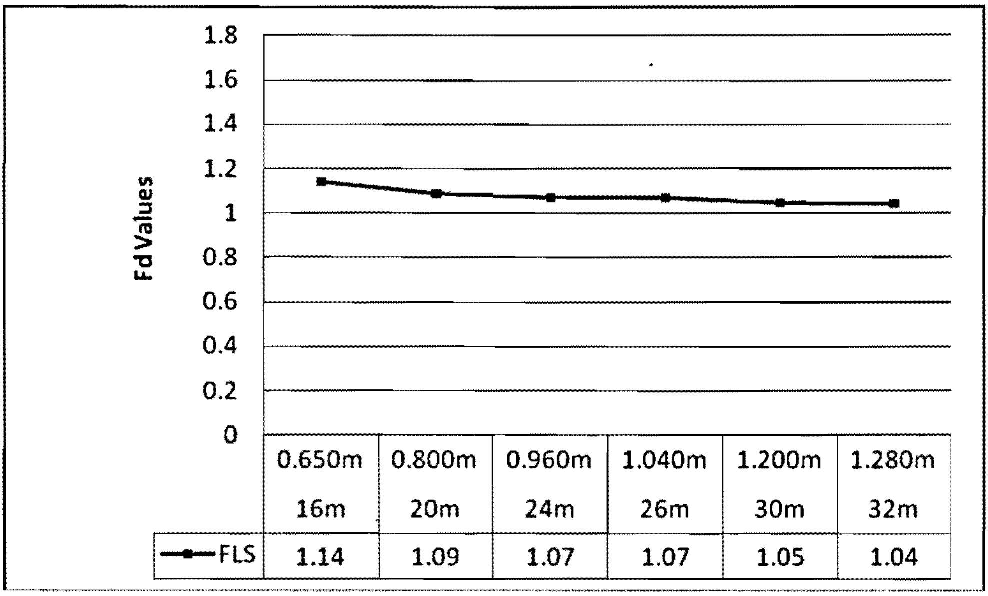


Figure 4.19 Effects of Span Length on the Deflection Distribution Factor for 2-Lanes Bridge of 7.396 m Width

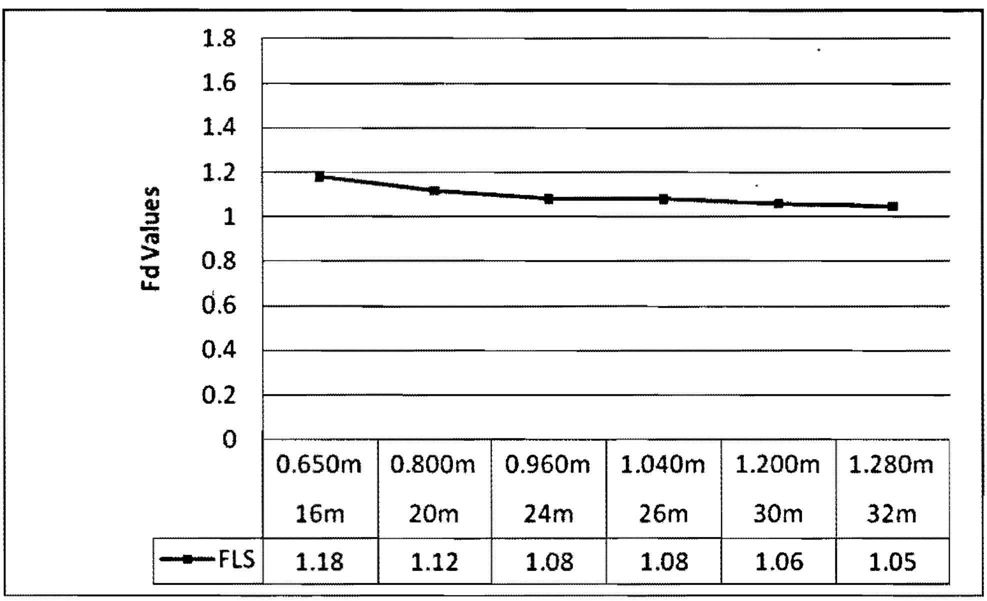


Figure 4.20 Effects of Span Length on the Deflection Distribution Factor for 2-Lanes Bridge of 8.631 m Width

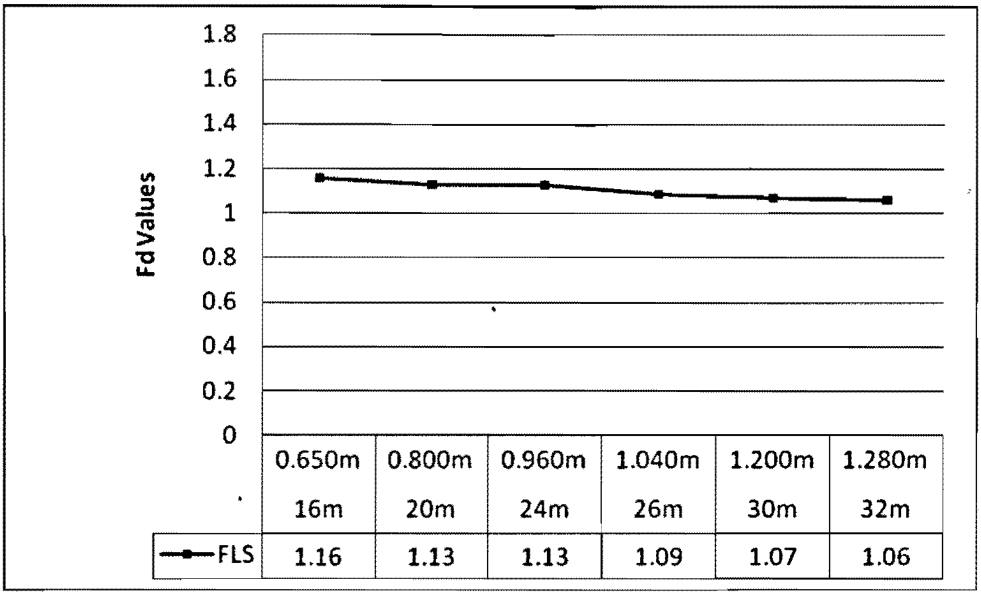


Figure 4.21 Effects of Span Length on the Deflection Distribution Factor for 2-Lanes Bridge of 9.866 m Width

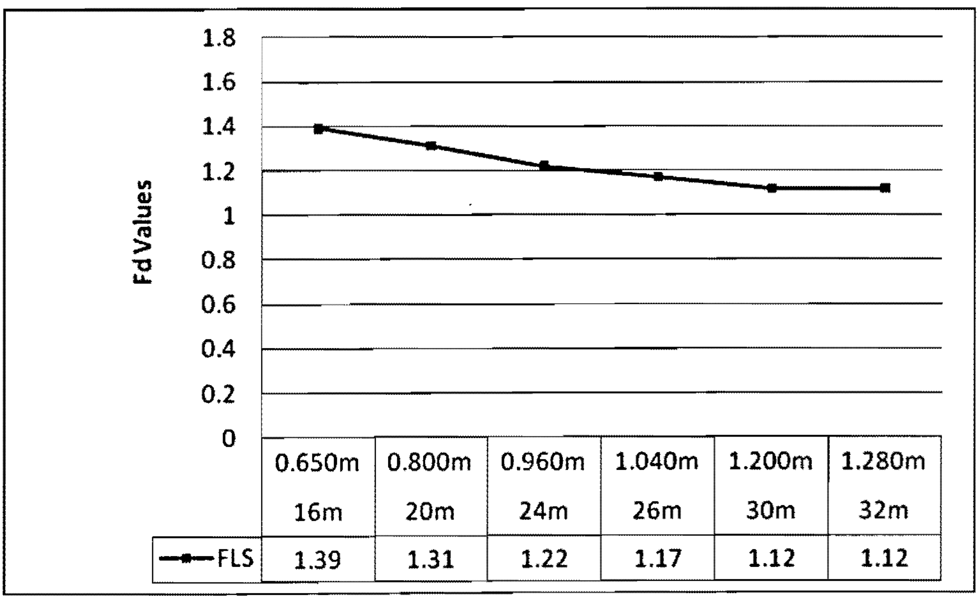


Figure 4.22 Effects of Span Length on the Deflection Distribution Factor For3-Lanes Bridge of 11.101 m Width

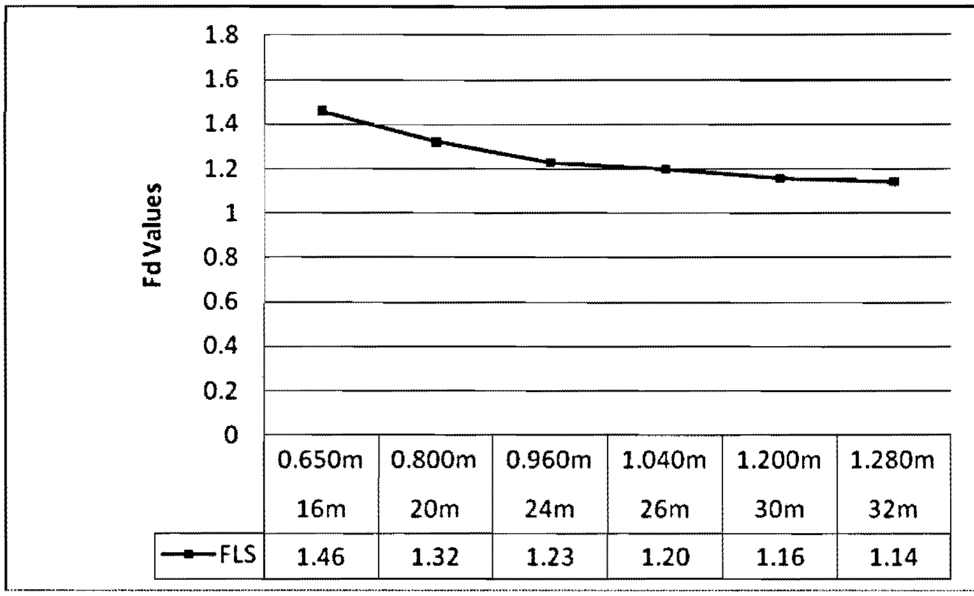


Figure 4.23 Effects of Span Length on the Deflection Distribution Factor For 3-Lanes Bridge of 12.336 m Width

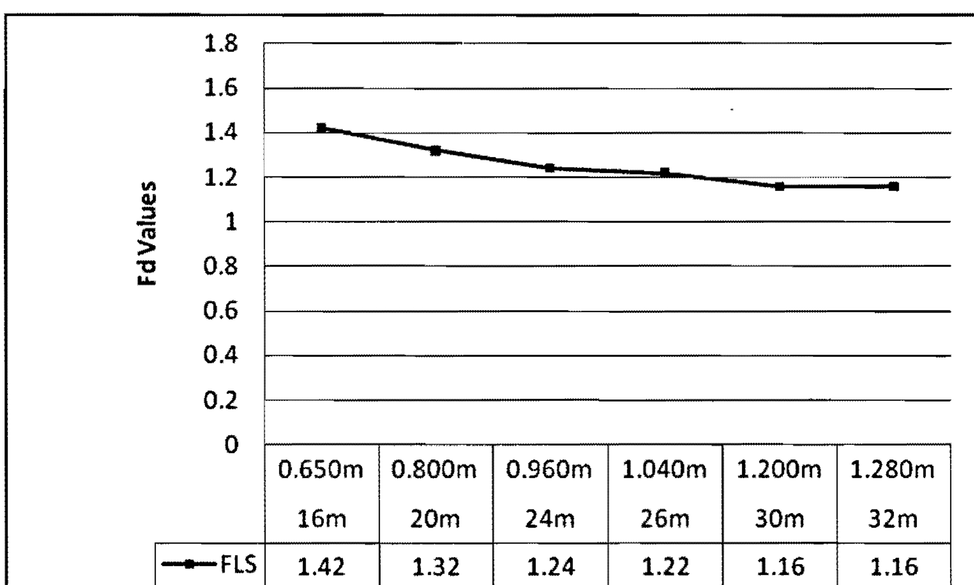


Figure 4.24 Effects of Span Length on the Deflection Distribution Factor For 3-Lanes Bridge of 13.571 m Width

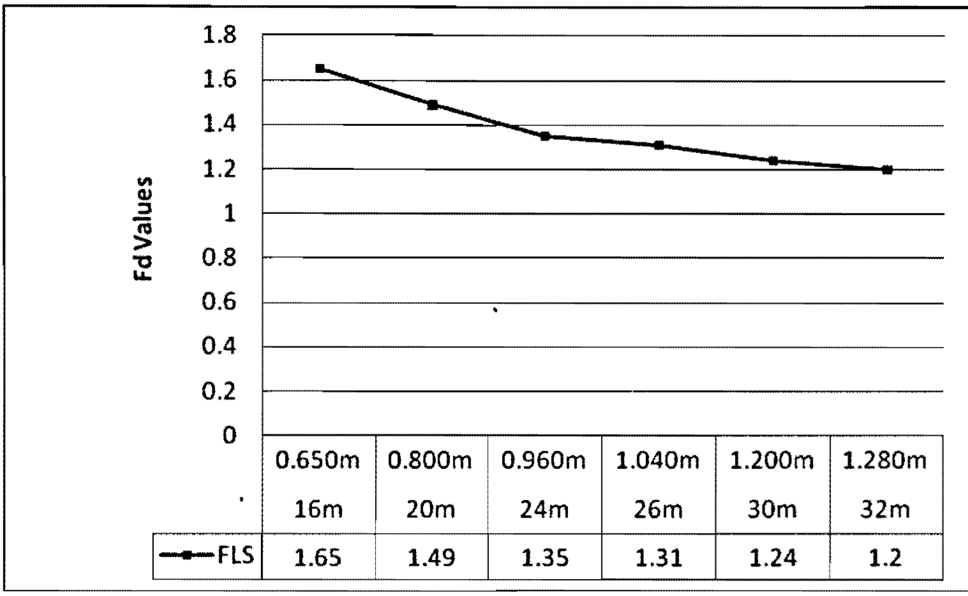


Figure 4.25 Effects of Span Length on the Deflection Distribution Factor For 4-Lanes Bridge of 14.806 m Width

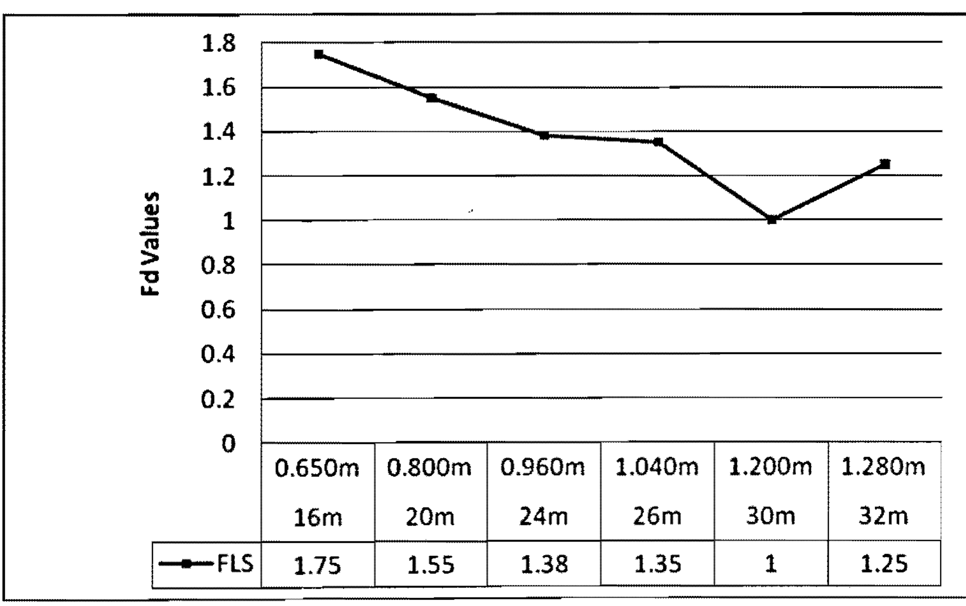


Figure 4.26 Effects of Span Length on the Deflection Distribution Factor For 4-Lanes Bridge of 16.041 m Width

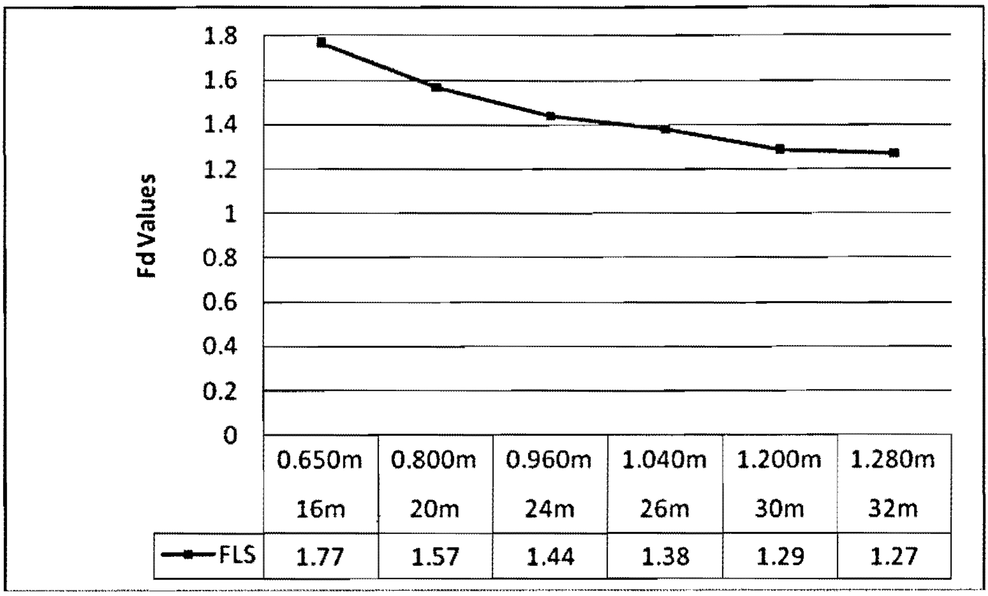


Figure 4.27 Effects of Span Length on the Deflection Distribution Factor For 4-Lanes Bridge of 17.276 m Width

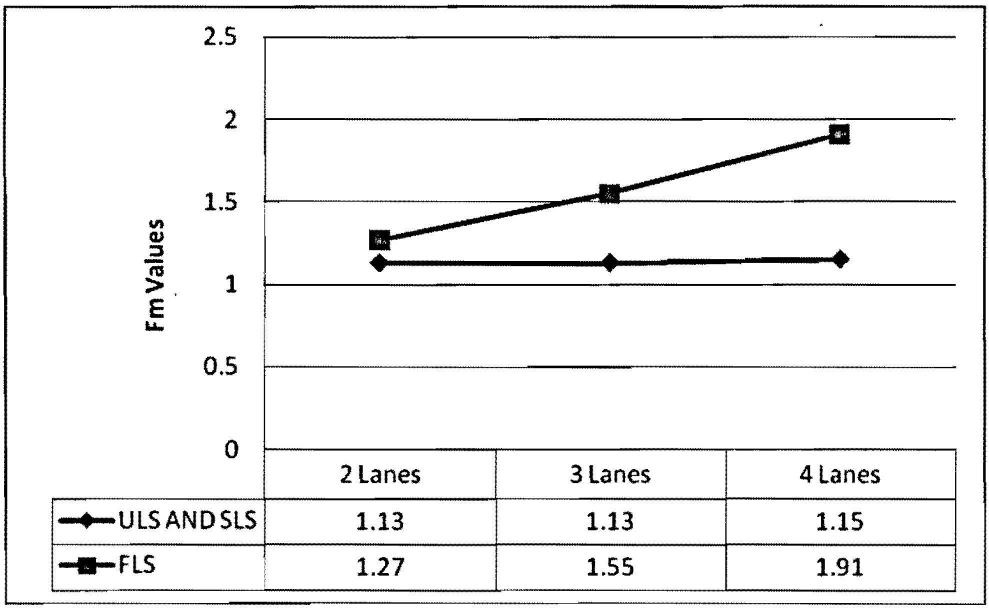


Figure 4.28 Effect of Number of Lanes on the Moment Distribution Factor For a 16-m Span Bridge

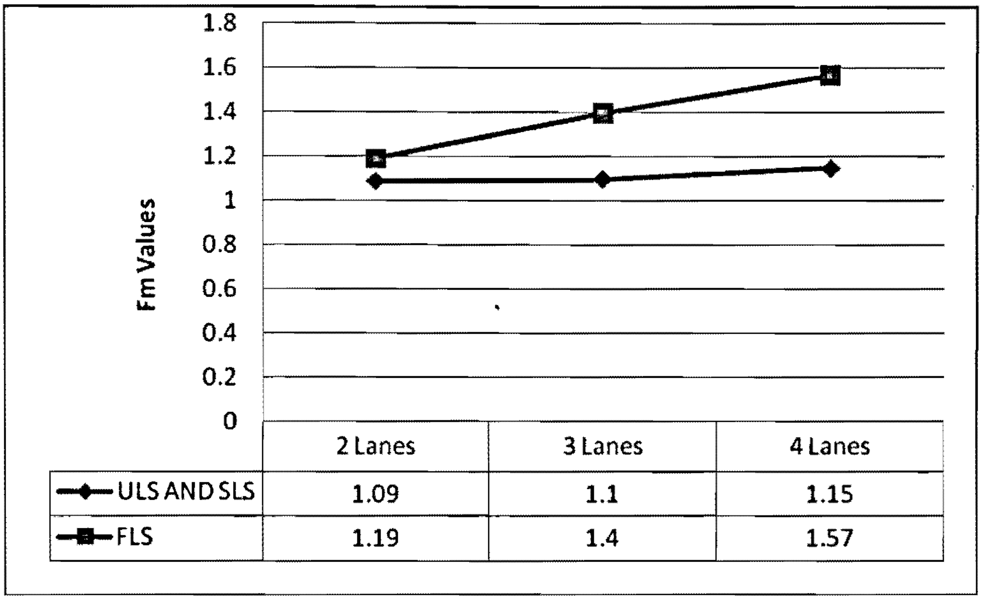


Figure 4.29 Effect of Number of Lanes on the Moment Distribution Factor For a 20-m Span Bridge

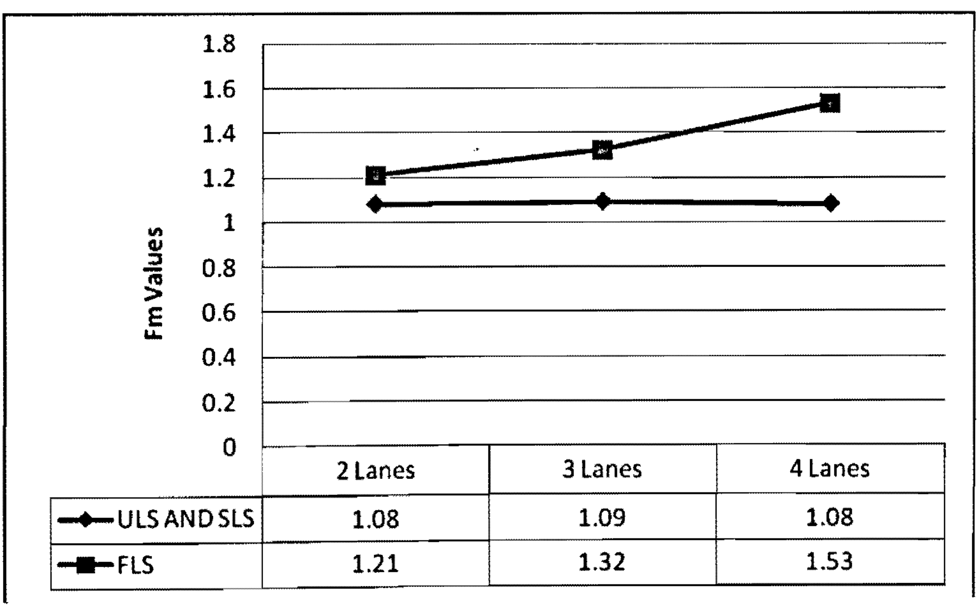
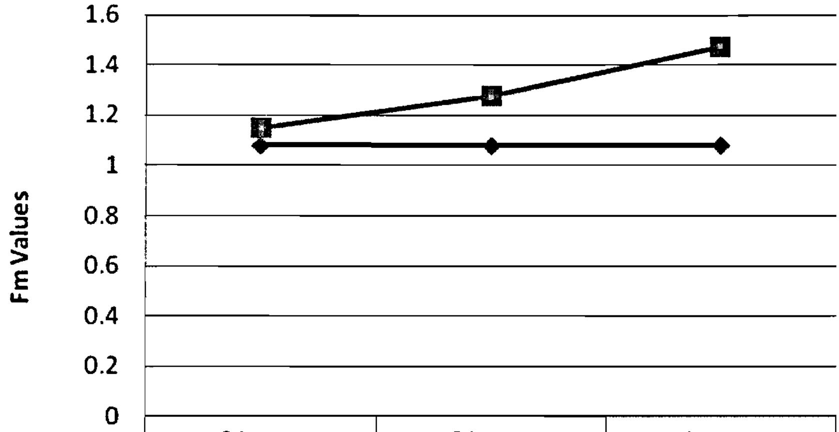
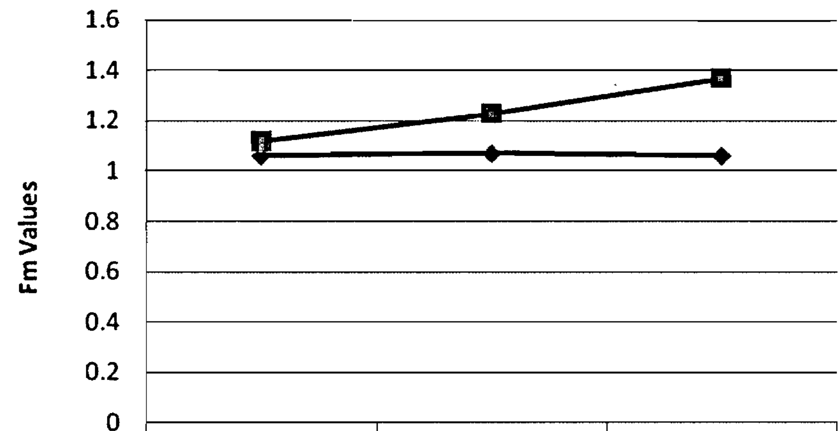


