This Is To Certify
That

SHEAR OPTIMIZATION OF PRESTRESSED BRIDGE GIRDERS

Submitted by

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SHEAR OPTIMIZATION OF PRESTRESSED BRIDGE GIRDERS

BY

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DEDICATED TO MY PARENTS AND WIFE

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f'_c = concrete compressive strength at 28 days

A_v = area of shear reinforcement at section

f_v = allowable tensile stress in shear reinforcement

V' = total shear – 0.02 f′c b jd

α = Angle of inclination of the web reinforcement w.r.t horizontal axis of the beam

jd = flexural lever arm

b = **bw** = width of web

s = spacing of shear steel

ν = shear stress at factored load level

V_s = shear force resisted by the stirrups

d = **dv** = distance from extreme compression fiber to the centroid of longitudinal tensile steel

V_c = nominal shear strength of concrete

V_u = shear force applied at factored loads

V_n = nominal shear strength of section

ϕ = Strength reduction factor for shear

V_d = shear due to self weight of member without load factor

V_i = factored shear at section

M_{max} = factored moment at section

y_t = distance of neutral axis from compression fiber

f_{pe} = stress due to effective prestress force

f_d = flexural stress at bottom face of the beam due to self weight without load factor

V_p = vertical component of effective prestress force at the section

f_{pc} = compressive stress in concrete (after losses) at centroid of section resisting externally applied loads or at junction of web and flange

V_{ci} = normal shear strength provided by concrete when diagonal cracking results from combined shear and moment

f_y = yield stress of stirrup steel

M_u =factored moment at section

V_{cw} = normal shear strength provide by concrete when cracking is due to shear alone

M_{cr} = moment causing flexural cracking at section

N_u = factored axial force

A_s = area of longitudinal steel

A_g = gross concrete area at section

ld = development length

la = additional embedment length at point of inflection

β = Ratio of tension reinforcement cutoff to total area of tension steel at section/ concrete tensile stress factor indicating the ability of diagonally cracked concrete to resist shear (for MCFT)

ρ = Percentage of reinforcement/steel ratio

ρ_v = percentage of vertical reinforcement

ρ_x = percentage of longitudinal reinforcement

θ = angle of inclination of cracks with longitudinal axis of beam

f_{sx} = tensile stress in longitudinal steel

f_{sy} = tensile stress in transverse steel

$\in_x$ = strain in x-direction

$\in_y$ = strain in y-direction

$\in_1$ = principal tensile strain

$\in_2$ = principal compressive strain

f_1 = principal tensile stress

f_2 = principal compressive stress

γ_m = diameter of strain circle

$\in'c$ = stain at which the concrete in a cylinder test reaches the peak stress

n = Es/Ec = modular ratio

w = crack width

a = aggregate size

f_{po} = stress in pre-stressing tendon when the surrounding concrete is at zero stress

A_{ps} = area of pre-stressing steel

$\mathbf{S_x}$ = crack spacing parameter

$\mathbf{S_{xe}}$ = equivalent crack spacing parameter

$\mathbf{f_{ps}}$ = ultimate strength of pre-stressing steel

T = tension in longitudinal reinforcement

K = factor representing the effect of pre-stress force on the concrete diagonal tensile strength

$\mathbf{f_t}$ = principal diagonal tension stress

$\mathbf{T_f}$ = tangential frictional force at crack

$\mathbf{N_f}$ = normal force at crack

$\mathbf{fd_{max}}$ = effective concrete strength of struts

λ = size reduction factor

$\mathbf{v_{cr}}$ = shear stress resulting in first diagonal tension cracking

$\mathbf{V_f}$ = vertical component of combined frictional forces Tf and Nf across the inclined crack in the web

$\mathbf{A_g}$ = Gross cross sectional area of the girder

γ_c = Density of concrete

G = Gravitational acceleration

H= Height of end diaphragm

W = Width of end diaphragm

$\mathbf{W_{trib}}$ =Tributary width of the slab

E = Moment arm – Distance from C.G. of diaphragm to C.L Bearing

H= Height of the interior diaphragm

W =Width of the interior diaphragm

$\mathbf{T_{web}}$ =Width of the girder web

S = Spacing of the exterior girders

$\mathbf{W_{cc}}$ =Width of the deck from curb to curb. In PG Super this is the distance between the insides of the traffic barriers

$\mathbf{t_{olay}}$ **=** Depth of the overlay

γ_{olay} =Density of the overlay

$\mathbf{N_{girders}}$ = Total number of girders

BR = Vehicular braking force

CE = Vehicular centrifugal force

CR =Creep

CT = Vehicular collision force

CV = Vessel collision force

FR = Friction

IC = Ice load

IM = Vehicular dynamic load allowance

LL = Vehicular live load

LS= Live load surcharge

PL = Pedestrian live load

SE = Settlement

SH = Shrinkage

TG = Temperature gradient

TU = Uniform temperature

WA = Water load and stream pressure

WL = Wind on live load

WS = Wind load on structure

Chapter 1

INTRODUCTION

1.1 GENERAL

Communication infrastructure is primary ingredient in scientific, economical and social development of a country. Amongst various modes of transportation, roads network is a major component. Bridges and roads are complementary to each other of which bridges take maximum toll of resources.

History of bridge engineering can be termed, as the history of evolution of civil engineering .It is all but impossible to date humanity's conception and creation of first bridge or the art of spanning space by artificial construction. Bridges were evolved as the basic need for transportation continually grew, owing to people mobile and nomadic lifestyle .The history of development of bridges is intertwined with the evolution of stronger materials.

Over the years, design procedures have been developed by the engineers to provide satisfactory margins of safety with economy. These procedures were based on the confidence of the engineer in the analysis of the load effects and the strength of the materials being provided. As the analysis techniques improved and quality control of materials improved, the design procedures, too changed. A general statement for assuring safety in engineering design is that the resistance provided by the materials and cross sections used should exceed the demands put on them by the applied loads, that is;

$$\text{Resistance} \geq \text{Effects of loads}$$

Using this simple principle, it is essential that both sides of inequality are evaluated for the same conditions. In other words, the evaluation of inequality must be done for a specific loading condition that links together resistance and the effect of loads. Evaluating both sides at that limit state provides this common link. When a particular loading condition reaches its limit state, failure is the assumed result, that is, the loading condition become a failure mode such a condition is referred to as a limit state. Examples of limit states for girder type bridges include deflection, cracking, fatigue, shear, torsion, buckling, settlement, bearing and sliding. Well-defined limit states are established so that a designer knows what is considered to be acceptable.

An important goal of design is to prevent a limit state from being reached. However, it is not the only goal, the other goals that must be considered and balanced in the overall design scheme are the functionality, economy and appearance. As it is not economical to design a bridge so that non-of its component could ever fail. Therefore, it becomes necessary to determine what is an acceptable level of risk and probability of failure. The determination of an acceptable margin of safety (how much greater resistance should be compared to the affects of load) is the responsibility of experts.

Pakistan with weak economic coefficient cannot afford to build expensive bridges. Choice is to be made for efficient yet economical bridge structures. Various agencies involved in construction in Pakistan do not review the National Highway Authority (NHA) design specifications for different bridge components, which involve over safety at the cost of economy. This practice is more pronounced in prestressed bridges, which are considered to be most economical for short a This would assist design engineers in detailing of shear reinforcement and site engineers in inspection.

nd medium span range (less than 164 feet). This study would focus on shear design aspect of short and medium span pre-stressed bridges in order to present an optimized shear design in the form of shear strength and stirrup detailing tables covering span lengths of 35 feet to 145 feet with different strand and girder spacing for NHA bridge girders. This would assist design engineers in detailing of shear reinforcement and site engineers in inspection.

1.2 PURPOSE OF RESEARCH

Pakistan with limited resources lack a single standard code of practice available to the design engineers. Though NHA had published the code in 1962 and revised in 1998, however, it is not being practiced in its true spirit.

Design specifications/codes are developed to suit own peculiar environments including construction practices, type of vehicular traffic and overload factors etc. Weak standards of testing, quality and lack of incorporating necessary upto date changes in design and construction practices results in uneconomical design.

Presently, a combination of different design specifications is being used because of which subjective FOS (as used in working stress design approach) is stretched without a rationale for our loading rates and the result is an over conservative design thus jeopardizing the very essence of economy.

Former research [27] was carried out on “evaluation of existing short and medium span prestressed girder bridges constructed on Grand Trunk road (Peshawar-Kharian section) with a view to economize flexural design”. In this study a number of prestressed girders fabricated and used as part of existing bridges superstructure (as per NHA Specifications) were analyzed for over design aspect from standpoint of flexural design. Based on these analyses, AASHTO standard girders were modified, analyzed and designed. These designed “I” sections besides giving desired structural capacity, presented an economical design.

An overall economical design is based on optimizing materials and their combinations against external loads and various load combinations. Since flexure alone is seldom a problem in bridge girders, effect of other forces/load effects including shear, torsion and axial forces must also form part of the overall design for purpose of its validation for implementation/use.

Keeping in view the economic factor without foregoing the safety concerns, it is intended through this study to carryout initial study of prevalent NHA specifications and design practices employed on existing and newly constructed prestressed bridges regarding shear design of prestressed "I“ girders. After the analysis of various existing pre-stressed bridges for the over design aspects, shear design would be optimized using AASHTO modified section with varying girder spacing, strand patterns and span lengths so as to recommend safe and economical design. Design tables will be developed which would assist design engineers in selection of optimized shear reinforcement ensuring safety and economy in the design.

1.3 SCOPE

The effects of external loading on structures seldom leads to flexure alone other action include shear, torsion and axial forces. Shear is most commonly encountered in combination with flexure .Its consideration in design logically follows that of flexure and represents a major step in designing the structure. Shear stresses produce diagonal tension that induces cracking in concrete. To ensure that such cracking does not lead to failure, transverse reinforcement resisting shear and /or torsion is generally provided in the form of stirrups or ties.

In earlier codes the design for shear was based on limiting the magnitude of diagonal tension under working loads thus providing a safety factor against cracking. However in prestressed concrete an overload may induce substantial changes in compressive stresses thus leading to disproportionately high increase in diagonal tension at some points of the section thus seriously jeopardizing the margin of safety.

Various types of cracking occur in prestressed concrete members namely, flexural cracking due to moments in mid span region, flexural shear cracking which is developed towards support from centerline of girder and web shear which is developed near the support region .To arrest such cracking, transverse reinforcement is provided. To achieve this it must be kept in mind that depending upon the zones of different crack pattern, distribution/spacing of reinforcement will vary along the span. Shear optimization, thus, would be based on development of transverse reinforcement at different zones of cracking without compromising safety yet ensuring economy in detailing of transverse reinforcement.

Former research [27] was carried out and six standard “I” sections were proposed based on flexural design using AASHTO/ACI working stress design approach. In order to validate the design for use, shear analysis of these sections would be carried out using AASHTO working stress and LRFD approaches (state of the art method) and after comparison of results, shear design tables will be based on economical method.

It is evident from current practices that in Pakistan, most of the designers have more faith in prestressed I-girder bridges. This is obvious from the fact that out of 50 bridges, 45 fall in this category only on Peshawar-Kharian section of Grand Trunk Road. Keeping the general trend in mind, following parameter of the bridges will be considered in the study:

a) Pre-stressed I-girder and T-bulb bridges.

b) Simply supported.

c) RCC slab of uniform thickness.

d) Overhang to accommodate sidewalks and railing of standard weight.

e) Outer wheel of truck is placed 2 feet from the curb.

f) Barriers and diaphragms will not be considered.

In the absence of standard design aids, coupled with fear of weak construction practices along with lack of quality control systems and equipment, the designer tends to increase the safety margins thereby over stepping the safety ranges resulting in an over conservative design. Presently a combination of British and AASHTO standards is being practiced. The effort should be to improve our weak construction practices. Considering present trend, it is intended through this work, first to analyze the selected bridges so as to highlight the weakness in the present highway bridge practices. The analysis is based on AASHTO procedures. In the second phase, the bridges, which are over safe and more conservative, will be subjected to revised design. While considering the revised design only the standard sections will be used which are 36, 42, 48, 54 inches deep I-girders and 63 and 72 inches deep T-bulb girders. Cross section and non-composite properties of these girders are shown in from Figure 1.1 to Figure 1.6. The revised design will be based on AASHTO standard (1996 edition) and LRFD bridge design specifications. For comparison of design procedures and in order to present design variations between the original and proposed designs two case studies, one for the existing bridge on Grand Trunk road and other for construction on motorway M-1, would be presented.

In the last phase of this study, design tables for shear capacity (to be provided by the shear reinforcement) and shear design tables for short span to medium span highway prestressed bridges will be developed. The base line for these tables will be to get maximum detailing output by economizing the effort and resources and at the same time not compromising the safety aspects. These design tables will certainly help in the design, detailing and inspection of shear reinforcement of any prestressed bridge, having span ranges from 35 feet to 145 feet.

1.4 AIM

To evaluate the NHA standard pre-stressed “I” and “T” girders being used in bridge superstructure with a view to present an optimized shear design in the form of design tables.

1.5 OBJECTIVES

To develop shear capacity and stirrups design/detailing tables for provision of optimized shear reinforcement in prestressed “I” and “T” girder bridges to include:

a) Flexural shear.

b) Web shear.

1.6 RESEARCH METHODOLOGY

Keeping in view the multi-dimensional scope of this research, a preliminary survey was carried out. The survey was aimed at ascertaining the common type of prestressed bridges presently in vogue. The survey was carried out in consultation with NHA, NLC, and KINGCRETE for selected section of Grand Trunk road and with Pakistan Motorway Consultant (PMC) for bridges on Peshawar-Islamabad Motorway (M-1). After procurement of relevant data, analysis of these bridges was carried out to ascertain whether the design was conservatives or otherwise. For this purpose design guidelines of ACI and AASHTO codes were used.

Prestressed concrete construction requires high quality materials, precise workmanship and careful design. The decision to use prestressing imposes on the designer the responsibility to check behavior of the girders carefully at all the critical locations and stages in the life of the structure. Keeping these aspects in mind, designs will be proposed for only those bridges, which are over conservative, as established earlier.

The proposed shear capacity design tables and stirrups/detailing design tables for six standard interior girder sections are prepared with following parameters as variables;

a) Girder spacing.

b) Strand pattern.

c) Span length

Research methodology would be as follows:

a) Literature review of shear theories and hypothesis with detailed coverage of Modified Compression Field Theories (MCFT) for pre-stressed concrete, as state of the art method for shear design.

b) Collection and collation of data from NHA and other sources on existing design details.

c) Design procedure based on currently used AASHTO bridge design specifications 1996 and ACI procedure and development of design tables.

d) Design procedure based on AASHTO LRFD Bridge design specification 1998/2000.

e) Case studies on shear design of an existing bridge and an under construction bridge on motorway (M-1).

f) Comparison of Allowable/Working stress design (WSD) and Load and Resistance Factor Design (LRFD) approaches for design variations and economic analysis.

g) Discussion on results, conclusion and recommendations.

Chapter 2

REVIEW OF LITERATURE

2.1 GENERAL

Regulatory standards encompassing various design procedures should be safe, simple to understand, easy to implement and should not add to either design or construction costs. These procedures can be most effective if they are based on relatively simple conceptual models rather than on complex empirical equations. This review introduces some approaches for the shear design of concrete beams. Although the approaches explained in the subsequent details of this review are relatively new, some of them have reached a sufficiently mature state that they have been implemented in codes of practice.

The objective is to refresh some of the new design approaches. Truss model approaches and related theories are discussed. These new approaches provide a unified, rational, and safe design framework for structural concrete under combined actions, including the effects of axial load, bending, torsion, and prestressing.

2.2 HISTORICAL DEVELOPMENT OF SHEAR DESIGN PROVISIONS

Most codes of practice use sectional methods for design of conventional beams under bending and shear. ACI Building Code 318-95M assumes that flexure and shear can be handled separately for the worst combination of flexure and shear at a given section. The interaction between flexure and shear is addressed indirectly by detailing rules for flexural reinforcement cutoff points. In addition, specific checks on the level of concrete stresses in the member are introduced to ensure sufficiently ductile behavior and control of diagonal crack widths at service load levels.

2.2.1 Truss Models

In the early l900s, truss models were used as conceptual tools in the analysis and design of reinforced concrete beams. Ritter (1899) postulated that after a reinforced concrete beam cracks due to diagonal tension stresses, it can be idealized as a parallel chord truss with compression diagonals inclined at 45° with respect to the longitudinal axis of the beam. Morsch (1920, 1922) later introduced the use of truss models for torsion. These truss models neglected the contribution of the concrete in tension. Withey (1907, 1908) introduced Ritter's truss model into the American literature and pointed out that this approach gave conservative results when compared with test evidence. Talbot (1909) confirmed this finding.

Historically, shear design in the United States has included a concrete contribution, Vc, to supplement the 45° sectional truss model to reflect test results in beams and slabs with little or no shear reinforcement and to ensure economy in the practical design of such members.

2.2.2 Standard and Modified Truss Models

More recently, several design procedures were developed to economize on the design of the stirrup reinforcement. One approach has been to add a concrete contribution term to the shear reinforcement capacity obtained, assuming a 45° truss (for example, ACI Building Code 318-95). Another procedure has been the use of a truss with a variable angle of inclination of the diagonals. The inclination of the truss diagonals is allowed to differ from 45° within certain limits suggested on the basis of the theory of plasticity. This approach is often referred to as the

"Standard Truss Model with no concrete contribution," and is explained by the existence of aggregate interlock and dowel forces in the cracks, which allow a lower inclination of the compression diagonals and the further mobilization of the stirrup reinforcement. A combination of the variable-angle truss and a concrete contribution has also been proposed. This procedure has been referred to as the Modified Truss Model approach.. In this approach, in addition to a variable angle of inclination of the diagonals, the concrete contribution for non prestressed concrete members diminishes with the level of shear stress. For pre-stressed concrete members, the concrete contribution is not considered to vary with the level of shear stress and is taken as a function of the level of pre-stress and the stress in the extreme tension fiber.

As mentioned previously, the truss model does not directly account for the components of the shear failure mechanism, such as aggregate interlock and friction, dowel action of the longitudinal steel, and shear carried across uncracked concrete. For prestressed beams, the larger the amount of prestressing, the lower the angle of inclination at first diagonal cracking.

Therefore, depending on the level of compressive stress due to prestress, pre-stressed concrete beams typically have much lower angles of inclined cracks at failure than non pre-stressed beams and hence require smaller amounts of stirrups.

In more recent design codes modified truss models are used. Attention was focused on the truss model with diagonals having a variable angle of inclination as a viable model for shear and torsion in reinforced and pre-stressed concrete beams. Further development on plasticity theories extended the applicability of the model to non yielding domains.

2.2.3 Strut And Tie Models (STM)

Extending the truss model for beams with uniformly inclined diagonals, all parts of the structure in the form of STM. This approach is particularly relevant in regions where the distribution of strains is significantly nonlinear along the depth. By analyzing a truss model consisting of linearly elastic members and neglecting the concrete tensile strength, Kupfer (1964) provided a solution for the inclination of the diagonal cracks. Collins and Mitchell (1980) abandoned the assumption of linear elasticity and developed the compression field theory (CFT) for members subjected to torsion and shear..

2.2.4 The ACI Design Procedures [10]

The ACI 318-95M sectional design approach for shear in beams is based on a parallel truss model with 45° constant inclination diagonals supplemented by an experimentally obtained concrete contribution. The contribution from the shear reinforcement, Vs, for the case of vertical stirrups (as is most often used in North American practice), can be derived from basic equilibrium considerations on a 45° truss model with constant stirrup spacing, and effective depth. The truss resistance is supplemented with a concrete contribution, for both reinforced and prestressed concrete beams.

2.3 COMPRESSION FIELD APPROACHES[28]

2.3.1 General

The cracked web of a reinforced concrete beam transmits shear in a relatively complex manner. As the load is increased, new cracks form while pre-existing cracks spread and change inclination. Because the section resists moment as well as shear, the longitudinal strains and the crack inclinations vary over the depth of the beam (Figure 2.1). The early truss models of Ritter (1899) and Morsch (1920, 1922) approximated this behavior by neglecting tensile stresses in the diagonally cracked concrete and by assuming that the shear would be carried by diagonal compressive stresses in the concrete, inclined at 45° to the longitudinal axis. The diagonal compressive concrete stresses push apart the top and bottom faces of the beam, while the tensile stresses in the stirrups pull them together. Equilibrium requires that theses two effects be equal. According to the 45° truss model, the shear capacity is reached when the stirrups yield and will correspond to a shear stress of:

$$\boldsymbol{v = Av\ fy / bw\ s = \rho\ fy} \qquad \textbf{(2.1)}$$

The reason why the 45° truss equation is often very conservative is that the angle of inclination of the diagonal compressive stresses measured from the longitudinal axis, θ, is typically less than 45°. The general form of (1.2) is:

$$\boldsymbol{v = \rho v\ fy \cot \theta} \qquad \textbf{(2.2)}$$

Most of the inclined cracks shown in Figure 2.1 are not so flat. Before the general truss equation can be used to determine the shear capacity of a given beam, or to design the stirrups to resist a given shear, it is necessary to know the angle θ.

Shear design procedures for reinforced concrete that determine the angle θ by considering the deformations of the transverse reinforcement, the longitudinal reinforcement, and the diagonally stressed concrete have become known a compression field approaches. With these methods, equilibrium conditions, compatibility conditions, and stress-strain relationships for both the reinforcement and the diagonally cracked concrete are used to predict the load-deformation response of a section subjected to shear.

Methods for determining θ applicable over the full loading range were developed by Collins and Mitchell (1974) for members in torsion, and were applied to shear design by Collins (1978). This procedure is called the Compression Field Theory (CFT).

2.3.2 Compression Field Theory (CFT) [15]

Figure 2.2 summarizes the basic relationships of the CFT. The shear stress, $\boldsymbol{v}$, applied to $\mathbf{sx}$, and $\mathbf{fsy}$, and $\mathbf{f_2}$, inclined at angle θ to the longitudinal axis. The equilibrium relationships between these stresses can be derived from Figures 2.2(a and b) as:

$$\boldsymbol{\rho v f s y = f c y = v \tan\theta} \tag{2.3}$$

$$\boldsymbol{\rho x\ f s x = f c s = v \cot\theta} \tag{2.4}$$

$$\boldsymbol{fs = v(\tan\theta + \cot\theta)} \tag{2.5}$$

If the longitudinal reinforcement elongates by a strain of $\in\mathbf{x}$, the transverse reinforcement elongates by $\in\mathbf{y}$, and the diagonal **y** compressed concrete shortens by $\in_2$, then the direction of principal compressive strain can be found from Wagner's (1929) equation, which can be derived from Mohr's circle of strain Figure 2.2(d) as:

$$\boldsymbol{\tan^2\theta = (\in x + \in_2) / (\in y + \in_2)} \tag{2.6}$$

Before this equation can be used to determine $\boldsymbol{\theta}$, stress-strain relationships for the reinforcement and the concrete are required. It is assumed that the reinforcement strains are related to the reinforcement stresses by the usual simple bilinear approximations shown in Figures 2.2(e and f). Thus, after the, $\in\mathbf{y}$, exceeds the yield strain of the stirrups, the stress in the stirrups is assumed to equal the yield stress **fy** and (2.3) becomes identical to (2.2).