Figure 4.30 Effect of Number of Lanes on the Moment Distribution Factor For a 24-m Span Bridge



	2 Lanes	3 Lanes	4 Lanes
ULS AND SLS	1.08	1.08	1.08
FLS	1.15	1.28	1.47

Figure 4.31 Effect of Number of Lanes on the Moment Distribution Factor For a 26-m Span Bridge



	2 Lanes	3 Lanes	4 Lanes
ULS AND SLS	1.06	1.07	1.06
FLS	1.12	1.23	1.37

Figure 4.32 Effect of Number of Lanes on the Moment Distribution Factor For a 30-m Span Bridge

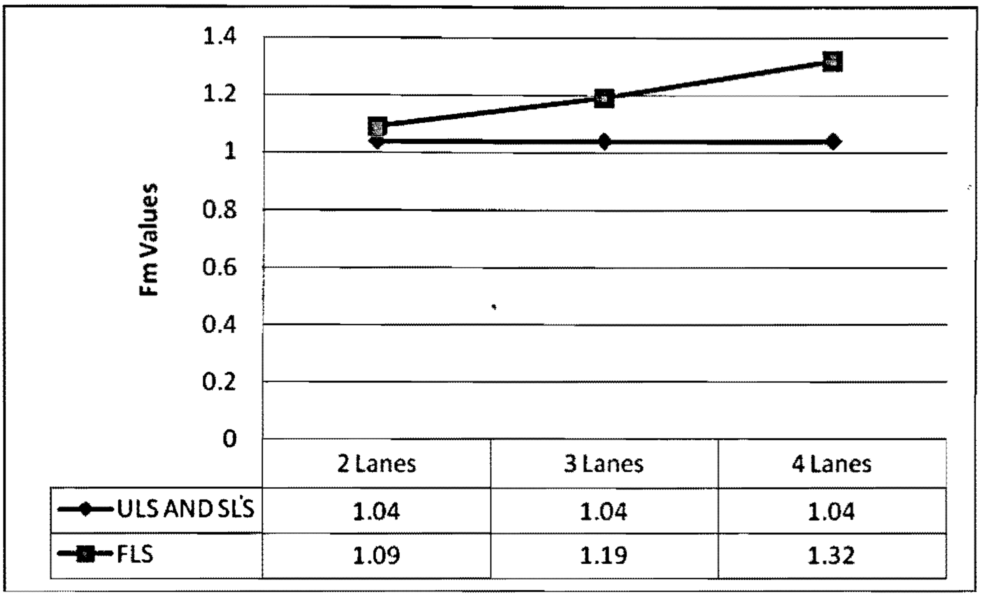


Figure 4.33 Effect of Number of Lanes on the Moment Distribution Factor For a 32-m Span Bridge

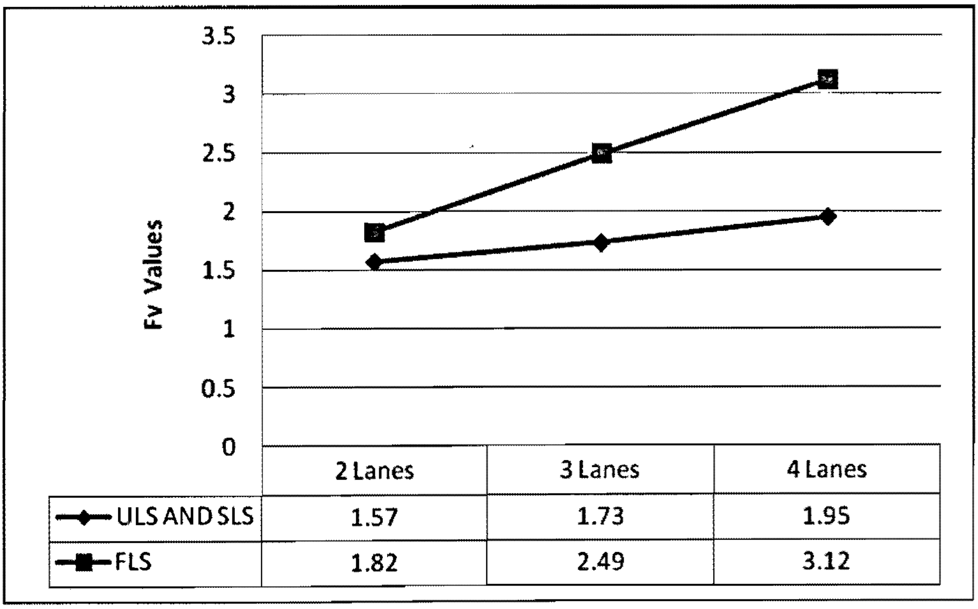


Figure 4.34 Effect of Number of Lanes on the Shear Distribution Factor For a 16-m Span Bridge

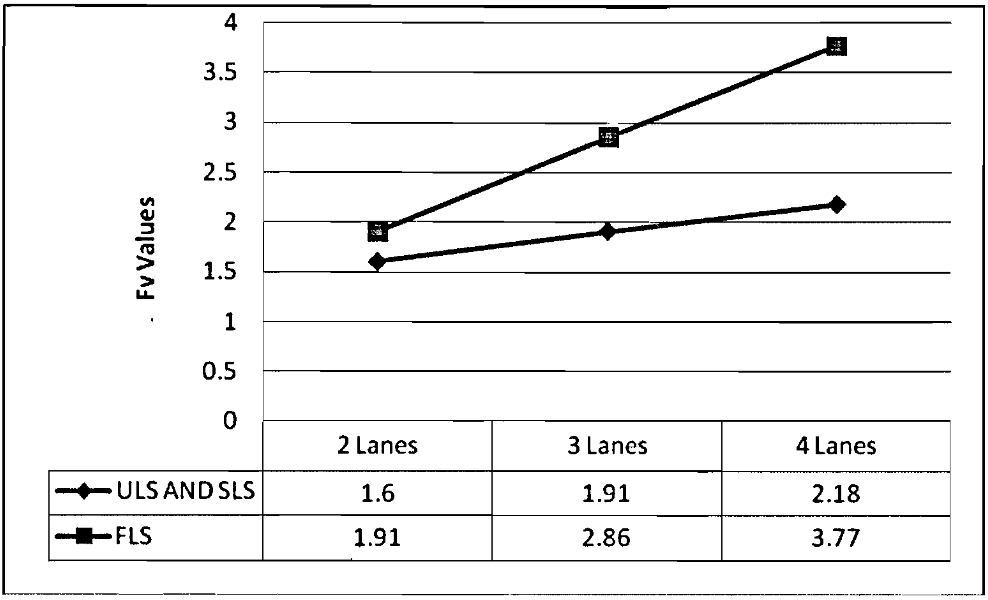


Figure 4.35 Effect of Number of Lanes on the Shear Distribution Factor For a 20-m Span Bridge

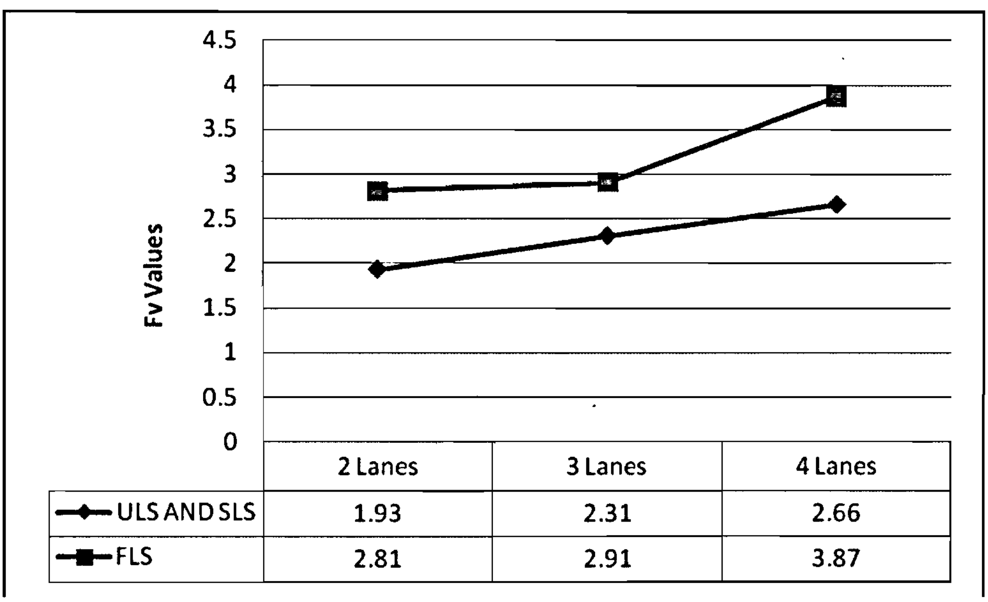
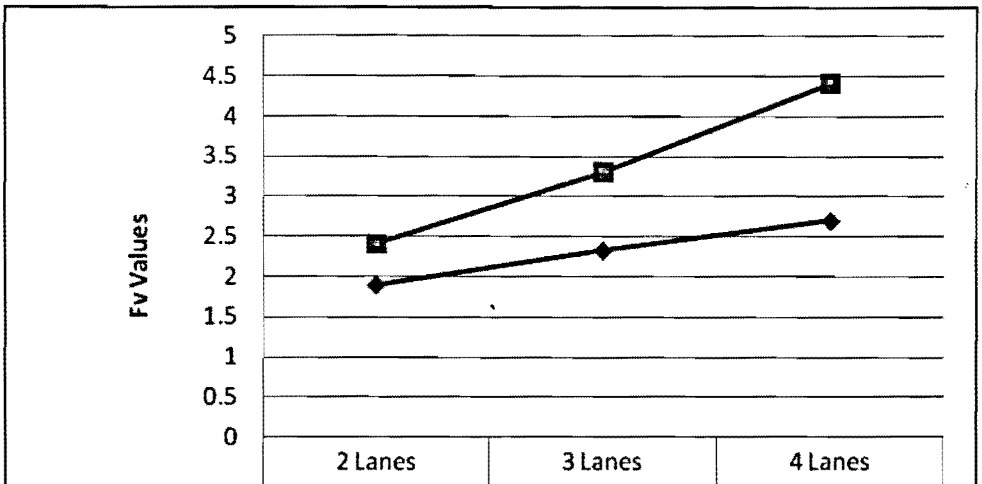
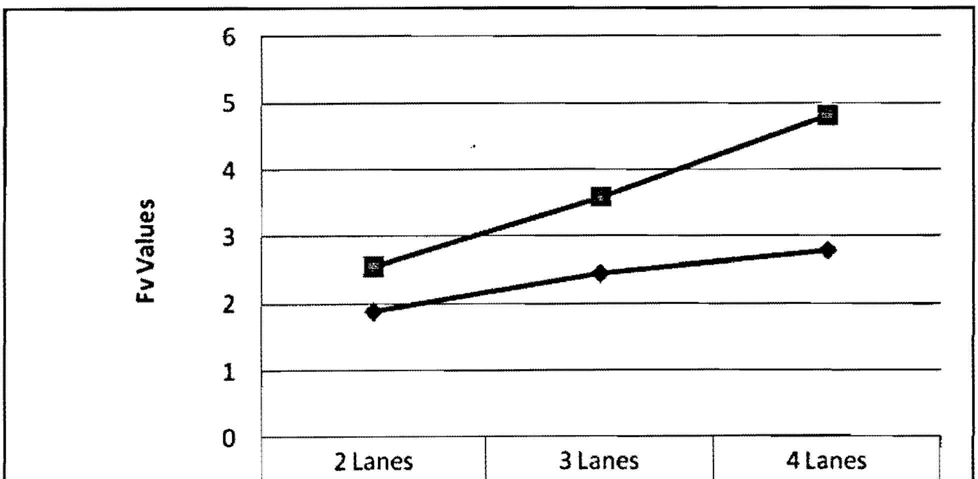


Figure 4.36 Effect of Number of Lanes on the Shear Distribution Factor For a 24-m Span Bridge



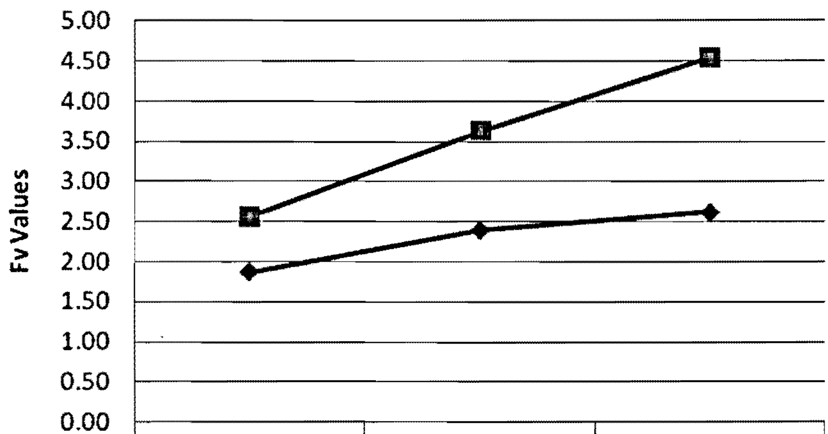
	2 Lanes	3 Lanes	4 Lanes
ULS AND SLS	1.9	2.33	2.7
FLS	2.41	3.31	4.41

Figure 4.37 Effect of Number of Lanes on the Shear Distribution Factor For a 26-m Span Bridge



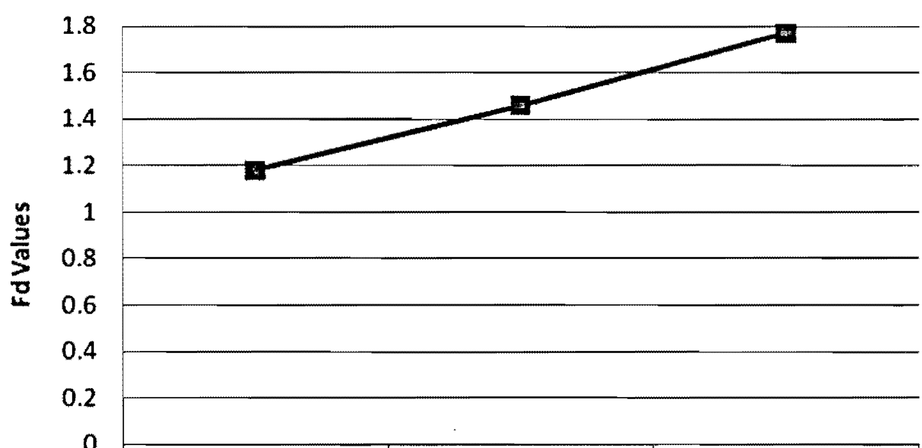
	2 Lanes	3 Lanes	4 Lanes
ULS AND SLS	1.88	2.45	2.79
FLS	2.55	3.59	4.81

Figure 4.38 Effect of Number of Lanes on the Shear Distribution Factor For a 30-m Span Bridge



	2 Lanes	3 Lanes	4 Lanes
ULS AND SLS	1.87	2.4	2.62
FLS	2.56	3.64	4.54

Figure 4.39 Effect of Number of Lanes on the Shear Distribution Factor For a 32-m Span Bridge



	2 Lanes	3 Lanes	4 Lanes
FLS	1.18	1.46	1.77

Figure 4.40 Effect of Number of Lanes on the Deflection Distribution Factor For a 16- m Span Bridge

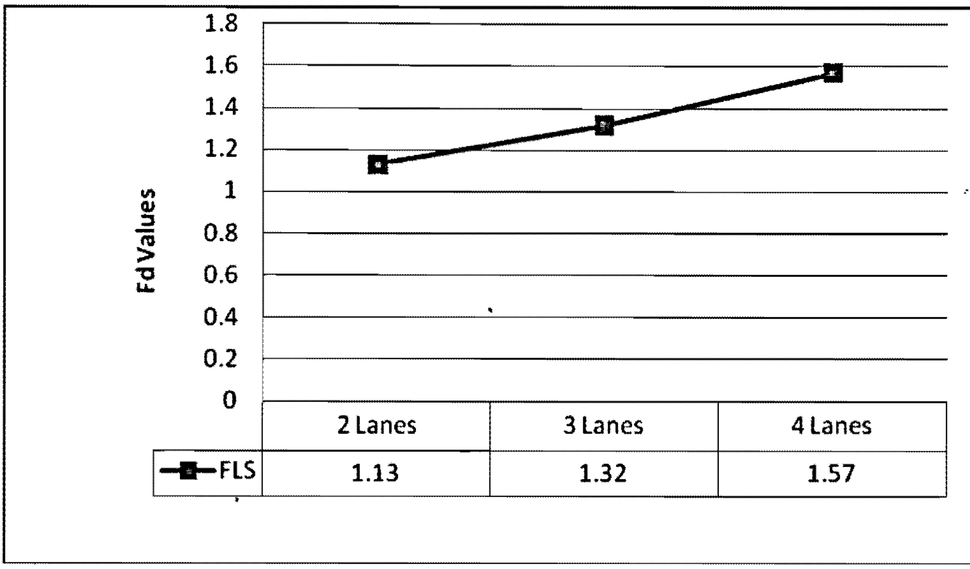


Figure 4.41 Effect of Number of Lanes on the Deflection Distribution Factor For a 20-m Span Bridge

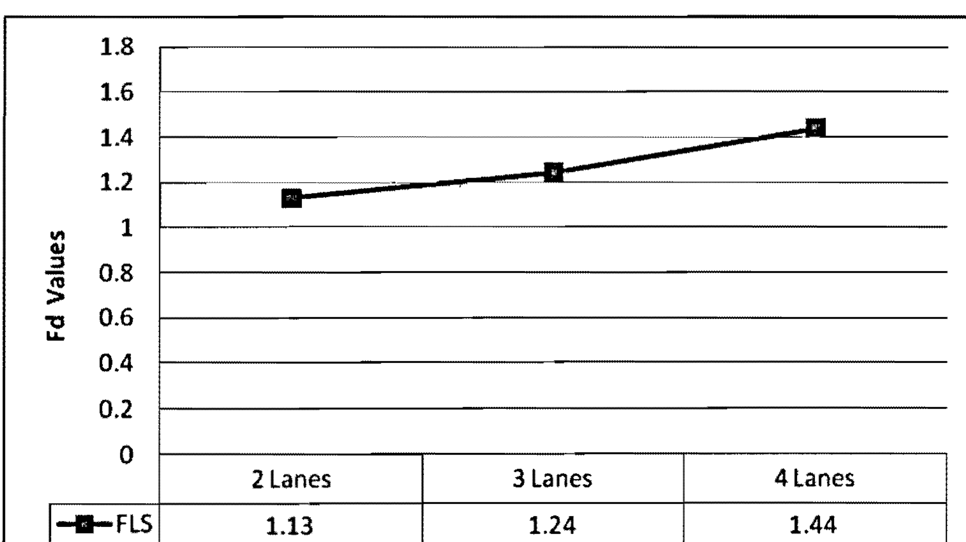


Figure 4.42 Effect of Number of Lanes on the Deflection Distribution Factor For a 24-m Span Bridge

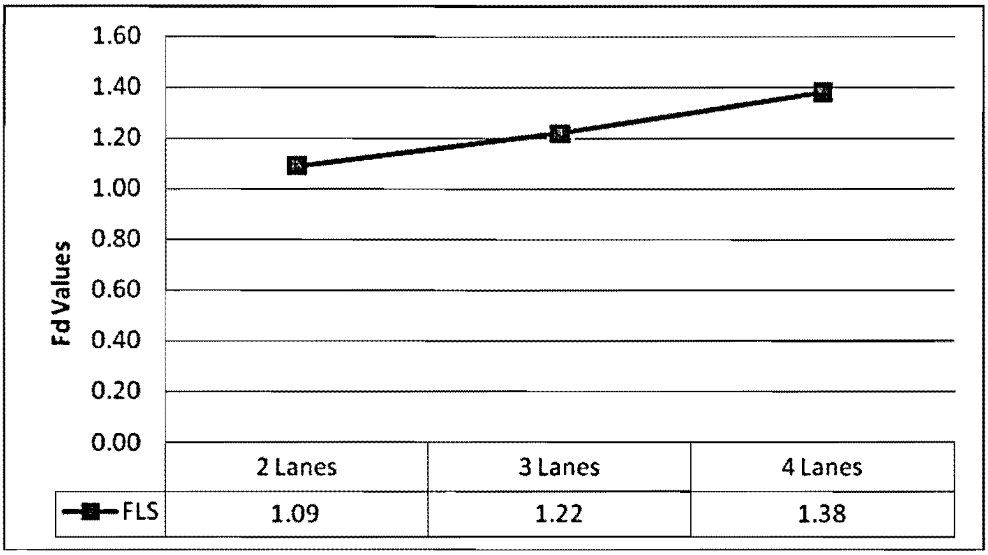


Figure 4.43 Effect of Number of Lanes on the Deflection Distribution Factor For a 26-m Span Bridge

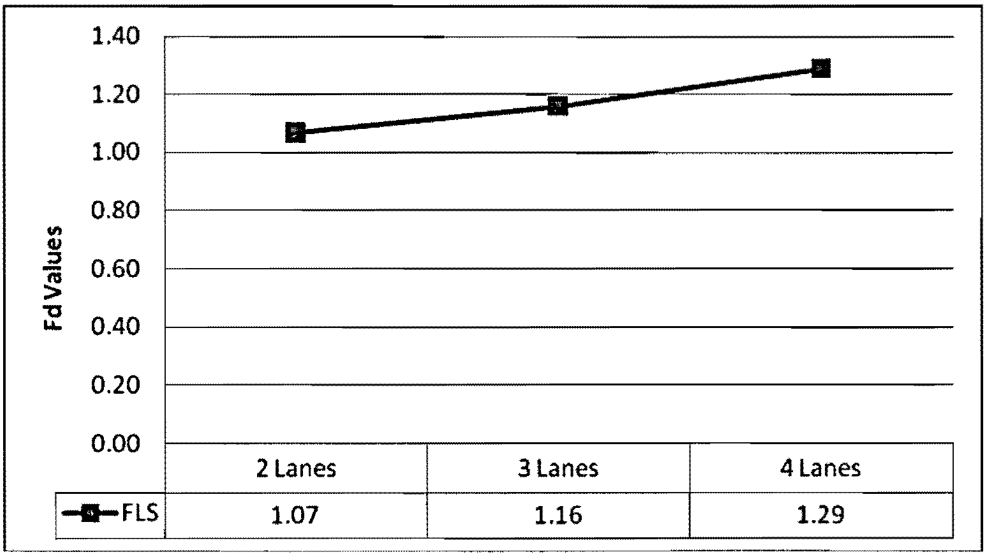


Figure 4.44 Effect of Number of Lanes on the Deflection Distribution Factor For a 30-m Span Bridge

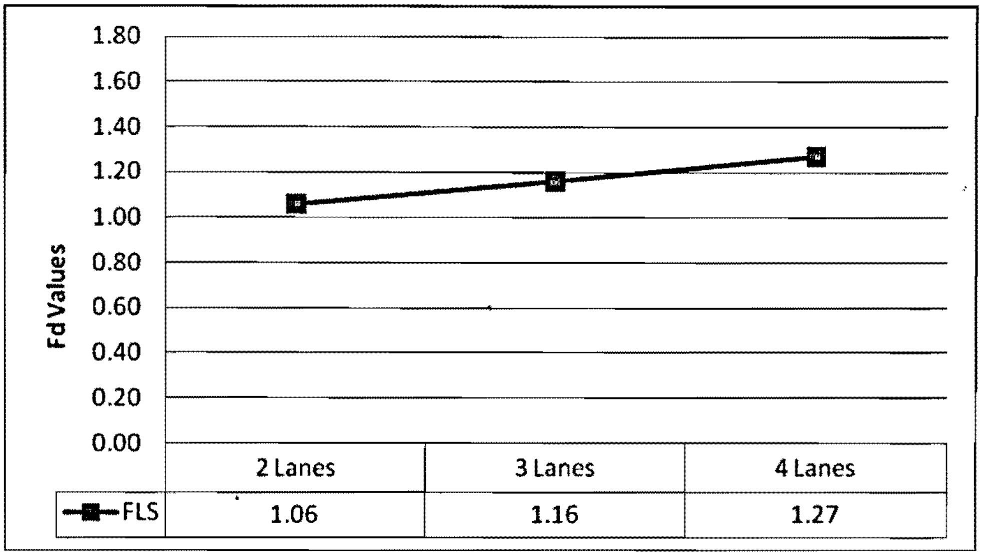


Figure 4.45 Effect of Number of Lanes on the Deflection Distribution Factor For a 32-m Span Bridge

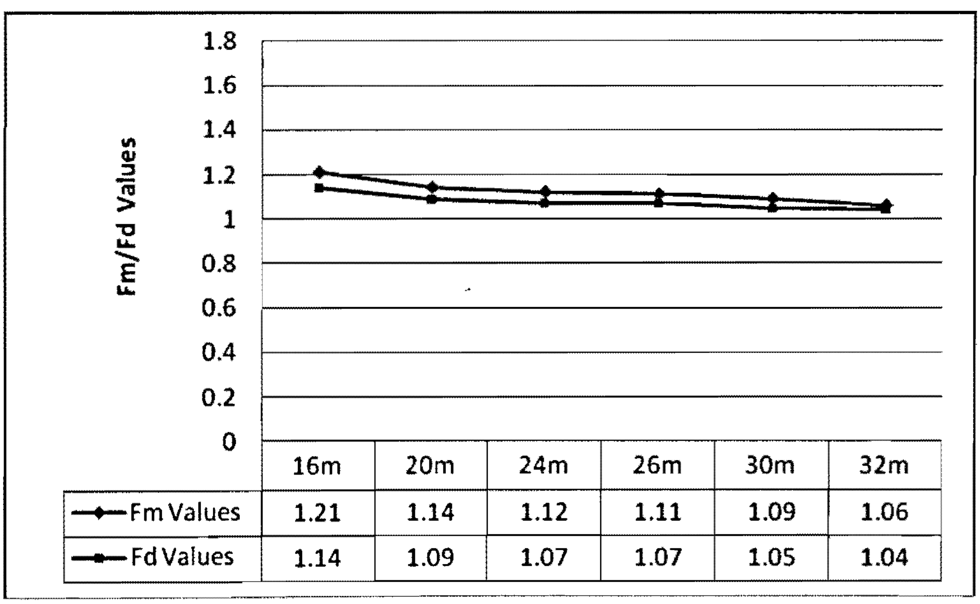
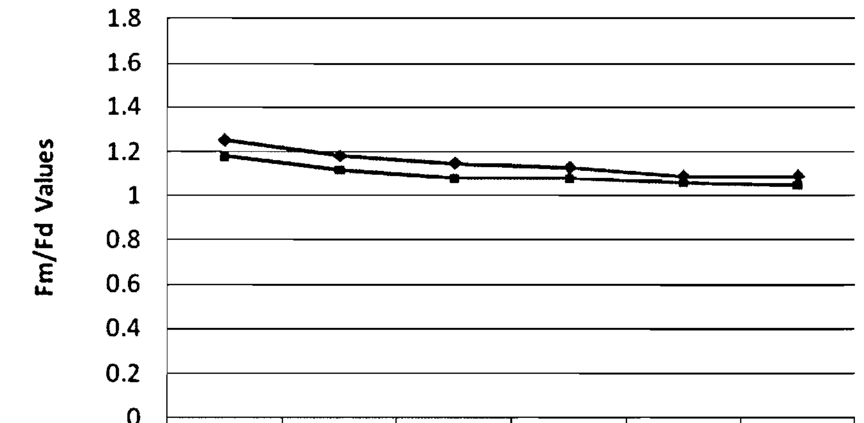
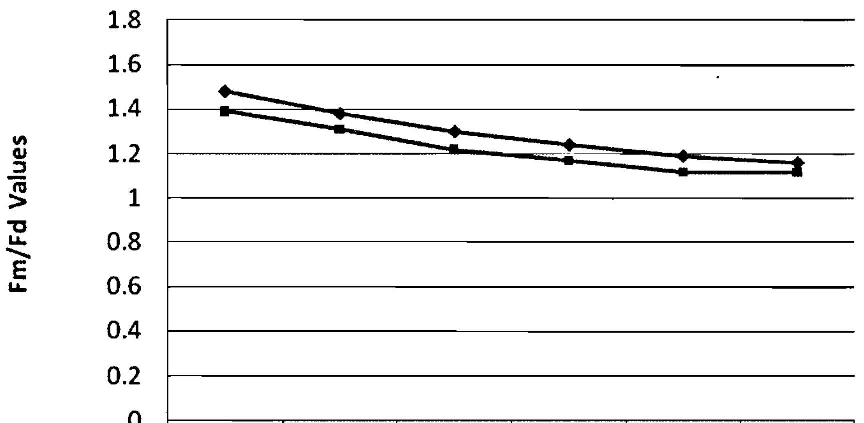


Figure 4.46 Comparison of Fm and Fd Values for 2-lane Bridges of 7.396-m Width



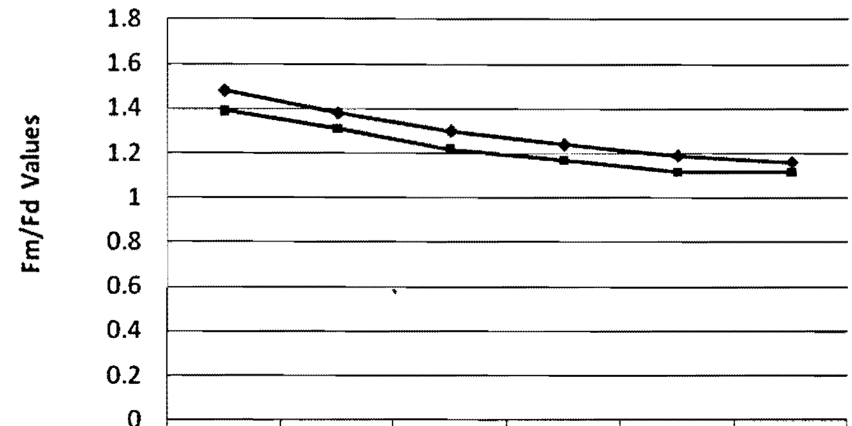
	16m	20m	24m	26m	30m	32m
Fm Values	1.25	1.18	1.15	1.13	1.09	1.09
Fd Values	1.18	1.12	1.08	1.08	1.06	1.05

Figure 4.47 Comparison of Fm and Fd Values 2-lane Bridges of 8.631 m Width



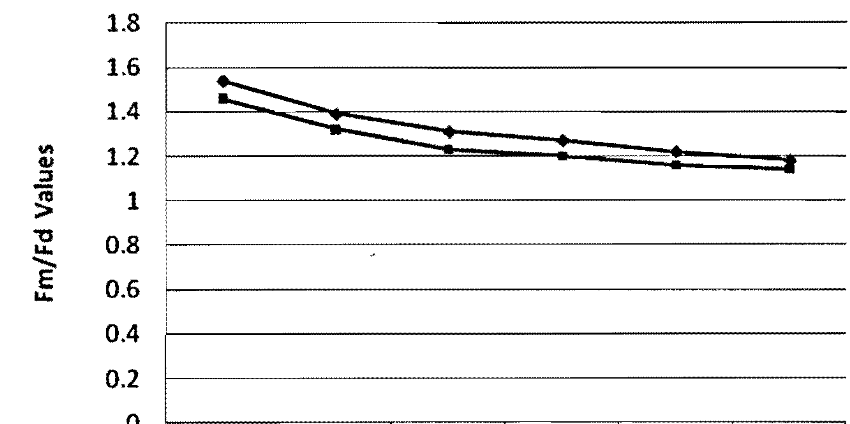
	16m	20m	24m	26m	30m	32m
Fm Values	1.48	1.38	1.3	1.24	1.19	1.16
Fd Values	1.39	1.31	1.22	1.17	1.12	1.12

Figure 4.48 Comparison of Fm and Fd Values for 2-lane Bridges of 9.866 m Width



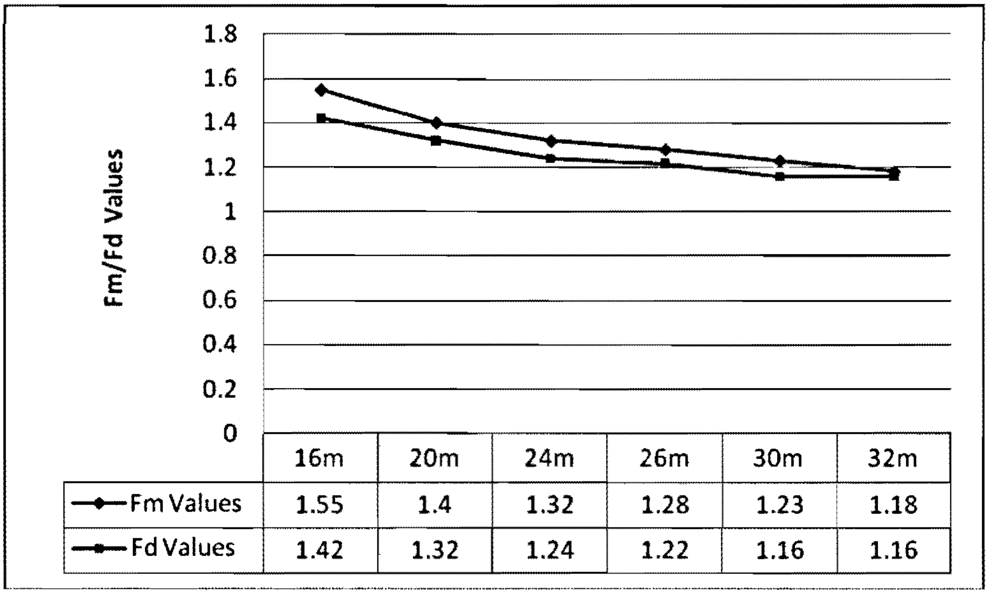
	16m	20m	24m	26m	30m	32m
Fm Values	1.48	1.38	1.3	1.24	1.19	1.16
Fd Values	1.39	1.31	1.22	1.17	1.12	1.12

Figure 4.49 Comparison of Fm and Fd Values for 3-lane Bridges of 11.101 m Width



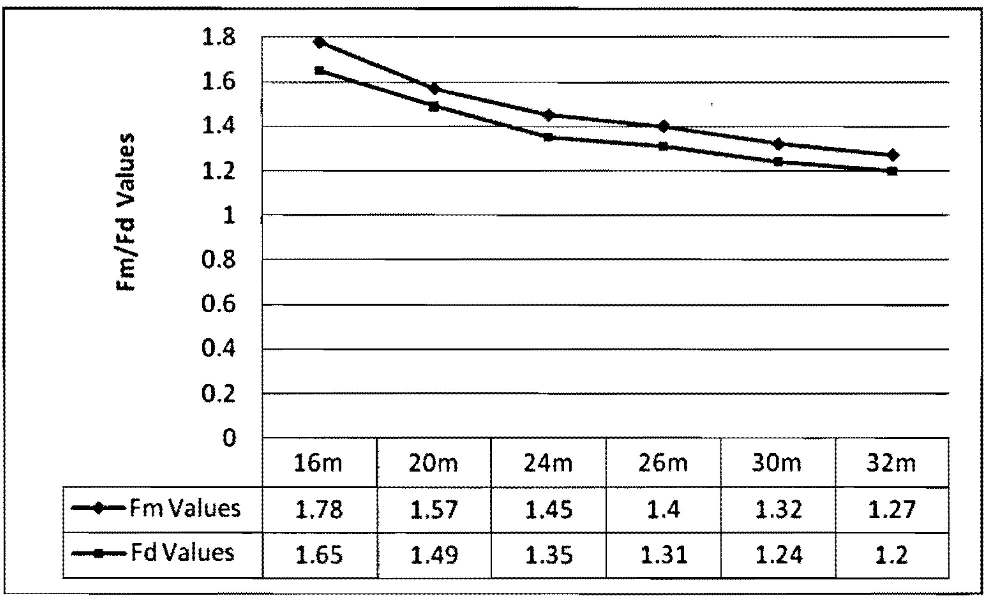
	16m	20m	24m	26m	30m	32m
Fm Values	1.54	1.39	1.31	1.27	1.22	1.18
Fd Values	1.46	1.32	1.23	1.20	1.16	1.14

Figure 4.50 Comparison of Fm and Fd Values for 3-lane Bridges of 12.336 m Width



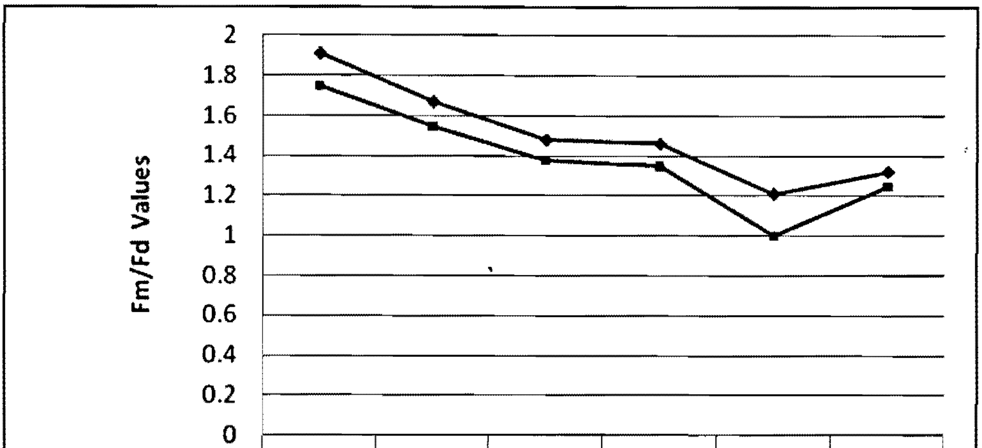
	16m	20m	24m	26m	30m	32m
Fm Values	1.55	1.4	1.32	1.28	1.23	1.18
Fd Values	1.42	1.32	1.24	1.22	1.16	1.16

Figure 4.51 Comparison of Fm and Fd Values for 3-lane Bridges of 13.571 m Width



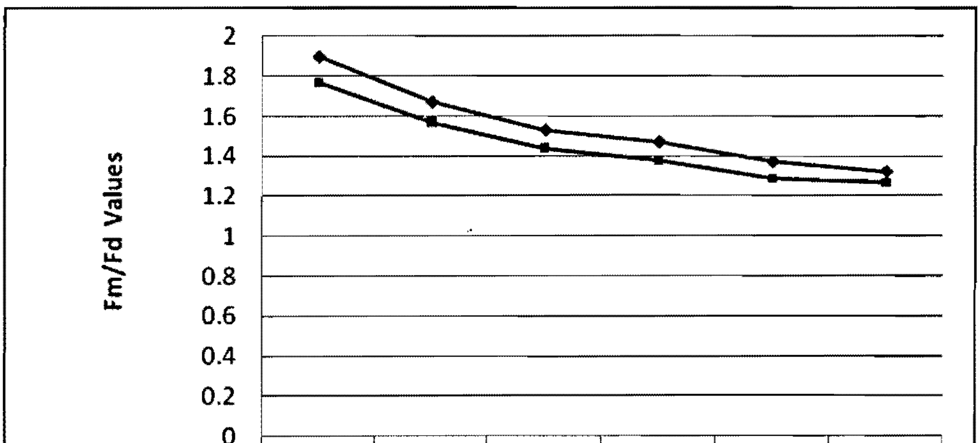
	16m	20m	24m	26m	30m	32m
Fm Values	1.78	1.57	1.45	1.4	1.32	1.27
Fd Values	1.65	1.49	1.35	1.31	1.24	1.2

Figure 4.52 Comparison of Fm and Fd Values for 4-lane Bridges of 14.806 m Width



	16m	20m	24m	26m	30m	32m
Fm Values	1.91	1.67	1.48	1.46	1.21	1.32
Fd Values	1.75	1.55	1.38	1.35	1	1.25

Figure 4.53 Comparison of Fm and Fd Values for 4-lane Bridges of 16.041 m Width



	16m	20m	24m	26m	30m	32m
Fm Values	1.9	1.67	1.53	1.47	1.37	1.32
Fd Values	1.77	1.57	1.44	1.38	1.29	1.27

Figure 4.54 Comparison of Fm and Fd Values for 4-lane Bridges of 17.276 m Width

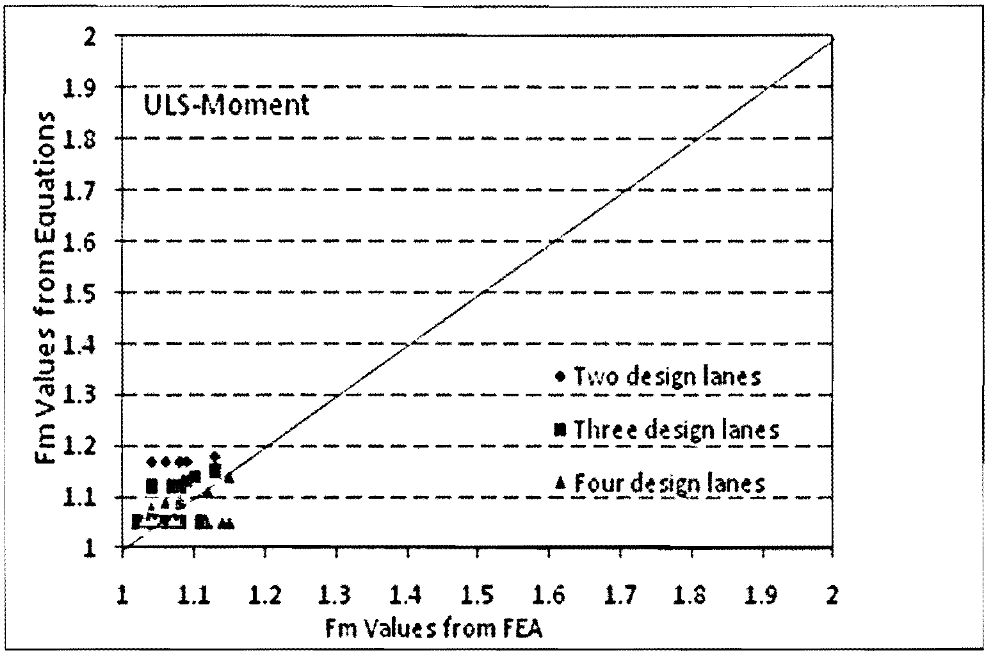


Figure 4.55 Comparison between the FEA results and those from the CHBDC Equations for solid slab bridges for ULS-Fm values

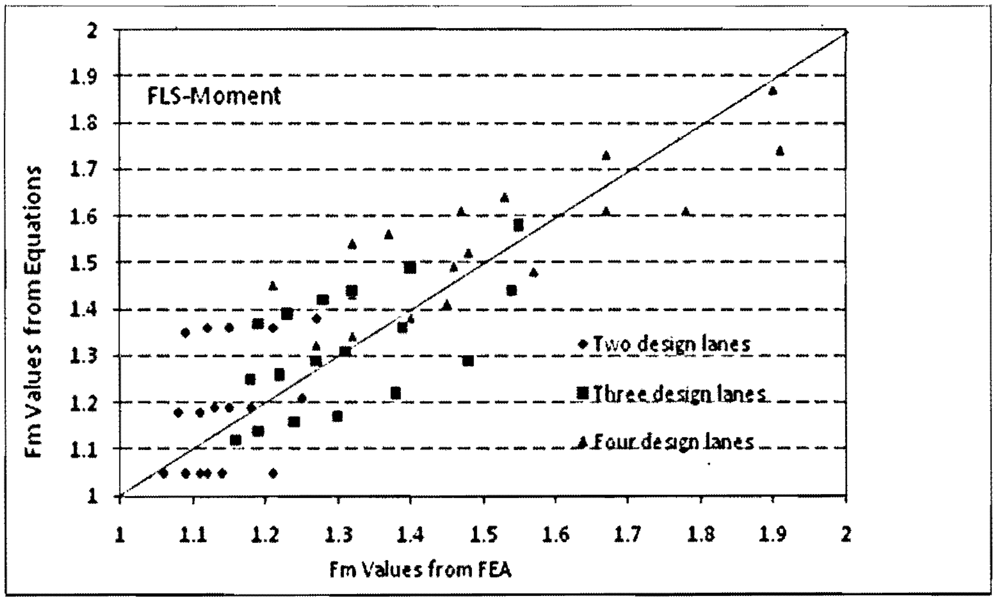


Figure 4.56 Comparison between the FEA results and those from the CHBDC Equations for solid slab bridges for FLS-Fm values

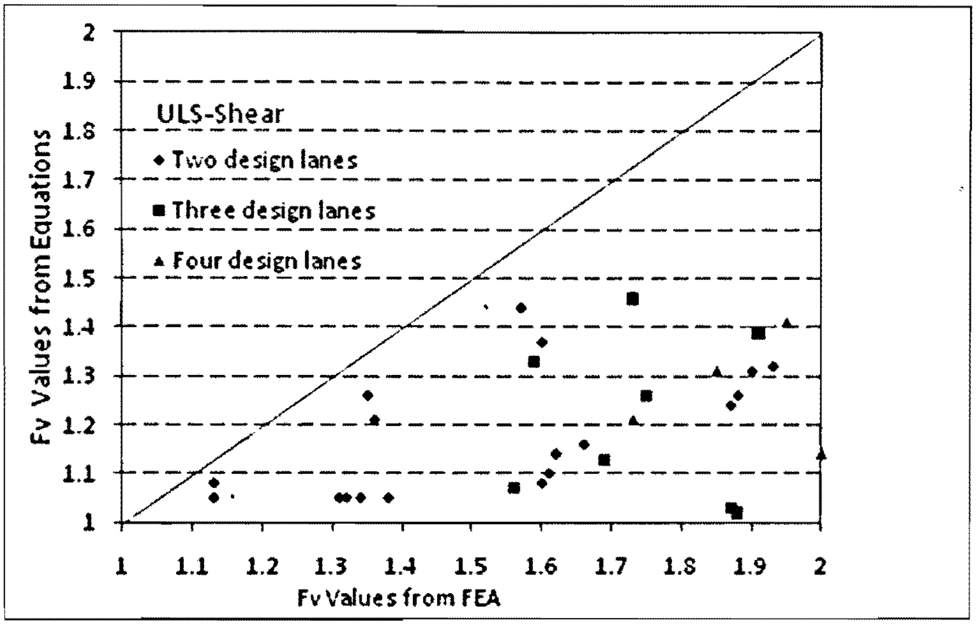


Figure 4.57 Comparison between the FEA results and those from the CHBDC Equations for solid slab bridges for ULS-Fv values