It was suggested that the diagonally cracked concrete fail at a low compressive stress because this stress must be transmitted across relatively wide cracks. If the initial cracks shown in Figure 2.2(a) formed at 45° to the longitudinal reinforcement, and if θ is less than 45°, then significant shear stresses must be transmitted across these initial cracks, Figure 2.2(b). The ability of the concrete to transmit shear across cracks depends on the width of the cracks, which, in turn, is related to the tensile straining of the concrete. The $\in_1$, can be derived from Figure 2.2(d) as:

$$\in_1 = \in x + (\in x + \in_2) \cot^2 \theta \qquad \textbf{(2.7)}$$

2.3.3 Stress-Strain Relationships for Diagonally Cracked Concrete

Since the CFT was published, a large amount of experimental research aimed at determining the stress-strain characteristics of diagonally cracked concrete has been conducted. These experimental statues provide strong evidence that the ability of diagonally cracked concrete to resist compression decreases as the amount of tensile straining increases.

For typical reinforced concrete beams ρx, will greatly exceed the ρv. In this situation there will be a substantial reduction in the inclination, θ, of the principal compressive stresses after cracking. For elements with both longitudinal and transverse reinforcement, the directions of principal stress in the concrete typically deviated by less than 10° from the directions of the principal strain (Vecchio and Collins 1986). It was found (Vecchio and Collins 1986; Belarbi and Hun 1994) that after cracking, the average principal tensile stress in the concrete decreases as the principal tensile strain increases.

2.3.4 Modified Compression Field Theory (MCFT)

2.3.4.1 The MCFT (Vecchio and. Collins 1986)[23] is a further development of the CFT that accounts for the influence of the tensile stresses in the cracked concrete. It is recognized that the local stresses in both the concrete and the reinforcement vary from point to point in the cracked concrete, with high reinforcement stresses but low concrete tensile stresses occurring at crack locations. Failure of the reinforced concrete element maybe governed not by average stresses, but rather by local stresses that occur at a crack.

It can be seen that the v_{ci}, on the crack face reduces the stress in the transverse reinforcement but increases the stress in the longitudinal reinforcement. The maximum possible value of v_{ci}, is taken (Bhide and Collins 1989) to be related to w, and **a**, by the relationship illustrated in Figure 2.3 (f) and given by:

$$V_{ci} \le 0.18\sqrt{f'c} \,/\, [0.3 + (24w \,/\, a+16)] \quad \text{(MPa, mm)} \tag{2.8}$$

The w, is taken as the crack spacing times the principal tensile strain, $\in_1$. At high loads, the average strain in the stirrups, $\in_y$, will typically exceed the yield strain of the reinforcement. If tensile stresses in the cracked concrete are ignored, as is done in the CFT, elements with no stirrups ($\rho v = 0$) are predicted to have no shear strength.

When these tensile stresses are accounted for, as is done in the MCFT, even members with no stirrups are predicted to have significant post cracking shear strengths. Figure 2.4 shows that predicted shear strengths are a function not only of the amount of stirrup reinforcement, but also of the amount of longitudinal reinforcement. Increasing the amount of longitudinal reinforcement increases the shear capacity. Increasing the amount of longitudinal reinforcement also increases the difference between the CFT prediction and the MCFT prediction. When the total longitudinal reinforcements is 10% of the web area, this longitudinal reinforcement remains well below yield stress, and the failure, for larger amounts of stirrups, is then governed by crushing of the concrete. The tensile stresses in the cracked concrete stiffen the element, reduce the concrete strains, and make it possible to resist larger shear stresses prior to failure. The predicted shear strength of elements that contain relatively small amounts of stirrups are influenced by the spacing of the diagonal cracks, $\mathbf{s_\theta}$. If this spacing is increased, ***w***, associated with a given value of $\in_1$, increases, and hence the tension can be transmitted through the cracked concrete decreases. It can be seen that the predicted shear capacity becomes more sensitive to crack spacing as the amount of stirrup reinforcement (ρv) is reduced.

2.3.4.2 Design Considerations [17]

Shear causes tensile stresses in the longitudinal reinforcement as well as in the stirrups. If a member contains an insufficient amount of longitudinal reinforcement, its shear strength may be limited by yielding of this reinforcement. To avoid this type of failure, the longitudinal reinforcement on the flexural tension side of the member must satisfy the following requirement:

$$\mathbf{Asfy+Apsfps \geq (M/\phi dv)+(0.5Nu/\phi)+[(Vu/\phi)-(0.5Vs)-Vp]} \qquad \mathbf{(2.9)}$$

Figure 2.5 illustrates the influence of shear on the tensile force required in the longitudinal reinforcement. Whereas the moment is zero at the simple support, there still needs to be considerable tension in the longitudinal reinforcement near this support. The required tension (T), at a simple support can be determined from the free-body diagram in Figure 2.5 as:

$$T = [(V_u/\phi) - 0.5\, V_s - V_p] \cot\theta \quad (2.10)$$

but

$$T \geq 0.5\, [(V_u/\phi) - V_p] \cot\theta \quad (2.11)$$

The reinforcement provided at the support must be detailed in such a manner that this tension force can be safely resisted and that premature anchorage failure do not occur.

For sections at least a distance **dv**, away from the maximum moment locations, the MCFT predicts that increasing the moment decreases the shear strength while increasing the shear decreases the flexural strength. This point is illustrated in Figure 2.6, which gives the shear-moment interaction diagram for section B of the beam described in Figure 2.1.

2.4 TRUSS APPROACHES WITH CONCRETE CONTRIBUTION

2.4.1 General

The traditional truss models assume that the compression struts are parallel to the direction of cracking and that no stresses are transferred across the cracks. This approach has been shown to yield conservative results when compared with test evidence. More recent theories consider one or both of the following two resisting mechanisms: (1) tensile stresses in concrete that exist transverse to the struts; or (2) shear stresses that are transferred across the inclined cracks by aggregate interlock or friction. Both mechanisms are interrelated and result in: (I) the angle of the principal compression stress in the web being less than the crack angle; and (2) a vertical component of the force along the crack that contributes to the shear strength of the member. The resisting mechanisms give rises to Vc. Theories typically assume that there is no transfer of tension across cracks.

2.4.2 Modified Sectional Truss Model Approach

In the so-called "modified sectional-truss model' approach (Ramirez and Breen 1991) the nominal shear strength of non pre-stressed or pre-stressed concrete beams with shear reinforcement is: Vn = Vc + Vs,

For non pre-stressed concrete beams, the additional concrete contribution. Vc has been suggested (Ramirez and Breen 1991) as:

$$\mathbf{Vc = 0.5(3\mathit{v}cr - \mathit{v})\ bw\ d} \qquad \textbf{(2.12)}$$

For pre-stressed concrete beams (Ramirez and Breen 1991), the additional concrete contribution takes the form of

$$\mathbf{Vc = K(\sqrt{f'c}/6)\ bw\ 0.9\ d} \qquad \textbf{(2.13)}$$

With f′c in Mpa.

The expression for the K factor can be derived from a Mohr circle analysis of an element at the neutral axis of a prestressed concrete beam prior to cracking, and is:

$$\mathbf{K = [\ 1 + fpc/ft]} \qquad \textbf{(2.14)}$$

This expression is the one used in ACI 318-95M as the basis for the web cracking criteria, **Vcw**. The factor K is usually limited to 2.0, and is set equal to 1.0 in those sections of the member where the ultimate flexural stress in the extreme tension fiber exceeds the concrete flexural tensile strength. This limitation is similar to the provision in 318-95M that limits the concrete contribution to the smaller of the two values, Vci and Vcw.

The strength provided by the shear reinforcement Vs, for beams with vertical stirrups represents the truss capacity in shear derived from the equilibrium condition by summing the vertical forces on an inclined crack free-body diagram. According to Ramirez and Breen (1991), the lower limit of angle of inclination, θ, for the truss diagonals is 30° for nonprestressed concrete and 25° for prestressed beams.

2.4.3 Truss Models with Crack Friction

2.4.3.1 Equilibrium of Truss Models with Crack Friction [21]

The truss model with crack friction starts with basic assumptions for the spacing and shape of cracks in a B region of a structural concrete member subjected to shear. It is assumed that forces are transferred across the cracks by friction, which depends on the crack displacements (slips and crack widths); hence, the strains in the member have to be calculated.

This approach was developed for the shear design of webs by several researchers, including Gambarova (1979), Dei Poli et al. (1987, 1990), Kupfer et al. (1979, 1983), Kirmair (1987), and Kupfer and Bulicek (1991), and Reineck (1990, 1991a). The approach uses the free-body diagram in Figure 2.7, which is obtained by separating the member along an inclined crack in the B region of a structural concrete member with transverse reinforcement. Vertical equilibrium of this body gives the basic equation:

$$\mathbf{Vn=Vs+Vc+Vp} \qquad \mathbf{(2.15)}$$

The dowel force of the longitudinal reinforcement, which has a role in members without transverse reinforcement, is neglected, Figure 2.7. This is also the case for all design methods with a concrete contribution such as ACI Building Code 318-95 M, with either the standard method or the modified truss model approach.

2.4.3.2 Inclination and Spacing of Inclined Cracks

In the use of the truss model with crack friction, a necessary condition is that the crack inclination and the crack spacing must be assumed or determined by nonlinear analysis. The angle of the inclined cracks is normally assumed at 45° for non prestressed concrete members. Kupfer et al. (1983) has pointed out that this angle could be up to 5° flatter. Flatter angles will appear for pre-stressed concrete members or for members with axial compression, and steeper angles will occur for members with axial tension.

The spacing of the inclined cracks is primarily determined by the amount and spacing of reinforcement, and relevant formulas have been proposed by Gambarova (1979), Kupfer and Moosecker (1979), Kirmair (1987), and Dei Poli et al. (1990).

2.4.3.3 Constitutive Laws For Crack Friction

The truss model with crack friction requires constitutive laws for the transfer of forces across cracks by friction or interface shear. Others have often used the constitutive law proposed by Watraven (1980) because it describes not only the shear stress-slip relation for different crack widths but also the associated normal stresses. It was based on a physical model for the contact areas between crack surfaces, and the proposed laws were corroborated with tests on concrete with normal as well as lightweight aggregates.

2.4.3.4 Determining Shear Resistance Vf = Vc due to Crack Friction

The shear force component Vf = Vc in (2.15) transferred by friction across the cracks depends on the available slip and on the crack width, requiring that the strains in the chords and in the web be determined. In addition, the displacements and the strains must be compatible with the forces in the model according to the constitutive laws for the shear force components. Often the capacity of the crack friction mechanism is reached before crushing of the concrete struts between the cracks. Figure 2.8 gives the results of different calculations of the shear force component Vf =Vc in terms of stress from Dei Poli et al. (1987) and Kupfer and Bulicek (1991), but similar results have been obtained by Leonhardt (1965) and Reineck (1990, 1991a).

In many codes crack friction governs the design for low and medium shear. For very high shear, the strength of the compression struts governs, which is characterized by the quarter circle in Figure 2.9. The crack friction approach considers the influence of axial forces (tension and compression) as well as pre-stress, as shown in Figure 2.10.

2.4.3.5 Stresses and Strength of Concrete between Cracks

The main function of the concrete between the cracks is to act as the struts of a truss formed together with the stirrups as described by Morsch (1920, 1922), Figure 2.11(a) The additional friction forces acting on the crack surfaces, result in a biaxial state of stress with a principal compression field at a flatter inclination than the crack angle **βcr.** The minor principal stress is tensile for small shear forces, so the two trusses shown in Figure 2.12 may visualize the state of stress. The usual truss model with uniaxial compression inclined at the angle θ in Figure 2.12(a) is superimposed on a truss with concrete tension ties perpendicular to the strata [Figure 2.12(b)]. Thus, there are two load paths for the shear transfer, as defined by Schlaich et al. (1987) and as also earlier shown by Reineck (1982), and with different explanations by Lipski (1971, 1972) and Vecchio and Collins (1986) in their MCFT.

The model in Figure 2.12(b) is the same as that proposed by Reineck (1989; 1991a,b) for members without transverse reinforcement, so that the transition from members with to members without transverse reinforcement is consistently covered.

2.4.4 Truss Models

Since the early 1900s, engineers have used truss models to follow the flow of internal forces in structural concrete members and to provide structural systems made out of concrete and reinforcement that ensure equilibrium. The original 45° truss model of Ritter (1899) and Morsch (1920, 1922) been adopted either explicitly or implicitly by most the codes as the basis for their shear and torsion design specifications.

More modern versions of design specifications for concrete structures have extended this concept by recognizing the capability for redistribution of internal forces of reinforced and prestressed concrete beams containing stirrup reinforcement. This approach has been set up as a variable-angle truss with some established semi empirical limits for the angle of inclination supplemented with a concrete contribution. The concrete contribution included the presence of prestressing as well as the possibility of a diminished contribution after significant redistribution of the internal forces.

Vechio and Collins (1986) introduced the MCFT based on the assumption that tensile stresses in the concrete between the cracks contribute significantly to the shear resistance. The basic assumption was that these tensile stresses transverse to the axis of the strut exist at points between the inclined cracks, but are zero at the cracks. In their derivation, the tensile strength of the concrete strut diminishes as the principal strain $\in_1$, increases. The explanation is that the tensile strength of the concrete may be limited by the ability of the crack surfaces to transmit shear stresses that will depend on the crack width and the maximum size of the aggregate.

Refined methods have attempted to supplement the truss model strength with a concrete contribution term. An example of such approaches has been called the truss analogy with crack friction. In this approach, shear stresses are transferred across the cracks by friction. It can be regarded as a development based on the shear-friction theory.

Truss models approaches have been generalized to all parts of the structure in the form of strut-and-tie models. Structural concrete members with an adequate distribution of minimum transverse and longitudinal reinforcement can be designed using the simple strut-and-tie models. Three key advantages of this approach are that:

(a) The flow of internal forces is clearly visualized by the designer.

(b) The effects of both shear and moment are accounted for simultaneously and directly in the design.

(c) The design of (Beam) B and (Distributed) D type regions and the transitions between them can be conducted in a unified and consistent manner. Thus, the design can be carried out for the entire member using a full-member truss model as a generalized strut-and-tie model. Alternatively, the design of B regions can be carried out using a sectional model.

(d) The use of strut-and-tie models is especially advantageous in the design of D region characterized by a complex flow of internal forces resulting in significant nonlinear distribution of strains.

Chapter 3

WORK METHODOLOGY AND MATERIALS

3.1 GENERAL

Girder must be safe against premature failures of other types than flexure. These premature failures maybe more dangerous than flexural failure in the sense that, should catastrophic overloading and collapse occur, it might take place suddenly and without warning. Flexural shear is an example. Pre-stressed concrete flexural members contain special shear reinforcement to ensure that flexural failure, which can be predicted accurately and is usually preceded by obvious cracking and large deflections, will occur before shear failure, which is abrupt and more difficult to predict accurately. Contrary to reinforced concrete where commonly the most critical section for shear is near the support, in pre-stressed concrete several sections along the span maybe more critical than the support section. That is why shear is to be investigated at several section (tenth points) along the span.

Former work [27] was carried out by analyzing the existing pre-stressed bridges for flexure only. A total of sixteen bridges were analyzed and six girder sections were suggested. The design outcome was in the form of modified AASHTO standard sections with reduced moment of inertia yet giving same flexural capacity as of existing bridge girders. For designing the prestressed bridge girders both strength and serviceability requirements are to be satisfied. Effect of external loads produces flexure, shear and torsion, all of which must be accounted for in the design therefore flexural design alone cannot be termed as complete design. As torsion is not of concern in simply supported bridges therefore it leaves shear design aspect to be looked in to.

In order to supplement the former work for use, analysis of same sixteen bridges was carried out for flexure as well as for shear. With the same flexural capacity, shear analysis was carried out at every tenth point along the span up to mid span. To investigate shear at every tenth point, geometrical and mechanical properties of girder section along with some basic loads are known. Rest all the design inputs is to be determined through an iterative process so as to arrive at an optimized solution. As it depend on many variables, a change in one may effect some or all the parameters, therefore designer has to restrict to certain assumptions and design parameters leading to an optimized design.

3.2 DESIGN LOADS

The engineer must consider all the loads that are expected on the bridge during its service life. Such loads may be divided in to two categories; permanent loads and transient loads. Permanent loads remain on the bridge for an extended period, usually for the entire service life. Transient loads typically include gravity loads due to vehicular, railway and pedestrian traffic as well as the lateral loads. For the purpose of this study following loads are considered;

(a) Weight of the girder.
(b) Weight of the slab.
(c) Asphalt concrete or topping weight.
(d) Impact load.

At present, universally accepted critical truck load is AASHTO’S HS20-44, having a total weight of 72 kips distributed over three axles as 8 kips at front axle and 32 kips each at rear two axles. The axle spacing between front and middle axle is variable between 14 feet to 30 feet between middle and rear axle.

For the purpose of this study a fix axle spacing of 14 feet between middle and rear axle is used. It is obvious that 3 axle tendon is most critical combination. AASHTO also uses 3 axle truck having a load of 16 ton each for the rear two axle. It should be remembered that for spans less than 37 feet, alternate military loading would control the design with 70 tons of gross weight. For spans greater than 37 feet HS20-44 will be used being more critical. While considering the lane load, when more than one lane is loaded, the live load effects are reduced because of improbability of all lanes having their maximum loading at the same time, because of which a reduction in loading intensity is suggested by AASHTO. Roughness of riding surface cause dynamic variation in axle loads for which a dynamic load allowance commonly known as impact factor is applied to the design truck loads. The impact factor is $I = 50 / L + 125$ where I not greater than 30 % and L is span in feet.

3.3 DESIGN VARIABLES

Design tables would base on following variables:

3.3.1 Span Lengths

35feet-145feet

3.3.2 Loads

Besides self-weight and superimposed dead loads standard AASHTO HS20-44 OR HL-93 truck with 14ft axle spacing shall be considered.

3.3.3 Strand/Tendon Profiles/Patterns

Following patterns will be used:

(1) Straight tendons (S).

(2) One point/two point draped tendons (D1/D2).

(3) Parabolic or draped tendons (D).

3.3.4 Girder Types

Following AASHTO modified girders are considered (see Figure 1.1 to 1.6):

(1) G –36” I GIRDER

(2) G-42” I GIRDER

(3) G-48” I GIRDER

(4) G-52” I GIRDER

(5) G-63” T-BULB GIRDER

(6) G-72” T-BULB GIRDER

3.4 ANALYSIS PROCEDURE

3.4.1 General

A designer should be able to comprehend the complexities involved in modeling the structure he wants to design. Modeling of bridge structures involves a number of variables in the form of structural components and applied loads so as to justify the inequality (resistance to be greater than or equal to the effect of applied loads) to be experienced during the lifetime of the structure.

A correct model generates correct results of analysis and leads to a refined design. In order to assess the accuracy of the software’s, sixteen existing bridges on Grand Trunk road (Rawalpindi-Kharain section) were modeled and analyzed besides the manual calculations and the selection was made on the convergence of results.

3.4.2 PG Super (WSDOT) [26]

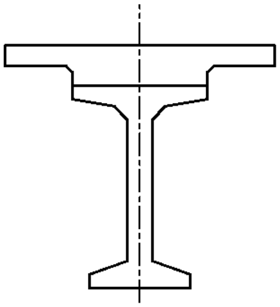
3.4.2.1. It is commercial software for analysis and design of pre-cast/pre-stressed bridges developed by Washington State Department Of Transportation (WSDOT). It has following salient features:

a) Based on AASHTO and Washington State Department Of Transportation (WSDOT) Load and Resistance Factor Design (LRFD) Bridge design specifications 1994 and 1998.

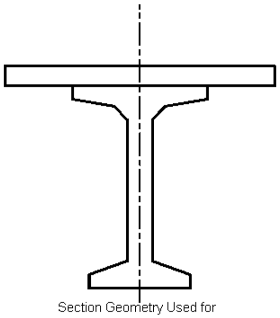
b) Girders are analyzed and designed.

c) Considers dead loads and live loads (HL-93) which is equivalent to HS20-44 used in AASHTO conventional design approach. Outputs are given for stresses, reactions, shears and moments from casting yard stage to lifting, hauling/handling and all service loads stages.

3.4.2.2. Modeling Details



Actual Section Geometry



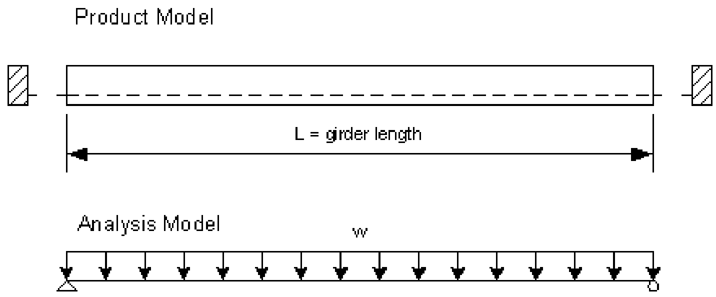
Section Geometry Used for
Property Calculations

3.4.2.2.1 Composite Section Properties

PG Super ignores the slab haunch and fillets when calculating composite section properties. The reason we do this is two folds. This provides the least-stiff section so it is likely to be conservative for computing stresses and deflections, and it makes structural modeling easy because it we have a prismatic section. Also, if camber in the field comes out too high, we may not actually have the slab pad we designed for at mid-span.

3.4.2.2.2 Structural Analysis Models

Generally the section describes the analytical models to calculate structural analysis results.



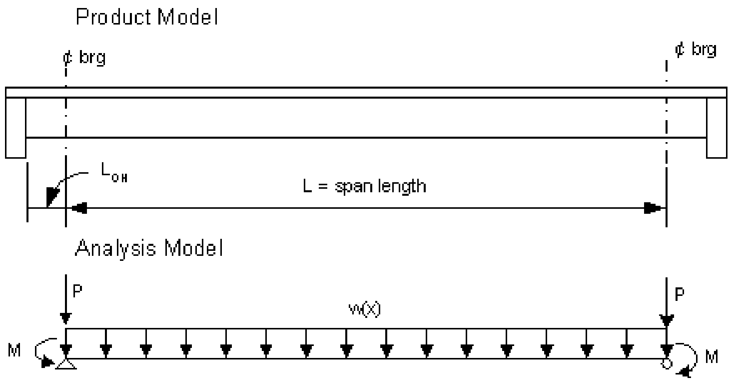
3.4.2.2.2.1 Casting Yard Stage

$W = Ag \gamma c g$

Material properties for concrete are based on the release strength.

3.4.2.2.2.2 Bridge Site Stage 1

The concentrated loads P and M are the loads induced by the cantilever portion of the girder and the end diaphragms. Because PG Super does not impose a restriction on the length of the overhangs or the size of the girders or diaphragms,



the induced moments and reactions can be significant, therefore they will be modeled.

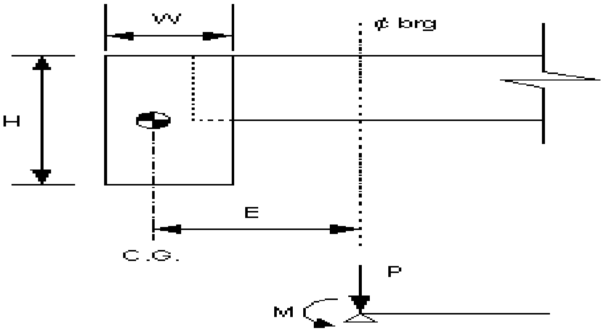
(1) Girder Cantilever Loads

Loads induced by the cantilever portion of the girder are:

$$W = Ag\ \gamma c\ L_{OH}$$

$$M = P\ (L_{OH} / 2)$$

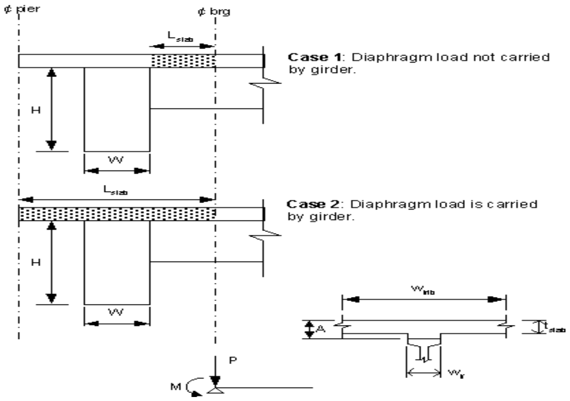
(2) Diaphragm Cantilever Loads



The loads induced by the diaphragms are:

$$P = H\ W\ \gamma c\ g\ Wtrib$$

$$M = P\ E$$



(3) Slab cantilever loads

The loads induced by the cantilever portion of the girder are:

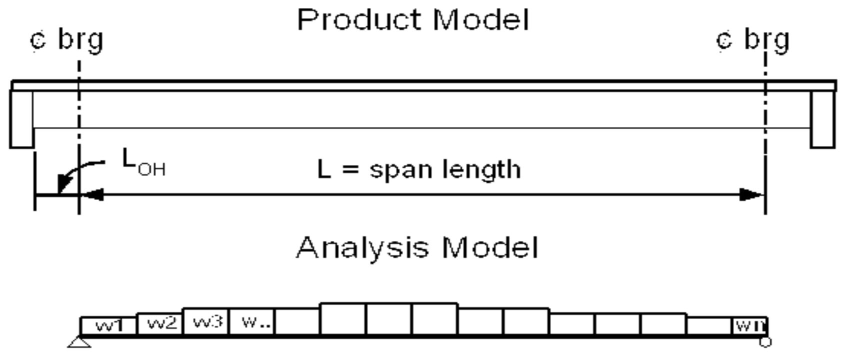
P = [Wtrib tslab + (A – tslab) Wtf] (Lslab) γcg

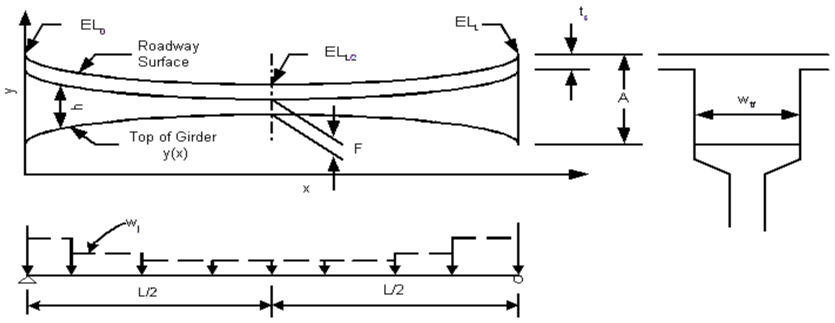
M = P (Lslab / 2)

(4) Slab Load in Main Span

Loads from the main slab on interior girders are uniform along the entire length of the girder. However, if the bridge is curved, the tributary width of the slab can change along the length of the girder as the bridge curves in or out. Hence, loads from the main slab for exterior girders are approximated with segments of uniform loads applied along the span. The load value for each segment is equal to the average tributary width taken at the ends of the segment.

For both types of girders, the main slab load is approximated as segments of uniform loads applied along the span

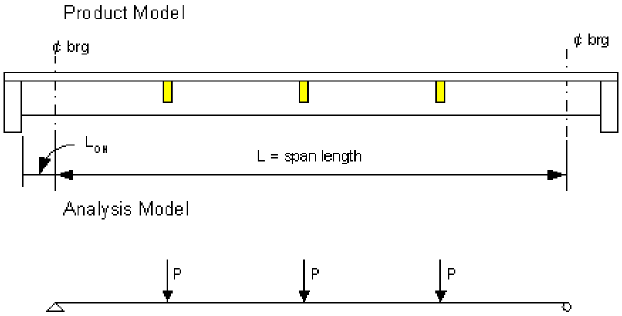




(5) Slab Pad Load in Main Span

The camber of the girder and the vertical curve form an hourglass shape. The top of girder is assumed to form a parabolic shape. The depth of the slab pad is A-t_s at the centerline of bearing and the fillet depth (F) at the centerline of span. The slab pad is approximated with segments of uniform loads.

(6) Intermediate Diaphragm Loads

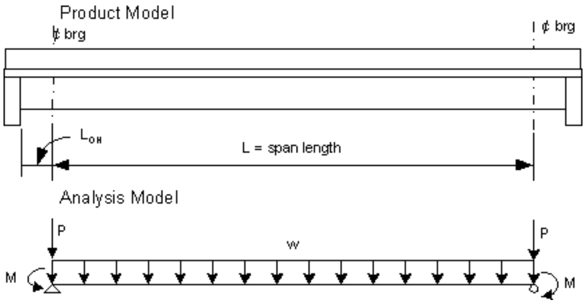


For interior girders, **P = H W γcg (Wtrib – tweb)** and for exterior girders, **P = H W γcg (S/2 – tweb/2)**

3.4.2.2.2.3 Bridge Site Stage 2

Superimposed dead loads are applied to the bridge in the stage 2 model. The superimposed dead loads consist of the traffic barrier and the overlay.

(1) Traffic Barrier Load

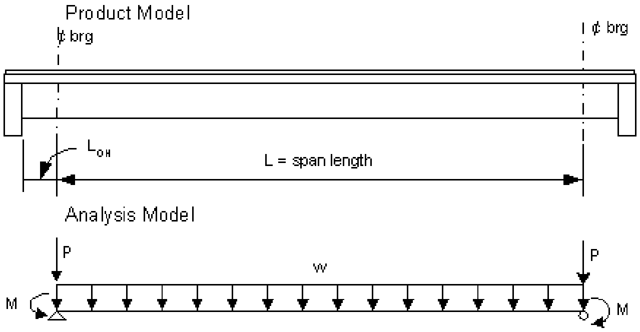


The basic traffic barrier load is **W = Asb γcg** . The traffic barrier load is distributed over *n* exterior girders, if there are 2*n* or more girders, otherwise the weight of the traffic barrier per girders is **W = 2W/N**, where N is the number of girders in the span. The cantilever portions of the load are:

$$P = W\ (W + L_{OH})$$

$$M = P\ (W + L_{OH}) / 2$$

(2) Overlay Load



The LRFD Specifications, Section 4.6.2.2.1, states that the overlay load may be evenly distributed over all the girders. This is what PG Super does. Hence for any girder:

$$w = (W_{cc}\ t_{olay}\ \gamma_{olay}) / N_{girders}$$

3.4.2.2.2.4 Bridge Site Stage 3

The live load is applied to stage 3. The HL93 live load model will be used and applied between the centerlines of bearings as per the LRFD specifications.

3.4.2.2.3 Locating the Critical Section for Shear

The LRFD Specification has made the determination of the critical section for shear a daunting calculation. This Section provides a discussion of the requirements, and assumptions for the algorithm to determine this location.

Article 5.8.3.2 states that the critical section for shear may be taken as the larger of **dv** or **0.5dv cot θ**. The LRFD Specification does not provide any information as to where d_v and θ are to be taken. WSDOT believes it should be at the location of the critical section. This makes the determination of the critical section for shear an iterative process since **dv** and **θ** vary based on location and Limit State.

The algorithm used to locate the critical section is as follows:

(a) Guess the location of the critical section X.

(b) Find d_v at X from the face of the support. Call this value X1

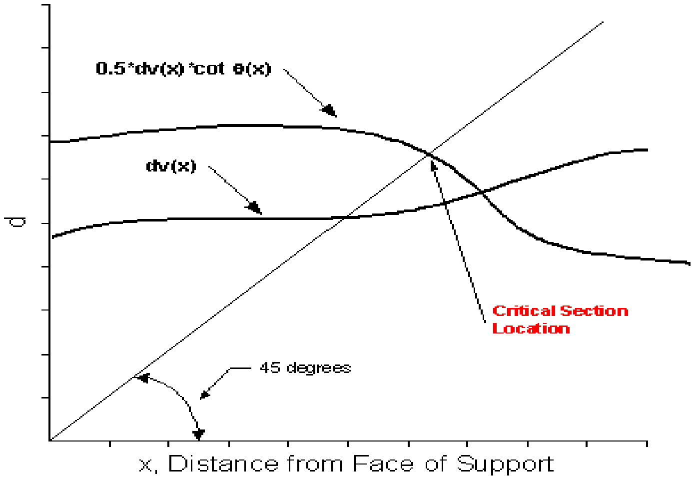
(c) Find θ at X from the face of the support.

(d) Using θ from Step 3 and d_v from Step 2, compute $0.5d_v\cot(\theta)$. Call this value X2.

(e) If X is not equal to the maximum of X1 and X2, go to Step 1 and repeat. Otherwise, X is the location of the critical section for shear.

(f) Repeat for each limit state used for shear design.

A graphical solution would look as follows:



Although accurate and true to the Specifications, this method is impractical because of the large computational cost of calculating force envelopes at each guessed location in order to determine θ(X) (a complete live load analysis would have to be run for every point). However, examination of many **dv** and θ graphs reveals that their shape is well behaved. Hence, it is practical to approximate the d_v and θ near the support. PG Super's implementation uses piecewise linear interpolation. The control points used to create the curves will be at the 0.00, 0.05, and 0.10 points along the girder. It is believed that the critical section for shear should always fall within this range.

3.4.3 COM-4 (89) [29]

ACI Educational Committee E705 developed this software in Fortran language with following features:

(a) Based on AASHTO working/allowable stress design specifications 1989 and 1992/1996.

(b) Both flexure and shear are considered in the program in addition to check for service load stresses and ultimate strength.

(c) Girders are analyzed and designed for dead load and live load (HS20-44).

(d) Outputs are given in terms of moments and shear envelopes based on which different design details are proposed.

(e) Beam line theory of composite section is used for structural model.

3.5 ASSUMPTIONS

For solution of engineering problem, certain assumptions enable the designer to focus his work on arriving at correct solution of the problem in hand by limiting the number of variables to be selected. In this study following assumptions are made;

3.5.1 Basic Assumptions

With reference to AASHTO 1996 section 9.13.2, following assumption are used;

(a) Strains vary linearly over the depth of the member.

(b) Before cracking, stress is linearly proportional to strain.

(c) After cracking, tension in the concrete is neglected. However, for MCFT tension in concrete is considered in the form of aggregate interlock by taking in to account the aggregate size.

3.5.2 Design Assumptions

For design it is imperative to make certain assumptions. These are made to simplify the problem. Some of assumptions used here are:

(a) Standard I and T-bulb girder sections of homogeneous, elastic and isotropic material.

(b) Bridge slab is of homogeneous, elastic and isotropic material.

(c) Bridge slab has a thickness of 7.5 inches.

(d) Asphalt layer is assumed to have a density of 125 lbs/ft^3.

(e) Parapet wall and railing is assumed to have a weight of 400 lbs/ft^3.

(f) All the girders are identical and equally spaced in a bridge.

(g) Girders are simply supported.

The reason for selecting 7.5-inch standard slab thickness is that the slab it should be capable of performing its intended role of load distribution to the girders. Only the selfweight of the parapet will be considered as they add to the over all dead weight of the structure. However, once poured monolithically with deck slab, it will add to the stiffness of the member. However, its stiffening effect will not be considered, thereby increasing the safety margin. [13]

3.5.3 Other Assumptions

(a) Vertical deflection and rotations are zero at supports. Stiffening effect of barrier and curb is ignored, because when the curb is monolithic with slab, they do have effect on the bending moment of edge/exterior girder, but the effect is too small and can be neglected.

(b) Barriers and diaphragms are not considered.

(c) No extreme event loads are considered.

(d) Limitation of AASHTO on strength of concrete for girder spacing and span are not considered.

3.6 PERMISSIBLE STRESSES [10]

AASHTO defined permissible stresses are considered, as;

(a) strand allowable stress = fsi = 0.75 fpu (low relaxation)

(b) Normal weight pre-stressed concrete with 6 ksi strength at 28 days with 80 % of design strength.

(c) Other stresses are as per AASHTO 1996.

3.7 MATERIALS

3.7.1 Steel

3.7.1.1 Pre-stressing steel

For the purpose of proposed design charts tables pre-stressing steel is 0.5 inch diameter, comprising uncoated 7-wire low relaxation grade 270 strand (as used in normal practice). The ultimate strength (fpu) of steel is 270 ksi and Modulus of Elasticity (Ep) is 28000 ksi.

3.7.1.2 Shear steel

The design tables proposed are based on using 2 # 3 bars U legged stirrups with yield strength (fy) of 40 ksi.

3.7.2 Concrete

Compressive strength of pre-stressed concrete at 28 days, in case of girder is 6 ksi and in case of deck slab is 3.6 ksi. Normal weight concrete with a density of 150 lbs/ft^3 is used for both girder and the deck slab.

Chapter 4

SHEAR DESIGN BY AASHTO/ACI STANDARD PROCEDURE

4.1 GENERAL

Shear stresses in regular beams are caused, not by direct shear or pure torsion, but by a combination of external loads and moment. In the regions of large bending moments, at about middle third of the beam span cracks develop almost perpendicular to the axis of the beam, called flexural cracks at about 50 % of the failure load in flexure. In the regions of high shear due to diagonal tension, inclined cracks develop as an extension of flexural cracks, called flexure shear cracks. The shear span to depth ratio in this case is of intermediate range varying between 2.5 and 5.5 for concentrated load. [5]

Beams that are most subject to shear compression (web shear) failure have smalls span to depth ratio of magnitude 2.5 for concentrated load and less than 5.0 for distributed loading. The inclined cracks are steeper than in the diagonal tension case. The shear compression type of failure, with the resulting crushing of the top compressive area of the concrete and failure to resist the flexural forces, leads to separation of the tension flange from the web in the flanged sections as the inclined cracks extend towards the support. Crushing of the web causes the beam to resemble a tied arch. This type of failure in pre-stressed beams can be better described as web shear failure. It is important to evaluate both the flexure shear capacity “Vci” and web shear capacity “Vcw” at each critical section in order to determine which predominates in determining the shear strength of the concrete section.

In flanged sections because of abrupt change of section at flange-web junction, a check of the section at the critical locations along the span becomes necessary particularly for web shear.

4.2 DESIGN BASIS [4]

The shear provision of the ACI Code correlate directly with the development of design based on conditions in the member at a hypothetical overload stage, with calculated dead loads and service live loads multiplied by the usual overload factors, except where otherwise noted. The design of cross sections subject to shear is to be based on the relation:

$$\mathbf{Vu \leq \varnothing \, Vn} \qquad \textbf{(4.1)}$$

The nominal shear strength Vn is calculated from the equation

$$\mathbf{Vn = Vc + Vs} \qquad \textbf{(4.2)}$$

The first critical section for shear assumed to be at a distance h/2 from the face of a support, and section located a distance less then h/2 are designed for the shear computed at h/2. This provision recognizes the beneficial effect of vertical compression in the concrete caused by the reaction. In special circumstances, those benefits are not obtained, and the shear at the support face may become critical.

4.3 NOMINAL SHEAR STRENGTH PROVIDED BY THE CONCRETE [4]

In (4.2), the value of Vc is to be taken equal to the smaller of V_{ci} and V_{cw}, determined by flexure-shear cracking and web-shear cracking respectively. These values are based on Equations (4.3) and (4.4).

First, in Equation (4.3) for flexure-shear cracking the term d/2 may be deleted, for the sake of simplicity. This has the effect of relating flexure-shear cracking to the load that causes flexural cracking at the section considered, rather than at a distance d/2 from the section considered, and makes the equation somewhat more conservative. Then, with slight notational changes,

$$\mathbf{V_{ci} = 0.6\sqrt{f'_c}\ b_w d + V_0 + V_i {*} Mcr/M_{max}} \qquad \mathbf{(4.3)}$$

Where **b_w** is the width of a rectangular section or the web width of a fanged section, and **d** is the depth from the compression face of the member to the centroid of the prestressing steel. On the basis of tests, the later value need not be taken less than 0.80h for this and all other code provisions relating to shear, except as specifically noted otherwise.

In Equation (4.3), Vi and M_{max} are, respectively, the factored* shear and bending moment at the section considered resulting from the superimposed dead load and live load and M_{cr} is the moment causing flexural cracking, computed by Equation (4.4):

$$\mathbf{M_{cr} = I_c/C_2\ (6\sqrt{f'_c} + f_{2p} - f_0)} \qquad \mathbf{(4.4)}$$

(Note that load factors, which are applicable identically to numerator and denominator here, will cancel; unfactored Vi and M_{max} can be used.)

In Equation (4.3), Vd is the shear due to the self-weight of the member and is computed without load factor. In Equation (4.5), f_o is the flexural stress at the bottom face of the beam, resulting from the self-weight of the member and is computed without load factor. The reason for separate consideration of self-weight was explained earlier. In applying Equation (4.3) V_{ci} need not be taken less than

$1.7\sqrt{f'_c}\, b_w\, d$, according to the code. The nominal shear strength corresponding to web-shear cracking is computed from Equation (4.5) without modification:

$$\mathbf{V_{cw} = (3.5\sqrt{f^1_c} + 0.3f_{cc})\, b_w d + V_p} \qquad \mathbf{(4.5)}$$

Where V_p is the vertical component of the effective prestress force at the section:

$$\mathbf{V_p = P_e \sin\theta}$$

In which θ is the slope of the tendon centroid line at the section.

Instead of using Equation (4.5), V_{cw} may be computed as the shear force corresponding to the dead load plus live load that results in a principal tensile stress of $4\sqrt{f'_c}$ at the centroid of the member, or at the intersection of the flange and web when the centroidal axis is in the flange.

For members with an effective pre-stress force not less than 40 percent of the tensile strength of the flexural reinforcement, an alternative to the use Equations (4.3) and (4.5) is permitted. The shear force V_c may be taken equal to

$$\mathbf{V_c = (0.6\sqrt{f'_c} + 700 * V_u d/M_u) b_w d} \qquad \mathbf{(4.6)}$$

In this equation, V_u and M_u are the factored shear and moment resulting from all loads, at the section considered, and the quantity $V_u d/M_u$ is not to be taken greater than 1.0. If Equation (4.6) is used, V_c need not be taken less than $2\sqrt{f'_c}\, b_w d$ and must not be taken larger than $5\sqrt{f'_c}\, b_w d$. In this equation, the actual effective depth "d" to the controid of the prestressing tendon is to be used in computing the term $V_u d/M_u$, according to ACI code. The usual lower bound for "d" or "0.80h" may be used in the final term "$b_w d$", which merely translates the nominal average shear stress V_c to shear force V_c. Equation (4.6) is simple to use compared with the more accurate Equations (4.3) and (4.5), but it may give very conservative and uneconomical results for certain classes of members.

4.4 REQUIRED AREA OF WEB REINFORCEMENT [4]

When shear reinforcement perpendicular to the axis of the member is used, its contribution to shear strength is:

$$\mathbf{V_s = A_u f_y d/s} \qquad \textbf{(4.7)}$$

But the value of V_s is not to be taken larger than $\mathbf{8\sqrt{f'_c}\ b_w d}$.

The total nominal shear strength V_n is found by summing the contributions of the steel and the concrete:

$$\mathbf{V_n = A_u f_y d/s + V_c} \qquad \textbf{(4.8)}$$

From Equation (4.1), in the limiting case, and Equation (4.2):

$$\mathbf{V_u = \varnothing Vn}$$

$$\mathbf{= \varnothing (V_s + V_c)} \qquad \textbf{(4.9)}$$

From which:

$$\mathbf{V_u = \varnothing (A_u f_y d/s + V_c)} \qquad \textbf{(4.10)}$$

The required cross-sectional area of one stirrup “A_v” may be calculated by suitable transposition of Equation (4.10):

$$\mathbf{A_v = (V_u - \varnothing V_c)\ s\ /\ \varnothing f_y d} \qquad \textbf{(4.11)}$$

Normally, in practical design, the engineer will select a trial stirrup size, for which the required spacing is found. Thus, a more convenient from of Equation (4.10) is:

$$\mathbf{S = \varnothing A_v f_y d\ /\ V_u - \varnothing V_c} \qquad \textbf{(4.12)}$$

If the spacing determined for the trial stirrup size is to close for placement economy or practicality, or if it is so large that maximum spacing requirement control over too great a part of the beam spans, than a revised bar size is selected and the calculation repeated.

4.5 MINIMUM WEB REINFORCEMENT [4]

At least a certain minimum area of shear reinforcement is to be provided in all pre-stressed concrete members, where the total factored shear force V_u is greater than one half of the shear strength $\varnothing V_c$ provided by the concrete. Based on successful performance, the following types of members are excepted from this requirement:

a. Slabs and footing.

b. Concrete joist construction (including ribbed members such as double –T beam).

c. Beams with a total depth not greater than the largest of 10 in; two and one-half times the thickness of the flange, and one-half of the web width.

The minimum area of shear reinforcement to be provided in all other causes is to be taken equal to the to the smaller of the following values:

$$\mathbf{A_u=50\ b_{ws}/f_y} \qquad \textbf{(4.13)}$$

And

$$\mathbf{A_u=A_p\ f_{pu}\ s^*\ \sqrt{}d/b_w\ /\ 80\ fy\ d} \qquad \textbf{(4.14)}$$

In which $A_p$is the cross-sectional area of the pre-stressing steel, fy is yield stress of the stirrup steel; f_{pu} is the ultimate tensile strength of the pre-stressing steel. All other terms are as previously defined.

Note that a decrease in b_w will result in a decrease in A_v, according to Equation (4.13), but in increase in A_v, according to Equation (4.14). The first equation was originally based on studies of reinforced concrete beams with web reinforcement, having a ratio of depth-to-web width of about two. The second equation was derived specifically for pre-stressed concrete beam, and was intended to ensure that in section with narrow webs, the ratio of web reinforcement would be greater than in thick-webbed sections. Equation (4.14) will generally require less shear reinforcement that Equation (4.13); however according to ACI code, it may be used only if the effective pre-stress is not less than 40 percent of the tensile strength of the pre-stressed reinforcement. The ACI code contain, in addition certain restrictions on the maximum spacing of web reinforcement to ensure that any potential diagonal crack will be crossed by at least a minimum amount of web steel. For pre-stressed members, this maximum spacing is not to exceed the smaller of 0.75h or 24 in. If the value of V_s exceeds $\mathbf{4\sqrt{f'_c}\ b_w d}$, these limits are reduced by one-half.

Chapter 5

SHEAR DESIGN BY LRFD APPROACH

5.1 GENERAL

In the design procedure domain, the design procedures based on Limit State were applicable to steel structures. Later on, with improvement in statistic and probability, this domain extended towards the concrete structures thereby presenting much reliable analysis solutions. This procedure enables analysis of response of the structure at each loading stage, thus, allowing suitable safety margin (FOS) at each stage and finally resulting in a realistic figure of FOS. Examples of limit states for girder type bridges include deflection, cracking, fatigue, shear, torsion, buckling, settlement, bearing and sliding. Well-defined limit states are established so that a designer knows what is considered to be acceptable FOS.