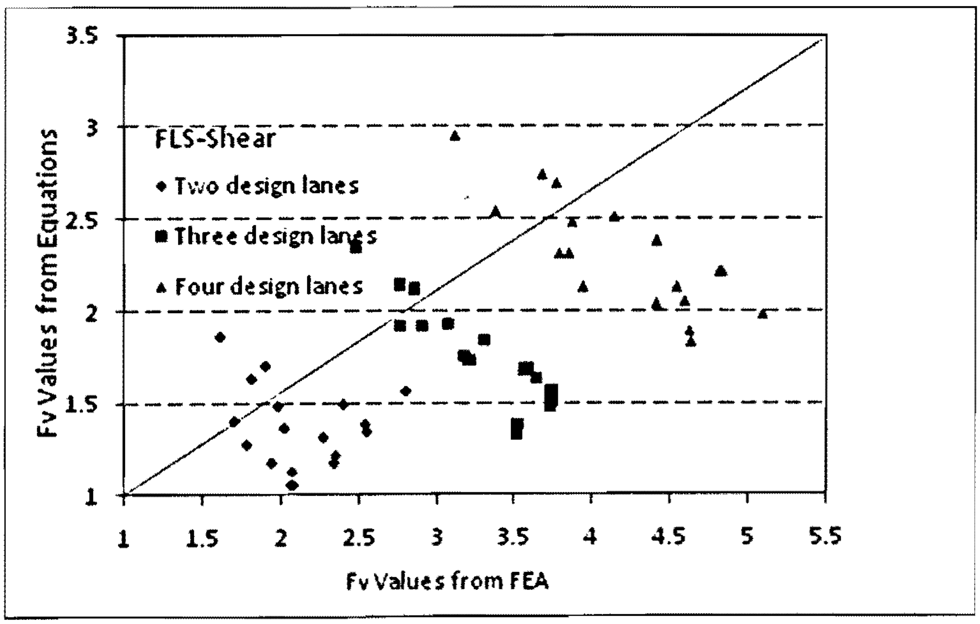


Figure 4.58 Comparison between the FEA results and those from the CHBDC Equations for solid slab bridges for FLS-Fv values

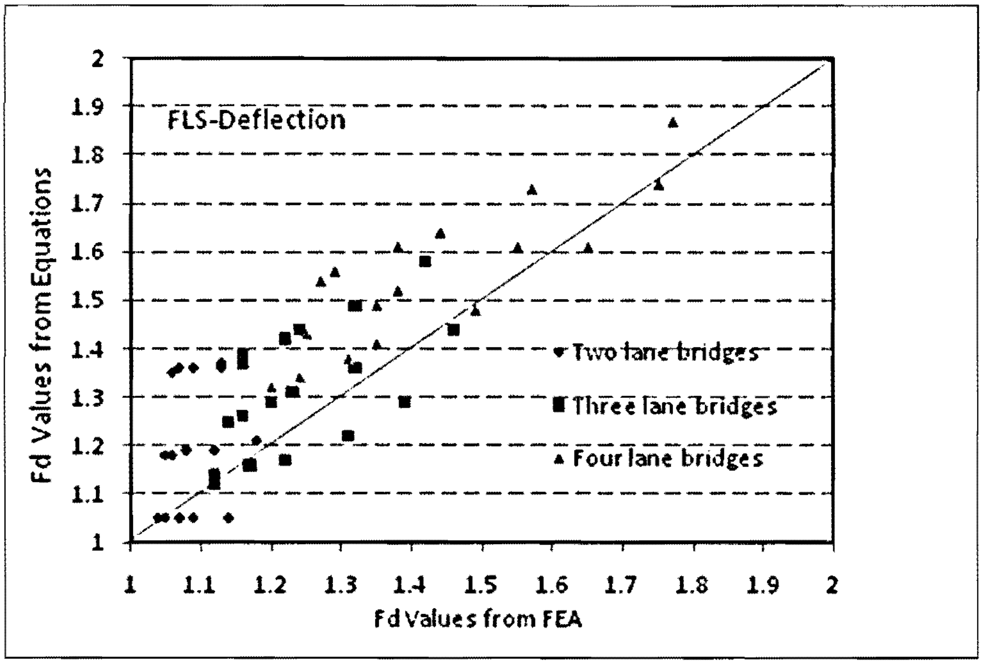


Figure 4.59 Comparison between the FEA results and those from the CHBDC Equations for solid slab bridges for Fd values

APPENDIX (A)

SUMMARY OF SENSITIVITY AND PARAMETRIC STUDIES

Table A.1: CASE SENSITIVITY STUDY FOR MODEL
2-LANES BRIDGE : 650mm THICK, 7.396m WIDTH, 16m LENGTH

COMPARISON OF SELF LOAD OF MODEL (115.37kN/m) BY SIMPLE BEAMFORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	7201.35 KN/m2	21.10 mm	907.28 KN
SIMPLE BEAM FORMULA	7089.22 KN/m2	20.70 mm	922.95 KN

COMPARISION OF UDL (10 KN/m2) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	4615.01 KN/m2	13.50 mm	581.76 KN
SIMPLE BEAM FORMULA	4544.36 KN/m2	13.32 mm	591.68 KN

COMPARISION OF POINT LOADS (100 KN) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	9998.58 KN/m2	22.4 mm	600.02 KN
SIMPLE BEAM FORMULA	9216.53 KN/m2	21.6 mm	600.00 KN

Table A.2: CASE SENSITIVITY STUDY FOR MODEL
2-LANES BRIDGE : 800mm THICK, 7.396m WIDTH, 20m LENGTH

COMPARISON OF SELF LOAD OF MODEL (142.0kN/m) BY SIMPLE BEAMFORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	9098.22 KN/m2	33.90 mm	1395.84 KN
SIMPLE BEAM FORMULA	8999.79 KN/m2	33.50 mm	1420.00 KN

COMPARISION OF UDL (10 KN/m2) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	4738.66 KN/m2	17.60 mm	727.02 KN
SIMPLE BEAM FORMULA	4687.50 KN/m2	17.40 mm	739.60 KN

COMPARISION OF POINT LOADS (100 KN) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	8150.45 KN/m2	23.30 mm	599.98 KN
SIMPLE BEAM FORMULA	7605.46 KN/m2	22.60 mm	600.00 KN

Table A.3: CASE SENSITIVITY STUDY FOR MODEL
2-LANES BRIDGE : 960mmTHICK, 7.396m WIDTH, 24m LENGTH

COMPARISON OF SELF LOAD OF MODEL (170.41KN/m) BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	10884.9 KN/m2	48.60 mm	2010.0 KN
SIMPLE BEAM FORMULA	10800.4 KN/m2	48.22 mm	2044.9 KN

COMPARISON OF UDL (10 KN/m2) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	4726.9 KN/m2	21.1 mm	872.4 KN
SIMPLE BEAM FORMULA	4687.5 KN/m2	20.9 mm	887.5 KN

COMPARISON OF POINT LOADS (100 KN) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	6734.6 KN/m2	23.30 mm	600.0 KN
SIMPLE BEAM FORMULA	6337.8 KN/m2	22.63 mm	600.0 KN

Table A.4: CASE SENSITIVITY STUDY FOR MODEL
2-LANES BRIDGE : 1040mm THICK, 7.396m WIDTH, 26m LENGTH

COMPARISON OF SELF LOAD OF MODEL (184.61kN/m) BY SIMPLE BEAMFORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	11779.18 KN/m2	57.00 mm	2359.00 KN
SIMPLE BEAM FORMULA	11700.37 KN/m2	56.60 mm	2399.93 KN

COMPARISION OF UDL (10 KN/m2) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	4719.22 KN/m2	22.80 mm	945.08 KN
SIMPLE BEAM FORMULA	4687.50 KN/m2	22.70 mm	961.48 KN

COMPARISION OF POINT LOADS (100 KN) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	6195.53 KN/m2	23.20 mm	600.00 KN
SIMPLE BEAM FORMULA	5050.36 KN/m2	22.60 mm	600.00 KN

Table A.5: CASE SENSITIVITY STUDY FOR MODEL
2-LANES BRIDGE : 1200mm THICK, 7.396m WIDTH, 30m LENGTH

COMPARISON OF SELF LOAD OF MODEL (213.0kN/m) BY SIMPLE BEAMFORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	13569.49 KN/m2	75.80 mm	3140.66 KN
SIMPLE BEAM FORMULA	13499.69 KN/m2	75.30 mm	3195.00 KN

COMPARISION OF UDL (10 KN/m2) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	4711.63 KN/m2	26.30 mm	1090.52 KN
SIMPLE BEAM FORMULA	4687.50 KN/m2	26.20 mm	1109.40 KN

COMPARISION OF POINT LOADS (100 KN) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	5341.29 KN/m2	23.20 mm	600.00 KN
SIMPLE BEAM FORMULA	5070.31 KN/m2	22.60 mm	600.00 KN

Table A.6: CASE SENSITIVITY STUDY FOR MODEL
2-LANES BRIDGE : 1280mm THICK, 7.396m WIDTH, 32m LENGTH

COMPARISON OF SELF LOAD OF MODEL (227.21kN/m) BY SIMPLE BEAMFORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	14465.38 KN/m2	86.10 mm	3573.38 KN
SIMPLE BEAM FORMULA	14400.31 KN/m2	85.70 mm	3635.36 KN

COMPARISION OF UDL (10 KN/m2) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	4708.78 KN/m2	28.00 mm	1163.20 KN
SIMPLE BEAM FORMULA	4687.50 KN/m2	27.90 mm	1183.36 KN

COMPARISION OF POINT LOADS (100 KN) ON MODEL BY SIMPLE BEAM FORMULA

OPTION	MAX STRESSES	MAX DEFORMATION	REACTION
BRIDGE SOLID SLAB MODEL	4996.74 KN/m2	23.20 mm	600.00 KN
SIMPLE BEAM FORMULA	4753.42 KN/m2	22.60 mm	600.00 KN

TABLE A.7: Fm VALUES FOR 2 LANES BRIDGE 16m LENGTH

2 LANE BRIDGE : 650mm Thick, 7.396m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	7.396	1147.2	0.02288	0.325	2729.65	0.68828
2-ULS	2	0.9	0.9	7.396	1147.2	0.02288	0.325	4719.11	1.07093
3-ULS	2	0.9	0.9	7.396	1147.2	0.02288	0.325	4724.13	1.07207
4-FLS	2	0.9	1	7.396	1147.2	0.02288	0.325	2648.62	1.20213

2 LANE BRIDGE : 650mm Thick, 8.631m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	8.631	1147.2	0.02288	0.325	2509.04	0.73829
2-ULS	2	0.9	0.9	8.631	1147.2	0.02288	0.325	4156.31	1.10071
3-ULS	2	0.9	0.9	8.631	1147.2	0.02288	0.325	4201.24	1.11261
4-FLS	2	0.9	1	8.631	1147.2	0.02288	0.325	2365.33	1.25281

2 LANE BRIDGE : 650mm Thick, 9.866m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	9.866	1147.2	0.02288	0.325	2365.24	0.79557
2-ULS	2	0.9	0.9	9.866	1147.2	0.02288	0.325	3762.15	1.13889
3-ULS	2	0.9	0.9	9.866	1147.2	0.02288	0.325	3674.92	1.11248
4-FLS	2	0.9	1	9.866	1147.2	0.02288	0.325	2105.27	1.27463

TABLE A.8: Fv VALUES FOR 2 LANES BRIDGE 16m LENGTH

2 LANE BRIDGE : 650mm Thick, 7.396m Width,16m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	7.396	326.8	90.1	1.1328363
2-ULS	2	0.9	0.9	7.396	326.8	96.8	1.0953684
3-ULS	2	0.9	0.9	7.396	326.8	93.18	1.0544053
4-FLS	2	0.9	1	7.396	326.8	75.86	1.7168316

2 LANE BRIDGE : 650mm Thick, 8.631m Width,16m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	2	0.9	1	8.631	326.8	92.2	1.3528121
2-ULS	2	0.9	0.9	8.631	326.8	98.5	1.3007244
3-ULS	2	0.9	0.9	8.631	326.8	81.43	1.0753096
4-FLS	2	0.9	1	8.631	326.8	69.1	1.8239194

2 LANE BRIDGE : 650mm Thick, 9.866m Width,16m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	2	0.9	1	9.866	326.8	93.7	1.5715426
2-ULS	2	0.9	0.9	9.866	326.8	98.7	1.4898626
3-ULS	2	0.9	0.9	9.866	326.8	60.3	0.91022
4-FLS	2	0.9	1	9.866	326.8	53.87	1.6263201

TABLE A.9: Fd VALUES FOR 2 LANES BRIDGE 16m LENGTH

2 LANE BRIDGE : 650mm Thick, 7.396m Width, 16m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
4-FLS	2	0.9	1	7.396	43.9	6.8	1.145622

2 LANE BRIDGE :650mm Thick, 8.631m Width, 16m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
4-FLS	2	0.9	1	8.631	43.9	6.02	1.183568

2 LANE BRIDGE : 650mm Thick, 9.866m Width, 16m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
4-FLS	2	0.9	1	9.866	43.9	5.2	1.168638

TABLE A.10: Fm VALUES FOR 2 LANES BRIDGE 20m LENGTH

2 LANE BRIDGE : 800mm Thick, 7.396m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	7.396	1617.9	0.04266	0.4	2410.09	0.65278
2-ULS	2	0.9	0.9	7.396	1617.9	0.04266	0.4	4329.09	1.05529
3-ULS	2	0.9	0.9	7.396	1617.9	0.04266	0.4	4332.29	1.05607
4-FLS	2	0.9	1	7.396	1617.9	0.04266	0.4	2356.21	1.14874

2 LANE BRIDGE : 800mm Thick, 8.631m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	8.631	1617.9	0.04266	0.4	2177.23	0.68818
2-ULS	2	0.9	0.9	8.631	1617.9	0.04266	0.4	3784.38	1.07655
3-ULS	2	0.9	0.9	8.631	1617.9	0.04266	0.4	3750.83	1.06701
4-FLS	2	0.9	1	8.631	1617.9	0.04266	0.4	2081.29	1.18414

2 LANE BRIDGE : 800mm Thick, 9.866m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	9.866	1617.9	0.04266	0.4	2018.18	0.72918
2-ULS	2	0.9	0.9	9.866	1617.9	0.04266	0.4	3357.84	1.09189
3-ULS	2	0.9	0.9	9.866	1617.9	0.04266	0.4	3290.87	1.07012
4-FLS	2	0.9	1	9.866	1617.9	0.04266	0.4	1843.61	1.199

TABLE A.11: Fv VALUES FOR 2 LANES BRIDGE 20m LENGTH

2 LANE BRIDGE : 800mm Thick, 7.396m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	7.396	349.7	96.7	1.1364362
2-ULS	2	0.9	0.9	7.396	349.7	107	1.1315013
3-ULS	2	0.9	0.9	7.396	349.7	104.48	1.1048528
4-FLS	2	0.9	1	7.396	349.7	85.04	1.7985583

2 LANE BRIDGE : 800mm Thick, 8.631m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	8.631	349.7	99.88	1.3695299
2-ULS	2	0.9	0.9	8.631	349.7	110.17	1.3595614
3-ULS	2	0.9	0.9	8.631	349.7	91.1	1.1242266
4-FLS	2	0.9	1	8.631	349.7	80.8	1.9944842

2 LANE BRIDGE : 800mm Thick, 9.866m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	9.866	349.7	102.09	1.6001334
2-ULS	2	0.9	0.9	9.866	349.7	110.83	1.5634098
3-ULS	2	0.9	0.9	9.866	349.7	74.57	1.0519125
4-FLS	2	0.9	1	9.866	349.7	67.89	1.9153639

TABLE A.12: Fd VALUES FOR 2 LANES BRIDGE 20m LENGTH

2 LANE BRIDGE : 800mm Thick, 7.396m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	7.396	52.6	7.8	1.096745

2 LANE BRIDGE :800mm Thick, 8.631m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	8.631	52.6	6.87	1.127281

2 LANE BRIDGE : 800mm Thick, 9.866m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	9.866	52.6	6.02	1.129151

TABLE A.13: Fm VALUES FOR 2 LANES BRIDGE 24m LENGTH

2 LANE BRIDGE : 960mm Thick, 7.396m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	7.396	2113.9	0.07373	0.48	2129.02	0.63566
2-ULS	2	0.9	0.9	7.396	2113.9	0.07373	0.48	3916.38	1.05237
3-ULS	2	0.9	0.9	7.396	2113.9	0.07373	0.48	3918.63	1.05298
4-FLS	2	0.9	1	7.396	2113.9	0.07373	0.48	2091.51	1.12402

2 LANE BRIDGE : 960mm Thick, 8.631m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	8.631	2113.9	0.07373	0.48	1901.4	0.66249
2-ULS	2	0.9	0.9	8.631	2113.9	0.07373	0.48	3406.82	1.06831
3-ULS	2	0.9	0.9	8.631	2113.9	0.07373	0.48	3382.17	1.06058
4-FLS	2	0.9	1	8.631	2113.9	0.07373	0.48	1834.55	1.15056

2 LANE BRIDGE : 960mm Thick, 9.866m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	9.866	2113.9	0.07373	0.48	1741.99	0.6938
2-ULS	2	0.9	0.9	9.866	2113.9	0.07373	0.48	3038.14	1.08902
3-ULS	2	0.9	0.9	9.866	2113.9	0.07373	0.48	2989.06	1.07143
4-FLS	2	0.9	1	9.866	2113.9	0.07373	0.48	1698.5	1.21766

TABLE A.14: Fv VALUES FOR 2 LANES BRIDGE 24m LENGTH

2 LANE BRIDGE : 960mm Thick, 7.396m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	7.396	395.6	133.0	1.3816087
2-ULS	2	0.9	0.9	7.396	395.6	145.76	1.3625391
3-ULS	2	0.9	0.9	7.396	395.6	136.82	1.2789696
4-FLS	2	0.9	1	7.396	395.6	104.51	1.9538826

2 LANE BRIDGE : 960mm Thick, 8.631m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	8.631	395.6	136.97	1.66019
2-ULS	2	0.9	0.9	8.631	395.6	150.43	1.6410027
3-ULS	2	0.9	0.9	8.631	395.6	106.68	1.163745
4-FLS	2	0.9	1	8.631	395.6	93.2	2.0340448

2 LANE BRIDGE : 960mm Thick, 9.866m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	9.866	395.6	139.82	1.9372319
2-ULS	2	0.9	0.9	9.866	395.6	152.74	1.9046168
3-ULS	2	0.9	0.9	9.866	395.6	87.95	1.0967072
4-FLS	2	0.9	1	9.866	395.6	112.94	2.8166482

TABLE A.15: Fd VALUES FOR 2 LANES BRIDGE 24m LENGTH

2 LANE BRIDGE : 960mm Thick, 7.396m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	7.396	58.96	8.6	1.078792

2 LANE BRIDGE :960mm Thick, 8.631m Width,24m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	8.631	58.96	7.4	1.083267

2 LANE BRIDGE : 960mm Thick, 9.866m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	9.866	58.96	6.8	1.13787

TABLE A.16: Fm VALUES FOR 2 LANES BRIDGE 26m LENGTH

2 LANE BRIDGE : 1040mm Thick, 7.396m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	7.396	2415.8	0.09374	0.52	2045.27	0.6271
2-ULS	2	0.9	0.9	7.396	2415.8	0.09374	0.52	3799.29	1.04841
3-ULS	2	0.9	0.9	7.396	2415.8	0.09374	0.52	3801.21	1.04894
4-FLS	2	0.9	1	7.396	2415.8	0.09374	0.52	2013.29	1.11113

2 LANE BRIDGE : 1040mm Thick, 8.631m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	8.631	2415.8	0.09374	0.52	1817.82	0.65043
2-ULS	2	0.9	0.9	8.631	2415.8	0.09374	0.52	3298.23	1.06212
3-ULS	2	0.9	0.9	8.631	2415.8	0.09374	0.52	3278.43	1.05574
4-FLS	2	0.9	1	8.631	2415.8	0.09374	0.52	1760.79	1.13404

2 LANE BRIDGE : 1040mm Thick, 9.866m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	9.866	2415.8	0.09374	0.52	1657.05	0.67774
2-ULS	2	0.9	0.9	9.866	2415.8	0.09374	0.52	2934.18	1.08009
3-ULS	2	0.9	0.9	9.866	2415.8	0.09374	0.52	2891.47	1.06436
4-FLS	2	0.9	1	9.866	2415.8	0.09374	0.52	1570.35	1.15611

TABLE A.17: Fv VALUES FOR 2 LANES BRIDGE 26m LENGTH

2 LANE BRIDGE : 1040mm Thick, 7.396m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	7.396	413.3	135.8	1.34968
2-ULS	2	0.9	0.9	7.396	413.3	149.9	1.3412296
3-ULS	2	0.9	0.9	7.396	413.3	145.11	1.2983711
4-FLS	2	0.9	1	7.396	413.3	116.51	2.0849455

2 LANE BRIDGE : 1040mm Thick, 8.631m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	8.631	413.3	140.26	1.6272603
2-ULS	2	0.9	0.9	8.631	413.3	155.36	1.622202
3-ULS	2	0.9	0.9	8.631	413.3	122.45	1.27857
4-FLS	2	0.9	1	8.631	413.3	109.5	2.285868

2 LANE BRIDGE : 1040mm Thick, 9.866m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	9.866	413.3	143.47	1.9026736
2-ULS	2	0.9	0.9	9.866	413.3	158.19	1.8880989
3-ULS	2	0.9	0.9	9.866	413.3	102.82	1.2272225
4-FLS	2	0.9	1	9.866	413.3	101.06	2.4124316

TABLE A.18: Fd VALUES FOR 2 LANES BRIDGE 26m LENGTH

2 LANE BRIDGE : 1040mm Thick, 7.396m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	7.396	62.54	9.04	1.0690732

2 LANE BRIDGE :1040mm Thick, 8.631m Width,26m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	8.631	62.54	7.8	1.0764599

2 LANE BRIDGE : 1040mm Thick, 9.866m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	9.866	62.54	6.9	1.0885098

TABLE A.19: Fm VALUES FOR 2 LANES BRIDGE 30m LENGTH

2 LANE BRIDGE : 1200mm Thick, 7.396m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	7.396	3025	0.144	0.6	1885.71	0.61473
2-ULS	2	0.9	0.9	7.396	3025	0.144	0.6	3552.56	1.0423
3-ULS	2	0.9	0.9	7.396	3025	0.144	0.6	3553.99	1.04272
4-FLS	2	0.9	1	7.396	3025	0.144	0.6	1861.67	1.09241

2 LANE BRIDGE : 1200mm Thick, 8.631m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	8.631	3025	0.144	0.6	1664.15	0.63309
2-ULS	2	0.9	0.9	8.631	3025	0.144	0.6	3074.87	1.05279
3-ULS	2	0.9	0.9	8.631	3025	0.144	0.6	3059.73	1.04761
4-FLS	2	0.9	1	8.631	3025	0.144	0.6	1621.27	1.1102

2 LANE BRIDGE : 1200mm Thick, 9.866m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	9.866	3025	0.144	0.6	1505.56	0.65472
2-ULS	2	0.9	0.9	9.866	3025	0.144	0.6	2725.82	1.06683
3-ULS	2	0.9	0.9	9.866	3025	0.144	0.6	2693.12	1.05403
4-FLS	2	0.9	1	9.866	3025	0.144	0.6	1440.36	1.12745

TABLE A.20: Fv VALUES FOR 2 LANES BRIDGE 30m LENGTH

2 LANE BRIDGE : 1200mm Thick, 7.396m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	7.396	441.5	141.2	1.3139138
2-ULS	2	0.9	0.9	7.396	441.5	158.51	1.3276783
3-ULS	2	0.9	0.9	7.396	441.5	154.98	1.2981111
4-FLS	2	0.9	1	7.396	441.5	125.22	2.0976832

2 LANE BRIDGE : 1200mm Thick, 8.631m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	8.631	441.5	146.53	1.5914187
2-ULS	2	0.9	0.9	8.631	441.5	165.03	1.6131075
3-ULS	2	0.9	0.9	8.631	441.5	137.02	1.3393201
4-FLS	2	0.9	1	8.631	441.5	120.9	2.3640925

2 LANE BRIDGE : 1200mm Thick, 9.866m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	9.866	441.5	150.36	1.8666815
2-ULS	2	0.9	0.9	9.866	441.5	168.75	1.8854898
3-ULS	2	0.9	0.9	9.866	441.5	120.61	1.3476084
4-FLS	2	0.9	1	9.866	441.5	114.37	2.5557745

TABLE A.21: Fd VALUES FOR 2 LANES BRIDGE 30m LENGTH

2 LANE BRIDGE : 1200mm Thick, 7.396m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	7.396	68.09	9.7	1.0536231

2 LANE BRIDGE :1200mm Thick, 8.631m Width,30m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	8.631	68.09	8.4	1.0647731

2 LANE BRIDGE : 1200mm Thick, 9.866m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	9.866	68.09	7.4	1.0722338

TABLE A.22: Fm VALUES FOR 2 LANES BRIDGE 32m LENGTH

2 LANE BRIDGE : 1280mm Thick, 7.396m Width, 32m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	7.396	3382.2	0.1747	0.64	1811.66	0.60078
2-ULS	2	0.9	0.9	7.396	3382.2	0.1747	0.64	3430.95	1.02399
3-ULS	2	0.9	0.9	7.396	3382.2	0.1747	0.64	3432.21	1.02436
4-FLS	2	0.9	1	7.396	3382.2	0.1747	0.64	1790.53	1.06879