The determination of an acceptable margin of safety (how much greater resistance should be compared to the affects of load) is the responsibility of experts. AASHTO developed new specifications for highway bridges based on Load and Resistance Factor Design (LRFD) in 1994 and now all of US State Department of Transportation (SDOT) has resorted to this code of practice.

5.2 LRFD BRIDGE DESIGN SPECIFICATIONS [2]

5.2.1 Introduction

This is a very brief introduction to the LRFD Specifications. It covers only a few general topics and a light treatment of concrete design. The objective is to provide an overall perspective of what LRFD is all about. Detailed information and in-depth technical discussions are included only for shear design of prestressed bridges. Following abbreviation will be used during this overview:

LRFD	AASHTO LRFD Bridge Design Specifications
SS	AASHTO Standard Specifications for Highway Bridges
STM	Strut and Tie Model (see shear and torsion design)
MCFT	Modified Compression Field Theory

5.2.2 Background

In 1986, the AASHTO Subcommittee on Bridges and Structures, sensing that the Standard Specifications for Highway Bridges may contain some inconsistencies and may not represent the state-of-the-art in bridge design, took what was essentially the first step in replacing it. The load and resistance factor design (LRFD) philosophy, which is considered to his the state-of-the-art in bridge design was completed in 1993, and the LRFD Specifications were adopted by AASHTO as a parallel specification to the Standard Specifications. Currently, several US States Department of Transportation (SDOT) has adopted or are very near to adopting the LRFD Specifications.

5.2.3 LRFD Philosophy

The LRFD Specifications embody the philosophy that bridges should be designed with the objectives of constructability, safety and serviceability in mind with due regard to issues of inspectability, economy and aesthetics. To achieve these objectives in the design of a bridge, certain specified limit states must be met: the structure must be exhibit significant ductility, the structure must have multiple load paths (i.e., be redundant), and the operational importance of the structure must be recognized.

5.2.4 Notation and Units

While some of the notations used in LRFD are similar to that of the Standard Specifications, some of it is actually quite different. In those instances where the notation in LRFD does differ from that of the Standard Specifications, the notation is generally the same as that used in ACI 318, the code for reinforced concrete building-type structures. With regard to the Customary US Units version, the units of “lb” and “psi” have been replaced by ‘KIP’ and ‘KSI’, respectively (note convention of using capital letters). Consequently, many of the familiar coefficients in equations have changed although the equations themselves are actually the same.

5.2.5 Load Types

The engineer must consider all the loads that are expected to be applied to the bridge during its service life. The LRFD Specifications separates loads into two categories: permanent loads and transient loads. Within each of these two broad categories are many sub-categories, and several additional load types have been defined. Each load type is now uniformly identified with a two-letter code.

5.2.5.1 Permanent Loads

With regard to permanent loads, several types are specified. Note that, previously, the structural dead load of a bridge was lumped into a single category. Now however, it is separated in to two categories, DC and DW, which allows different load factors to be applied to each type.

Symbol	Description
DD	Downdrag
DC	Dead load of structural components

	and non structural attachments
DW	Dead load of wearing surfaces and utilities
EH	Horizontal earth pressure
ES	Earth surcharge load
EV	Vertical pressure from dead load Of earth fill.

5.2.5.2 Transient Loads

As the name implies, these loads change with time and may be applied from several directions and/or locations. Typically such loads are highly variable. The transient load types defined in LRFD are:

Symbol	Description
BR	Vehicular braking force
CE	Vehicular centrifugal force
CR	Creep
CT	Vehicular collision force
CV	Vessel collision force
FR	Friction
IC	Ice load
IM	Vehicular dynamic load allowance
LL	Vehicular live load
LS	Live load surcharge
PL	Pedestrian live load

SE	Settlement
SH	Shrinkage
TG	Temperature gradient
TU	Uniform temperature
WA	Water load and stream pressure
WL	Wind on live load
WS	Wind load on structure

5.2.5.2.1 Live Load

One of the most significant changes introduced into bridge design with the new specifications is the vehicular live load model. In LRFD, there are three components of load which are as follows:

Design Truck: An 8-kip axle followed by two 32-kip axles. The distance between the first pair of axles is fixed at l4 feet while the back axles are variably spaced between 14 and 32 feet.

Design Tandem: Consists of a pair of 25-kip axles with a fixed spacing of 4 feet.

Design Lane: A uniform distributed load of 0.64-kips per foot (KLF).

From a configuration standpoint the LRFD design truck is identical to the axle load portion of the HS2O-44 truck of the Standard Specifications. It should be noted, however, that the LRFD design truck is not scaleable like the HS2O. That is, there is no, for example, HS25 equivalent under LRFD.

5.2.5.2.2 Application of Vehicular Live Load.

Generally, two combinations of the vehicular live load components must be investigated for all bridge types to determine the worst-case live load effects. Collectively, these combinations are termed HL-93 and are as follows:

Design truck + design lane

Design tandem + design lane

For continuous bridges, between the points of dead load contra flexure and for determining the worst-case reactions at interior piers, a special provision is made. In this case, 90% of the effect of two design trucks and 90% of the design lane are considered. The axle spacing of the trucks in this case is fixed at 14.0 ft and distance between the front axle of one truck and the rear axle of the other need not be less than 50.0 ft. When determining the worst-case loading, skip loading and other techniques should be used to cause the extreme force effect. Axles that do not contribute to the extreme force effect should be neglected.

5.2.5.2.4 Fatigue Load

A special vehicle is used for fatigue analysis. It consists of one design truck, as specified above, but with the rear (32-kip) axle spacing fixed at 32.0 ft and without an accompanying uniform load.

5.2.5.2.4 Pedestrian Load

The railing for pedestrian and/or bicycle must be designed for a load of 0.73 N/mm both transversely and vertically on each longitudinal element in the railing system. In addition the railing must be designed to sustain a single concentrated load of 980 N applied to top rail at any location and any direction.

5.2.5.3 Multiple Presence Factor

Trucks will be present in the adjacent lanes on roadways with multiple design lanes but it is unlikely that three adjacent lanes will be loaded simultaneously with heavy loads. Therefore, some adjustments in the design loads are necessary. To account for the effects of multiple lanes on a bridge, multiple presence factors are given. They are provided for the cases of one lane, two lanes, three lanes, and three or more lanes. It should be noted that the effects of multiple presence factors have been factored into the approximate live distribution factor equations given in the LRFD Specifications. However, for fatigue analysis, where one lane is considered, the distribution factored obtained using the approximate method must be divided by the one-lane multiple presence factor of 1.2. Table for Multiple presence factors "m" (LRFD Table 3.6.1.1.2-1).

Number of loaded lanes	Multiple Presence Factors "m"
1	1.2
2	1.00
3	0.85
> 3	0.65

5.2.5.4 Dynamic Affects

The roadway surface is not perfectly smooth; thus the vehicle suspension must react to the roadway roughness by compression and extension of the suspension system. This oscillation creates axle forces the exceed the static weight during the time the acceleration is upwards and is less when the acceleration is downwards, commonly called impact or Dynamic Load Allowance (DLA). This DLA is illustrated as under;

Component	IM(DLA) %
Deck joints- all limit states	75
All other components	
Fatigue and fracture limit states	15
All other limit states	33

These factors to be applied to the static load as $U_{L+1} = U_L (1+IM)$

Where, U_{L+1} is live load effect plus allowance for dynamic loading.

5.2.6 Load Modifiers/ Modification Factors

Load modification factor 'h' is a factor which takes in to account the ductility, redundancy and operational importance of the bridge is given by ;

$$h = h_D h_R h_I \geq 0.95$$

Where, h_D is for ductility, h_R is for redundancy and h_I for operational importance. The first two factors refer to the strength of the bridge and third refer to the consequence of a bridge being out of service. Reinforced concrete can be made ductile by limiting flexural reinforcement and providing confinement with hoops or stirrups.

(a) Ductility Factor 'h_D'

= 1.05 for non ductile components and connections

= 0.95 for ductile components and connections

(b) Redundancy Factor 'h_R'

It significantly affects the safety margin of bridge structure. An indeterminate structure is redundant because it has multiple load paths and a single path structure is non-redundant.

= 1.05 for non redundant members

= 0.95 for redundant members

(c) Operational Importance Factor "h_I

A bridge can be considered of operational importance if it is on the shortest path between residential areas and a hospital or school or provide access for police, fire and rescue vehicles to homes, businesses and industrial plants. Following requirement apply to extreme and strength limit states;

= 1.05 for a bridge of operational importance

= 0.95 for a non important bridge

5.2.7 Load Combination and Load Factors

The load factors for each of limit states are entirely different from those of the SS. LRFD Tables 3.4.1-1 and 3.4.1-2 give the load factors and load combinations for each limit state. For example, for a simple-span prestressed concrete girder, Strength Limit State I is defined as follows:

Q= 1.25DC+ 1.5DW+ 1.75LL

Where Q is the total force effect and DC, DW, and LL are as defined above

Load factors for various load combination, as given in LRFD Table 3.4.1-1 are;

Load combination	DC	LL					TU			Use of one these at a time			
	DD	IM	WA	WS	WL	FR	CR	TG	SE				
	D W	CE					SH						
	EH	BR											
Limit State	EV	PL								EQ	1C	CT	CV
	ES	LS											
Strength I	gp	1.75	1			1	0.5/1.2	gtg	gse				
Strength II	gp	1.35	1			1	0.5/1.2	gtg	gse				
Strength III	gp		1	1.4		1	0.5/1.2	gtg	gse				
Strength IV EH,EV,	gp/ 1.5												
ES,DW and DC			1			1	0.5/1/2						
ONLY													
Strength V	gp	1.35	1	0.4	0.4	1	0.5/1.2	gtg	gse				
Exterme Event I	gp	geq	1			1				1			
Extreme Event II	gp	0.5	1			1					1	1	1
Service I	1	1	1	0.3	0.3	1	1/1.2	gtg	gse				
Service II	1	1.3	1			1	1/1.2						
Service III	1	0.8	1			1	1/1.2	gtg	gse				
Fatigue		0.75											

- Load factors for permanent loads, gp

5.2.8 Load Factors for Permanent Loads “gp”

Type of Load	Load Factor "gp"	
	Max	Min
DC: component and attachment	1.25	0.9
DD: down drag	1.8	0.45
DW:wearing surface and utilities	1.5	0.65
EH:horizontal earth pressure		
active	1.5	0.9
rest	1.35	0.9
EV:vertical earth pressure		
overall stability	1.35	N/A
Retaining structure	1.35	1
rigid burried structure	1.3	0.9
rigid frame	1.35	0.9
flexible burried structure	1.95	0.9
Flexible metal box culverts	1.5	0.9
ES:earth surcharge	1.5	0.75

5.2.9 Resistance Factor

Resistance factors, f, are statistically based multipliers which are applied to the nominal resistance of the member. For concrete, these factors are as follows:

Application	Resistance Factor”f”
Flexure and Tension	
reinforced concrete	0.90
prestressed concrete	1.00
Shear and Torsion	
normal weight concrete	0.90
light-weightconcrete	0.70
Axial Compression	0.75
Bearing on Concrete	0.70

Compression in Strut-and-Tie Models	0.70
Compression in Anchorage Zones	
Normal weight concrete	0.80
light-weight concrete	0.65
Tension Steel in Anchorage Zones	1.00

5.2.10 Limit States

In LRFD, the design framework consists of satisfying what are called limit states. All limit states shall satisfy: **h gi Q_1 f Rn = Rr**

where:

h = Load modifier
gi = Load factors
Qi = Force effects
f= Resistance factors
Rn = Nominal resistance
Rr = Factored resistance

To obtain an understanding of this concept, it is helpful to refer to the actual definition of “limit state” contained in the LRFD Specifications:

5.2.10.1 Limit State. “A condition beyond which the bridge or component ceases to satisfy the provisions for which it was designed.” (LRFD 1.2)

5.2.10.1.1 Strength Limit State

The strength Limit State refers to providing sufficient strength or resistance to satisfy the inequality of **h ≤ gi Qi ≤ f Rn**. The load modifier, which for all non strength limit states is 1.00 for the statistically significant load combinations that a bridge is expected to experience in its design life. Strength limit states include the evaluation of resistance to bending, shear, torsion and axial load. The resistance factor “f” will usually be less than 1.00. There are five strength limit states and fortunately not all apply in every situation and some can be eliminated by inspection. These are;

(a) **Strength I**. Basic load combination relating to normal vehicular use of the bridge without wind.

(b) **Strength II**. Relating to use of bridge by special or permit vehicle without wind.

(c) **Strength III**. Relating to bridge exposed to wind velocity greater than 55 MPH or 90 KMPH.

(d) **Strength IV**. Relating to very high dead load/ live load force effects ratios.

(e) **Strength V**. Relating to load combination relating to normal vehicular use of bridge with wind of 55MPH or 90KMPH.

5.2.10.1.2 Extreme Event

This state refers to the structural survival of a bridge during a major earthquake or flood or when collided by a vessel, vehicle or ice flow. The probability of these events occurring simultaneously is very low; therefore they are specified to be applied separately. Extreme events are described as;

(a) **ExtremeEvent I**. Load combination including earthquake.

(b) **Extreme Event II.** Ice vessel and vehicle collision.

5.2.10.1.3 Service Limit State.

Service limit states refer to restriction on stresses, deflections and crack width of bridge components that occur normal service condition. For this state resistance factor “f” = 1.0. There are three service limit state load combinations as under;

(a) **Service I**. Refers to the load combination relating to the normal operational life of the bridge with 55MPH or 90KMPH wind, and with all loads taken at their normal values. It is used to investigate compressive stresses in prestressed concrete components.

(b) **Service II**. Refers to the load combination relating only to steel structures so as to control yielding.

(c) **Service III**. Refers to the load combination relating only to the tension in prestressed concrete structures with the objective of crack control. The statistical significance of the 0.80 factor on live load is that the event is expected to occur about once a year for bridges with two lanes less often for bridges with more than two lanes and about once a day for bridges with a single traffic lane.

5.2.10.1.4 Fatigue and Fracture Limit State

Refers to a set of restriction on stresses ranges caused by a design truck. The restrictions depend on the number of stress range excursions expected to occur during the design life of the bridge. They are intended to limit crack growth under repetitive loads and to prevent fracture due to cumulative stress effects in steel elements, components and connections. For fatigue limit state and fracture limit state “f” =1.0. Under the SS, these same types of design checks are performed. However, they are performed in a different framework.

5.2.11 Analysis

5.2.11.1 General

The LRFD Specifications state that any reasonable method of analysis may be used for the analysis of a bridge, provided that the method satisfies the requirements of equilibrium and compatibility and utilizes stress-strain relationships for the proposed material. Among the types of analyses specifically mentioned as acceptable in the Specifications are:

- Classical force and displacement method
- Finite difference method
- Finite element method
- Folded plate method
- Finite strip method
- Grillage analogy method
- Series or other harmonic methods
- Yield line method

As a side note, the Specifications caution the engineer about the use of computer programs, which are based on the above methods. It clearly states that the designer is the one who is responsible for the results when a program is used. The implication is that a program is merely a design aid and that the engineer can use whatever tools are at his or her disposal. However, he or she takes full responsibility for their use. It suggests that when a software is used, that the name, version number, and release date of the program be indicated in the contract documents.

5.2.11.2 Approximate Method

In lieu of detailed analyses, if certain criteria are met, the approximate methods of analysis given in the LRFD Specifications can be used. These methods are, of course, empirical, but can save considerable time over more refined methods: If the approximate methods can be used, only a few relatively simple equations need to be processed. Compared to the amount of effort required to perform, for example, a finite element analysis or even a simple frame analysis, the amount of work saved by using the approximate method can be considerable.

5.2.11.3 Strip Method for Decks

Decks can be designed by either the empirical method or by the so-called traditional method. As the name implies the empirical method is not a rational method; there is no analysis involved. Rather, reinforcement is specified in terms of a required area of steel per foot for the top and bottom layers of reinforcement in the deck, which is the same in both directions. However, to be able to use the empirical method, several criteria must first be met which are outlined in Chapter 9 of specifications.

The traditional method involves dividing the deck up into transverse strips that are of different widths depending what is being investigated. Strip widths are specified for positive moment, negative moment and the design of the overhang.

5.2.11.4 Distribution Factors for Beam-Slab Bridges

With regard to the so-called simplified analysis of beam-slab bridges, the live load distribution equations are still considerably more complex in the LRFD Specifications than those of the Standard Specifications. Previously, there was only a single distribution factor, which was applicable to both shear and moment which, was usually computed with a very simple equation (e.g., S/5.5). Now, however, there are separate equations for the distribution factors for shear and moment, and these equations are functions of several parameters. Nevertheless, if applicable, it is certainly more practical to use the distribution factor equations rather than having to resort to the alternative which is to do a grillage or finite element analysis. To be able to use the live load distribution factors specified in the LRFD Specifications, however, the following conditions must first be met.

a. Constant cross section
b. Number of beams is four or more.
c. Beams are parallel
d. Beams have same stiffness
e. Roadway portion of overhang does not exceed 3.0 ft (910mm).
f. The plan curvature is small. (Art 4.6.1.2)
g. Cross section is similar to cases covered

Other restrictions may also apply for each individual distribution factor case. These are generally stated in terms of a range of applicability in the tables.

5.2.11.5 Distribution Factor for Moment

To determine the applicable distribution factor equation, the correct LRFD classification of bridge type must first be determined. For a typical prestressed I-girder bridge with a composite deck, the bridge type is Type “k” (case covered). For moment in interior beams, Table 4.6.2.2.2b-1 is referenced. For two or more lanes loaded, the distribution factor is:

$$\mathbf{DF = 0.075 + (S/9.5)^{0.6} (S/L)^{0.2} (Kg/12Lts^{3})^{0.1}}$$

where,

$$\mathbf{Kg = n(l + A\, eg^2)} \quad \text{(LRFD 46221-1)1}$$

Provided that:

- $3.5 \leq S \leq 16$
- $4.5 \leq ts \leq 12.0$
- $20 \leq L \leq 240$
- Number of beams ≥ 4
- $30° \leq \theta \leq 60°$

slab (in), L = span length (ft)

5.2.11.6 Distribution Factor for Shear

The distribution factor equation for shear for an interior beam of a type (k) bridge (prestressed I girder bridge with cast in place deck slab) with two or more lanes loaded (LRPD 4.6.2.2.3a-1) is:

$$\mathbf{DF = 0.2 + S/12 - (S/35)^{2.0}}$$

5.2.11.7 The Lever Rule

For cases where the beam spacing exceeds the maximum spacing given in the tables, the lever rule is to be used for determining the live load distribution factor. As with the Standard Specifications, this involves assuming the deck to be hinged at interior supports, in which case the live load distribution factor is the reaction of the supported member at the support. When lever rule is used, multiple presence factors (Art 3.6.1.1.2) must be applied to the loads. (Note: For the cases covered in the tables, multiple presence factors are already accounted for in the equations).

5.2.11.8 Distribution of Superimposed Dead Load to Stringers

Permanent loads may be uniformly distributed among all beams if the conditions required for applicability are met (Art. 4.6.2.2.1). That is, the superimposed dead load can be equally distributed to each beam provided that the criteria for use of the live load distribution factors are met. This corresponds to the provision in the Standard Specifications that allows equal distribution of the weight of curbs, railing and wearing surface to all roadway stringers or beams if they are placed after the slab has cured.

5.2.12 Concrete Design

5.2.12.1 Overview

What is contained in Chapters 8 and 9 in the SS is now combined into a single chapter, Chapter 5 of the LRFD. This supports the LRFD notion of structural concrete rather than having separate treatments of reinforced concrete and prestressed concrete. The goal is to provide one chapter that provides a smooth transition between reinforced concrete and fully prestressed concrete, including all degrees of partial prestress.

5.2.12.2 Prestress Losses

As with the SS, there are four components of prestress loss; elastic shortening, shrinkage, creep, and steel relaxation. The procedures and equations given in the LRFD Specs for the computation of these losses are essentially the same as in the Standards Specifications. The nomenclature, however, has been changed to the following:

$$\boldsymbol{\Delta fp_T = \Delta fp_{ES} + \Delta fp_{SR} + \Delta fp_{CR} + \Delta fp_R}$$

Only two minor changes have been introduced into the actual computations, both of which relate to steel relaxation. First, steel relaxation loss now consists of two components, one that represents loss at transfer and the other that represents loss after transfer (i.e., long-term). The other change is that relaxation is put in terms of stress-relieved strands. For low-relaxation strands, 30% of the stress-relieved value is taken. Recall that in the SS, two separate equations were used for long-term steel relaxation whereby relaxation for low-relaxation steel is 25% of the value for stress-relieved.

5.2.12.3 Transfer Length

The distance from the terminal point of a pretension seven-wire strand to the point where the full amount of prestress has been transferred to the concrete is assumed to be 60 strand diameters. Note that this is slightly longer than the 50-strand diameter that is assumed under the Standard Specifications.

5.2.12.4 Flexural Strength

The strength Limit State requires that the following relationship be satisfied:

$$\mathbf{Mr = \phi Mn > Mu}$$

where,

f = 1.0 for flexure of prestrèssed concrete (LRFD 5.5.4.2),   = 0.90 for flexure of reinforced concrete, For cases of partially prestressed components, f may be taken as:

$$\mathbf{f = 0.90 + 0.10\,(PPR)} \quad \text{(LRFD 5.5.4.2.1-1)}$$

Where the partial prestress ratio, PPR (LRFD 5.5.4.2.1-2), is defined as:

$$\mathbf{PPR = Aps\ fpy / (Aps\ fpy + As\ fy)} \qquad \mathbf{(5.1)}$$

5.2.12.5 Rectangular Sections

To evaluate Mn, the nominal flexural resistance of a beam cross section, it must first be determined whether the section acts as a rectangular beam or as a T-beam. For the section to act as a rectangular section, the neutral axis must be located within the flange of the beam. For a rectangular beam, the depth of the neutral axis, measured from the extreme compression fiber of the beam, is:

$$\mathbf{C = (Apsfpu+Asfy-A'sf'y) / (0.85f'c\beta_1 b+kApsfpu/dp)} \qquad \mathbf{(5.2)}$$

where,

β_1 = Ratio of the depth of equivalent uniformly stressed compression zone assumed in the strength limit state to the depth of the actual compression zone (LRFD 5.7.2.2).

$$\mathbf{k=2(1.04\text{–}fpy/fpu)} \qquad \mathbf{(5.3)}$$

Note that “k” is essentially the same as the “g” parameter of the standard specifications, which is a factor for the type of prestressing steel used.

For low-relaxation prestressing steel k = 0.28 and for stress-relieved steel, k = 0.35.

If the section functions as a rectangular beam the strength is given as follows;

$$\mathbf{Mn=Apsfps(dp-a/2)+Asfy(ds-a/2)-A's\ f'y(d's-a/2)} \qquad \mathbf{(5.4)}$$

where,

fps =Average stress in the strands at:

$$\mathbf{Mn= fpu(1- k\ c/dp)} \qquad \mathbf{(5.5)}$$

Provided fpe ≤ 0.5fpu

$a=\beta_1 c$

5.2.12.5.1 Flanged Sections

If the neutral axis drops outside of the flange, then the section acts as a T-beam in which case the depth of the neutral axis is computed by:

$$\mathbf{C = [Apsfps + Asfy - A'sf'y - 0.85\beta_1 f'c(b\text{-}bw)hf] / [0.85f'c\beta_1 bw + kApsfpu/dp]} \qquad \mathbf{(5.6)}$$

The flexural strength of a T-section is then given by:

$$\mathbf{Mn=Apsfps(dp\text{-}a/2)+Asfy(ds\text{-}a/2)\text{-}A'sf'y(d's\text{-}a/2)+0.85f'c(b\text{-}w)\beta_1 hf(a/2\text{-}hf/2)} \qquad \mathbf{(5.7)}$$

5.2.12.5.2 Other Cross Sections

For sections that do not behave as a rectangular or a simple T-section, or for cases in which fpe< 0.5fpu the idealized formulae given in the LRFD Specifications cannot be used. A more general approach to evaluating the nominal flexural resistance is required. In such cases, a strain compatibility procedure is most often employed. The beam cross section is divided into trapezoidal-shaped layers of different material type and each layer of reinforcing is modeled separately.

5.2.12.6 Limits of Reinforcement

5.2.12.6.1 Maximum Steel

The limitation on the amount of steel at a particular cross section is expressed in terms of a limiting depth of neutral axis. The maximum amount of steel that can be contained within in a section is such that the depth to the neutral axis of the section can be no more than 42% of the depth to the centroid of the tensile reinforcement That is,

$$\mathbf{c\ /de \leq 0.42}$$

$$\mathbf{de = (Apsfpsdp + Asfyds) / (Apsfps + Asfy)} \tag{5.8}$$

If the above ratio is exceeded, then the section is deemed to be over-reinforced. Reinforced concrete sections, as indicated by a PPR <0.50, are not permitted to be over-reinforced. However, if the section is prestressed or partially prestressed (PPR 0.50), then the section is permitted to be over-reinforced provided that the section is sufficiently ductile.

5.2.12.6.2 Minimum Steel

At every section, the flexural resistance of a member must be at least 20% greater than the moment required to crack the section (LRFD 5.7.3.3.2). The cracking moment Mcr, is the moment required causing first cracking based on the modulus of rupture as specified in Article 5.4.2.6. That is,

$$\mathbf{Mr \geq 1.2\ Mcr}$$

If a section contains so pre-stressing steel, the cracking ratio may be considered satisfied if the following ratio of steel is satisfied (LRFD 5.7.3.3.2-1):

$$\boldsymbol{\rho}\mathbf{min \geq 0.03\ f'c/\ fy}$$

5.2.12.7 Crack Control

The tensile stress in mild steel at the service limit state, fsa, cannot exceed the following (LRFD 5.7.3.41):

$$\mathbf{fsa \leq z\ /(dc\ A)^{1/3} \leq 0.6\ fy}$$

where,

Z = Crack width parameter (Kips/in) = 170 Kips/in for moderate exposure conditions = 130 Kips/in for severe exposure conditions

5.2.12.8 Fatigue Limit State

5.2.12.8.1 Prestressing Tendons

Stress range limitations are imposed on prestressing tendons. For radii of curvature greater than 30.0 ft, the stress range must be limited to 18.0 KSl, and for radii of curvature less than or equal to 12.0 ft, the stress range may not exceed 30.0 ft (LRFD 5.5.3.3). When the radius of curvature is between 12.0 ft and 30.0 ft, a linear interpolation between these limits is performed.

For pretension girders with draped strands, the drape point is assumed to be a point of curvature. At that point, the radius of curvature is assumed to be less than or equal to 12.0 ft. The allowable stress range under fatigue loading is, therefore, 10 ksi . The strands that will experience the greatest change in stress will be those in the bottom-most row of the strand pattern. Assuming the lowest level of strands to be located 2.00 in from the bottom of the girder, the stress range caused by the fatigue loading at that level is.

$$\mathbf{D_f = M_f(Y_{bc}-2.00)(Ep/Ec) / Ic} \qquad \mathbf{(5.9)}$$

5.2.12.8.2 Reinforcing Bars

The stress range in straight reinforcing bars is not permitted to exceed:

$$\mathbf{f_t\text{-}21\text{-}0.33f_{min}+8(r/h)} \qquad \mathbf{(5.10)}$$

5.2.12.9 Shear and Torsion

With the LRFD Specifications, a completely new method Called Modified Compression Field Theory (MCFT), of shear design has been adopted. The new method is a simple, unified method that is applicable to both prestressed and nonprestressed members. Unlike the previous empirical method, however, MCFT is a rational method that gives physical significance to the parameters being calculated.

5.2.12.9.1 Design of Stirrups

For shear design, as before, the following basic relationship must be satisfied at each section:

$$\mathbf{Vu \leq \phi\, Vn}$$

Where; $$\mathbf{Vn=Vc+Vs+Vp} \qquad \mathbf{(5.11)}$$

This relationship is similar to the method of shear design prescribed in the AASHTO Standard Specifications. However, with LRFD, Vu is computed in an entirely different manner. The equation for Vc is now

$$\mathbf{Vc = 0.0316\beta\sqrt{f'c}* b_v* d_v} \qquad \mathbf{(5.12)}$$

The value of "β" at a given section must be obtained through an iterative process. The following two parameters must be computed as part of this process.

$$\mathbf{v = (Vu\text{-}\phi Vp)/\phi\ b_v\, d_v} \qquad \mathbf{(5.13)}$$

$$\mathbf{\in x = (\ Mu/dv + 0.5Nu + 0.5Vu\ \cot\theta\ \text{-}\ Aps\ fpo\ )\ /\ (\ Es\ \ As + Ep\ Aps\ )} \qquad \mathbf{(5.14)}$$

where,

$$\mathbf{fpo=fpe+fpcEp/Ec} \qquad \mathbf{(5.15)}$$

fpc = Net stress at c.g of composite section at final conditions (KSI). If $\in x$ is negative, $\in x$ must be reduced by multiplying by the following factor:

$$\mathbf{F = (EsAs+EpAps)/EcAc + EcAs + EpAps} \qquad \mathbf{(5.16)}$$

where,

Ac = Area of concrete on flexural tension side = Area of beam below h/2 (in^2),

Aps = Area of strand on tension side (in^2).

A first trial value of "θ" is assumed in order to compute the initial value of $\in x$. Then, knowing v and $\in x$, LRFD Table 5.8.3.4.2-1 is used to look up The corresponding values of "β" and "θ" . If "θ" is not within a reasonable tolerance of the assumed “θ” then the current value of “θ” is used to compute a new $\in x$, and a new look-up in The table performed. When convergence is reached, Vc can be then be calculated.

The critical section for shear, the section closest to The support that must be considered, is the greater of:

(a) 0.5 dv cotq or (LRFD 5.8.3.2)

(a) dv

where,

dv = Effective shear depth = distance between resultants of tensile and compressive forces. But dv need not be taken less than the greater of:

(a) O.9de (LRFD 5.8.2.7)

(a) O.72h

The maximum shear capacity of a section is given by :

$$\mathbf{Vn = 0.25\, f'c\; bv\; dv + Vp} \qquad \mathbf{(5.17)}$$

Assuming vertical stirrups, the contribution from the stirrups is:

$$\mathbf{Vs = Av\; fy\; dv\cot\theta\, /\, S} \qquad \mathbf{(5.18)}$$

The minimum transverse reinforcement is:

$$\mathbf{Av = 0.0316\, \sqrt{f'c}\; bvs/fy} \qquad \mathbf{(5.19)}$$

5.2.12.9.2 Longitudinal Reinforcement.

One of the cornerstone principles of modified compression field theory is the recognition that shears causes tension in longitudinal steel. At each section of the beam not subjected to torsion, the capacity of the longitudinal reinforcement must be checked for sufficiency. To determine the required tensile capacity of the longitudinal reinforcement the following expression is used:

$$\mathbf{Asfy+Apsfps \geq [Mu/dv\phi=0.5Nu/\phi+(Vu/\phi-0.5Vs-Vp)cot\theta]} \qquad \mathbf{(5.20)}$$

In the above expression, Aps, is the amount of prestressing steel on the flexural tension side of the cross section. The flexural tension portion of the cross section is the region from the mid-height of the cross section to the extreme tension fiber. At the ends of beams with draped strand patterns, generally only the straight-strand portion of the strand pattern will be effective as Aps. Note that the effects of partial strand development must considered when computing Aps. For the special case of the inside edge of the bearing area at simple-end supports, the longitudinal reinforcement on the flexural tension side of the member must resist a force of:

$$\mathbf{Asfy + Aps \geq (Vu/\phi - 0.5Vs - Vp)\ cot\theta} \qquad \mathbf{(5.21)}$$

5.2.12.9.3 Interface Shear

Shear acting at the interface of the beam and deck is given by;

$$\mathbf{Vuh = Vu\ Q / I} \qquad \mathbf{(5.22)}$$

$$\mathbf{Vn = c\ Acv + \mu\ (Avf\ fy + Pe)} \qquad \mathbf{(5.23)}$$

Solving for Avf;

$$\mathbf{Avf = Vn - c\ Acv / \mu fy} \qquad \mathbf{(5.24)}$$

The LRFD Specifications limits bv to 36.00 in.

For a roughened surface; c = 0.100 ksi, μ = 1.000

The minimum steel that must be provided is:

$$\mathbf{Avf \geq 0.05\ bv\ s / fyy} \qquad \mathbf{(5.25)}$$

5.3 SHEAR DESIGN BY LRFD APPROACH

5.3.1 General

LRFD specifications employ a different approach for shear design of prestressed concrete members, called as Modified Compression Field Theory

(MCFT). It is a simple and unified method unlike empirical method used in AASHTO standard specifications.

5.3.2 Shear Design Procedure [9]

The shear design of members with web reinforcement consists of following steps.

a. Step 1. Determine the factored shear “Vu” and moment “Mu” envelopes due to the strength I limit state. Values are determined at the tenth points to each span. Interpolation can easily be made for vales at critical sections such as a distance “dv” from the face of a support. In the derivation of the MCFT, “dv” is defined as the lever arm between the resultant compressive force and the resultant tensile force in flexure. The AASHTO [A5.8.2.7] adds that “dv” need not be less than 0.9de or 0.72h, where “de” is the distance from extreme compression fiber to the centroid of the tensile reinforcement and “h” is the overall depth of the member.

b. Step 2. Estimate a value of θ, say 40°, and the longitudinal strain “$\in x$” from equation 4.14. For a prestressed beam fpo = fpe + fpc/Ep/Ec.

c. Step 3. Use the calculated values of “v/f′c” and $\in x$, to determine θ from [29] and compare with the value estimated in step 3. If different, recalculate “$\in x$” and repeat step 4 until the estimated value of θ agrees with the value from [29]. When it does, select β from the chart. This chart is for shear design of members with web reinforcement.

d. Step 4. Calculate $Vc = 0.083\beta\sqrt{f'c}\ bv\ dv$

e. Step 5. Calculate prestress contribution to shear resistance “Vp”. Check for transfer length = 60 strand diameters and critical section for shear $\geq 0.5dv \cot\theta$ or dv [AASHTO A5.8.3.2]. If $dv >$ transfer length so full value of Vp can be used.

f. Step 6. Calculate the required web reinforcement strength $Vs = Vu/\phi - Vp - 0.083\beta\sqrt{f'c}\, bv\, dv$.

g. Step 7. Calculate the required spacing of stirrups as, $s \leq Av\, fy\, dv \cot\theta / Vs$. the spacing must not exceed the value limited by the minimum transverse reinforcement of AASHTO [A5.8.2.5] that is, $s \leq Av\, fy / 0.083\sqrt{f'c}\, bv$. It also must satisfy the maximum spacing requirements of AASHTO [A5.8.2.7] that is, if $Vu < 0.1f'c\, bv\, dv$, then $s \leq 0.9dv \leq 600mm$ and if $Vu \geq 0.1f'c\, bv\, dv$, then $s \leq 0.4dv \leq 300mm$.

h. Step 8. Check the adequacy of the longitudinal reinforcement [AASHTO A5.8.3.5] by $Asfy + Aps \geq Mu/dv\phi_f + 0.5Nu/\phi_\alpha + (Vu/\phi v - 0.5Vs - Vp) \cot\theta$, where ϕf, $\phi\alpha$ and ϕv are the resistance factors for flexure, axial load and shear. If the inequality is satisfied, either add more longitudinal reinforcement or increase the amount of stirrups.

5.4 SHEAR DESIGN METHODOLOGY FOR PRESTRESSED BRIDGE GIRDERS

5.4.1 Problem Statement [3]

A simply supported pretension concrete bridge girder (Figure 5.1) of “K” type bridge [AASHTO table 4.6.2.2.1-1] with a span length of 82 feet center to center of bearings is to be designed for shear for HL-93 live load (HS20-44 equivalent). The roadway width is 48 feet with 7.5” thick deck slab and allow for future wearing surface of 3” thick bituminous overlay. There are total of 5 girders spaced at 8 feet center to center. Other relevant details for shear design are as under:

a) fc girder = 6 ksi

b) fc deck slab = 4 ksi

c) Prestressing steel = 28, ½ in, G 270 low relaxation strands (Aps = 4.284 in2)

d) 12 strands harped at third points (Figure 5.1)

e) End eccentricity Ee = 10.2 in

f) Eccentricity at center Ec = 20.9 in

g) Diaphram and barrier weight are not considered

h) Density of overlay = 125 pcf

i) Ag = 685 in2

j) fpu = 270 ksi

k) fps = 263 ksi at critical section

l) fpc = fpo =164 ksi

m) Pe = 702.58

n) Ep = 28000 ksi

o) Ec = 4570.12 ksi

5.4.2 Solution Methodology [9]

5.4.2.1 Load and resistance factors [A5.5.4.2.1]

a. Resistance factor for shear and torsion for a normal weight concrete fv = 0.90
b. Load modifier / modification factor for strength I limit state (as applicable) h = 0.95

5.4.2.2 Applicable Load Combination [Table A3.4.1-1]

Shear is to be investigated for strength I limit state U = h [1.25 DC + 1.50 DW + 1.75 (LL +IM)]

5.4.2.3 Live Load Distribution Factor for Shear "DF"

a. Distribution factors for moments and shears are calculated for one design lane load or two or more design lane loads, for both interior and exterior girders separately. In this case exterior girder is being considered for which whichever gives the higher value so shall be applied for calculations of shear forces.
b. For "K" type cross section [Table A4.6.2.2.1-1] and considering exterior girder with deck [TableA4.6.2.2.3b, Table A4.6.2.2.3b-1] (ref [9] P- 610,611,639 and Table 6.5)
c. Applying lever rule, for one design lane loaded R = P/2(0.92 + 8 / 8) = 0.558 P. [9]
d. With multiple presence factor for one lane "m" = 1.2, distribution factor "DF"
e. becomes = 1.2 * 0.558 = 0.670

5.4.2.4 Loads at exterior girder

a. DC

Weight of overhang = [{(4*12) * 7.5}/ 144] * 150/1000 = 0.375 k/ft

Weight of girder = (685/144) * 150/1000 = 0.714 k/ft

Weight of slab

For exterior girder effective flange width [A4.6.2.6-1]

1/8 effective span = 1/8(82) = 10.25 ft

be | 6 ts + ¼ bf = 6(7.5) + ¼(22) = 4.21 ft

Width of overhang = 4 ft (governs)

so be = S/2 + 4 = 8 *12/2 + 4 * 12 = 96 in

Weight of slab = {(96 * 7.5)/144} * 150/1000 = 0.75 k/ft

DC = 0.375 + 0.714 + 0.75 = 1.84 k/ft

b. DW

Load taken by the composite member = 3 in overlay

DW = (96 * 3/144) * 125/1000 = 0.250 k/ft

DW = 0.250 k/ft

5.4.2.4 Impact Factor for Live Load (IM)

Impact factor or dynamic load allowance (DLA) as per AASHTO A3.6.2.1 for other than deck joints and fatigue is IM = 0.33

5.4.2.5 Effective Depth of Prestressing Steel "dv" [9].

dp = from top of deck slab to the centroid of prestressing steel

a. At mid span: dp = (54 + 7.5) –3.7 = 57.80 in

Dv = dp –a/2 0.9 dp = 0.9 (57.80) = 52.02 in

0.72 h = 0.72 (61.50) = 44.28 in governs

a = B c where B for 6 ksi concrete = 0.75

and from c = [Aps fpu +As fy +As fy – 0.85 Bfc (b-bw) hf]/ [0.85 fc B bw + k Aps (fpu/dp)] c = 5.39 in so a = 0.75 * 5.39 = 4.04 in

therefore dv = 57.80 – 4.04/2 = 55.78 in [A5.8.2.7]

b. At girder end : dp = (54 + 7.5) – 14.40 = 47.10 in

and bv max of 0.9dp = 0.9(47.10) = 43.39 in or 0.72h = 0.72(61.5) = 44.28 in (governs)

5.4.2.6 Prestress Contribution to Shear Resistance “Vp”

Transfer length [A5.8.2.3] = 60 strands diameters = 60 * 0.5 = 30 in

Critical section for shear ≥ 0.5 dv cot θ or dv [A5.8.3.2]. Since dv > transfer length therefore full value of Vp will be used. Critical section for shear at dv = 44.28 in or 3.69 ft from the support [9].

$$\theta = \tan^{-1} (14.40 /23.64 *12) = 2.906°$$

$$Vp = Pe \sin \theta = 702.58 \sin 2.906° = 35.618 \text{ kips}$$

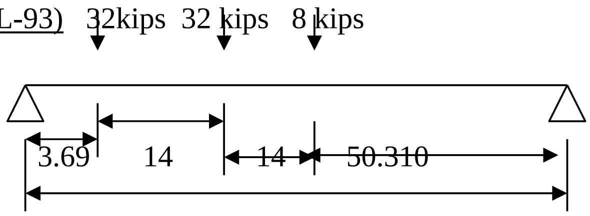
<u>Vp = 35.618 kips</u>

5.4.2.7 Determinition of Concrete Nominal Shear Strength “Vc”

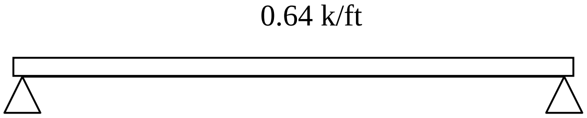
Shear design would be at the critical section at distance dv = 3.69 ft from support and at tenth points along the span. For other places necessary interpolation between tenth points can be done.

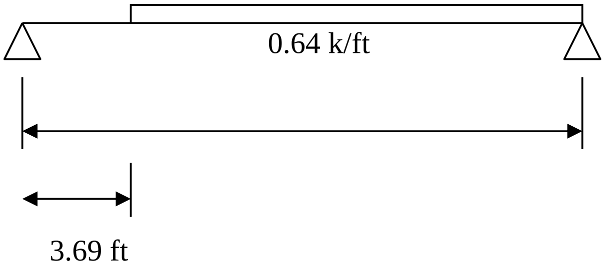
a. <u>Live load placement for maximum shear at “dv”</u>

(1) <u>Truck load (HL-93)</u>



(2) Lane load. Design lane load consists of uniformly distributed load of 0.64 k/ft and it is assume to occupy a region of 9.84-ft transversely.





b. Shear due to truck load “Vtr”

$Vtr = [\ 32\ (64.310 + 78.310)/\ 82 + (50.310\ /\ 82) = 60.57$ kips

c. Shear due to design lane load “Vlane”

$Vlane = ½\ (63.62)\ (78.310/82)^2 = 29.01$ kips

d. Maximum ultimate shear force “Vu”

$Vu = h\ [1.25\ DC + 1.50\ DW + 1.75 * DF * (LL + IM)]$

Now considering $dv = 3.69$ ft $= 44.28$ in

$X = dv\ /\ L = 44.28\ /\ 82 * 12 = 0.045$

For a unit load of $w = 1$ k/ft, shear at $x = Vx = w * L(0.5 – X) =$

$W * 82\ (0.5 – 0.045)$

$Vx = 37.310\ w$, Substituting the values in general equation

$Vu = 0.95\ [\{1.25(1.84)(37.310)\} + \{1.5(0.250)(37.310)\} +$

$\{1.75 * 0.670 *(60.57)(1+0.33)\} + 29.01]$

Vu = 223.27 kips

e. Maximum ultimate moment “Mu”

As above for moment at x = Mx = 0.5 w L2 (x – x2)

$= 0.5\ w\ (82)^2\ (0.045 - 0.045^2)$

Mx = 144.82 w for unit moment

(1) Moment due to truck load Mtr = 3.69(Vtr) = 3.69(60.57) = 223.5 k-ft

(2) Moment due to lane load M lane = 115.22 k-ft

Substituting the values in general equation

Mu = 0.95 [{1.25(1.84)(144.482)} + {1.5(0.250)(144.482)} + {1.75 * 0.670 * (223.50)(1+0.33)} + 115.22}]

Mu = 785.224 k-ft

f. Calculating “Vc”

(1) Shear stress v = (Vu/ϕ -Vp) / bv dv where bv = 7 in and ϕ = 0.9

So v = (223.27 / 0.9 – 35.618) / (7 * 44.28) = 0.685 ksi

And v/f′c = 0.685/6 = 0.114

(2) Longitudinal strain “∈x”

∈x = [(Mu/dv) + 0.5 Nu + 0.5 Vu cotθ - Aps fpo] / [EsAs + EpAps]

where Mu = 785.224 k-ft = 9422.69 k-in, Vu = 223.27 kips, Nu = 0, dv = 44.28 in

Es and As = 0, Ep = 28000 ksi, fpo = fpe = 164 ksi

Substituting the values

$\in x = [(9422.69/44.28) + 0.5 * 223.27 * \cot \theta - 4.284 * 164] / [28000 * 4.28]$

$\in x = -0.00408 + 0.00093 \cot \theta$

Assuming $\theta = 36°$, $\in x = -0.0028$ (pre-compression). Since $\in x$ is negative, so it shall be reduced by a factor $F\in = (EpAs + EpAps) / (EcAc + EsAs + EpAps)$.

$Ac = 371\ in^2$

$F\in = (28000 * 4.284)/[(4570.12 * 371) + (28000 * 4.284) = 0.06624$

$F\in = 0.06624$

So $\in x = -0.0028 * 0.06624 = -0.00019$

$\in x = -0.00019$

Now using $v/ f'c = 0.114$ and $\in x = -0.00019$ and making a look up on chart [29] gives

$$\theta = 22°$$

Since assumed value and obtained value do not converge so making a second iteration and assuming $\theta = 20°$ giving $\in x = -0.001525$ being negative, reduced to

$\in x = 0.06624 * (-0.001525) = -0.00101$

Now with $v / f'c = 0.114$ and $\in x = -0.00101$, obtained a value $\theta = 21° \cong 20°$, so values converged.