2 LANE BRIDGE : 1280mm Thick, 8.631m Width, 32m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	8.631	3382.2	0.1747	0.64	1594.53	0.61707
2-ULS	2	0.9	0.9	8.631	3382.2	0.1747	0.64	2966.32	1.03315
3-ULS	2	0.9	0.9	8.631	3382.2	0.1747	0.64	2952.96	1.0285
4-FLS	2	0.9	1	8.631	3382.2	0.1747	0.64	1556.84	1.08447

2 LANE BRIDGE : 1280mm Thick, 9.866m Width, 32m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	2	0.9	1	9.866	3382.2	0.1747	0.64	1438.43	0.63631
2-ULS	2	0.9	0.9	9.866	3382.2	0.1747	0.64	2626.12	1.04554
3-ULS	2	0.9	0.9	9.866	3382.2	0.1747	0.64	2597.26	1.03405
4-FLS	2	0.9	1	9.866	3382.2	0.1747	0.64	1381.12	1.09973

TABLE A.23: Fv VALUES FOR 2 LANES BRIDGE 32m LENGTH

2 LANE BRIDGE : 1280mm Thick, 7.396m Width, 32m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	7.396	452.9	142.3	1.2909115
2-ULS	2	0.9	0.9	7.396	452.9	160.81	1.313039
3-ULS	2	0.9	0.9	7.396	452.9	157.52	1.2861757
4-FLS	2	0.9	1	7.396	452.9	127.04	2.0746033

2 LANE BRIDGE : 1280mm Thick, 8.631m Width, 32m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	8.631	452.9	147.95	1.5663949
2-ULS	2	0.9	0.9	8.631	452.9	167.93	1.6001367
3-ULS	2	0.9	0.9	8.631	452.9	141.12	1.3446751
4-FLS	2	0.9	1	8.631	452.9	123.6	2.3556589

2 LANE BRIDGE : 1280mm Thick, 9.866m Width, 32m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	2	0.9	1	9.866	452.9	152.03	1.8399058
2-ULS	2	0.9	0.9	9.866	452.9	172.09	1.8744093
3-ULS	2	0.9	0.9	9.866	452.9	126.09	1.373376
4-FLS	2	0.9	1	9.866	452.9	117.78	2.5657264

TABLE A.24: Fd VALUES FOR 2 LANES BRIDGE 32m LENGTH

2 LANE BRIDGE : 1280mm Thick, 7.396m Width, 32m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	7.396	70.31	9.9	1.041394

2 LANE BRIDGE :1280mm Thick, 8.631m Width,32m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	8.631	70.31	8.6	1.055705

2 LANE BRIDGE : 1280mm Thick, 9.866m Width, 32m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
4-FLS	2	0.9	1	9.866	70.31	7.6	1.066443

TABLE A.25: Fm VALUES FOR 3 LANES BRIDGE 16m LENGTH

3 LANE BRIDGE : 650mm Thick, 11.101m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-USL	3	0.8	1	11.101	1147.2	0.02288	0.325	2269.68	0.64424
2-ULS	3	0.8	0.9	11.101	1147.2	0.02288	0.325	3661.57	0.93539
3-ULS	3	0.8	0.8	11.101	1147.2	0.02288	0.325	4720.37	1.07189
4-ULS	3	0.8	0.9	11.101	1147.2	0.02288	0.325	3576.93	0.91377
5-ULS	3	0.8	0.8	11.101	1147.2	0.02288	0.325	4711.86	1.06996
6-FLS	3	0.8	1	11.101	1147.2	0.02288	0.325	2172.92	1.48026
7-FLS	3	0.8	1	11.101	1147.2	0.02288	0.325	1814.33	1.23598

3 LANE BRIDGE : 650mm Thick, 12.336m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-USL	3	0.8	1	12.336	1147.2	0.02288	0.325	2205.48	0.69566
2-ULS	3	0.8	0.9	12.336	1147.2	0.02288	0.325	3478.08	0.98737
3-ULS	3	0.8	0.8	12.336	1147.2	0.02288	0.325	4369.09	1.1025
4-ULS	3	0.8	0.9	12.336	1147.2	0.02288	0.325	3317.88	0.94189
5-ULS	3	0.8	0.8	12.336	1147.2	0.02288	0.325	4315.76	1.08904
6-FLS	3	0.8	1	12.336	1147.2	0.02288	0.325	2041.65	1.54557
7-FLS	3	0.8	1	12.336	1147.2	0.02288	0.325	1698.23	1.2856

3 LANE BRIDGE : 650mm Thick, 13.571m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-USL	3	0.8	1	13.571	1147.2	0.02288	0.325	2162.08	0.75025
2-ULS	3	0.8	0.9	13.571	1147.2	0.02288	0.325	3328.81	1.0396
3-ULS	3	0.8	0.8	13.571	1147.2	0.02288	0.325	4077.32	1.13188
4-ULS	3	0.8	0.9	13.571	1147.2	0.02288	0.325	3115.88	0.9731
5-ULS	3	0.8	0.8	13.571	1147.2	0.02288	0.325	3982.61	1.10558
6-FLS	3	0.8	1	13.571	1147.2	0.02288	0.325	1871.62	1.5587
7-FLS	3	0.8	1	13.571	1147.2	0.02288	0.325	1591.95	1.32579

TABLE A.26: Fv VALUES FOR 3 LANES BRIDGE 16m LENGTH

3 LANE BRIDGE : 650mm Thick, 11.101m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	3	0.8	1	11.101	326.8	94.8	1.3421917
2-ULS	3	0.8	0.9	11.101	326.8	133.1	1.6957219
3-ULS	3	0.8	0.8	11.101	326.8	105.59	1.1955881
4-ULS	3	0.8	0.9	11.101	326.8	99.81	1.2714093
5-ULS	3	0.8	0.8	11.101	326.8	92.31	1.0452196
6-FLS	3	0.8	1	11.101	326.8	81.57	2.7708341
7-FLS	3	0.8	1	11.101	326.8	37.36	1.2690739

3 LANE BRIDGE : 650mm Thick, 12.336m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	3	0.8	1	12.336	326.8	95.7	1.5056677
2-ULS	3	0.8	0.9	12.336	326.8	113	1.5995655
3-ULS	3	0.8	0.8	12.336	326.8	105.31	1.3250756
4-ULS	3	0.8	0.9	12.336	326.8	89.43	1.2659216
5-ULS	3	0.8	0.8	12.336	326.8	81.73	1.0283775
6-FLS	3	0.8	1	12.336	326.8	73.4	2.7722027
7-FLS	3	0.8	1	12.336	326.8	36.74	1.3868563

3 LANE BRIDGE : 650mm Thick, 13.571m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-USL	3	0.8	1	13.571	326.8	96.2	1.6640186
2-ULS	3	0.8	0.9	13.571	326.8	111.6	1.7385248
3-ULS	3	0.8	0.8	13.571	326.8	103.62	1.4343401
4-ULS	3	0.8	0.9	13.571	326.8	80.15	1.2481437
5-ULS	3	0.8	0.8	13.571	326.8	72.03	0.9970615
6-FLS	3	0.8	1	13.571	326.8	60.04	2.4932767
7-FLS	3	0.8	1	13.571	326.8	36.74	1.5256993

TABLE A.27: Fd VALUES FOR 3 LANES BRIDGE 16m LENGTH

3 LANE BRIDGE : 650mm Thick, 11.101m Width, 16m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	11.101	43.9	5.5	1.390786

3 LANE BRIDGE : 650mm Thick, 12.336m Width, 16m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	12.336	43.9	5.2	1.461212

3 LANE BRIDGE : 650mm Thick, 13.571m Width, 16m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	13.571	43.9	4.6	1.422018

TABLE A.28: Fm VALUES FOR 3 LANES BRIDGE 20m LENGTH

3 LANE BRIDGE : 800mm Thick, 11.101m Width, 20m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	11.101	1617.9	0.04266	0.4	1906.75	0.58137
2	3	0.8	0.9	11.101	1617.9	0.04266	0.4	3232.03	0.88691
3	3	0.8	0.8	11.101	1617.9	0.04266	0.4	4330.06	1.05619
4	3	0.8	0.9	11.101	1617.9	0.04266	0.4	3173.79	0.87092
5	3	0.8	0.8	11.101	1617.9	0.04266	0.4	4311.23	1.0516
6	3	0.8	1	11.101	1617.9	0.04266	0.4	1890.16	1.38315
7	3	0.8	1	11.101	1617.9	0.04266	0.4	1596.14	1.168

3 LANE BRIDGE : 800mm Thick, 12.336m Width, 20m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	12.336	1617.9	0.04266	0.4	1827.33	0.61914
2	3	0.8	0.9	12.336	1617.9	0.04266	0.4	3035.33	0.92559
3	3	0.8	0.8	12.336	1617.9	0.04266	0.4	3979.68	1.07872
4	3	0.8	0.9	12.336	1617.9	0.04266	0.4	2934.97	0.89499
5	3	0.8	0.8	12.336	1617.9	0.04266	0.4	3927.66	1.06462
6	3	0.8	1	12.336	1617.9	0.04266	0.4	1716.73	1.396
7	3	0.8	1	12.336	1617.9	0.04266	0.4	1477.48	1.20145

3 LANE BRIDGE : 800mm Thick, 13.571m Width, 20m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	13.571	1617.9	0.04266	0.4	1770.11	0.6598
2	3	0.8	0.9	13.571	1617.9	0.04266	0.4	2877.49	0.96531
3	3	0.8	0.8	13.571	1617.9	0.04266	0.4	3691.34	1.10074
4	3	0.8	0.9	13.571	1617.9	0.04266	0.4	2728.34	0.91527
5	3	0.8	0.8	13.571	1617.9	0.04266	0.4	3610.05	1.0765
6	3	0.8	1	13.571	1617.9	0.04266	0.4	1572.26	1.40652
7	3	0.8	1	13.571	1617.9	0.04266	0.4	1373.05	1.22831

TABLE A.29: Fv VALUES FOR 3 LANES BRIDGE 20m LENGTH

3 LANE BRIDGE : 800mm Thick, 11.101m Width, 20m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	11.101	349.7	103.8	1.372282
2-ULS	3	0.8	0.9	11.101	349.7	131.8	1.568727
3-ULS	3	0.8	0.8	11.101	349.7	122.78	1.299191
4-ULS	3	0.8	0.9	11.101	349.7	121.56	1.447066
5-ULS	3	0.8	0.8	11.101	349.7	112.55	1.190942
6-FLS	3	0.8	1	11.101	349.7	101.39	3.21856
7-FLS	3	0.8	1	11.101	349.7	28.03	0.889794

3 LANE BRIDGE : 800mm Thick, 12.336m Width, 20m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	12.336	349.7	105.7	1.553318
2-ULS	3	0.8	0.9	12.336	349.7	132.63	1.754494
3-ULS	3	0.8	0.8	12.336	349.7	123.09	1.447372
4-ULS	3	0.8	0.9	12.336	349.7	115.11	1.522731
5-ULS	3	0.8	0.8	12.336	349.7	105.62	1.241949
6-FLS	3	0.8	1	12.336	349.7	87.6	3.089115
7-FLS	3	0.8	1	12.336	349.7	25.69	0.906239

3 LANE BRIDGE : 800mm Thick, 13.571m Width, 20m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	13.571	349.7	106.0	1.714
2-ULS	3	0.8	0.9	13.571	349.7	131.6	1.914716
3-ULS	3	0.8	0.8	13.571	349.7	121.27	1.568731
4-ULS	3	0.8	0.9	13.571	349.7	105.91	1.54129
5-ULS	3	0.8	0.8	13.571	349.7	95.66	1.237443
6-FLS	3	0.8	1	13.571	349.7	73.93	2.869042
7-FLS	3	0.8	1	13.571	349.7	25.51	0.989981

TABLE A.30: Fd VALUES FOR 3 LANES BRIDGE 20m LENGTH

3 LANE BRIDGE : 800mm Thick, 11.101m Width, 20m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	11.101	52.6	6.2	1.308483

3 LANE BRIDGE : 800mm Thick, 12.336m Width, 20m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	12.336	52.6	5.6	1.313338

3 LANE BRIDGE : 800mm Thick, 13.571m Width, 20m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	13.571	52.6	5.1	1.315819

TABLE A.31: Fm VALUES FOR 3 LANES BRIDGE 24m LENGTH

3 LANE BRIDGE : 960mm Thick, 11.101m Width, 24m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	11.101	2113.9	0.0737	0.48	1627	0.5468
2	3	0.8	0.9	11.101	2113.9	0.0737	0.48	2850.3	0.8622
3	3	0.8	0.8	11.101	2113.9	0.0737	0.48	3913.9	1.0524
4	3	0.8	0.9	11.101	2113.9	0.0737	0.48	2809.2	0.8498
5	3	0.8	0.8	11.101	2113.9	0.0737	0.48	3896.4	1.0477
6	3	0.8	1	11.101	2113.9	0.0737	0.48	1615.4	1.3031
7	3	0.8	1	11.101	2113.9	0.0737	0.48	1408.6	1.1362

3 LANE BRIDGE : 960mm Thick, 12.336m Width, 24m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	12.336	2113.9	0.0737	0.48	1542.4	0.5761
2	3	0.8	0.9	12.336	2113.9	0.0737	0.48	2654.5	0.8923
3	3	0.8	0.8	12.336	2113.9	0.0737	0.48	3631.6	1.0851
4	3	0.8	0.9	12.336	2113.9	0.0737	0.48	2583.3	0.8684
5	3	0.8	0.8	12.336	2113.9	0.0737	0.48	3583	1.0706
6	3	0.8	1	12.336	2113.9	0.0737	0.48	1465	1.3132
7	3	0.8	1	12.336	2113.9	0.0737	0.48	1295.1	1.1609

3 LANE BRIDGE : 960mm Thick, 13.571m Width, 24m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	13.571	2113.9	0.0737	0.48	1479.1	0.6078
2	3	0.8	0.9	13.571	2113.9	0.0737	0.48	2497.5	0.9236
3	3	0.8	0.8	13.571	2113.9	0.0737	0.48	3307.1	1.0871
4	3	0.8	0.9	13.571	2113.9	0.0737	0.48	2391.2	0.8843
5	3	0.8	0.8	13.571	2113.9	0.0737	0.48	3343.5	1.099
6	3	0.8	1	13.571	2113.9	0.0737	0.48	1340.2	1.3216
7	3	0.8	1	13.571	2113.9	0.0737	0.48	1197.1	1.1805

TABLE A.32: Fv VALUES FOR 3 LANES BRIDGE 24m LENGTH

3 LANE BRIDGE : 960mm Thick, 11.101m Width, 24m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	11.101	395.6	142.0	1.659818
2-ULS	3	0.8	0.9	11.101	395.6	178.4	1.876872
3-ULS	3	0.8	0.8	11.101	395.6	168.45	1.575635
4-ULS	3	0.8	0.9	11.101	395.6	151.9	1.598435
5-ULS	3	0.8	0.8	11.101	395.6	141.98	1.328042
6-FLS	3	0.8	1	11.101	395.6	133.41	3.743641
7-FLS	3	0.8	1	11.101	395.6	58.84	1.651119

3 LANE BRIDGE : 960mm Thick, 12.336m Width, 24m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	12.336	395.6	143.6	1.865914
2-ULS	3	0.8	0.9	12.336	395.6	180.98	2.116313
3-ULS	3	0.8	0.8	12.336	395.6	183.55	1.907881
4-ULS	3	0.8	0.9	12.336	395.6	139.02	1.625648
5-ULS	3	0.8	0.8	12.336	395.6	142.09	1.476931
6-FLS	3	0.8	1	12.336	395.6	102.3	3.18971
7-FLS	3	0.8	1	12.336	395.6	58.49	1.823894

3 LANE BRIDGE : 13.571m Width, 24m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	13.571	395.6	145.0	2.072585
2-ULS	3	0.8	0.9	13.571	395.6	180.2	2.317636
3-ULS	3	0.8	0.8	13.571	395.6	168.42	1.925874
4-ULS	3	0.8	0.9	13.571	395.6	127.02	1.634026
5-ULS	3	0.8	0.8	13.571	395.6	115.26	1.317992
6-FLS	3	0.8	1	13.571	395.6	84.76	2.907679
7-FLS	3	0.8	1	13.571	395.6	57.42	1.969785

TABLE A.33: Fd VALUES FOR 3 LANES BRIDGE 24m LENGTH

3 LANE BRIDGE : 960mm Thick, 11.101m Width, 24m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	11.101	58.96	6.5	1.223821

3 LANE BRIDGE : 960mm Thick, 12.336m Width, 24m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	12.336	58.96	5.9	1.234437

3 LANE BRIDGE : 960mm Thick, 13.571m Width, 24m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	13.571	58.96	5.4	1.242934

TABLE A.34: Fm VALUES FOR 3 LANES BRIDGE 26m LENGTH

3 LANE BRIDGE : 1040mm Thick, 11.101m Width, 26m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	11.101	2415.8	0.0937	0.52	1539.8	0.5315
2	3	0.8	0.9	11.101	2415.8	0.0937	0.52	2735.8	0.8498
3	3	0.8	0.8	11.101	2415.8	0.0937	0.52	3795.1	1.0479
4	3	0.8	0.9	11.101	2415.8	0.0937	0.52	2700.5	0.8389
5	3	0.8	0.8	11.101	2415.8	0.0937	0.52	3779	1.0435
6	3	0.8	1	11.101	2415.8	0.0937	0.52	1501.2	1.2435
7	3	0.8	1	11.101	2415.8	0.0937	0.52	1352.9	1.1207

3 LANE BRIDGE : 1040mm Thick,12.336m Width, 26m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	12.336	2415.8	0.0937	0.52	1452.5	0.5571
2	3	0.8	0.9	12.336	2415.8	0.0937	0.52	2538.6	0.8763
3	3	0.8	0.8	12.336	2415.8	0.0937	0.52	3506	1.0758
4	3	0.8	0.9	12.336	2415.8	0.0937	0.52	2477.4	0.8552
5	3	0.8	0.8	12.336	2415.8	0.0937	0.52	3462.5	1.0624
6	3	0.8	1	12.336	2415.8	0.0937	0.52	1386.5	1.2763
7	3	0.8	1	12.336	2415.8	0.0937	0.52	1240.4	1.1418

3 LANE BRIDGE : 1040mm Thick, 13.571m Width, 26m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	13.571	2415.8	0.0937	0.52	1386.4	0.585
2	3	0.8	0.9	13.571	2415.8	0.0937	0.52	2380.3	0.9039
3	3	0.8	0.8	13.571	2415.8	0.0937	0.52	3194.6	1.0784
4	3	0.8	0.9	13.571	2415.8	0.0937	0.52	2288.8	0.8692
5	3	0.8	0.8	13.571	2415.8	0.0937	0.52	3137.9	1.0592
6	3	0.8	1	13.571	2415.8	0.0937	0.52	1267.6	1.2836
7	3	0.8	1	13.571	2415.8	0.0937	0.52	1144.1	1.1586

TABLE A.35: Fv VALUES FOR 3 LANES BRIDGE 26m LENGTH

3 LANE BRIDGE : 1040mm Thick, 11.101m Width, 26m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	11.101	413.3	145.9	1.632829
2-ULS	3	0.8	0.9	11.101	413.3	187.2	1.885834
3-ULS	3	0.8	0.8	11.101	413.3	176.31	1.578528
4-ULS	3	0.8	0.9	11.101	413.3	170.32	1.715511
5-ULS	3	0.8	0.8	11.101	413.3	159.41	1.42722
6-FLS	3	0.8	1	11.101	413.3	129	3.464866
7-FLS	3	0.8	1	11.101	413.3	45.13	1.212166

3 LANE BRIDGE : 1040mm Thick, 12.336m Width, 26m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	12.336	413.3	147.8	1.838361
2-ULS	3	0.8	0.9	12.336	413.3	186.78	2.090598
3-ULS	3	0.8	0.8	12.336	413.3	192.84	1.918602
4-ULS	3	0.8	0.9	12.336	413.3	161.76	1.810553
5-ULS	3	0.8	0.8	12.336	413.3	164.83	1.639925
6-FLS	3	0.8	1	12.336	413.3	119.8	3.576037
7-FLS	3	0.8	1	12.336	413.3	44.65	1.332694

3 LANE BRIDGE : 1040mm Thick, 13.571m Width, 26m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	13.571	413.3	149.4	2.043749
2-ULS	3	0.8	0.9	13.571	413.3	189.8	2.337574
3-ULS	3	0.8	0.8	13.571	413.3	176.93	1.936541
4-ULS	3	0.8	0.9	13.571	413.3	150.37	1.851565
5-ULS	3	0.8	0.8	13.571	413.3	137.47	1.504642
6-FLS	3	0.8	1	13.571	413.3	100.84	3.311153
7-FLS	3	0.8	1	13.571	413.3	43.53	1.429339

TABLE A.36: Fd VALUES FOR 3 LANES BRIDGE 26m LENGTH

3 LANE BRIDGE : 1040mm Thick, 11.101m Width, 26m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
7	3	0.8	1	11.101	62.54	6.6	1.171516

3 LANE BRIDGE : 1040mm Thick, 12.336m Width, 26m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
7	3	0.8	1	12.336	62.54	6.1	1.203224

3 LANE BRIDGE : 1040mm Thick, 13.571m Width, 26m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
7	3	0.8	1	13.571	62.54	5.6	1.215184

TABLE A.37: Fm VALUES FOR 3 LANES BRIDGE 30m LENGTH

3 LANE BRIDGE : 1200mm Thick, 11.101m Width, 30m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	11.101	3025	0.144	0.6	1388.3	0.5095
2	3	0.8	0.9	11.101	3025	0.144	0.6	2518.5	0.8318
3	3	0.8	0.8	11.101	3025	0.144	0.6	3545.6	1.0409
4	3	0.8	0.9	11.101	3025	0.144	0.6	2491.8	0.823
5	3	0.8	0.8	11.101	3025	0.144	0.6	3532.6	1.0371
6	3	0.8	1	11.101	3025	0.144	0.6	1359.2	1.1971
7	3	0.8	1	11.101	3025	0.144	0.6	1204.6	1.0609

3 LANE BRIDGE : 1200mm Thick, 12.336m Width, 30m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	12.336	3025	0.144	0.6	1299.5	0.5299
2	3	0.8	0.9	12.336	3025	0.144	0.6	2328.9	0.8547
3	3	0.8	0.8	12.336	3025	0.144	0.6	3230.8	1.054
4	3	0.8	0.9	12.336	3025	0.144	0.6	2282.5	0.8377
5	3	0.8	0.8	12.336	3025	0.144	0.6	3202	1.0446
6	3	0.8	1	12.336	3025	0.144	0.6	1249.8	1.2232
7	3	0.8	1	12.336	3025	0.144	0.6	1139.2	1.1149

3 LANE BRIDGE : 1200mm Thick,13.571m Width, 30m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	13.571	3025	0.144	0.6	1231	0.5522
2	3	0.8	0.9	13.571	3025	0.144	0.6	2197	0.8871
3	3	0.8	0.8	13.571	3025	0.144	0.6	2979.5	1.0694
4	3	0.8	0.9	13.571	3025	0.144	0.6	2109.6	0.8518
5	3	0.8	0.8	13.571	3025	0.144	0.6	2937.6	1.0543
6	3	0.8	1	13.571	3025	0.144	0.6	1141.5	1.229
7	3	0.8	1	13.571	3025	0.144	0.6	1047.5	1.1278

TABLE A.38: Fv VALUES FOR 3 LANES BRIDGE 30m LENGTH

3 LANE BRIDGE : 1200mm Thick, 11.101m Width, 30m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	11.101	441.5	153.3	1.605748
2-ULS	3	0.8	0.9	11.101	441.5	203.5	1.918788
3-ULS	3	0.8	0.8	11.101	441.5	191.36	1.603841
4-ULS	3	0.8	0.9	11.101	441.5	190.44	1.795646
5-ULS	3	0.8	0.8	11.101	441.5	178.31	1.494465
6-FLS	3	0.8	1	11.101	441.5	140.22	3.525668
7-FLS	3	0.8	1	11.101	441.5	47.63	1.197601

3 LANE BRIDGE : 1200mm Thick, 12.336m Width, 30m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	12.336	441.5	155.6	1.811282
2-ULS	3	0.8	0.9	12.336	441.5	209.05	2.190408
3-ULS	3	0.8	0.8	12.336	441.5	195.05	1.816638
4-ULS	3	0.8	0.9	12.336	441.5	187.02	1.95958
5-ULS	3	0.8	0.8	12.336	441.5	173.03	1.61155
6-FLS	3	0.8	1	12.336	441.5	133.5	3.731256
7-FLS	3	0.8	1	12.336	441.5	44.3	1.237791

3 LANE BRIDGE : 1200mm Thick, 13.571m Width, 30m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	13.571	441.5	157.5	2.016695
2-ULS	3	0.8	0.9	13.571	441.5	213.0	2.454768
3-ULS	3	0.8	0.8	13.571	441.5	198.48	2.033652
4-ULS	3	0.8	0.9	13.571	441.5	180.85	2.084639
5-ULS	3	0.8	0.8	13.571	441.5	166.37	1.704649
6-FLS	3	0.8	1	13.571	441.5	117.04	3.597621
7-FLS	3	0.8	1	13.571	441.5	39.24	1.206174

TABLE A.39: Fd VALUES FOR 3 LANES BRIDGE 30m LENGTH

3 LANE BRIDGE : 1200mm Thick, 11.101m Width, 30m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	11.101	68.09	6.9	1.124936

3 LANE BRIDGE : 1200mm Thick, 12.336m Width, 30m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	12.336	68.09	6.4	1.159501

3 LANE BRIDGE : 1200mm Thick, 13.571m Width, 30m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	13.571	68.09	5.8	1.155996

TABLE A.40: Fm VALUES FOR 3 LANES BRIDGE 32m LENGTH

3 LANE BRIDGE : 1280mm Thick, 11.101m Width, 32m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	11.101	3382.2	0.1747	0.64	1322.4	0.4937
2	3	0.8	0.9	11.101	3382.2	0.1747	0.64	2418	0.8124
3	3	0.8	0.8	11.101	3382.2	0.1747	0.64	3423	1.0223
4	3	0.8	0.9	11.101	3382.2	0.1747	0.64	2394.6	0.8045
5	3	0.8	0.8	11.101	3382.2	0.1747	0.64	3411.4	1.0188
6	3	0.8	1	11.101	3382.2	0.1747	0.64	1296.9	1.1619
7	3	0.8	1	11.101	3382.2	0.1747	0.64	1198.3	1.0736

3 LANE BRIDGE : 1280mm Thick, 12.336m Width, 32m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	12.336	3382.2	0.1747	0.64	1234	0.5119
2	3	0.8	0.9	12.336	3382.2	0.1747	0.64	2226.4	0.8312
3	3	0.8	0.8	12.336	3382.2	0.1747	0.64	3140.2	1.0421
4	3	0.8	0.9	12.336	3382.2	0.1747	0.64	2185.7	0.816
5	3	0.8	0.8	12.336	3382.2	0.1747	0.64	3109.5	1.0319
6	3	0.8	1	12.336	3382.2	0.1747	0.64	1190.3	1.1851
7	3	0.8	1	12.336	3382.2	0.1747	0.64	1093	1.0882

3 LANE BRIDGE : 1280mm Thick, 13.571m Width, 32m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1	3	0.8	1	13.571	3382.2	0.1747	0.64	1165.4	0.5319
2	3	0.8	0.9	13.571	3382.2	0.1747	0.64	2072.1	0.8511
3	3	0.8	0.8	13.571	3382.2	0.1747	0.64	2859.1	1.0439
4	3	0.8	0.9	13.571	3382.2	0.1747	0.64	2011	0.826
5	3	0.8	0.8	13.571	3382.2	0.1747	0.64	2819.3	1.0293
6	3	0.8	1	13.571	3382.2	0.1747	0.64	1086.7	1.1903
7	3	0.8	1	13.571	3382.2	0.1747	0.64	1003.9	1.0995

TABLE A.41: Fv VALUES FOR 3 LANES BRIDGE 32m LENGTH

3 LANE BRIDGE : 1280mm Thick, 11.101m Width, 32m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	11.101	452.9	155.1	1.584325
2-ULS	3	0.8	0.9	11.101	452.9	208.9	1.920493
3-ULS	3	0.8	0.8	11.101	452.9	196.57	1.606038
4-ULS	3	0.8	0.9	11.101	452.9	196.82	1.80909
5-ULS	3	0.8	0.8	11.101	452.9	184.46	1.507095
6-FLS	3	0.8	1	11.101	452.9	143.02	3.505553
7-FLS	3	0.8	1	11.101	452.9	53.64	1.314766

3 LANE BRIDGE : 1280mm Thick, 12.336m Width, 32m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	12.336	452.9	157.6	1.788616
2-ULS	3	0.8	0.9	12.336	452.9	213.05	2.17613
3-ULS	3	0.8	0.8	12.336	452.9	219.31	1.991174
4-ULS	3	0.8	0.9	12.336	452.9	192.59	1.967148
5-ULS	3	0.8	0.8	12.336	452.9	161.95	1.470387
6-FLS	3	0.8	1	12.336	452.9	137.1	3.73512
7-FLS	3	0.8	1	12.336	452.9	47.9	1.304691

3 LANE BRIDGE : 1280mm Thick, 13.571m Width, 32m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-USL	3	0.8	1	13.571	452.9	159.6	1.992651
2-ULS	3	0.8	0.9	13.571	452.9	214.1	2.406013
3-ULS	3	0.8	0.8	13.571	452.9	199.18	1.989454
4-ULS	3	0.8	0.9	13.571	452.9	184.14	2.069136
5-ULS	3	0.8	0.8	13.571	452.9	169.22	1.690207
6-FLS	3	0.8	1	13.571	452.9	121.72	3.6473
7-FLS	3	0.8	1	13.571	452.9	42.87	1.284585

TABLE A.42: Fd VALUES FOR 3 LANES BRIDGE 32m LENGTH

3 LANE BRIDGE : 1280mm Thick, 11.101m Width, 32m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	11.101	70.31	7.1	1.120994

3 LANE BRIDGE : 1280mm Thick, 12.336m Width, 32m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	12.336	70.31	6.5	1.140435

3 LANE BRIDGE : 1280mm Thick, 13.571m Width, 32m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
6-FLS	3	0.8	1	13.571	70.31	6	1.1581

TABLE A.43: Fm VALUES FOR 4 LANES BRIDGE 16m LENGTH

4 LANE BRIDGE : 650mm Thick, 14.806m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	14.806	1147.2	0.0229	0.325	2132.7	0.692
2-ULS	4	0.7	0.9	14.806	1147.2	0.0229	0.325	3352.3	0.979
3-ULS	4	0.7	0.8	14.806	1147.2	0.0229	0.325	4169.6	1.0824
4-ULS	4	0.7	0.7	14.806	1147.2	0.0229	0.325	4750.6	1.0791
5-ULS	4	0.7	0.9	14.806	1147.2	0.0229	0.325	3499.8	1.0221
6-ULS	4	0.7	0.9	14.806	1147.2	0.0229	0.325	2741.1	0.8005
7-ULS	4	0.7	0.8	14.806	1147.2	0.0229	0.325	4327.7	1.1235
8-ULS	4	0.7	0.7	14.806	1147.2	0.0229	0.325	4957.3	1.1261
9-ULS	4	0.7	0.7	14.806	1147.2	0.0229	0.325	5021.8	1.1407
10-ULS	4	0.7	0.7	14.806	1147.2	0.0229	0.325	5053	1.1478
11-ULS	4	0.7	0.9	14.806	1147.2	0.0229	0.325	2703.1	0.7894
12-FLS	4	0.7	1	14.806	1147.2	0.0229	0.325	1963.2	1.7838
13-FLS	4	0.7	1	14.806	1147.2	0.0229	0.325	1572.7	1.4289

4 LANE BRIDGE : 650mm Thick, 16.041m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	16.041	1147.2	0.0229	0.325	2112.7	0.7428
2-ULS	4	0.7	0.9	16.041	1147.2	0.0229	0.325	3264	1.0328
3-ULS	4	0.7	0.8	16.041	1147.2	0.0229	0.325	3985.3	1.1209
4-ULS	4	0.7	0.7	16.041	1147.2	0.0229	0.325	4498.3	1.107
5-ULS	4	0.7	0.9	16.041	1147.2	0.0229	0.325	3107.4	0.9832
6-ULS	4	0.7	0.9	16.041	1147.2	0.0229	0.325	2598	0.822
7-ULS	4	0.7	0.8	16.041	1147.2	0.0229	0.325	3846.4	1.0818
8-ULS	4	0.7	0.7	16.041	1147.2	0.0229	0.325	4431.6	1.0906
9-ULS	4	0.7	0.7	16.041	1147.2	0.0229	0.325	4480.6	1.1026
10-ULS	4	0.7	0.7	16.041	1147.2	0.0229	0.325	4453.3	1.0959
11-ULS	4	0.7	0.9	16.041	1147.2	0.0229	0.325	2537.3	0.8028
12-FLS	4	0.7	1	16.041	1147.2	0.0229	0.325	1941.6	1.9113
13-FLS	4	0.7	1	16.041	1147.2	0.0229	0.325	1520.7	1.497

4 LANE BRIDGE : 650mm Thick, 17.276m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	17.276	1147.2	0.0229	0.325	2029.2	0.7683
2-ULS	4	0.7	0.9	17.276	1147.2	0.0229	0.325	3179.7	1.0835
3-ULS	4	0.7	0.8	17.276	1147.2	0.0229	0.325	3829.4	1.1599
4-ULS	4	0.7	0.7	17.276	1147.2	0.0229	0.325	4243.2	1.1246
5-ULS	4	0.7	0.9	17.276	1147.2	0.0229	0.325	2952.8	1.0062
6-ULS	4	0.7	0.9	17.276	1147.2	0.0229	0.325	2515.9	0.8573
7-ULS	4	0.7	0.8	17.276	1147.2	0.0229	0.325	3653.8	1.1068
8-ULS	4	0.7	0.7	17.276	1147.2	0.0229	0.325	4098.7	1.0863
9-ULS	4	0.7	0.7	17.276	1147.2	0.0229	0.325	4175.4	1.1066
10-ULS	4	0.7	0.7	17.276	1147.2	0.0229	0.325	4172.6	1.1059
11-ULS	4	0.7	0.9	17.276	1147.2	0.0229	0.325	2424	0.826
12-FLS	4	0.7	1	17.276	1147.2	0.0229	0.325	1797.7	1.9059
13-FLS	4	0.7	1	17.276	1147.2	0.0229	0.325	1453.2	1.5407

TABLE A.44: Fv VALUES FOR 4 LANES BRIDGE 16m LENGTH

4 LANE BRIDGE : 650mm Thick, 14.806m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	14.806	326.8	96.82	1.566617
2-ULS	4	0.7	0.9	14.806	326.8	119.28	1.737032
3-ULS	4	0.7	0.8	14.806	326.8	118.84	1.538333
4-ULS	4	0.7	0.7	14.806	326.8	109.0	1.234362
5-ULS	4	0.7	0.9	14.806	326.8	110.52	1.609463
6-ULS	4	0.7	0.9	14.806	326.8	57.96	0.844051
7-ULS	4	0.7	0.8	14.806	326.8	110.1	1.424809
8-ULS	4	0.7	0.7	14.806	326.8	98.94	1.120644
9-ULS	4	0.7	0.7	14.806	326.8	95.28	1.079189
10-ULS	4	0.7	0.7	14.806	326.8	96.55	1.093574
11-ULS	4	0.7	0.9	14.806	326.8	55.22	0.804149
12-FLS	4	0.7	1	14.806	326.8	74.72	3.385264
13-FLS	4	0.7	1	14.806	326.8	37.18	1.684477

4 LANE BRIDGE : 650mm Thick, 16.041m Width, 16m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	16.041	326.8	97.18	1.703602
2-ULS	4	0.7	0.9	16.041	326.8	117.5	1.853996
3-ULS	4	0.7	0.8	16.041	326.8	115.92	1.625697
4-ULS	4	0.7	0.7	16.041	326.8	106.83	1.310939
5-ULS	4	0.7	0.9	16.041	326.8	95.54	1.507367
6-ULS	4	0.7	0.9	16.041	326.8	57.51	0.907355
7-ULS	4	0.7	0.8	16.041	326.8	93.86	1.316321
8-ULS	4	0.7	0.7	16.041	326.8	83.14	1.020233
9-ULS	4	0.7	0.7	16.041	326.8	77.52	0.951269
10-ULS	4	0.7	0.7	16.041	326.8	79.24	0.972375
11-ULS	4	0.7	0.9	16.041	326.8	50.68	0.799596
12-FLS	4	0.7	1	16.041	326.8	75.13	3.687761
13-FLS	4	0.7	1	16.041	326.8	36.18	1.77590

4 LANE BRIDGE : 650mm Thick, 17.276m Width, 16m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-ULS	4	0.7	1	17.276	326.8	97.45	1.839861
2-ULS	4	0.7	0.9	17.276	326.8	114.93	1.952896
3-ULS	4	0.7	0.8	17.276	326.8	112.62	1.701017
4-ULS	4	0.7	0.7	17.276	326.8	104.44	1.380283
5-ULS	4	0.7	0.9	17.276	326.8	83.62	1.420875
6-ULS	4	0.7	0.9	17.276	326.8	57.47	0.976533
7-ULS	4	0.7	0.8	17.276	326.8	81.29	1.227807
8-ULS	4	0.7	0.7	17.276	326.8	71.03	0.938735
9-ULS	4	0.7	0.7	17.276	326.8	62.33	0.823755
10-ULS	4	0.7	0.7	17.276	326.8	65.9	0.871465
11-ULS	4	0.7	0.9	17.276	326.8	49.4	0.839407
12-FLS	4	0.7	1	17.276	326.8	58.95	3.116341
13-FLS	4	0.7	1	17.276	326.8	36.27	1.917382

TABLE A.45: Fd VALUES FOR 4 LANES BRIDGE 16m LENGTH

4 LANE BRIDGE : 650mm Thick, 14.806m Width, 16m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
12-FLS	4	0.7	1	14.806	43.9	4.9	1.652606

4 LANE BRIDGE : 650mm Thick, 16.041m Width, 16m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
12-FLS	4	0.7	1	16.041	43.9	4.8	1.753913

4 LANE BRIDGE : 650mm Thick, 17.276m Width, 16m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
12-FLS	4	0.7	1	17.276	43.9	4.5	1.770888

TABLE A.46: Fm VALUES FOR 4 LANES BRIDGE 20m LENGTH

4 LANE BRIDGE : 800mm Thick, 14.806m Width, 20m Length

Load Cases	n	R_L	R_L'	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	14.806	1617.9	0.04266	0.4	1728.56	0.60252
2-ULS	4	0.7	0.9	14.806	1617.9	0.04266	0.4	2848.67	0.89366
3-ULS	4	0.7	0.8	14.806	1617.9	0.04266	0.4	3690.74	1.02918
4-ULS	4	0.7	0.7	14.806	1617.9	0.04266	0.4	4356.79	1.06305
5-ULS	4	0.7	0.9	14.806	1617.9	0.04266	0.4	3222.14	1.01082
6-ULS	4	0.7	0.9	14.806	1617.9	0.04266	0.4	2397.32	0.75207
7-ULS	4	0.7	0.8	14.806	1617.9	0.04266	0.4	4066.15	1.13387
8-ULS	4	0.7	0.7	14.806	1617.9	0.04266	0.4	4714.35	1.15029
9-ULS	4	0.7	0.7	14.806	1617.9	0.04266	0.4	4678.22	1.14148
10-ULS	4	0.7	0.7	14.806	1617.9	0.04266	0.4	4699.18	1.14659
11-ULS	4	0.7	0.9	14.806	1617.9	0.04266	0.4	2373.22	0.74451
12-FLS	4	0.7	1	14.806	1617.9	0.04266	0.4	1613.21	1.57448
13-FLS	4	0.7	1	14.806	1617.9	0.04266	0.4	1335.76	1.30369

4 LANE BRIDGE : 800mm Thick, 16.041m Width, 20m Length

Load Cases	n	R_L	R_L'	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	16.041	1617.9	0.04266	0.4	1628.29	0.61491
2-ULS	4	0.7	0.9	16.041	1617.9	0.04266	0.4	2753.95	0.93601
3-ULS	4	0.7	0.8	16.041	1617.9	0.04266	0.4	3513.52	1.06149
4-ULS	4	0.7	0.7	16.041	1617.9	0.04266	0.4	4089.77	1.08113
5-ULS	4	0.7	0.9	16.041	1617.9	0.04266	0.4	2642.41	0.8981
6-ULS	4	0.7	0.9	16.041	1617.9	0.04266	0.4	2262.56	0.769
7-ULS	4	0.7	0.8	16.041	1617.9	0.04266	0.4	3412.31	1.03091
8-ULS	4	0.7	0.7	16.041	1617.9	0.04266	0.4	4027.45	1.06466
9-ULS	4	0.7	0.7	16.041	1617.9	0.04266	0.4	4061.16	1.07357
10-ULS	4	0.7	0.7	16.041	1617.9	0.04266	0.4	4007.47	1.05938
11-ULS	4	0.7	0.9	16.041	1617.9	0.04266	0.4	2205.38	0.74956
12-FLS	4	0.7	1	16.041	1617.9	0.04266	0.4	1581.36	1.67214
13-FLS	4	0.7	1	16.041	1617.9	0.04266	0.4	1278.96	1.35238

4 LANE BRIDGE : 800mm Thick, 17.276m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	17.276	1617.9	0.04266	0.4	1676.18	0.68173
2-ULS	4	0.7	0.9	17.276	1617.9	0.04266	0.4	2669.2	0.97705
3-ULS	4	0.7	0.8	17.276	1617.9	0.04266	0.4	3356.61	1.09216
4-ULS	4	0.7	0.7	17.276	1617.9	0.04266	0.4	3905.35	1.11187
5-ULS	4	0.7	0.9	17.276	1617.9	0.04266	0.4	2507.11	0.91772
6-ULS	4	0.7	0.9	17.276	1617.9	0.04266	0.4	2154.28	0.78857
7-ULS	4	0.7	0.8	17.276	1617.9	0.04266	0.4	3209.07	1.04415
8-ULS	4	0.7	0.7	17.276	1617.9	0.04266	0.4	3894.08	1.10866
9-ULS	4	0.7	0.7	17.276	1617.9	0.04266	0.4	3942.49	1.12244
10-ULS	4	0.7	0.7	17.276	1617.9	0.04266	0.4	3809.13	1.08447
11-ULS	4	0.7	0.9	17.276	1617.9	0.04266	0.4	2098.05	0.76798
12-FLS	4	0.7	1	17.276	1617.9	0.04266	0.4	1468.11	1.6719
13-FLS	4	0.7	1	17.276	1617.9	0.04266	0.4	1213.95	1.38246

TABLE A.47: Fv VALUES FOR 4 LANES BRIDGE 20m LENGTH

4 LANE BRIDGE : 800mm Thick, 14.806m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	14.806	349.7	106.86	1.615843
2-ULS	4	0.7	0.9	14.806	349.7	142.28	1.93629
3-ULS	4	0.7	0.8	14.806	349.7	145.21	1.756591
4-ULS	4	0.7	0.7	14.806	349.7	130.8	1.384278
5-ULS	4	0.7	0.9	14.806	349.7	147.34	2.005152
6-ULS	4	0.7	0.9	14.806	349.7	44.89	0.610909
7-ULS	4	0.7	0.8	14.806	349.7	150.3	1.817559
8-ULS	4	0.7	0.7	14.806	349.7	133.72	1.415398
9-ULS	4	0.7	0.7	14.806	349.7	128.39	1.358981
10-ULS	4	0.7	0.7	14.806	349.7	131.09	1.38756
11-ULS	4	0.7	0.9	14.806	349.7	43.86	0.596891
12-FLS	4	0.7	1	14.806	349.7	89.73	3.799092
13-FLS	4	0.7	1	14.806	349.7	30.68	1.298965

4 LANE BRIDGE : 800mm Thick, 16.041m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	16.041	349.7	107.54	1.761764
2-ULS	4	0.7	0.9	16.041	349.7	140.6	2.072883
3-ULS	4	0.7	0.8	16.041	349.7	144.56	1.894593
4-ULS	4	0.7	0.7	16.041	349.7	128.5	1.473254
5-ULS	4	0.7	0.9	16.041	349.7	123.53	1.8213
6-ULS	4	0.7	0.9	16.041	349.7	27.2	0.401189
7-ULS	4	0.7	0.8	16.041	349.7	125.06	1.639027
8-ULS	4	0.7	0.7	16.041	349.7	106.6	1.222341
9-ULS	4	0.7	0.7	16.041	349.7	99.16	1.137136
10-ULS	4	0.7	0.7	16.041	349.7	126.86	1.454791
11-ULS	4	0.7	0.9	16.041	349.7	41.09	0.605838
12-FLS	4	0.7	1	16.041	349.7	90.47	4.149926
13-FLS	4	0.7	1	16.041	349.7	28.7	1.31557

4 LANE BRIDGE : 800mm Thick, 17.276m Width, 20m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	17.276	349.7	108.14	1.907989
2-ULS	4	0.7	0.9	17.276	349.7	137.76	2.187536
3-ULS	4	0.7	0.8	17.276	349.7	137.9	1.94617
4-ULS	4	0.7	0.7	17.276	349.7	128.26	1.584086
5-ULS	4	0.7	0.9	17.276	349.7	112.57	1.787536
6-ULS	4	0.7	0.9	17.276	349.7	43.84	0.69615
7-ULS	4	0.7	0.8	17.276	349.7	112.57	1.588921
8-ULS	4	0.7	0.7	17.276	349.7	98.29	1.213939
9-ULS	4	0.7	0.7	17.276	349.7	90.3	1.114764
10-ULS	4	0.7	0.7	17.276	349.7	94.0	1.161202
11-ULS	4	0.7	0.9	17.276	349.7	39.86	0.63295
12-FLS	4	0.7	1	17.276	349.7	76.51	3.779773
13-FLS	4	0.7	1	17.276	349.7	23.26	1.149099

TABLE A.48: Fd VALUES FOR 4 LANES BRIDGE 20m LENGTH

4 LANE BRIDGE : 800mm Thick, 14.806m Width, 20m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
12-FLS	4	0.7	1	14.806	52.6	5.3	1.491859

4 LANE BRIDGE : 800mm Thick, 16.041m Width, 20m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
12-FLS	4	0.7	1	16.041	52.6	5.1	1.555306

4 LANE BRIDGE : 800mm Thick, 17.276m Width, 20m Length

Load Cases	n	RL	RL'	B	DT	Dmax	Fd
12-FLS	4	0.7	1	17.276	52.6	4.8	1.576517

TABLE A.49: Fm VALUES FOR 4 LANES BRIDGE 24m LENGTH

4 LANE BRIDGE : 960mm Thick, 14.806m Width, 24m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1-ULS	4	0.7	1	14.806	2113.9	0.0737	0.48	1431.4	0.55
2-ULS	4	0.7	0.9	14.806	2113.9	0.0737	0.48	2439.7	0.8437
3-ULS	4	0.7	0.8	14.806	2113.9	0.0737	0.48	3251.7	0.9995
4-ULS	4	0.7	0.7	14.806	2113.9	0.0737	0.48	3934.7	1.0583
5-ULS	4	0.7	0.9	14.806	2113.9	0.0737	0.48	2392.2	0.8272
6-ULS	4	0.7	0.9	14.806	2113.9	0.0737	0.48	2109.8	0.7296
7-ULS	4	0.7	0.8	14.806	2113.9	0.0737	0.48	3208	0.9861
8-ULS	4	0.7	0.7	14.806	2113.9	0.0737	0.48	3888.7	1.0459
9-ULS	4	0.7	0.7	14.806	2113.9	0.0737	0.48	3902.6	1.0497
10-ULS	4	0.7	0.7	14.806	2113.9	0.0737	0.48	3886.3	1.0453
11-ULS	4	0.7	0.9	14.806	2113.9	0.0737	0.48	2093.5	0.7239
12-FLS	4	0.7	1	14.806	2113.9	0.0737	0.48	1350.4	1.4529
13-FLS	4	0.7	1	14.806	2113.9	0.0737	0.48	1151.4	1.2388

4 LANE BRIDGE : 960mm Thick, 16.041m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	16.041	2113.9	0.0737	0.48	1395.1	0.5808
2-ULS	4	0.7	0.9	16.041	2113.9	0.0737	0.48	2342.7	0.8777
3-ULS	4	0.7	0.8	16.041	2113.9	0.0737	0.48	3080.2	1.0258
4-ULS	4	0.7	0.7	16.041	2113.9	0.0737	0.48	3681.5	1.0728
5-ULS	4	0.7	0.9	16.041	2113.9	0.0737	0.48	2251.2	0.8434
6-ULS	4	0.7	0.9	16.041	2113.9	0.0737	0.48	1980.2	0.7419
7-ULS	4	0.7	0.8	16.041	2113.9	0.0737	0.48	2998.2	0.9985
8-ULS	4	0.7	0.7	16.041	2113.9	0.0737	0.48	3608.5	1.0515
9-ULS	4	0.7	0.7	16.041	2113.9	0.0737	0.48	3631.3	1.0582
10-ULS	4	0.7	0.7	16.041	2113.9	0.0737	0.48	3609.4	1.0518
11-ULS	4	0.7	0.9	16.041	2113.9	0.0737	0.48	1949.2	0.7303
12-FLS	4	0.7	1	16.041	2113.9	0.0737	0.48	1276.4	1.4878
13-FLS	4	0.7	1	16.041	2113.9	0.0737	0.48	1094.6	1.2759