Value of “Vc”

Vc = β √f′c* bv* dv, with v/f′c = 0.114 and θ = 20° value of β obtained from chart (figue 5.3) is β = 2.85 so Vc = 2.85 √6000 * 7 * 44.28 / 1000 = 68.43 kips

<u>Vc = 68.43 kips</u>

5.4.2.8 Stirrups Spacing "s"

Vs = Vu/ϕ - Vc – Vp = (223.27/ 0.9) – 68.43 – 35.18 = 144 .47 kips

<u>Vs = 144.47 kips</u>

Using # 4 bars (Ab = 0.20) double legged stirrups with fy = 60 ksi, the required stirrup spacing at critical section is

s = Av fy dv cot θ / Vs = (2 * 0.20 * 60 * 44.28 * cot 20°) / 144.47 = 20.21 in. **<u>s = 20.21 in</u>**

<u>Use # 4 bar double-legged stirrups @ 20 in c/c up to 3.69 ft from support</u>

5.4.2.9 Check For Longitudinal Steel [A5.8.3.5]

Asfy + Apsfps ≥ [(Mu/ϕf dv) + (0.5 Nu/ϕa) + (Vu/ϕv – 0.5 Vs – Vp) cot θ]

fps = 266 ksi at mid span and 263 ksi at critical section

so 4.284*263 ≥ [(9422.69/1.0*44.28) +(223.27/0.9 – 0.5*144.27 – 35.62) cot 20°

1126.69 ≥ 355.77 kips (No longitudinal steel is required).

Chapter 6

ANALYSIS OF CURRENT DESIGN PRACTICES

6.1 GENERAL

In order to present certain analysis procedures or design details, it is customary to develop an insight of behavior or response of various structural components against external loads, which requires its integration with prevailing design practices making a virtual structural model. This whole system is well understood when certain case studies are undertaken and thoroughly investigated / analyzed to see various design details, variation in design and reasons for such variation.

Foregoing in view, two case studies are taken, one for an existing bridge and other for under construction bridge so a to assess the variations in previous and present design practices/details. Salients of these bridges are as under:

Type of Bridge	Span(ft)	No of Girders	Girder Type	Girder Spacing(ft)
Dina Nullah bridge on Rawalpidi-Kharian section	**98.43**	**4**	**80.71" I-section**	**8.86**
Hisara Drain bridge on Peshawar-Islamabad Motorway M-1	**98.59**	**6**	**70.86" I-Section**	**15.73**

The reasons for the selection and making comparison of the two are as under:

a) Girder span lengths are almost equivalent, so span length effect is not considered.

b) Assessment of effect of variation in concrete contribution to resist shear "Vc" because of variation in the cross sectional depth which is almost 10 inches and in shear area which is about 62 inch^2.

c) Difference in girder spacing is about 8.87 feet. Since it is the most sensitive parameter-influencing shear so its variation will be assessed.

d) To assess the effect of girders concrete strength and cross-section properties on shear resistance.

e) Variations and deficiencies if any, of shear design details will be addressed so as to propose a new design.

f) To assess economic effects of implementation of LRFD Bridge Design Specification.

6.2 CASE STUDY- EXISTING BRIDGE ON DINA NULLAH

6.2.1 General Bridge Information

Number of Spans	1
Girder Type	DINA NULLAH INTERIOR GIRDER
Girder Concrete	5 KSI
Slab Concrete	3 KSI
Pre-stressing Strands	0.50 in Dia. Grade 270 Low Relaxation

6.2.2 Spans

Span #	# Girder Lines	Girder Spacing (ft)
1	4	8.858 ft

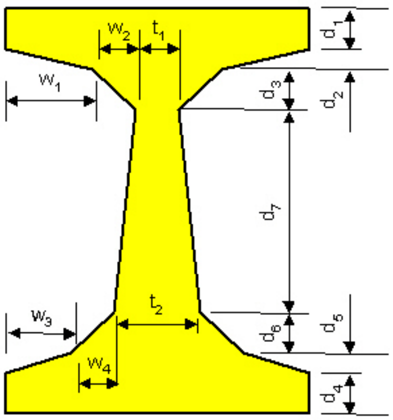
6.2.3 Slab Geometry

<u>Dimensions</u>
Gross Depth = 7.87 in
Overhang = 4.757 ft
A = 9.09 in
Fillet = 1.22 in

<u>Surfacing</u>
Overlay Depth = 1.97 in
Overlay Density = 125 lbf/ft^3
Sacrificial Depth = 0.50 in

<u>Material</u>
Concrete DINA 3 KSI

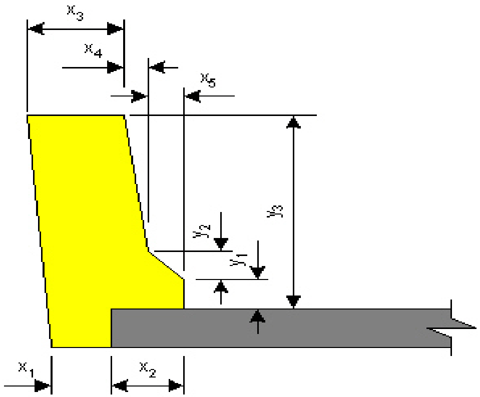
6.2.4 Girder Dimensions



d_1 = 7.87 in
d_2 = 3.94 in
d_3 = 0.00 in
d_4 = 13.78 in
d_5 = 8.86 in
d_6 = 0.00 in
d_7 = 46.26 in
w_1 = 5.31 in
w_2 = 0.00 in
w_3 = 8.27 in
w_4 = 0.00 in
t_1 = 7.09 in
t_2 = 7.09 in

GirderLength=98.43ft

6.2.5 Barrier Dimensions



X_1 = 0.00 in
X_2 = 15.75 in
X_3 = 6.69 in
X_4 = 1.97 in
X_5 = 7.09 in
Y_1 = 7.09 in
Y_2 = 9.84 in
Y_3 = 37.01 in

Traffic Barrier Area = 385.882 in^2

6.2.6 Connection Details

Connection	Girder End Distance (ft)	Girder Bearing Offset (ft)	End Diaphragm Width (W) (in)	End Diaphragm Height (H) (in)	End Diaphragm C.G. Distance (ft)
DINA End Type AASHTO	0.246	0.246	23.62	80.71	0.246

6.2.7 Intermediate Diaphragms

Diaphragm Height = 80.71 in

Diaphragm Width = 23.62 in

# of Diaphragms (spaced evenly over flexible span length) = 3

6.2.8 Section Properties

	Girder	Composite
Area (in^2)	977.664	-
I_x (in^4)	709501.231	1591947.466
I_y (in^4)	24344.151	-
$Y_{t\ girder}$ (in)	46.14	28.07
$Y_{t\ slab}$ (in)	-	35.45
Y_b (in)	34.57	52.63
$S_{t\ girder}$ (in^3)	15377.775	56704.787
S_b (in^3)	20523.298	30245.428
$S_{t\ slab}$ (in^3)	-	44908.967
Q_{slab} (in^3)	-	17660.308
Eff Flg Width (in)	-	97.35
Perimeter (in)	214.63	-

6.2.9 Materials

Girder 5 ksi Concrete

f'_c	5.000 KSI
Density for Weight Calculations g_c	150 lbf/ft^3
Density for Strength Calculations g_c	150 lbf/ft^3
Max Aggregate Size	0.75 in

Slab 3ksi Concrete

f'_c	3.000 KSI
Density for Weight Calculations g_c	150 lbf/ft^3
Density for Strength Calculations g_c	150 lbf/ft^3
Max Aggregate Size	0.75 in

6.2.10 Prestressing Force and Strand Stresses

Prestressing for this girder

Number of straight strands (N_s) = 0 (P_{jack} = 0.00 kip)

Number of harped strands (N_h) = 40 (P_{jack} = 1091.78 kip)

Number of temporary strands (N_t) = 0 (P_{jack} = 0.00 kip)

A_{ps} (with temporary strands) = 5.760 in^2

A_{ps} (without temporary strands) = 5.760 in^2

P_{jack} (with temporary strands) = 1091.78 kip

P_{jack} (without temporary strands) = 1091.78 kip

Prestress Transfer Length = 30.00 in

6.2.11 Comparison of Shear Capacity and Design of Original and Proposed Girder

6.2.11.1 Effective Shear Dimensions

Location from Left Support (ft)	b_v (in)	Moment Arm (in)	d_e (in)	h (in)	d_v (in)
(0.0L) 0.00	7.09	51.07	53.93	88.08	63.42
(CS) 5.28	7.09	55.01	57.89	88.08	63.42
(H) 6.73	7.09	56.11	58.99	88.08	63.42
(0.1L) 9.79	7.09	58.44	61.32	88.08	63.42
(1.5H) 10.09	7.09	58.67	61.55	88.08	63.42
(0.2L) 19.59	7.09	65.91	68.79	88.08	65.91
(0.3L) 29.38	7.09	73.39	76.27	88.08	73.39

(HP) 39.17	7.09	80.87	83.75	88.08	80.87
(0.5L) 48.97	7.09	80.87	83.75	88.08	80.87
(HP) 58.76	7.09	80.87	83.75	88.08	80.87
(0.7L) 68.55	7.09	73.39	76.27	88.08	73.39
(0.8L) 78.35	7.09	65.91	68.79	88.08	65.91
(1.5H) 87.84	7.09	58.67	61.55	88.08	63.42
(0.9L) 88.14	7.09	58.44	61.32	88.08	63.42
(H) 91.21	7.09	56.11	58.99	88.08	63.42
(CS) 92.65	7.09	55.01	57.89	88.08	63.42
(1.0L) 97.93	7.09	51.07	53.93	88.08	63.42

6.2.11.2 Shear Parameter Summary - Strength I Limit State

Location from Left Support (ft)	f'_c (KSI)	v/f'_c	e_x x 1000	b	θ (deg)
(0.0L) 0.00	5.000	0.182	2	1.08	36.00
(CS) 5.28	5.000	0.146	0.164	2.49	27.48
(H) 6.73	5.000	0.142	0.44	2.35	31.08
(0.1L) 9.79	5.000	0.134	0.211	2.5	27.73
(1.5H) 10.09	5.000	0.133	0.251	2.48	28.33
(0.2L) 19.59	5.000	0.103	1.98	1.45	38.85
(0.3L) 29.38	5.000	0.0606	2	1.69	42.58
(HP) 39.17	5.000	0.0533	2	1.71	42.87
(0.5L) 48.97	5.000	0.0335	2	1.72	43.00
(HP) 58.76	5.000	0.0518	2	1.71	42.93
(0.7L) 68.55	5.000	0.0578	2	1.7	42.69
(0.8L) 78.35	5.000	0.0975	1.93	1.51	39.14
(1.5H) 87.84	5.000	0.126	0.225	2.51	27.63
(0.9L) 88.14	5.000	0.127	0.184	2.53	27.02
(H) 91.21	5.000	0.135	0.401	2.39	30.39
(CS) 92.65	5.000	0.139	0.135	2.53	26.70
(1.0L) 97.93	5.000	0.174	2	1.12	36.05

6.2.11.3 Shear Capacity and Design of Original Girder

(3) Nominal Shear Resistance - Strength I Limit State

Location from Left Support (ft)	f'_c (KSI)	b_v (in)	d_v (in)	V_p (kip)	V_c (kip)	V_s (kip)	$V_{n1}{}^1$ (kip)	$V_{n2}{}^2$ (kip)	V_n (kip)	ϕ	ϕV_n (kip)
(0.0L) 0.00	5.000	7.09	63.42	5.20	34.28	289.38	328.85	566.98	328.85	0.9	295.97
(CS) 5.28	5.000	7.09	63.42	52.81	79.23	404.30	536.33	614.59	536.33	0.9	482.70
(H) 6.73	5.000	7.09	63.42	52.81	74.53	348.77	476.11	614.59	476.11	0.9	428.50
(0.1L) 9.79	5.000	7.09	63.42	52.81	79.49	260.91	393.20	614.59	393.20	0.9	353.88
(1.5H) 10.09	5.000	7.09	63.42	52.81	78.90	254.37	386.07	614.59	386.07	0.9	347.46
(0.2L) 19.59	5.000	7.09	65.91	52.81	47.77	176.94	277.51	636.66	277.51	0.9	249.76
(0.3L) 29.38	5.000	7.09	73.39	52.81	62.13	86.35	201.29	702.88	201.29	0.9	181.16
(HP) 39.17	5.000	7.09	80.87	0.00	69.30	94.19	163.48	716.33	163.48	0.9	147.13
(0.5L) 48.97	5.000	7.09	80.87	0.00	69.67	93.75	163.42	716.33	163.42	0.9	147.08
(HP) 58.76	5.000	7.09	80.87	0.00	69.46	93.99	163.45	716.33	163.45	0.9	147.11
(0.7L) 68.55	5.000	7.09	73.39	52.81	62.42	86.02	201.24	702.88	201.24	0.9	181.12
(0.8L) 78.35	5.000	7.09	65.91	52.81	49.73	175.09	277.62	636.66	277.62	0.9	249.86
(1.5H) 87.84	5.000	7.09	63.42	52.81	79.80	261.97	394.58	614.59	394.58	0.9	355.12

(0.9L) 88.14	5.000	7.09	63.42	52.81	80.46	268.95	402.21	614.59	402.21	0.9	361.99
(H) 91.21	5.000	7.09	63.42	52.81	76.00	358.50	487.31	614.59	487.31	0.9	438.58
(CS) 92.65	5.000	7.09	63.42	52.81	80.29	418.10	551.20	614.59	551.20	0.9	496.08
(1.0L) 97.93	5.000	7.09	63.42	5.20	35.48	288.82	329.49	566.98	329.49	0.9	296.54

[1] $V_{n1} = V_c + V_s + V_p$
$V_{n2} = 0.25f'_c b_v d_v + V_p$

(2) Ultimate Shears for Strength I Limit State

Location from Left Support (ft)	Stirrups Required	Stirrups Provided	$\lvert V_u \rvert$ (kip)	ϕV_n (kip)	Status
(0.0L) 0.00	Yes	Yes	343.01	295.97	Fail
(CS) 5.28	Yes	Yes	343.01	482.70	Pass
(H) 6.73	Yes	Yes	334.95	428.50	Pass
(0.1L) 9.79	Yes	Yes	317.84	353.88	Pass
(1.5H) 10.09	Yes	Yes	316.20	347.46	Pass
(0.2L) 19.59	Yes	Yes	263.88	249.76	Fail
(0.3L) 29.38	Yes	Yes	189.37	181.16	Fail
(HP) 39.17	Yes	Yes	137.42	147.13	Pass
(0.5L) 48.97	Yes	Yes	86.48/85.47	147.08	Pass
(HP) 58.76	Yes	Yes	133.65	147.11	Pass
(0.7L) 68.55	Yes	Yes	182.83	181.12	Fail
(0.8L) 78.35	Yes	Yes	252.56	249.86	Fail
(1.5H) 87.84	Yes	Yes	302.18	355.12	Pass
(0.9L) 88.14	Yes	Yes	303.74	361.99	Pass
(H) 91.21	Yes	Yes	319.98	438.58	Pass
(CS) 92.65	Yes	Yes	327.64	496.08	Pass
(1.0L) 97.93	Yes	Yes	327.64	296.54	Fail

Actual design section failed because of lower bar size i.e # 3 used instead of using # 4 bar

(3) Stirrup Detailing Check

Location from Left Support (ft)	Bar Size	S (in)	S_{max} (in)	S_{min} (in)	A_v/S (in^2/in)	A_v/S_{min} (in^2/in)	Status
(0.0L) 0.00	#4 (13M)	6.89	12.00	1.00	0.0571	0.0086	Pass
(CS) 5.28	#4 (13M)	6.89	12.00	1.00	0.0571	0.0086	Pass
(H) 6.73	#4 (13M)	6.89	12.00	1.00	0.0571	0.0086	Pass
(0.1L) 9.79	#3 (10M)	5.91	12.00	1.00	0.0373	0.0086	Pass

(1.5H) 10.09	#3 (10M)	5.91	12.00	1.00	0.0373	0.0086	Pass
(0.2L) 19.59	#3 (10M)	5.91	12.00	1.00	0.0373	0.0086	Pass
(0.3L) 29.38	#3 (10M)	11.81	24.00	1.00	0.0186	0.0086	Pass
(HP) 39.17	#3 (10M)	11.81	24.00	1.00	0.0186	0.0086	Pass
(0.5L) 48.97	#3 (10M)	11.81	24.00	1.00	0.0186	0.0086	Pass
(HP) 58.76	#3 (10M)	11.81	24.00	1.00	0.0186	0.0086	Pass
(0.7L) 68.55	#3 (10M)	11.81	24.00	1.00	0.0186	0.0086	Pass
(0.8L) 78.35	#3 (10M)	5.91	12.00	1.00	0.0373	0.0086	Pass
(1.5H) 87.84	#3 (10M)	5.91	12.00	1.00	0.0373	0.0086	Pass
(0.9L) 88.14	#3 (10M)	5.91	12.00	1.00	0.0373	0.0086	Pass
(H) 91.21	#4 (13M)	6.89	12.00	1.00	0.0571	0.0086	Pass
(CS) 92.65	#4 (13M)	6.89	12.00	1.00	0.0571	0.0086	Pass
(1.0L) 97.93	#4 (13M)	6.89	12.00	1.00	0.0571	0.0086	Pass

(4) Transverse Reinforcement Stirrup Zones

Top flange stirrups are #4 (13M) at 9.84 in spacing. Bottom flange confinement stirrups are #4 (13M) ending in Zone 4

Zone	Zone Start (ft)	Zone End (ft)	Bar Spacing (in)	Bar Size
1	0.00	8.45	6.89	#4 (13M)
2	8.45	19.93	5.91	#3 (10M)
3	19.93	28.13	7.87	#3 (10M)
4	28.13	70.29	11.81	#3 (10M)
3	70.29	78.49	7.87	#3 (10M)
2	78.49	89.98	5.91	#3 (10M)
1	89.98	98.43	6.89	#4 (13M)

Number of stirrups

15
24
13
22
Total at L/2 = 74 NOs

6.2.11.4 Proposed Shear Design of Girder

(1) Ultimate Shears for Strength I Limit State

Location from Left Support (ft)	Stirrups Required	Stirrups Provided	$\lvert V_u \rvert$ (kip)	ϕV_n (kip)	Status
(0.0L) 0.00	Yes	Yes	343.01	361.78	Pass
(CS) 5.28	Yes	Yes	343.01	553.13	Pass
(H) 6.73	Yes	Yes	334.95	507.82	Pass
(0.1L) 9.79	Yes	Yes	317.84	344.56	Pass
(1.5H) 10.09	Yes	Yes	316.20	338.38	Pass
(0.2L) 19.59	Yes	Yes	263.88	277.42	Pass

(0.3L) 29.38	Yes	Yes	189.37	189.86	Pass
(HP) 39.17	Yes	Yes	137.42	156.62	Pass
(0.5L) 48.97	Yes	Yes	86.48/85.47	156.52	Pass
(HP) 58.76	Yes	Yes	133.65	156.58	Pass
(0.7L) 68.55	Yes	Yes	182.83	189.78	Pass
(0.8L) 78.35	Yes	Yes	252.56	277.23	Pass
(1.5H) 87.84	Yes	Yes	302.18	345.76	Pass
(0.9L) 88.14	Yes	Yes	303.74	352.38	Pass
(H) 91.21	Yes	Yes	319.98	520.11	Pass
(CS) 92.65	Yes	Yes	327.64	553.13	Pass
(1.0L) 97.93	Yes	Yes	327.64	362.22	Pass

(2) Nominal Shear Resistance - Strength I Limit State

Location from Left Support (ft)	f'_c (KSI)	b_v (in)	d_v (in)	V_p (kip)	V_c (kip)	V_s (kip)	$V_{n1}{}^1$ (kip)	$V_{n2}{}^2$ (kip)	V_n (kip)	ϕ	ϕV_n (kip)
(0.0L) 0.00	5.000	7.09	63.42	5.20	34.28	362.50	401.98	566.98	401.98	0.9	361.78
(CS) 5.28	5.000	7.09	63.42	52.81	79.23	506.46	638.49	614.59	614.59	0.9	553.13
(H) 6.73	5.000	7.09	63.42	52.81	74.53	436.90	564.24	614.59	564.24	0.9	507.82
(0.1L) 9.79	5.000	7.09	63.42	52.81	79.49	250.55	382.84	614.59	382.84	0.9	344.56
(1.5H) 10.09	5.000	7.09	63.42	52.81	78.90	244.27	375.97	614.59	375.97	0.9	338.38
(0.2L) 19.59	5.000	7.09	65.91	52.81	47.77	207.67	308.25	636.66	308.25	0.9	277.42
(0.3L) 29.38	5.000	7.09	73.39	52.81	62.13	96.02	210.96	702.88	210.96	0.9	189.86
(HP) 39.17	5.000	7.09	80.87	0.00	69.29	104.73	174.02	716.33	174.02	0.9	156.62
(0.5L) 48.97	5.000	7.09	80.87	0.00	69.67	104.25	173.91	716.33	173.91	0.9	156.52
(HP) 58.76	5.000	7.09	80.87	0.00	69.46	104.51	173.97	716.33	173.97	0.9	156.58
(0.7L) 68.55	5.000	7.09	73.39	52.81	62.42	95.64	210.87	702.88	210.87	0.9	189.78

(0.8L) 78.35	5.000	7.09	65.91	52.81	49.73	205.50	308.03	636.66	308.03	0.9	277.23
(1.5H) 87.84	5.000	7.09	63.42	52.81	79.80	251.57	384.18	614.59	384.18	0.9	345.76
(0.9L) 88.14	5.000	7.09	63.42	52.81	80.46	258.28	391.54	614.59	391.54	0.9	352.38
(H) 91.21	5.000	7.09	63.42	52.81	76.00	449.09	577.90	614.59	577.90	0.9	520.11
(CS) 92.65	5.000	7.09	63.42	52.81	80.29	523.74	656.84	614.59	614.59	0.9	553.13
(1.0L) 97.93	5.000	7.09	63.42	5.20	35.48	361.79	402.47	566.98	402.47	0.9	362.22

[1] $V_{n1} = V_c + V_s + V_p$

[2] $V_{n2} = 0.25f'_c b_v d_v + V_p$

(3) Stirrup Detailing Check

Location from Left Support (ft)	Bar Size	S (in)	S_{max} (in)	S_{min} (in)	A_v/S (in^2/in)	A_v/S_{min} (in^2/in)	Status
(0.0L) 0.00	#4 (13M)	5.50	12.00	1.00	0.0716	0.0086	Pass
(CS) 5.28	#4 (13M)	5.50	12.00	1.00	0.0716	0.0086	Pass
(H) 6.73	#4 (13M)	5.50	12.00	1.00	0.0716	0.0086	Pass
(0.1L) 9.79	#4 (13M)	11.00	12.00	1.00	0.0358	0.0086	Pass
(1.5H) 10.09	#4 (13M)	11.00	12.00	1.00	0.0358	0.0086	Pass
(0.2L) 19.59	#4 (13M)	9.00	12.00	1.00	0.0437	0.0086	Pass
(0.3L) 29.38	#4 (13M)	19.00	24.00	1.00	0.0207	0.0086	Pass
(HP) 39.17	#4 (13M)	19.00	24.00	1.00	0.0207	0.0086	Pass
(0.5L) 48.97	#4 (13M)	19.00	24.00	1.00	0.0207	0.0086	Pass
(HP) 58.76	#4 (13M)	19.00	24.00	1.00	0.0207	0.0086	Pass
(0.7L) 68.55	#4 (13M)	19.00	24.00	1.00	0.0207	0.0086	Pass
(0.8L) 78.35	#4 (13M)	9.00	12.00	1.00	0.0437	0.0086	Pass
(1.5H) 87.84	#4 (13M)	11.00	12.00	1.00	0.0358	0.0086	Pass
(0.9L) 88.14	#4 (13M)	11.00	12.00	1.00	0.0358	0.0086	Pass
(H) 91.21	#4 (13M)	5.50	12.00	1.00	0.0716	0.0086	Pass
(CS) 92.65	#4 (13M)	5.50	12.00	1.00	0.0716	0.0086	Pass
(1.0L) 97.93	#4 (13M)	5.50	12.00	1.00	0.0716	0.0086	Pass

(4) Transverse Reinforcement Stirrup Zones

Top flange stirrups are #4 (13M) at 9.84 in spacing.

Bottom flange confinement stirrups are #4 (13M) ending in Zone 4

Zone	Zone Start (ft)	Zone End (ft)	Bar Spacing (in)	Bar Size	**Number of stirrups**
1	0.00	8.50	5.50	#4 (13M)	**19**
2	8.50	19.50	11.00	#4 (13M)	**12**
3	19.50	27.70	9.00	#4 (13M)	**11**
4	27.70	70.73	19.00	#4 (13M)	**14**
3	70.73	78.93	9.00	#4 (13M)	**Total stirrups at L/2 = 56**
2	78.93	89.93	11.00	#4 (13M)	
1	89.93	98.43	5.50	#4 (13M)	

6.3 CASE STUDY-HISARA DRAIN BRIDGE “ISLAMABAD-PESHAWAR MOTORWAY” (M-1)

6.3.1 General Bridge Information

Number of Spans	1
Girder Type	G-1800 M1
Girder Concrete	MI-5KSI
Slab Concrete	MI-3KSI
Prestressing Strands	0.50 in Dia. Grade 270 Low Relaxation

6.3.2 Spans

Span #	# Girder Lines	Girder Spacing (ft)
1	6	15.730 ft

6.3.3 Slab Geometry

Dimensions
Gross Depth = 7.87 in
Overhang = 6.562 ft
A = 9.53 in
Fillet = 1.22 in

Surfacing
Overlay Depth = 2.00 in
Overlay Density = 150 lbf/ft^3
Sacrificial Depth = 0.50 in

Material
Concrete MI-3KSI

6.3.4 G-1800 M1 Dimensions

d_1 = 7.87 in
d_2 = 5.91 in
d_3 = 0.00 in
d_4 = 11.81 in
d_5 = 7.87 in
d_6 = 0.00 in
d_7 = 37.40 in
w_1 = 6.30 in
w_2 = 0.00 in
w_3 = 8.27 in
w_4 = 0.00 in
t_1 = 7.09 in
t_2 = 7.09 in

GirderLength=98.59ft

6.3.5 Section Properties

	Girder	Composite
Area (in^2)	899.001	-
I_x (in^4)	524601.538	1152153.468
I_y (in^4)	23593.643	-
$Y_{t\ girder}$ (in)	38.83	22.48
$Y_{t\ slab}$ (in)	-	29.86
Y_b (in)	32.03	48.38
$S_{t\ girder}$ (in^3)	13508.884	51244.112
S_b (in^3)	16377.256	23813.427
$S_{t\ slab}$ (in^3)	-	38588.227
Q_{slab} (in^3)	-	14698.841
Eff Flg Width (in)	-	98.33
Perimeter (in)	197.58	-

5.2.6 Barrier Dimensions

X_1 = 0.00 in
X_2 = 15.75 in
X_3 = 6.69 in
X_4 = 1.97 in
X_5 = 7.09 in
Y_1 = 7.09 in
Y_2 = 9.84 in
Y_3 = 37.01 in

Traffic Barrier Area = 385.882 in^2

6.3.7 Connection Details

Connection	Girder End Distance (ft)	Girder Bearing Offset (ft)	End Diaphragm Width (W) (in)	End Diaphragm Height (H) (in)	End Diaphragm C.G. Distance (ft)
M-1	2.323	3.340	9.06	62.99	3.340

6.3.8 Intermediate Diaphragms

Diaphragm Height = 60.28 in

Diaphragm Width = 9.06 in

# of Diaphragms (spaced evenly over flexible span length) = 3

6.3.9 Materials

Girder Concrete-5ksi

f'_c	5.000 KSI
Density for Weight Calculations g_c	150 lbf/ft^3
Density for Strength Calculations g_c	150 lbf/ft^3
Max Aggregate Size	0.75 in

Slab Concrete-3KSI

f'_c	3.000 KSI
Density for Weight Calculations g_c	150 lbf/ft^3
Density for Strength Calculations g_c	150 lbf/ft^3
Max Aggregate Size	0.75 in

6.3.10 Prestressing Force and Strand Stresses

Prestressing for this girder

Number of straight strands (N_s) = 0 (P_{jack} = 0.00 kip)

Number of harped strands (N_h) = 36 (P_{jack} = 1125.76 kip)

Number of temporary strands (N_t) = 0 (P_{jack} = 0.00 kip)

A_{ps} (with temporary strands) = 5.508 in^2

A_{ps} (without temporary strands) = 5.508 in^2

P_{jack} (with temporary strands) = 1125.76 kip

P_{jack} (without temporary strands) = 1125.76 kip

Prestress Transfer Length = 30.00 in

6.3.11 Comparison of Shear Capacity and Design of Original and Proposed Girder

6.3.11.1 Effective Shear Dimensions

Location from Left Support (ft)	b_v (in)	Moment Arm (in)	d_e (in)	h (in)	d_v (in)
(0.0L) 0.00	7.09	52.04	54.98	78.24	56.33
(CS) 4.69	7.09	54.33	57.27	78.24	56.33
(H) 5.91	7.09	54.92	57.86	78.24	56.33
(1.5H) 8.86	7.09	56.35	59.30	78.24	56.35
(0.1L) 9.39	7.09	56.62	59.56	78.24	56.62
(0.2L) 18.79	7.09	61.20	64.14	78.24	61.20
(0.3L) 28.18	7.09	65.78	68.73	78.24	65.78
(HP) 37.58	7.09	70.37	73.32	78.24	70.37
(0.5L) 46.97	7.09	70.37	73.32	78.24	70.37
(HP) 56.36	7.09	70.37	73.32	78.24	70.37
(0.7L) 65.76	7.09	65.78	68.73	78.24	65.78
(0.8L) 75.15	7.09	61.20	64.14	78.24	61.20
(0.9L) 84.55	7.09	56.62	59.56	78.24	56.62
(1.5H) 85.08	7.09	56.35	59.30	78.24	56.35
(H) 88.03	7.09	54.92	57.86	78.24	56.33
(CS) 89.22	7.09	54.34	57.28	78.24	56.33
(1.0L) 93.94	7.09	52.04	54.98	78.24	56.33

6.3.11.3 Shear Parameter Summary - Strength I Limit State

Location from Left Support (ft)	f'_c (KSI)	v/f'_c	e_x x 1000	b	θ (deg)
(0.0L) 0.00	5.000	0.256	-0.187	2.36	28.13
(CS) 4.69	5.000	0.234	-0.0302	2.36	28.97
(H) 5.91	5.000	0.229	0.127	2.32	30.59
(1.5H) 8.86	5.000	0.216	1.2	1.37	35.07
(0.1L) 9.39	5.000	0.212	1.4	1.26	35.48
(0.2L) 18.79	5.000	0.158	2	1.2	36.66
(0.3L) 28.18	5.000	0.108	2	1.42	38.70
(HP) 37.58	5.000	0.0832	2	1.58	41.02
(0.5L) 46.97	5.000	0.0523	2	1.71	42.91
(HP) 56.36	5.000	0.0814	2	1.6	41.24
(0.7L) 65.76	5.000	0.104	2	1.43	38.84

(0.8L) 75.15	5.000	0.152	2	1.23	36.91
(0.9L) 84.55	5.000	0.203	1.36	1.31	35.01
(1.5H) 85.08	5.000	0.207	1.15	1.44	34.77
(H) 88.03	5.000	0.219	0.102	2.35	29.88
(CS) 89.22	5.000	0.224	-0.0331	2.39	28.46
(1.0L) 93.94	5.000	0.246	-0.194	2.37	27.79

6.3.11.4 Shear Capacity and Design of Original Girder

(3) Ultimate Shears for Strength I Limit State

Location from Left Support (ft)	Stirrups Required	Stirrups Provided	$\lvert V_u \rvert$ (kip)	ϕV_n (kip)	Status
(0.0L) 0.00	Yes	Yes	452.35	413.17	Fail
(CS) 4.69	Yes	Yes	452.35	404.27	Fail
(H) 5.91	Yes	Yes	442.66	383.43	Fail
(1.5H) 8.86	Yes	Yes	419.14	313.13	Fail
(0.1L) 9.39	Yes	Yes	414.89	307.95	Fail
(0.2L) 18.79	Yes	Yes	341.12	317.34	Fail
(0.3L) 28.18	Yes	Yes	257.52	216.84	Fail
(HP) 37.58	Yes	Yes	186.68	191.07	Pass
(0.5L) 46.97	Yes	Yes	117.28/116.76	186.12	Pass
(HP) 56.36	Yes	Yes	182.61	190.45	Pass
(0.7L) 65.76	Yes	Yes	249.91	216.53	Fail
(0.8L) 75.15	Yes	Yes	328.92	315.95	Fail
(0.9L) 84.55	Yes	Yes	399.14	313.44	Fail
(1.5H) 85.08	Yes	Yes	403.18	317.76	Fail
(H) 88.03	Yes	Yes	425.59	392.61	Fail
(CS) 89.22	Yes	Yes	434.59	411.74	Fail
(1.0L) 93.94	Yes	Yes	434.59	418.09	Fail

(3) Nominal Shear Resistance - Strength I Limit State

Location from Left Support (ft)	f'_c (KSI)	b_v (in)	d_v (in)	V_p (kip)	V_c (kip)	V_s (kip)	V_{n1}[1] (kip)	V_{n2}[2] (kip)	V_n (kip)	ϕ	ϕV_n (kip)
(0.0L) 0.00	5.00	7.09	56.33	32.84	66.59	359.64	459.07	531.86	459.07	0.9	413.17
(CS) 4.69	5.00	7.09	56.33	35.35	66.54	347.30	449.19	534.36	449.19	0.9	404.27
(H) 5.91	5.00	7.09	56.33	35.35	65.50	325.18	426.03	534.36	426.03	0.9	383.43
(1.5H) 8.86	5.00	7.09	56.35	35.35	38.64	273.93	347.92	534.55	347.92	0.9	313.13
(0.1L) 9.39	5.00	7.09	56.62	35.35	35.72	271.10	342.16	536.87	342.16	0.9	307.95
(0.2L) 18.79	5.00	7.09	61.20	35.35	36.66	280.59	352.60	577.46	352.60	0.9	317.34
(0.3L) 28.18	5.00	7.09	65.78	35.35	46.78	158.81	240.93	618.07	240.93	0.9	216.84
(HP) 37.58	5.00	7.09	70.37	0.00	55.85	156.45	212.30	623.35	212.30	0.9	191.07
(0.5L) 46.97	5.00	7.09	70.37	0.00	60.40	146.39	206.80	623.35	206.80	0.9	186.12
(HP) 56.36	5.00	7.09	70.37	0.00	56.36	155.25	211.61	623.35	211.61	0.9	190.45
(0.7L) 65.76	5.00	7.09	65.78	35.35	47.25	157.99	240.59	618.07	240.59	0.9	216.53
(0.8L) 75.15	5.00	7.09	61.20	35.35	37.65	278.05	351.05	577.46	351.05	0.9	315.95
(0.9L) 84.55	5.00	7.09	56.62	35.35	37.04	275.87	348.26	536.87	348.26	0.9	313.44
(1.5H) 85.08	5.00	7.09	56.35	35.35	40.65	277.07	353.07	534.55	353.07	0.9	317.76
(H) 88.03	5.00	7.09	56.33	35.35	66.26	334.63	436.24	534.36	436.24	0.9	392.61
(CS) 89.22	5.00	7.09	56.33	35.35	67.50	354.64	457.49	534.36	457.49	0.9	411.74
(1.0L) 93.94	5.00	7.09	56.33	32.84	67.00	364.71	464.55	531.86	464.55	0.9	418.09

[1] $V_{n1} = V_c + V_s + V_p$

[2] $V_{n2} = 0.25f'_c b_v d_v + V_p$

(3) Stirrup Detailing Check

Location from Left Support (ft)	**Bar Size**	S (in)	S_{max} (in)	S_{min} (in)	A_v/S (in^2/in)	A_v/S_{min} (in^2/in)	Status
(0.0L) 0.00	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass
(CS) 4.69	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass
(H) 5.91	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass
(1.5H) 8.86	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass
(0.1L) 9.39	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass
(0.2L) 18.79	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass
(0.3L) 28.18	#4 (13M)	11.81	12.00	1.00	0.0333	0.0086	Pass
(HP) 37.58	#4 (13M)	11.81	24.00	1.00	0.0333	0.0086	Pass
(0.5L) 46.97	#4 (13M)	11.81	24.00	1.00	0.0333	0.0086	Pass
(HP) 56.36	#4 (13M)	11.81	24.00	1.00	0.0333	0.0086	Pass
(0.7L) 65.76	#4 (13M)	11.81	12.00	1.00	0.0333	0.0086	Pass
(0.8L) 75.15	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass
(0.9L) 84.55	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass
(1.5H) 85.08	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass
(H) 88.03	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass
(CS) 89.22	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass
(1.0L) 93.94	#4 (13M)	6.69	12.00	1.00	0.0588	0.0086	Pass

(4) Transverse Reinforcement Stirrup Zones

Top flange stirrups are #4 (13M) at 10.00 in spacing.

Bottom flange confinement stirrups are #4 (13M) ending in Zone 3

Zone	Zone Start (ft)	Zone End (ft)	Bar Spacing (in)	Bar Size
1	0.00	4.43	6.69	#4 (13M)
2	4.43	24.51	6.69	#4 (13M)
3	24.51	74.08	11.81	#4 (13M)
2	74.08	94.16	6.69	#4 (13M)
1	94.16	98.59	6.69	#4 (13M)

Number of stirrups

8
36
25
Total stirrups at L/2
= 64 NOs

6.3.11.4 Proposed Shear capacity and shear design

(1) Ultimate Shears for Strength I Limit State

Location from Left Support (ft)	Stirrups Required	Stirrups Provided	$\lvert V_u \rvert$ (kip)	ϕV_n (kip)	Status
(0.0L) 0.00	Yes	Yes	452.35	468.97	Pass
(CS) 4.69	Yes	Yes	452.35	480.93	Pass
(H) 5.91	Yes	Yes	442.66	480.93	Pass
(1.5H) 8.86	Yes	Yes	419.14	421.77	Pass
(0.1L) 9.39	Yes	Yes	414.89	415.47	Pass
(0.2L) 18.79	Yes	Yes	341.12	428.63	Pass
(0.3L) 28.18	Yes	Yes	257.52	264.48	Pass
(HP) 37.58	Yes	Yes	186.68	191.07	Pass
(0.5L) 46.97	Yes	Yes	117.28/116.76	186.12	Pass
(HP) 56.36	Yes	Yes	182.61	190.45	Pass
(0.7L) 65.76	Yes	Yes	249.91	263.93	Pass
(0.8L) 75.15	Yes	Yes	328.92	426.23	Pass
(0.9L) 84.55	Yes	Yes	399.14	422.85	Pass
(1.5H) 85.08	Yes	Yes	403.18	427.65	Pass
(H) 88.03	Yes	Yes	425.59	480.93	Pass
(CS) 89.22	Yes	Yes	434.59	480.93	Pass
(1.0L) 93.94	Yes	Yes	434.59	474.68	Pass

(2) Nominal Shear Resistance - Strength I Limit State

Location from Left Support (ft)	f'_c (KSI)	b_v (in)	d_v (in)	V_p (kip)	V_c (kip)	V_s (kip)	$V_{n1}{}^1$ (kip)	$V_{n2}{}^2$ (kip)	V_n (kip)	ϕ	ϕV_n (kip)
(0.0L) 0.00	5.0	7.09	56.33	32.84	66.59	421.64	521.08	531.86	521.08	0.9	468.97
(CS) 4.69	5.0	7.09	56.33	35.35	66.54	500.35	602.24	534.36	534.36	0.9	480.93
(H) 5.91	5.0	7.09	56.33	35.35	65.50	468.48	569.33	534.36	534.36	0.9	480.93
(1.5H) 8.86	5.0	7.09	56.35	35.35	38.64	394.65	468.64	534.55	468.64	0.9	421.77
(0.1L) 9.39	5.0	7.09	56.62	35.35	35.72	390.56	461.63	536.87	461.63	0.9	415.47
(0.2L) 18.79	5.0	7.09	61.20	35.35	36.66	404.25	476.25	577.46	476.25	0.9	428.63
(0.3L) 28.18	5.0	7.09	65.78	35.35	46.78	211.74	293.87	618.07	293.87	0.9	264.48

(HP) 37.58	5.0	7.09	70.37	0.00	55.85	156.45	212.30	623.35	212.30	0.9	191.07
(0.5L) 46.97	5.0	7.09	70.37	0.00	60.40	146.39	206.80	623.35	206.80	0.9	186.12
(HP) 56.36	5.0	7.09	70.37	0.00	56.36	155.25	211.61	623.35	211.61	0.9	190.45
(0.7L) 65.76	5.0	7.09	65.78	35.35	47.25	210.65	293.25	618.07	293.25	0.9	263.93
(0.8L) 75.15	5.0	7.09	61.20	35.35	37.65	400.58	473.59	577.46	473.59	0.9	426.23
(0.9L) 84.55	5.0	7.09	56.62	35.35	37.04	397.44	469.83	536.87	469.83	0.9	422.85
(1.5H) 85.08	5.0	7.09	56.35	35.35	40.65	399.16	475.17	534.55	475.17	0.9	427.65
(H) 88.03	5.0	7.09	56.33	35.35	66.26	482.09	583.70	534.36	534.36	0.9	480.93
(CS) 89.22	5.0	7.09	56.33	35.35	67.50	510.93	613.77	534.36	534.36	0.9	480.93
(1.0L) 93.94	5.0	7.09	56.33	32.84	67.00	427.59	527.43	531.86	527.43	0.9	474.68

[1] $V_{n1} = V_c + V_s + V_p$

[2] $V_{n2} = 0.25f'_c b_v d_v + V_p$

(3) Stirrup Detailing Check

Location from Left Support (ft)	Bar Size	S (in)	S_{max} (in)	S_{min} (in)	A_v/S (in^2/in)	A_v/S_{min} (in^2/in)	Status
(0.0L) 0.00	#4 (13M)	5.71	12.00	1.00	0.0690	0.0086	Pass
(CS) 4.69	#4 (13M)	4.65	12.00	1.00	0.0847	0.0086	Pass
(H) 5.91	#4 (13M)	4.65	12.00	1.00	0.0847	0.0086	Pass
(1.5H) 8.86	#4 (13M)	4.65	12.00	1.00	0.0847	0.0086	Pass
(0.1L) 9.39	#4 (13M)	4.65	12.00	1.00	0.0847	0.0086	Pass
(0.2L) 18.79	#4 (13M)	4.65	12.00	1.00	0.0847	0.0086	Pass
(0.3L) 28.18	#4 (13M)	8.86	12.00	1.00	0.0444	0.0086	Pass
(HP) 37.58	#4 (13M)	11.81	24.00	1.00	0.0333	0.0086	Pass
(0.5L) 46.97	#4 (13M)	11.81	24.00	1.00	0.0333	0.0086	Pass
(HP) 56.36	#4 (13M)	11.81	24.00	1.00	0.0333	0.0086	Pass
(0.7L) 65.76	#4 (13M)	8.86	12.00	1.00	0.0444	0.0086	Pass
(0.8L) 75.15	#4 (13M)	4.65	12.00	1.00	0.0847	0.0086	Pass
(0.9L) 84.55	#4 (13M)	4.65	12.00	1.00	0.0847	0.0086	Pass
(1.5H) 85.08	#4 (13M)	4.65	12.00	1.00	0.0847	0.0086	Pass
(H) 88.03	#4 (13M)	4.65	12.00	1.00	0.0847	0.0086	Pass
(CS) 89.22	#4 (13M)	4.65	12.00	1.00	0.0847	0.0086	Pass
(1.0L) 93.94	#4 (13M)	5.71	12.00	1.00	0.0690	0.0086	Pass

(4) Transverse Reinforcement Stirrup Zones

Top flange stirrups are #4 (13M) at 10.00 in spacing.

Bottom flange confinement stirrups are #4 (13M) ending in Zone 4

Zone	Zone Start (ft)	Zone End (ft)	Bar Spacing (in)	Bar Size
1	0.00	4.43	5.71	#4 (13M)
2	4.43	24.51	4.65	#4 (13M)
3	24.51	31.07	8.86	#4 (13M)
4	31.07	67.52	11.81	#4 (13M)
3	67.52	74.08	8.86	#4 (13M)
2	74.08	94.16	4.65	#4 (13M)
1	94.16	98.59	5.71	#4 (13M)

<u>Number of stirrups</u>

10
52
9
19
<u>Total stirrups at L/2 = 90 NOs</u>

6.4 OBSERVATIONS AND FINDINGS

a) Use of lower bar size.

b) Use of low strength class D concrete i.e. 5ksi, as per NHA specifications.

c) No specifications provided or adhered with respect to detailing of shear reinforcement in different zones along the span.

d) Dina nullah case, with girder spacing of about 9 feet have 40 strands, whereas Hisara Drain case, with 16 feet of girder spacing has 36 strands. Besides flexural failure of second case, there is no longitudinal steel contribution to shear as defined in MCFT.

e) In slab-girder bridges, Load distribution depends on girder spacing and so is the resistance, which is related to increase or decrease in the cross sectional area of the girders. Dina nullah with 80.71 inch deep and 7.1 inch web width has 9 feet of girder spacing whereas Hisara Drain Bridge with 70.86 inch deep and 7.1 inch web width has 16 feet girder spacing thus offset the girder spacing-cross section compatibility.

Chapter 7

COMPARISON OF ASD/LFD AND LRFD METHODS

7.1 DEVELOPMENT OF DESIGN PROCEDURES [9]

Over the year, design procedures have been developed by engineers to provide satisfactory margins of safety. These procedures were based on the engineer's confidence in the analysis of the load effects and the strength of the material being provided. As analysis techniques improved and quality control on materials became better, the design procedure changed. To understand were we are today, it is helpful to look at the design procedure of earlier AASHTO specifications.

7.2 VARIABILITY OF LOADS

In regard to uncertainties in design, one other point, concerning the ASD method, needs to be emphasized. Allowable stress design does not recognize that different loads have different levels of uncertainly. Dead, live, and wind loads are all treated equally in ASD. The safety factor is applied to the resistance side of the design inequality, and the load side is not factored. In ASD, safety is determined by:

$$\text{Resistance, R / Safety Factor, F} \geq \text{effect of loads. Q}$$

For ASD, fixed values of design loads are selected, usually from a specification or design code. The varying degree of predictability of the different load types is not considered. Finally, because the safety factor chosen is based on experience and judgment, quantitative measure of risk cannot be determined for ASD.

Only the trend is known: If the safety factor is higher, the number of failures is lower. However, if the safety factor is increased by a certain amount, it is known by how much this increases the probability of survival. Also, it is more meaningful to decision-makers to say. “This bridge has a probability of in 10,000 of failing in 75 years of service,” than to say, “This bridge has a safety factor of 2.3.”