4 LANE BRIDGE : 960mm Thick, 17.276m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	17.276	2113.9	0.0737	0.48	1367.4	0.613
2-ULS	4	0.7	0.9	17.276	2113.9	0.0737	0.48	2258.3	0.9112
3-ULS	4	0.7	0.8	17.276	2113.9	0.0737	0.48	2930.9	1.0512
4-ULS	4	0.7	0.7	17.276	2113.9	0.0737	0.48	3464.1	1.0872
5-ULS	4	0.7	0.9	17.276	2113.9	0.0737	0.48	2141.4	0.8641
6-ULS	4	0.7	0.9	17.276	2113.9	0.0737	0.48	1876.8	0.7573
7-ULS	4	0.7	0.8	17.276	2113.9	0.0737	0.48	2822.9	1.0125
8-ULS	4	0.7	0.7	17.276	2113.9	0.0737	0.48	3360.1	1.0545
9-ULS	4	0.7	0.7	17.276	2113.9	0.0737	0.48	3396.1	1.0658
10-ULS	4	0.7	0.7	17.276	2113.9	0.0737	0.48	3378.3	1.0602
11-ULS	4	0.7	0.9	17.276	2113.9	0.0737	0.48	1839	0.742
12-FLS	4	0.7	1	17.276	2113.9	0.0737	0.48	1220.2	1.5318
13-FLS	4	0.7	1	17.276	2113.9	0.0737	0.48	1034.1	1.2982

TABLE A.50: Fv VALUES FOR 4 LANES BRIDGE 24m LENGTH

4 LANE BRIDGE : 960mm Thick, 14.806m Width, 24m Length

Load Cases	n	R_L	R_L'	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	14.806	395.6	146.15	1.95354
2-ULS	4	0.7	0.9	14.806	395.6	193.36	2.326122
3-ULS	4	0.7	0.8	14.806	395.6	200.56	2.144656
4-ULS	4	0.7	0.7	14.806	395.6	182.1	1.703944
5-ULS	4	0.7	0.9	14.806	395.6	167.47	2.014666
6-ULS	4	0.7	0.9	14.806	395.6	81.65	0.98225
7-ULS	4	0.7	0.8	14.806	395.6	174.7	1.867592
8-ULS	4	0.7	0.7	14.806	395.6	153.24	1.433817
9-ULS	4	0.7	0.7	14.806	395.6	147.92	1.384039
10-ULS	4	0.7	0.7	14.806	395.6	150.88	1.411735
11-ULS	4	0.7	0.9	14.806	395.6	78.05	0.938942
12-FLS	4	0.7	1	14.806	395.6	105.31	3.941405
13-FLS	4	0.7	1	14.806	395.6	60.27	2.255707

4 LANE BRIDGE : 960mm Thick, 16.041m Width, 24m Length

Load Cases	n	R_L	R_L'	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	16.041	395.6	147.11	2.130391
2-ULS	4	0.7	0.9	16.041	395.6	192.2	2.505161
3-ULS	4	0.7	0.8	16.041	395.6	197.81	2.291687
4-ULS	4	0.7	0.7	16.041	395.6	180.0	1.824988
5-ULS	4	0.7	0.9	16.041	395.6	143.73	1.8733
6-ULS	4	0.7	0.9	16.041	395.6	88.03	1.147335
7-ULS	4	0.7	0.8	16.041	395.6	149.31	1.7298
8-ULS	4	0.7	0.7	16.041	395.6	126.5	1.281942
9-ULS	4	0.7	0.7	16.041	395.6	117.89	1.195067
10-ULS	4	0.7	0.7	16.041	395.6	122.98	1.246665
11-ULS	4	0.7	0.9	16.041	395.6	73.31	0.955483
12-FLS	4	0.7	1	16.041	395.6	95.06	3.854544
13-FLS	4	0.7	1	16.041	395.6	57.1	2.31329

4 LANE BRIDGE : 960mm Thick, 17.276m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	17.276	395.6	147.91	2.306888
2-ULS	4	0.7	0.9	17.276	395.6	189.67	2.66238
3-ULS	4	0.7	0.8	17.276	395.6	193.58	2.415346
4-ULS	4	0.7	0.7	17.276	395.6	176.83	1.930558
5-ULS	4	0.7	0.9	17.276	395.6	137.27	1.926846
6-ULS	4	0.7	0.9	17.276	395.6	80.53	1.130392
7-ULS	4	0.7	0.8	17.276	395.6	141.18	1.761538
8-ULS	4	0.7	0.7	17.276	395.6	118.47	1.293407
9-ULS	4	0.7	0.7	17.276	395.6	106.8	1.165562
10-ULS	4	0.7	0.7	17.276	395.6	112.7	1.230522
11-ULS	4	0.7	0.9	17.276	395.6	71.62	1.005323
12-FLS	4	0.7	1	17.276	395.6	88.64	3.870942
13-FLS	4	0.7	1	17.276	395.6	56.34	2.460389

TABLE A.51: Fd VALUES FOR 4 LANES BRIDGE 24m LENGTH

4 LANE BRIDGE : 960mm Thick, 14.806m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
12-FLS	4	0.7	1	14.806	58.96	5.4	1.356045

4 LANE BRIDGE : 960mm Thick, 16.041m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
12-FLS	4	0.7	1	16.041	58.96	5.1	1.387536

4 LANE BRIDGE : 960mm Thick, 17.276m Width, 24m Length

Load Cases	n	R_L	$R_{L'}$	B	D_T	Dmax	Fd
12-FLS	4	0.7	1	17.276	58.96	4.9	1.43576

TABLE A.52: Fm VALUES FOR 4 LANES BRIDGE 26m LENGTH

4 LANE BRIDGE : 1040mm Thick, 14.806m Width, 26m Length

Load Cases	n	R_L	R_L'	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	14.806	2415.8	0.0937	0.520	1335.8	0.5271
2-ULS	4	0.7	0.9	14.806	2415.8	0.0937	0.520	2311.1	0.8207
3-ULS	4	0.7	0.8	14.806	2415.8	0.0937	0.520	3118.3	0.9844
4-ULS	4	0.7	0.7	14.806	2415.8	0.0937	0.520	3813.3	1.0533
5-ULS	4	0.7	0.9	14.806	2415.8	0.0937	0.520	2270.2	0.8062
6-ULS	4	0.7	0.9	14.806	2415.8	0.0937	0.520	2024.5	0.7189
7-ULS	4	0.7	0.8	14.806	2415.8	0.0937	0.520	3080.5	0.9724
8-ULS	4	0.7	0.7	14.806	2415.8	0.0937	0.520	3771.3	1.0417
9-ULS	4	0.7	0.7	14.806	2415.8	0.0937	0.520	3783.2	1.045
10-ULS	4	0.7	0.7	14.806	2415.8	0.0937	0.520	3767	1.0405
11-ULS	4	0.7	0.9	14.806	2415.8	0.0937	0.520	2010.7	0.714
12-FLS	4	0.7	1	14.806	2415.8	0.0937	0.520	1266.6	1.3994
13-FLS	4	0.7	1	14.806	2415.8	0.0937	0.520	1094.9	1.2097

4 LANE BRIDGE : 1040mm Thick, 16.041m Width, 26m Length

Load Cases	n	R_L	R_L'	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	16.041	2415.8	0.0937	0.520	1296.8	0.5544
2-ULS	4	0.7	0.9	16.041	2415.8	0.0937	0.520	2212.1	0.8511
3-ULS	4	0.7	0.8	16.041	2415.8	0.0937	0.520	2947	1.0079
4-ULS	4	0.7	0.7	16.041	2415.8	0.0937	0.520	3596.2	1.0762
5-ULS	4	0.7	0.9	16.041	2415.8	0.0937	0.520	2143	0.8245
6-ULS	4	0.7	0.9	16.041	2415.8	0.0937	0.520	1895.8	0.7294
7-ULS	4	0.7	0.8	16.041	2415.8	0.0937	0.520	2883	0.986
8-ULS	4	0.7	0.7	16.041	2415.8	0.0937	0.520	3579.1	1.071
9-ULS	4	0.7	0.7	16.041	2415.8	0.0937	0.520	3599.4	1.0771
10-ULS	4	0.7	0.7	16.041	2415.8	0.0937	0.520	3517.8	1.0527
11-ULS	4	0.7	0.9	16.041	2415.8	0.0937	0.520	1879.7	0.7232
12-FLS	4	0.7	1	16.041	2415.8	0.0937	0.520	1226.4	1.4679
13-FLS	4	0.7	1	16.041	2415.8	0.0937	0.520	1037.6	1.242

4 LANE BRIDGE : 1040mm Thick, 17.276m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	17.276	2415.8	0.0937	0.520	1266.4	0.5831
2-ULS	4	0.7	0.9	17.276	2415.8	0.0937	0.520	2126.5	0.8812
3-ULS	4	0.7	0.8	17.276	2415.8	0.0937	0.520	2798.6	1.0308
4-ULS	4	0.7	0.7	17.276	2415.8	0.0937	0.520	3348.2	1.0791
5-ULS	4	0.7	0.9	17.276	2415.8	0.0937	0.520	2025.4	0.8393
6-ULS	4	0.7	0.9	17.276	2415.8	0.0937	0.520	1792	0.7425
7-ULS	4	0.7	0.8	17.276	2415.8	0.0937	0.520	2704.7	0.9962
8-ULS	4	0.7	0.7	17.276	2415.8	0.0937	0.520	3254.8	1.049
9-ULS	4	0.7	0.7	17.276	2415.8	0.0937	0.520	3258.7	1.0502
10-ULS	4	0.7	0.7	17.276	2415.8	0.0937	0.520	3267	1.0529
11-ULS	4	0.7	0.9	17.276	2415.8	0.0937	0.520	1760.4	0.7294
12-FLS	4	0.7	1	17.276	2415.8	0.0937	0.520	1140.2	1.4699
13-FLS	4	0.7	1	17.276	2415.8	0.0937	0.520	978.35	1.2612

TABLE A.53: Fv VALUES FOR 4 LANES BRIDGE 26m LENGTH

4 LANE BRIDGE : 1040mm Thick, 14.806m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	14.806	413.3	150.69	1.927963
2-ULS	4	0.7	0.9	14.806	413.3	204.8	2.357888
3-ULS	4	0.7	0.8	14.806	413.3	213.96	2.189964
4-ULS	4	0.7	0.7	14.806	413.3	193.1	1.729665
5-ULS	4	0.7	0.9	14.806	413.3	188.55	2.171118
6-ULS	4	0.7	0.9	14.806	413.3	69.7	0.802813
7-ULS	4	0.7	0.8	14.806	413.3	197.75	2.024048
8-ULS	4	0.7	0.7	14.806	413.3	173.5	1.553681
9-ULS	4	0.7	0.7	14.806	413.3	167.59	1.50093
10-ULS	4	0.7	0.7	14.806	413.3	171.02	1.531649
11-ULS	4	0.7	0.9	14.806	413.3	66.75	0.768614
12-FLS	4	0.7	1	14.806	413.3	123.36	4.419231
13-FLS	4	0.7	1	14.806	413.3	44.1	1.580549

4 LANE BRIDGE : 1040mm Thick, 16.041m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	16.041	413.3	151.79	2.104026
2-ULS	4	0.7	0.9	16.041	413.3	203.7	2.541465
3-ULS	4	0.7	0.8	16.041	413.3	211.28	2.342914
4-ULS	4	0.7	0.7	16.041	413.3	199.1	1.93177
5-ULS	4	0.7	0.9	16.041	413.3	176.58	2.2029
6-ULS	4	0.7	0.9	16.041	413.3	70.3	0.877512
7-ULS	4	0.7	0.8	16.041	413.3	184.13	2.041844
8-ULS	4	0.7	0.7	16.041	413.3	166.1	1.611183
9-ULS	4	0.7	0.7	16.041	413.3	156.6	1.519102
10-ULS	4	0.7	0.7	16.041	413.3	162.46	1.576349
11-ULS	4	0.7	0.9	16.041	413.3	61.61	0.768602
12-FLS	4	0.7	1	16.041	413.3	124.65	4.837916
13-FLS	4	0.7	1	16.041	413.3	46.4	1.80243

4 LANE BRIDGE : 1040mm Thick, 17.276m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	17.276	413.3	152.74	2.280198
2-ULS	4	0.7	0.9	17.276	413.3	201.16	2.702738
3-ULS	4	0.7	0.8	17.276	413.3	206.9	2.471344
4-ULS	4	0.7	0.7	17.276	413.3	187.86	1.963144
5-ULS	4	0.7	0.9	17.276	413.3	162.67	2.185595
6-ULS	4	0.7	0.9	17.276	413.3	68.37	0.918603
7-ULS	4	0.7	0.8	17.276	413.3	168.44	2.011662
8-ULS	4	0.7	0.7	17.276	413.3	142.38	1.487876
9-ULS	4	0.7	0.7	17.276	413.3	129.4	1.352339
10-ULS	4	0.7	0.7	17.276	413.3	136.4	1.42528
11-ULS	4	0.7	0.9	17.276	413.3	60.21	0.808967
12-FLS	4	0.7	1	17.276	413.3	105.5	4.409915
13-FLS	4	0.7	1	17.276	413.3	42.21	1.764384

TABLE A.54: Fd VALUES FOR 4 LANES BRIDGE 26m LENGTH

4 LANE BRIDGE : 1040mm Thick, 14.806m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	DT	Dmax	Fd
12-FLS	4	0.7	1	14.806	62.54	5.5	1.302095

4 LANE BRIDGE : 1040mm Thick, 16.041m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	DT	Dmax	Fd
12-FLS	4	0.7	1	16.041	62.54	5.3	1.359407

4 LANE BRIDGE : 1040mm Thick, 17.276m Width, 26m Length

Load Cases	n	R_L	$R_{L'}$	B	DT	Dmax	Fd
12-FLS	4	0.7	1	17.276	62.54	5	1.381196

TABLE A.55: Fm VALUES FOR 4 LANES BRIDGE 30m LENGTH

4 LANE BRIDGE : 1200mm Thick, 14.806m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	14.806	3025.0	0.144	0.6	1177.5	0.494
2-ULS	4	0.7	0.9	14.806	3025.0	0.144	0.6	2084.5	0.7871
3-ULS	4	0.7	0.8	14.806	3025.0	0.144	0.6	2864.7	0.9615
4-ULS	4	0.7	0.7	14.806	3025.0	0.144	0.6	3558.9	1.0451
5-ULS	4	0.7	0.9	14.806	3025.0	0.144	0.6	2053.4	0.7753
6-ULS	4	0.7	0.9	14.806	3025.0	0.144	0.6	1864.8	0.7041
7-ULS	4	0.7	0.8	14.806	3025.0	0.144	0.6	2835.8	0.9518
8-ULS	4	0.7	0.7	14.806	3025.0	0.144	0.6	3524.9	1.0352
9-ULS	4	0.7	0.7	14.806	3025.0	0.144	0.6	3534.5	1.038
10-ULS	4	0.7	0.7	14.806	3025.0	0.144	0.6	3519.5	1.0336
11-ULS	4	0.7	0.9	14.806	3025.0	0.144	0.6	1854.5	0.7002
12-FLS	4	0.7	1	14.806	3025.0	0.144	0.6	1125.3	1.3219
13-FLS	4	0.7	1	14.806	3025.0	0.144	0.6	994.84	1.1686

4 LANE BRIDGE : 1200mm Thick, 16.041m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	16.041	3025.0	0.144	0.6	1003.9	0.4563
2-ULS	4	0.7	0.9	16.041	3025.0	0.144	0.6	1721.3	0.7041
3-ULS	4	0.7	0.8	16.041	3025.0	0.144	0.6	2300.9	0.8367
4-ULS	4	0.7	0.7	16.041	3025.0	0.144	0.6	2792.9	0.8886
5-ULS	4	0.7	0.9	16.041	3025.0	0.144	0.6	1669.3	0.6829
6-ULS	4	0.7	0.9	16.041	3025.0	0.144	0.6	1479.2	0.6051
7-ULS	4	0.7	0.8	16.041	3025.0	0.144	0.6	2252.7	0.8191
8-ULS	4	0.7	0.7	16.041	3025.0	0.144	0.6	2742.5	0.8726
9-ULS	4	0.7	0.7	16.041	3025.0	0.144	0.6	2757.9	0.8775
10-ULS	4	0.7	0.7	16.041	3025.0	0.144	0.6	2738.2	0.8712
11-ULS	4	0.7	0.9	16.041	3025.0	0.144	0.6	1463.2	0.5986
12-FLS	4	0.7	1	16.041	3025.0	0.144	0.6	950.97	1.2103
13-FLS	4	0.7	1	16.041	3025.0	0.144	0.6	808.87	1.0294

4 LANE BRIDGE : 1200mm Thick, 17.276m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	17.276	3025.0	0.144	0.6	1101.7	0.5393
2-ULS	4	0.7	0.9	17.276	3025.0	0.144	0.6	1898.3	0.8363
3-ULS	4	0.7	0.8	17.276	3025.0	0.144	0.6	2552.7	0.9997
4-ULS	4	0.7	0.7	17.276	3025.0	0.144	0.6	3111.8	1.0663
5-ULS	4	0.7	0.9	17.276	3025.0	0.144	0.6	1821.3	0.8024
6-ULS	4	0.7	0.9	17.276	3025.0	0.144	0.6	1639.1	0.7221
7-ULS	4	0.7	0.8	17.276	3025.0	0.144	0.6	2480.4	0.9714
8-ULS	4	0.7	0.7	17.276	3025.0	0.144	0.6	3047	1.0441
9-ULS	4	0.7	0.7	17.276	3025.0	0.144	0.6	3060.4	1.0487
10-ULS	4	0.7	0.7	17.276	3025.0	0.144	0.6	3042.9	1.0427
11-ULS	4	0.7	0.9	17.276	3025.0	0.144	0.6	1615.9	0.7119
12-FLS	4	0.7	1	17.276	3025.0	0.144	0.6	1006.4	1.3794
13-FLS	4	0.7	1	17.276	3025.0	0.144	0.6	882.12	1.2091

TABLE A.56: Fv VALUES FOR 4 LANES BRIDGE 30m LENGTH

4 LANE BRIDGE : 1200mm Thick, 14.806m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	14.806	441.5	159.1	1.904946
2-ULS	4	0.7	0.9	14.806	441.5	225.6	2.432031
3-ULS	4	0.7	0.8	14.806	441.5	239.02	2.290199
4-ULS	4	0.7	0.7	14.806	441.5	214.2	1.796087
5-ULS	4	0.7	0.9	14.806	441.5	213.51	2.301493
6-ULS	4	0.7	0.9	14.806	441.5	73.2	0.788508
7-ULS	4	0.7	0.8	14.806	441.5	226.91	2.174166
8-ULS	4	0.7	0.7	14.806	441.5	198.0	1.659597
9-ULS	4	0.7	0.7	14.806	441.5	197.71	1.657585
10-ULS	4	0.7	0.7	14.806	441.5	195.32	1.637547
11-ULS	4	0.7	0.9	14.806	441.5	79.95	0.861807
12-FLS	4	0.7	1	14.806	441.5	137.96	4.626582
13-FLS	4	0.7	1	14.806	441.5	59.7	2.001409

4 LANE BRIDGE : 1200mm Thick, 16.041m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	16.041	441.5	146.25	1.897748
2-ULS	4	0.7	0.9	16.041	441.5	202.4	2.363485
3-ULS	4	0.7	0.8	16.041	441.5	210.59	2.186102
4-ULS	4	0.7	0.7	16.041	441.5	189.2	1.718095
5-ULS	4	0.7	0.9	16.041	441.5	182.55	2.1319
6-ULS	4	0.7	0.9	16.041	441.5	54.3	0.634373
7-ULS	4	0.7	0.8	16.041	441.5	190.75	1.980146
8-ULS	4	0.7	0.7	16.041	441.5	163.7	1.486654
9-ULS	4	0.7	0.7	16.041	441.5	153.7	1.39573
10-ULS	4	0.7	0.7	16.041	441.5	154.45	1.402906
11-ULS	4	0.7	0.9	16.041	441.5	64.34	0.751391
12-FLS	4	0.7	1	16.041	441.5	126.41	4.592849
13-FLS	4	0.7	1	16.041	441.5	50.4	1.83191

4 LANE BRIDGE : 1200mm Thick, 17.276m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	V_T	Vmax	Fv
1-ULS	4	0.7	1	17.276	441.5	161.58	2.258094
2-ULS	4	0.7	0.9	17.276	441.5	222.46	2.798008
3-ULS	4	0.7	0.8	17.276	441.5	232.3	2.597465
4-ULS	4	0.7	0.7	17.276	441.5	209.37	2.048174
5-ULS	4	0.7	0.9	17.276	441.5	191.74	2.411625
6-ULS	4	0.7	0.9	17.276	441.5	55.65	0.699942
7-ULS	4	0.7	0.8	17.276	441.5	204.06	2.281405
8-ULS	4	0.7	0.7	17.276	441.5	169.74	1.660492
9-ULS	4	0.7	0.7	17.276	441.5	154.7	1.512873
10-ULS	4	0.7	0.7	17.276	441.5	163.6	1.600231
11-ULS	4	0.7	0.9	17.276	441.5	50.4	0.63391
12-FLS	4	0.7	1	17.276	441.5	122.95	4.811063
13-FLS	4	0.7	1	17.276	441.5	51.08	1.998773

TABLE A.57: Fd VALUES FOR 4 LANES BRIDGE 30m LENGTH

4 LANE BRIDGE : 1200mm Thick, 14.806m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	DT	Dmax	Fd
12-FLS	4	0.7	1	14.806	68.09	5.7	1.239451

4 LANE BRIDGE : 1200mm Thick, 16.041m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	DT	Dmax	Fd
12-FLS	4	0.7	1	16.041	68.09	4.2	0.989458

4 LANE BRIDGE : 1200mm Thick, 17.276m Width, 30m Length

Load Cases	n	R_L	$R_{L'}$	B	DT	Dmax	Fd
12-FLS	4	0.7	1	17.276	68.09	5.1	1.293987

TABLE A.58: Fm VALUES FOR 4 LANES BRIDGE 32m LENGTH

4 LANE BRIDGE : 1280mm Thick, 14.806m Width, 32m Length

Load Cases	n	R_L	R_L'	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	14.806	3382.2	0.1747	0.640	1111.5	0.4743
2-ULS	4	0.7	0.9	14.806	3382.2	0.1747	0.640	1985.4	0.7626
3-ULS	4	0.7	0.8	14.806	3382.2	0.1747	0.640	2747.8	0.9381
4-ULS	4	0.7	0.7	14.806	3382.2	0.1747	0.640	3473.9	1.0378
5-ULS	4	0.7	0.9	14.806	3382.2	0.1747	0.640	1958	0.7521
6-ULS	4	0.7	0.9	14.806	3382.2	0.1747	0.640	1791.2	0.688
7-ULS	4	0.7	0.8	14.806	3382.2	0.1747	0.640	2722.3	0.9294
8-ULS	4	0.7	0.7	14.806	3382.2	0.1747	0.640	3443.7	1.0288
9-ULS	4	0.7	0.7	14.806	3382.2	0.1747	0.640	3447.7	1.0299
10-ULS	4	0.7	0.7	14.806	3382.2	0.1747	0.640	3438.1	1.0271
11-ULS	4	0.7	0.9	14.806	3382.2	0.1747	0.640	1728.2	0.6638
12-FLS	4	0.7	1	14.806	3382.2	0.1747	0.640	1065.6	1.2734
13-FLS	4	0.7	1	14.806	3382.2	0.1747	0.640	950.62	1.1359

4 LANE BRIDGE : 1280mm Thick, 16.041m Width, 32m Length

Load Cases	n	R_L	R_L'	B	M_T	I	y	Smax	Fm
1-ULS	4	0.7	1	16.041	3382.2	0.1747	0.640	1068.5	0.494
2-ULS	4	0.7	0.9	16.041	3382.2	0.1747	0.640	1885.7	0.7847
3-ULS	4	0.7	0.8	16.041	3382.2	0.1747	0.640	2581	0.9547
4-ULS	4	0.7	0.7	16.041	3382.2	0.1747	0.640	3194.9	1.034
5-ULS	4	0.7	0.9	16.041	3382.2	0.1747	0.640	1839.4	0.7654
6-ULS	4	0.7	0.9	16.041	3382.2	0.1747	0.640	1667	0.6937
7-ULS	4	0.7	0.8	16.041	3382.2	0.1747	0.640	2537.6	0.9387
8-ULS	4	0.7	0.7	16.041	3382.2	0.1747	0.640	3147.1	1.0186
9-ULS	4	0.7	0.7	16.041	3382.2	0.1747	0.640	3158.8	1.0224
10-ULS	4	0.7	0.7	16.041	3382.2	0.1747	0.640	3139.9	1.0163
11-ULS	4	0.7	0.9	16.041	3382.2	0.1747	0.640	1653.3	0.688
12-FLS	4	0.7	1	16.041	3382.2	0.1747	0.640	1021.9	1.323
13-FLS	4	0.7	1	16.041	3382.2	0.1747	0.640	894.99	1.1587

4 LANE BRIDGE : 1280mm Thick, 17.276m Width, 32m Length

Load Cases	n	RL	RL'	B	MT	I	y	Smax	Fm
1-ULS	4	0.7	1	17.276	3382.2	0.1747	0.640	1034.1	0.5149
2-ULS	4	0.7	0.9	17.276	3382.2	0.1747	0.640	1800.3	0.8069
3-ULS	4	0.7	0.8	17.276	3382.2	0.1747	0.640	2441.3	0.9725
4-ULS	4	0.7	0.7	17.276	3382.2	0.1747	0.640	2995.9	1.0443
5-ULS	4	0.7	0.9	17.276	3382.2	0.1747	0.640	1732.4	0.7764
6-ULS	4	0.7	0.9	17.276	3382.2	0.1747	0.640	1570.6	0.7039
7-ULS	4	0.7	0.8	17.276	3382.2	0.1747	0.640	2377.3	0.9471
8-ULS	4	0.7	0.7	17.276	3382.2	0.1747	0.640	2928.8	1.0209
9-ULS	4	0.7	0.7	17.276	3382.2	0.1747	0.640	2947.5	1.0274
10-ULS	4	0.7	0.7	17.276	3382.2	0.1747	0.640	2932.3	1.0221
11-ULS	4	0.7	0.9	17.276	3382.2	0.1747	0.640	1550.3	0.6948
12-FLS	4	0.7	1	17.276	3382.2	0.1747	0.640	950.26	1.3249
13-FLS	4	0.7	1	17.276	3382.2	0.1747	0.640	840.44	1.1718

TABLE A.59: Fv VALUES FOR 4 LANES BRIDGE 32m LENGTH

4 LANE BRIDGE : 1280mm Thick, 14.806m Width, 32m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-ULS	4	0.7	1	14.806	452.9	158.9	1.854778
2-ULS	4	0.7	0.9	14.806	452.9	233.1	2.448994
3-ULS	4	0.7	0.8	14.806	452.9	248.55	2.321567
4-ULS	4	0.7	0.7	14.806	452.9	247.6	2.023198
5-ULS	4	0.7	0.9	14.806	452.9	222	2.332775
6-ULS	4	0.7	0.9	14.806	452.9	80.2	0.842636
7-ULS	4	0.7	0.8	14.806	452.9	237.49	2.218261
8-ULS	4	0.7	0.7	14.806	452.9	231.9	1.89521
9-ULS	4	0.7	0.7	14.806	452.9	224.86	1.837755
10-ULS	4	0.7	0.7	14.806	452.9	229.46	1.87535
11-ULS	4	0.7	0.9	14.806	452.9	75.59	0.794299
12-FLS	4	0.7	1	14.806	452.9	141.93	4.639911
13-FLS	4	0.7	1	14.806	452.9	64.7	2.114816

4 LANE BRIDGE : 1280mm Thick, 16.041m Width, 32m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-ULS	4	0.7	1	16.041	452.9	162.78	2.059075
2-ULS	4	0.7	0.9	16.041	452.9	232.6	2.648488
3-ULS	4	0.7	0.8	16.041	452.9	245.6	2.485158
4-ULS	4	0.7	0.7	16.041	452.9	220.0	1.94819
5-ULS	4	0.7	0.9	16.041	452.9	213.56	2.43127
6-ULS	4	0.7	0.9	16.041	452.9	71.4	0.81262
7-ULS	4	0.7	0.8	16.041	452.9	276.33	2.796334
8-ULS	4	0.7	0.7	16.041	452.9	236.3	2.092697
9-ULS	4	0.7	0.7	16.041	452.9	182.3	1.614283
10-ULS	4	0.7	0.7	16.041	452.9	189.47	1.677682
11-ULS	4	0.7	0.9	16.041	452.9	82.78	0.942408
12-FLS	4	0.7	1	16.041	452.9	143.72	5.090335
13-FLS	4	0.7	1	16.041	452.9	63.3	2.24128

4 LANE BRIDGE : 1280mm Thick, 17.276m Width, 32m Length

Load Cases	n	RL	RL'	B	VT	Vmax	Fv
1-ULS	4	0.7	1	16.041	452.9	164.06	2.075266
2-ULS	4	0.7	0.9	16.041	452.9	230.41	2.6231
3-ULS	4	0.7	0.8	16.041	452.9	242.4	2.452877
4-ULS	4	0.7	0.7	16.041	452.9	217.96	1.929949
5-ULS	4	0.7	0.9	16.041	452.9	202.04	2.300122
6-ULS	4	0.7	0.9	16.041	452.9	62.53	0.711872
7-ULS	4	0.7	0.8	16.041	452.9	214.03	2.165887
8-ULS	4	0.7	0.7	16.041	452.9	179.81	1.592146
9-ULS	4	0.7	0.7	16.041	452.9	164.6	1.457379
10-ULS	4	0.7	0.7	16.041	452.9	173.8	1.538842
11-ULS	4	0.7	0.9	16.041	452.9	78.3	0.891861
12-FLS	4	0.7	1	16.041	452.9	128.21	4.540995
13-FLS	4	0.7	1	16.041	452.9	56.09	1.986619

TABLE A.60: Fd VALUES FOR 4 LANES BRIDGE 32m LENGTH

4 LANE BRIDGE : 1280mm Thick, 14.806m Width, 32m Length

Load Cases	n	R_L	$R_{L'}$	B	DT	Dmax	Fd
12-FLS	4	0.7	1	15	70.31	5.7	1.200316

4 LANE BRIDGE : 1280mm Thick, 16.041m Width, 32m Length

Load Cases	n	R_L	$R_{L'}$	B	DT	Dmax	Fd
12-FLS	4	0.7	1	16.041	70.31	5.5	1.254807

4 LANE BRIDGE : 1280mm Thick, 17.276m Width, 32m Length

Load Cases	n	R_L	$R_{L'}$	B	DT	Dmax	Fd
12-FLS	4	0.7	1	17.276	70.31	5.2	1.277702

2 LANE BRIDGE

BRIDGE				Fm-ULS		Fm-FLS		Fv-ULS		Fv-FLS		Fd-FLS	
SPAN (m)	LANE	Thick-ness (m)	Width (m)	FEA	CHBDC	FEA	CHBDC	FEA	CHBDC	FEA	CHBDC	FEA	CHBDC
16	2	0.650	7.396	1.07	1.05	1.21	1.05	1.13	1.08	1.71	1.4	1.14	1.05
16	2	0.650	8.631	1.11	1.05	1.25	1.21	1.35	1.26	1.82	1.63	1.18	1.21
16	2	0.650	9.866	1.13	1.18	1.27	1.38	1.57	1.44	1.62	1.86	1.16	1.38
20	2	0.800	7.396	1.05	1.05	1.14	1.05	1.13	1.05	1.79	1.27	1.09	1.05
20	2	0.800	8.631	1.07	1.05	1.18	1.19	1.36	1.21	1.99	1.48	1.12	1.19
20	2	0.800	9.866	1.09	1.17	1.19	1.37	1.6	1.37	1.91	1.7	1.13	1.37
24	2	0.960	7.396	1.05	1.05	1.12	1.05	1.38	1.05	1.95	1.17	1.07	1.05
24	2	0.960	8.631	1.06	1.05	1.15	1.19	1.66	1.16	2.03	1.36	1.08	1.19
24	2	0.960	9.866	1.08	1.17	1.21	1.36	1.93	1.32	2.81	1.56	1.13	1.36
26	2	1.040	7.396	1.04	1.05	1.11	1.05	1.34	1.05	2.08	1.12	1.07	1.05
26	2	1.040	8.631	1.06	1.05	1.13	1.19	1.62	1.14	2.28	1.31	1.08	1.19
26	2	1.040	9.866	1.08	1.17	1.15	1.36	1.9	1.31	2.41	1.49	1.09	1.36
30	2	1.200	7.396	1.04	1.05	1.09	1.05	1.32	1.05	2.09	1.05	1.05	1.05
30	2	1.200	8.631	1.05	1.05	1.11	1.18	1.61	1.1	2.36	1.21	1.06	1.18
30	2	1.200	9.866	1.06	1.17	1.12	1.36	1.88	1.26	2.55	1.38	1.07	1.36
32	2	1.280	7.396	1.02	1.05	1.06	1.05	1.31	1.05	2.07	1.05	1.04	1.05
32	2	1.280	8.631	1.03	1.05	1.08	1.18	1.6	1.08	2.35	1.17	1.05	1.18
32	2	1.280	9.866	1.04	1.17	1.09	1.35	1.87	1.24	2.56	1.34	1.06	1.35

TABLE A.61

3 LANE BRIDGE

3LANE Factors from FEA and CHBDC Code													
BRIDGE				Fm-ULS		Fm-FLS		Fv-ULS		Fv-FLS		Fd-FLS	
SPAN (m)	LANE	Thick-ness (m)	Width (m)	FEA	CHBDC	FEA	CHBDC	FEA	CHBDC	FEA	CHBDC	FEA	CHBDC
16	3	0.650	11.101	1.07	1.05	1.48	1.29	1.69	1.13	2.77	1.92	1.39	1.29
16	3	0.650	12.336	1.11	1.05	1.54	1.44	1.59	1.33	2.77	2.14	1.46	1.44
16	3	0.650	13.571	1.13	1.15	1.55	1.58	1.73	1.46	2.49	2.35	1.42	1.58
20	3	0.800	11.101	1.05	1.05	1.38	1.22	1.56	1.07	3.21	1.73	1.31	1.22
20	3	0.800	12.336	1.07	1.05	1.39	1.36	1.75	1.26	3.08	1.93	1.32	1.36
20	3	0.800	13.571	1.1	1.14	1.4	1.49	1.91	1.39	2.86	2.12	1.32	1.49
24	3	0.960	11.101	1.05	1.05	1.3	1.17	1.87	1.03	3.74	1.57	1.22	1.17
24	3	0.960	12.336	1.08	1.05	1.31	1.31	2.11	1.21	3.18	1.75	1.23	1.31
24	3	0.960	13.571	1.09	1.13	1.32	1.44	2.31	1.32	2.91	1.92	1.24	1.44
26	3	1.040	11.101	1.04	1.05	1.24	1.16	1.88	1.02	3.46	1.51	1.17	1.16
26	3	1.040	12.336	1.07	1.05	1.27	1.29	2.09	1.18	3.57	1.68	1.2	1.29
26	3	1.040	13.571	1.08	1.12	1.28	1.42	2.33	1.31	3.31	1.84	1.22	1.42
30	3	1.200	11.101	1.04	1.05	1.19	1.14	1.91	0.978	3.52	1.38	1.12	1.14
30	3	1.200	12.336	1.05	1.05	1.22	1.26	2.19	1.14	3.73	1.54	1.16	1.26
30	3	1.200	13.571	1.07	1.12	1.23	1.39	2.45	1.26	3.59	1.69	1.16	1.39
32	3	1.280	11.101	1.02	1.05	1.16	1.12	1.92	0.962	3.51	1.33	1.12	1.12
32	3	1.280	12.336	1.04	1.05	1.18	1.25	2.17	1.12	3.73	1.48	1.14	1.25
32	3	1.280	13.571	1.04	1.12	1.19	1.37	2.4	1.23	3.64	1.63	1.16	1.37

TABLE A.62

4 LANE BRIDGE

4LANE Factors from FEA and CHBDC Code

BRIDGE				Fm-ULS		Fm-FLS		Fv-ULS		Fv-FLS		Fd-FLS	
SPAN (m)	LANE	Thick-ness (m)	Width (m)	FEA	CHBDC	FEA	CHBDC	FEA	CHBDC	FEA	CHBDC	FEA	CHBDC
16	4	0.650	14.806	1.14	1.05	1.78	1.61	1.73	1.21	3.38	2.54	1.65	1.61
16	4	0.650	16.041	1.12	1.05	1.91	1.74	1.85	1.31	3.68	2.74	1.75	1.74
16	4	0.650	17.276	1.15	1.14	1.9	1.87	1.95	1.41	3.12	2.95	1.77	1.87
20	4	0.800	14.806	1.15	1.05	1.57	1.48	2	1.14	3.79	2.31	1.49	1.48
20	4	0.800	16.041	1.08	1.05	1.67	1.61	2.07	1.23	4.14	2.51	1.55	1.61
20	4	0.800	17.276	1.12	1.11	1.67	1.73	2.18	1.33	3.77	2.69	1.57	1.73
24	4	0.960	14.806	1.05	1.05	1.45	1.41	2.32	1.09	3.94	2.13	1.35	1.41
24	4	0.960	16.041	1.07	1.05	1.48	1.52	2.51	1.18	3.85	2.31	1.38	1.52
24	4	0.960	17.276	1.08	1.1	1.53	1.64	2.66	1.27	3.87	2.48	1.44	1.64
26	4	1.040	14.806	1.05	1.05	1.4	1.38	2.35	1.06	4.41	2.04	1.31	1.38
26	4	1.040	16.041	1.07	1.05	1.46	1.49	2.54	1.15	4.83	2.21	1.35	1.49
26	4	1.040	17.276	1.08	1.09	1.47	1.61	2.7	1.25	4.41	2.38	1.38	1.61
30	4	1.200	11.101	1.04	1.05	1.32	1.34	2.43	1.03	4.62	1.89	1.24	1.34
30	4	1.200	12.336	0.88	1.05	1.21	1.45	2.36	1.12	4.59	2.05	0.98	1.45
30	4	1.200	13.571	1.06	1.09	1.37	1.56	2.79	1.2	4.81	2.21	1.29	1.56
32	4	1.280	14.806	1.04	1.05	1.27	1.32	2.44	1.01	4.63	1.83	1.2	1.32
32	4	1.280	16.041	1.03	1.05	1.32	1.43	2.64	1.09	5.09	1.98	1.25	1.43
32	4	1.280	17.276	1.04	1.08	1.32	1.54	2.62	1.09	4.54	2.13	1.27	1.54
						TABLE A.63							

2 LANE BRIDGE

TABLE A.64

2LANE- Factors from FEA and CHBDC Code																
BRIDGE				Fm-ULS			Fm-FLS			Fv-ULS		Fv-FLS		Fd-FLS		
SPAN (m)	LANE	Thickness (m)	Width (m)	FEA	CHBDC Exterior	CHBDC Interior	FEA	CHBDC Exterior	CHBDC Interior	FEA	CHBDC	FEA	CHBDC	FEA	CHBDC Exterior	CHBDC Interior
16	2	0.650	7.396	1.07	1.05	1.05	1.21	1.05	1.05	1.13	1.08	1.71	1.4	1.14	1.05	1.05
16	2	0.650	8.631	1.11	1.05	1.05	1.25	1.16	1.21	1.35	1.26	1.82	1.63	1.18	1.16	1.21
16	2	0.650	9.866	1.13	1.18	1.18	1.27	1.33	1.38	1.57	1.44	1.62	1.86	1.16	1.33	1.38
20	2	0.800	7.396	1.05	1.05	1.05	1.14	1.05	1.05	1.13	1.05	1.79	1.27	1.09	1.05	1.05
20	2	0.800	8.631	1.07	1.05	1.05	1.18	1.14	1.19	1.36	1.21	1.99	1.48	1.12	1.14	1.19
20	2	0.800	9.866	1.09	1.17	1.16	1.19	1.31	1.37	1.6	1.37	1.91	1.7	1.13	1.31	1.37
24	2	0.960	7.396	1.05	1.05	1.05	1.12	1.05	1.05	1.38	1.05	1.95	1.17	1.07	1.05	1.05
24	2	0.960	8.631	1.06	1.05	1.05	1.15	1.13	1.19	1.66	1.16	2.03	1.36	1.08	1.13	1.19
24	2	0.960	9.866	1.08	1.17	1.16	1.21	1.29	1.36	1.93	1.32	2.81	1.56	1.13	1.29	1.36
26	2	1.040	7.396	1.04	1.05	1.05	1.11	1.05	1.05	1.34	1.05	2.08	1.12	1.07	1.05	1.05
26	2	1.040	8.631	1.06	1.05	1.05	1.13	1.13	1.19	1.62	1.14	2.28	1.31	1.08	1.13	1.19
26	2	1.040	9.866	1.08	1.17	1.16	1.15	1.28	1.36	1.9	1.31	2.41	1.49	1.09	1.28	1.36
30	2	1.200	7.396	1.04	1.05	1.05	1.09	1.05	1.05	1.32	1.05	2.09	1.05	1.05	1.05	1.05
30	2	1.200	8.631	1.05	1.05	1.05	1.11	1.12	1.18	1.61	1.1	2.36	1.21	1.06	1.12	1.18
30	2	1.200	9.866	1.06	1.17	1.15	1.12	1.27	1.36	1.88	1.26	2.55	1.38	1.07	1.27	1.36
32	2	1.280	7.396	1.02	1.05	1.05	1.06	1.05	1.05	1.31	1.05	2.07	1.05	1.04	1.05	1.05
32	2	1.280	8.631	1.03	1.05	1.05	1.08	1.11	1.18	1.6	1.08	2.35	1.17	1.05	1.11	1.18
32	2	1.280	9.866	1.04	1.17	1.15	1.09	1.27	1.35	1.87	1.24	2.56	1.34	1.06	1.27	1.35

3 LANE BRIDGE

TABLE A.65

3LANE Factors from FEA and CHBDC Code																
BRIDGE				Fm-ULS			Fm-FLS			Fv-ULS		Fv-FLS		Fd-FLS		
SPAN (m)	LANE	Thickn -ess (m)	Width (m)	FEA	CHBDC		FEA	CHBDC		FEA	CHBDC	FEA	CHBDC	FEA	CHBDC	
					Exterior	Interior		Exterior	Interior						Exterior	Interior
16	3	0.650	11.101	1.07	1.05	1.05	1.48	1.29	1.26	1.69	1.13	2.77	1.92	1.39	1.29	1.26
16	3	0.650	12.336	1.1	1.05	1.05	1.54	1.44	1.41	1.59	1.33	2.77	2.14	1.46	1.44	1.41
16	3	0.650	13.571	1.13	1.15	1.15	1.55	1.58	1.55	1.73	1.46	2.49	2.35	1.42	1.58	1.55
20	3	0.800	11.101	1.05	1.05	1.05	1.38	1.22	1.21	1.56	1.07	3.21	1.73	1.31	1.22	1.21
20	3	0.800	12.336	1.07	1.05	1.05	1.39	1.36	1.34	1.75	1.26	3.08	1.93	1.32	1.36	1.34
20	3	0.800	13.571	1.1	1.13	1.14	1.4	1.49	1.47	1.91	1.39	2.86	2.12	1.32	1.49	1.47
24	3	0.960	11.101	1.05	1.05	1.05	1.3	1.17	1.17	1.87	1.03	3.74	1.57	1.22	1.17	1.17
24	3	0.960	12.336	1.08	1.05	1.05	1.31	1.31	1.29	2.11	1.21	3.18	1.75	1.23	1.31	1.29
24	3	0.960	13.571	1.09	1.12	1.13	1.32	1.44	1.43	2.31	1.32	2.91	1.92	1.24	1.44	1.43
26	3	1.040	11.101	1.04	1.05	1.05	1.24	1.16	1.15	1.88	1.02	3.46	1.51	1.17	1.16	1.15
26	3	1.040	12.336	1.07	1.05	1.05	1.27	1.29	1.28	2.09	1.18	3.57	1.68	1.2	1.29	1.28
26	3	1.040	13.571	1.08	1.12	1.12	1.28	1.42	1.41	2.33	1.31	3.31	1.84	1.22	1.42	1.41
30	3	1.200	11.101	1.04	1.05	1.05	1.19	1.14	1.13	1.92	0.978	3.52	1.38	1.12	1.14	1.13
30	3	1.200	12.336	1.05	1.05	1.05	1.22	1.26	1.26	2.19	1.14	3.73	1.54	1.16	1.26	1.26
30	3	1.200	13.571	1.07	1.12	1.12	1.23	1.27	1.39	2.45	1.26	3.59	1.69	1.16	1.27	1.39
32	3	1.280	11.101	1.02	1.05	1.05	1.16	1.12	1.12	1.92	0.962	3.5	1.33	1.12	1.12	1.12
32	3	1.280	12.336	1.04	1.05	1.05	1.18	1.25	1.25	2.17	1.12	3.73	1.48	1.14	1.25	1.25
32	3	1.280	13.571	1.04	1.12	1.13	1.19	1.37	1.37	2.4	1.23	3.64	1.63	1.16	1.37	1.37

4 LANE BRIDGE

4LANE Factors from FEA and CHBDC Code

BRIDGE				Fm-ULS			Fm-FLS			Fv-ULS		Fv-FLS		Fd-FLS		
SPAN (m)	LANE	Thickn-ess (m)	Width (m)	FEA	CHBDC		FEA	CHBDC		FEA	CHBDC	FEA	CHBDC	FEA	CHBDC	
					Exterior	Interior		Exterior	Interior						Exterior	Interior
16	4	0.650	14.806	1.14	1.05	1.05	1.78	1.61	1.5	1.73	1.21	3.38	2.54	1.65	1.61	1.5
16	4	0.650	16.041	1.12	1.05	1.05	1.91	1.74	1.63	1.85	1.31	3.68	2.74	1.75	1.74	1.63
16	4	0.650	17.276	1.15	1.14	1.11	1.9	1.87	1.75	1.95	1.41	3.12	2.95	1.77	1.87	1.75
20	4	0.800	14.806	1.15	1.05	1.05	1.57	1.48	1.41	2	1.14	3.79	2.31	1.49	1.48	1.41
20	4	0.800	16.041	1.08	1.05	1.05	1.67	1.61	1.52	2.07	1.23	4.14	2.51	1.55	1.61	1.52
20	4	0.800	17.276	1.12	1.11	1.09	1.67	1.73	1.64	2.18	1.33	3.77	2.69	1.57	1.73	1.64
24	4	0.960	14.806	1.05	1.05	1.05	1.45	1.41	1.35	2.32	1.09	3.94	2.13	1.35	1.41	1.35
24	4	0.960	16.041	1.07	1.05	1.05	1.48	1.52	1.46	2.51	1.18	3.85	2.31	1.38	1.52	1.46
24	4	0.960	17.276	1.08	1.1	1.08	1.53	1.64	1.57	2.66	1.27	3.87	2.48	1.44	1.64	1.57
26	4	1.040	14.806	1.05	1.05	1.05	1.4	1.38	1.33	2.35	1.06	4.41	2.04	1.31	1.38	1.33
26	4	1.040	16.041	1.07	1.05	1.05	1.46	1.49	1.44	2.54	1.15	4.83	2.21	1.35	1.49	1.44
26	4	1.040	17.276	1.08	1.09	1.08	1.47	1.61	1.55	2.7	1.25	4.4	2.38	1.38	1.61	1.55
30	4	1.200	14.806	1.04	1.05	1.05	1.32	1.34	1.29	2.43	1.03	4.62	1.89	1.24	1.34	1.29
30	4	1.200	16.041	0.88	1.05	1.05	1.21	1.45	1.41	2.36	1.12	4.59	2.05	0.98	1.45	1.41
30	4	1.200	17.276	1.06	1.09	1.07	1.37	1.56	1.51	2.79	1.2	4.81	2.21	1.29	1.56	1.51
32	4	1.280	14.806	1.04	1.05	1.05	1.27	1.32	1.28	2.44	1.01	4.63	1.83	1.2	1.32	1.28
32	4	1.280	16.041	1.03	1.05	1.05	1.32	1.43	1.39	2.64	1.09	5.09	1.98	1.25	1.43	1.39
32	4	1.280	17.276	1.04	1.08	1.07	1.32	1.54	1.49	2.62	1.09	4.54	2.13	1.27	1.54	1.49

TABLE A.66