7.3 SHORTCOMINGS OF ASD [9]

As just shown, ASD is not well suited for design of modern structures. Its major shortcomings can be summarized as follows:

a. The resistance concepts are based on elastic behavior of isotropic, homogeneous materials.
b. It does not embody a reasonable measure of strength, which is a more fundamental measure of resistance than is allowable stress.
c. The safety factor is applied only to resistance. Loads are considered to be deterministic (without variation).
d. Selection of a safety factor is subjective, and it does not provide a measure of reliability in terms of probability of failure.

What is needed to overcome these deficiencies is a method that is (a) based on the strength of material, (b) consider variability not only in resistance but also in the effect of loads, and (c) provides a measure of safety related to probability of failure. Such a method is incorporated in the AASHTO 1998/2000 LRFD Bridge Specifications.

7.4 ADVANTAGE OF LRFD METHOD [9]

a. Account for variability in both resistance and load.
b. Achieves fairly uniform levels of safety for different limit states and bridge types without involving complex probability or statistical analysis.
c. Provides a rational and consistent method of design.

7.5 DISADVANTAGE OF LRFD METHOD

a. Requires a change in design philosophy (from previous ASHTO methods).

b. Requires an understanding of the basic concepts of probability and statistics.

c. Requires availability of sufficient statistical data and probability design algorithms to make adjustments and resistance factors to meet individual situations.

7.6 COMPARISON [24]

The basic explanation of the differences between ASD and LRFD methods is the common concept of comparison of applied forces with available resistance to ensure that a certain level of reserve capacity is available to account for the uncertainty in both the loads and resistance. This reserve capacity provides confidence to the engineer that his design is safe against poor performance or worse, catastrophic failure. The method of defining and quantifying these uncertainties is the fundamental difference between these two methods of design.

Structural elements such as structural foundations, bridge beams and girders, or earth-retaining walls are designed to support, or resist, anticipated service loads, including vehicular live loads, superstructure dead loads, or lateral soil loads. In ASD, to account for the possibilities that structural elements are overloaded during their service life and that the materials providing resistance to the load are not as strong as expected, engineers apply a global safety factor on the resistance side of the design equation to ensure that the structural elements are large enough to account for all uncertainties in design. In this way, global factors of safety account for the uncertainty in both loads and resistance. The general forms of the equation appear as follows:

Resistance provided (R) > Loads applied (G L)

ASD: R / F.S. > G L, where the Factor of Safety (F.S.) = 1.5 to 3.5

Although the ASD approach ensures that the supporting design element is sufficient to carry potential overloads, the approach does not supply the designer with two vital pieces of information. The total capacity of the supporting element cannot be ascertained with ASD, and therefore, the mode of failure cannot be predicted with certainty. Often, this means that the global factors of safety are set at overly conservative levels.

In some cases, global factors of safety are not conservative. This may be difficult to imagine since structural elements do not frequently fail. However, rather than attributing this to the quality of the analytical method, this can, in large part, be attributed to the fact that engineers employ judgment and experience in the design process. The ASD method does not provide a rational means to define the level of safety of the design element.

In LRFD, uncertainties in both applied loads and structural and material resistance can be better discerned when they are separated and studied individually. Likewise, if safety factors can be applied in the design equation, both on the load and resistance sides, the designer can better use analytical tools to establish the total capacity of design elements. The designer can more accurately predict dead loads such as the weight of concrete and steel in the superstructure; however, they may apply a more conservative load factor to transient or vehicular live loads. The general form of the LRFD equation takes on the following simplified appearance:

LRFD: N R > G m L

In this equation, resistance factors (N) are values less than one to account for the uncertainty that the materials providing resistance may not be as strong as anticipated. Load factors (m) are values greater than one to account for the possibility that overloads will be applied to the element during its service life. With the LRFD approach, the designer can better assign margins of safety to each portion of the design equation as suited to the level of confidence with which each load and resistance can be predicted. Therefore, designs can be based on risk and reliability concepts. By calibrating the load and resistance factors to an overall margin of safety, designers can ensure that all designs have prescribed margins of safety against failure.

Designer of reinforced concrete structures have realized this for some time, and adopted strength design procedure many years ago. Would designers also go toward strength design procedures. Both concrete and wood are nonlinear materials whose properties change with time and with changes in ambient conditions. In concrete, the initial stress state is unknown because it varies with placement method, temperature gradient, restrain to shrinkage, water content, and degree of consolidation. The only values that can be well defined are the strengths of concrete at its limit states. The ultimate strength is independent of pre-stress and stresses associated with numerous manufacturing and constructions processes, all of which are difficult to predict and are highly variable. In short, the ultimate strength is easier and more reliably predicted than behavior at lower load levels. That is the rational for the adoption of the strength design procedures".

7.7 COMPARISON OF SHEAR DESIGN APPROACHES

a. Dina Nullah bridge

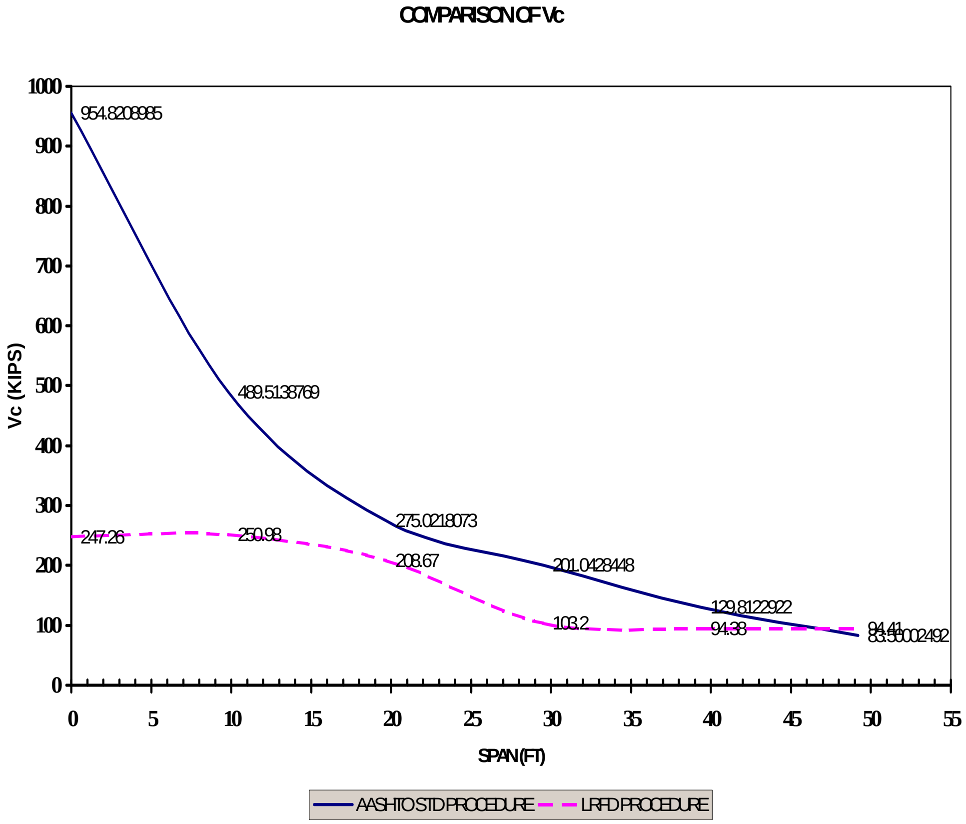


Figure 7.1: Comparison between AASHTO Standard and LRFD code Procedure for Calculation of Vc

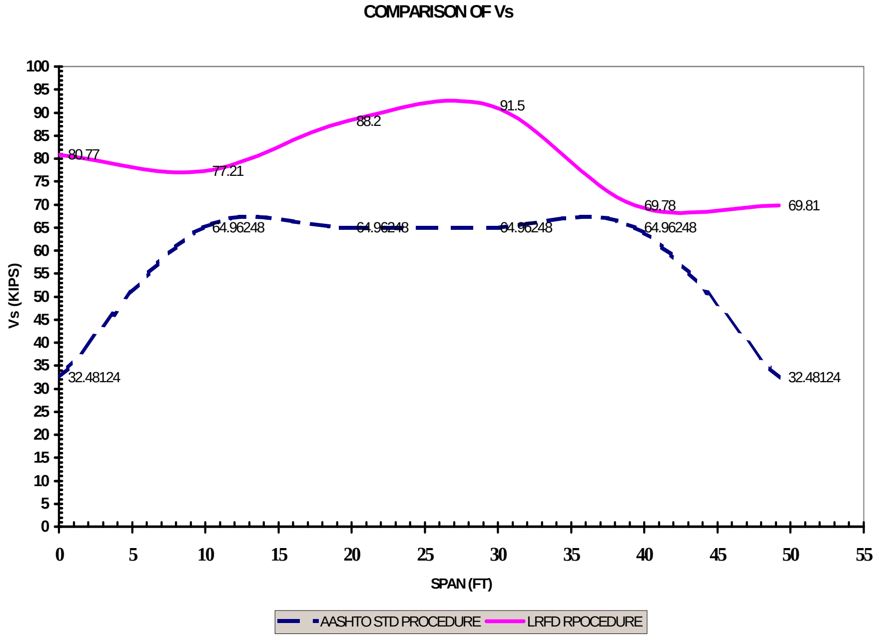


Figure 7.2: Comparison of Vs

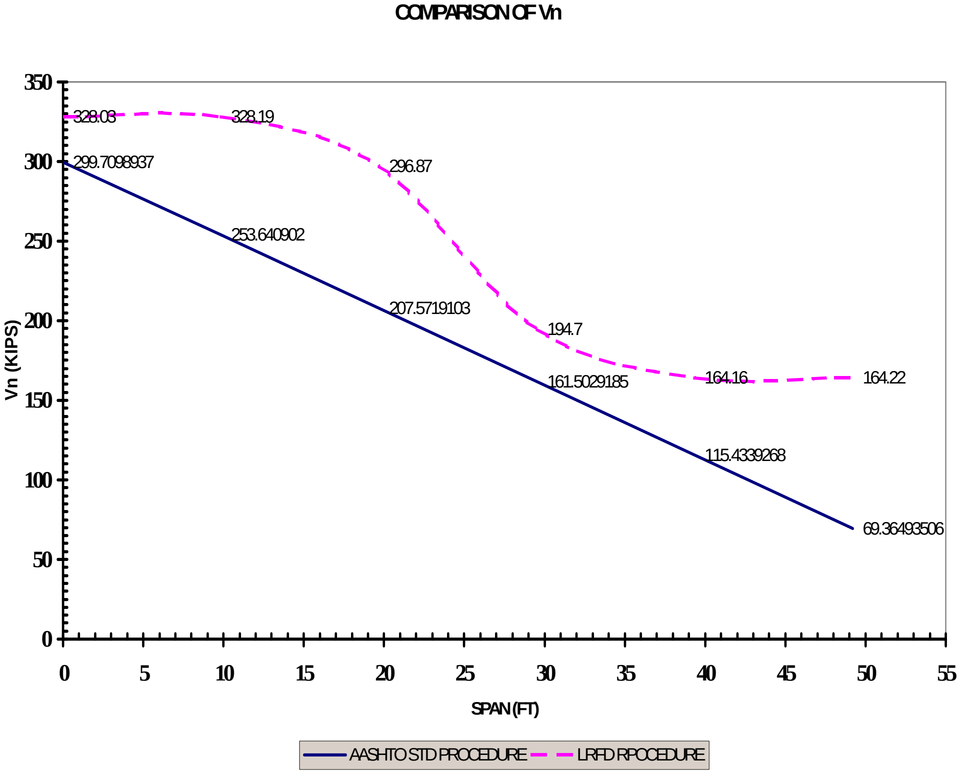


Figure 7.3: Comparison of Nominal Shear Resistance Vn = Vc + Vs

b. Hisara Drain Bridge

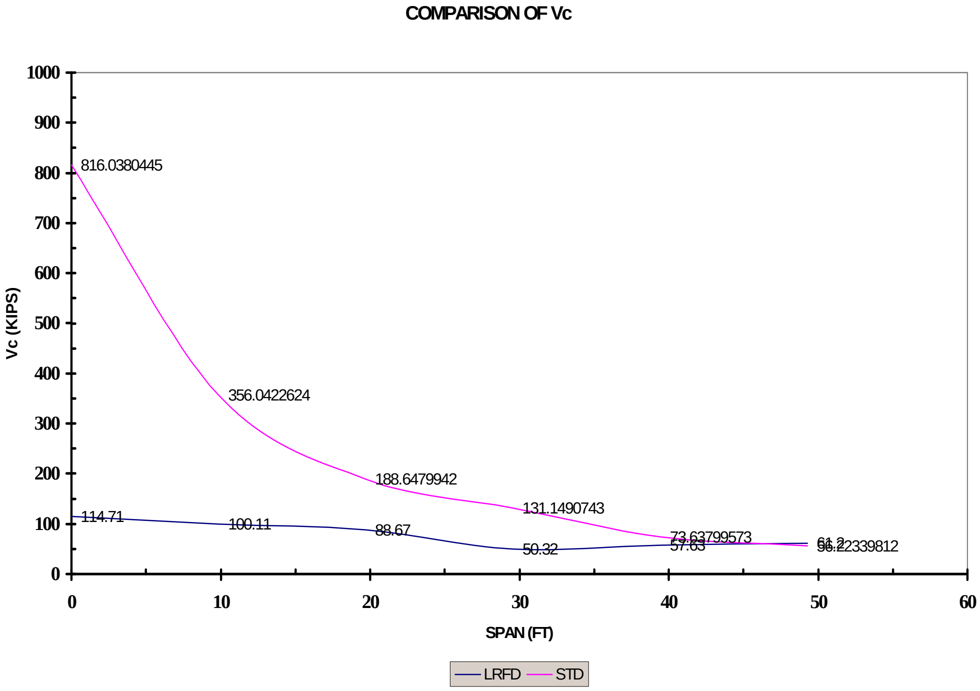


Figure 7.4: Comparison of Vc

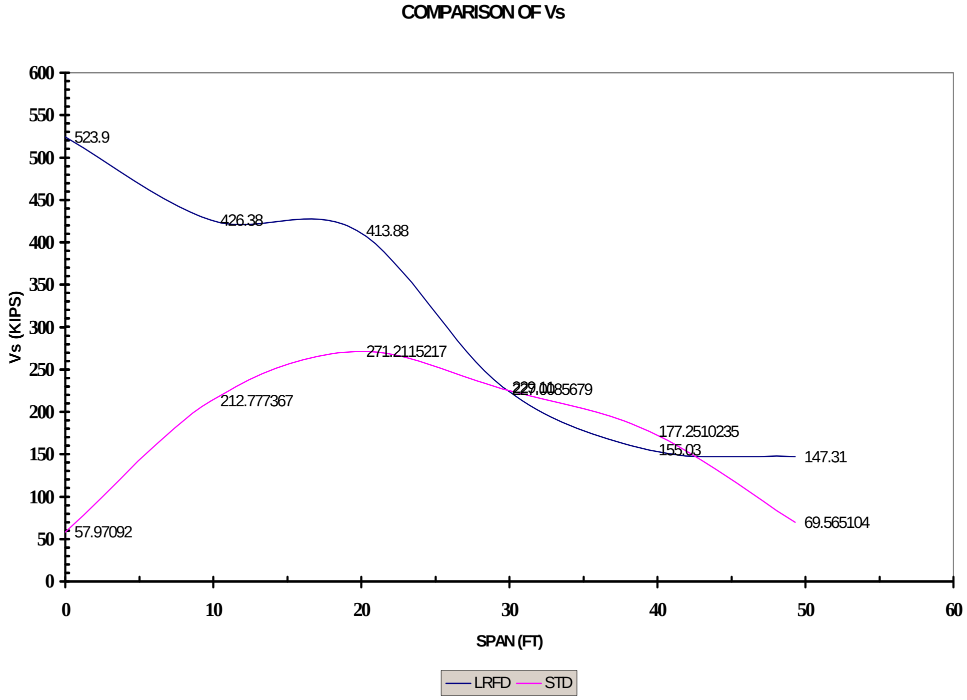


Figure 7.5: Comparison of Vs

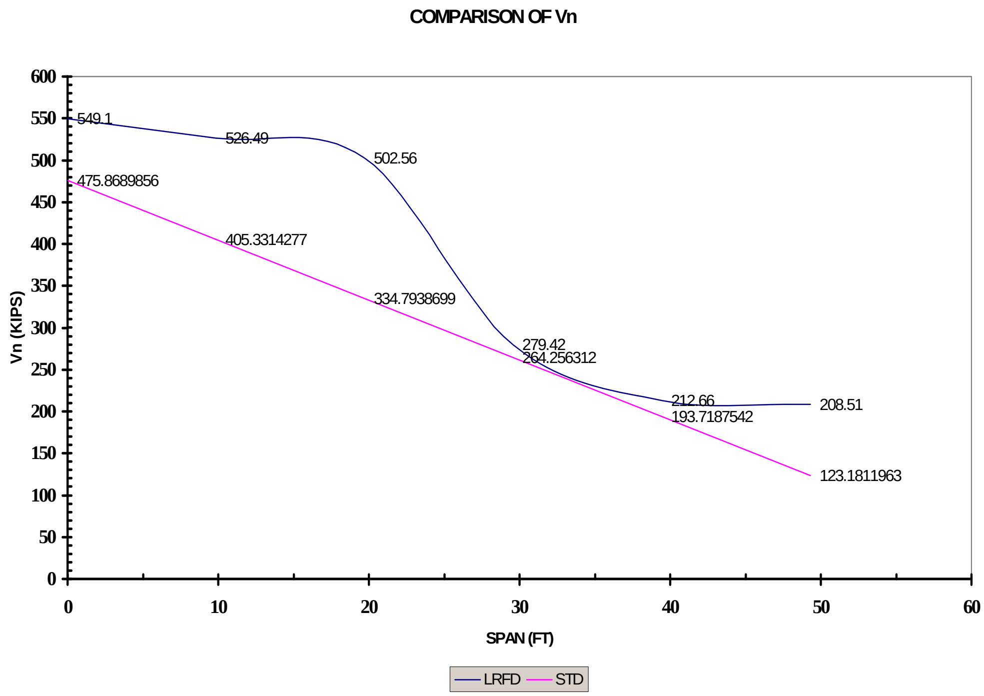


Figure 7.6: Comparison of Nominal Shear Resistance Vn = Vc +Vs

c. In both the cases the uniform behavior is observed as under:

1) In case of LRFD procedure for estimating shear resistance provided by concrete Vc demonstrates a lower bound curve because of measuring the actual cracking angle at all tenth points along the span whereas in case of AASHTO Standard procedure the cracking angle is assumed to constant.

2) Providing stirrup steel covers the deficiency in shear strength of concrete. Therefore the requirement of stirrups is increased in case of LRFD procedure than AASHTO Standard procedure. This can be seen by observing Vn curves which in both the cases present an upper bound and therefore are over conservative.

7.8 SALIENT CONCLUSIONS

a. ACI code 318-95 and AASHTO standard design procedure in predicting shear capacity of prestressed beams is less conservative.

b. Shear span to depth ratio affects the shear strength of the concrete. More is the ratio lesser is the strength.

c. LRFD approach for shear based on MCFT is more realistic and over conservative in predicting the concrete strength in resisting shears. This is because of measuring actual crack angle at the section under investigation (to be intercepted by shear reinforcement) rather than empirical equations assuming angle of crack as 45 degree, which is a remote possibility.

d. For prestressed bridge girders, shear strength is influenced by the percentage of prestressing reinforcement so as to resist tensile stresses developed at the crack parallel to the longitudinal axis of the member.

e. Above case studies demonstrate a lesser contribution from concrete in case of LRFD approach. This is because of calculating Vc by using actual cracking angle (lesser than 45 degrees). This consequently leads to using fewer stirrups so as to compensate for the nominal capacity of the section under investigation.

f. From foregoing inference can be drawn that the LRFD shear design approach is more conservative therefore less economical than AASHTO/ACI standard design approach. Shear capacity and stirrup design/detailing tables are therefore based on AASHTO/ACI Standard Design procedure.

7.9 SIMPLIFIED METHOD FOR SHEAR DESIGN OF PRESTRESSED CONCRETE GIRDERS BASED ON LRFD [30]

The new AASHTO LRFD Bridge Design Specifications incorporate the MCFT for shear design of prestressed and non-prestressed concrete members. This method is based on the variable-angle truss analogy model and takes into account the inclination of diagonal shear cracks, strain in longitudinal steel and the applied shear stress on a section. This is a realistic approach to predict the shear resistance of any section of a concrete member. However, for pre-stressed concrete sections, an iterative process is required to determine the shear resistance of the sections. In an effort to simplify the process, a parametric study can be undertaken resulting in a simplified method using fixed shear design parameters for NHA standard girders. The simplified method saves significant time in shear design of pre-stressed girders, especially when it is applied to standardize the shear reinforcement in a series of standard pre-stressed concrete girders. The LRFD Specifications predict the shear resistance of pre-stressed girders more accurately than the Standard Specification.

The LRFD requires more shear reinforcement in pre-stressed girders than LFD. A simplified method using fixed shear design parameters of θ and β may be utilized to simplify the LRFD shear design of pre-stressed girders. The vertical components of harped or draped strands contribute as much as 10% of the total shear resistance of the section.

Chapter 8

DEVELOPMENT OF DESIGN TABLES

8.1 GENERAL

a. As it has been said earlier that the optimization is a process of saving cost and time involved in designing a bridge structure or its components so is the development of standard design aids based on certain parameters and assumptions. Each of the bridge structural components can be designed with the variety of combinations in terms of girder spacing, span lengths and girder cross section which are the controlling design parameters in slab-girder bridges.

b. In Pakistan, slab-girder bridges have prestressed girders, which are critical for cracking either because of preloading or due to the service load effects. These condition warrants meticulous shear investigation/analysis during each load stage and the design which vary with the controlling design parameters. For example, the parabolic profile of prestressing steel contributes ten percent to offset the shear force effect which if considered results in economizing the shear reinforcement at the section under investigation.

c. Another aspect, which is to be considered for optimization, is the adoption of design procedure that is based on (different code of practice) simplicity, safety and economy. In Pakistan, most of the designers are using AASHTO Standard Specifications for highway bridges alongwith British code for certain bridge components. Before developing the design aid it is essential to consider the state of the art design procedure which should be compared with the existing practices for simplicity, safety and economy.

8.2 ADOPTION OF DESIGN PROCEDURE

a. Without jeopardizing the safety and economy, the accuracy and simplicity of the design procedure depends upon the tools available for analysis and design that is the softwares. As mentioned earlier for accuracy and simplicity sixteen existing bridges were analyzed alontwith the manual calculations. Once the accuracy of the software was ascertained the economic comparison/analysis between the AASHTO Standard and LRFD design procedures (for shear) was carryout. Which reflected results favorable to AASHTO standard procedure for shear design of prestressed bridge girders, as under:

   1) It is more economical as compared to LRFD design procedure because the LRFD procedure demands more shear steel at the section.
   2) The AASHTO standard procedure is simpler and safer since it is being practiced with a negligible rate of probable failure.
   3) Presently the issue of adoption of design procedure for shear design of prestressed bridge girders is controversial between the researchers and the designers.

8.3 DEVELOPMENT OF DESIGN AID (DESIGN TABLES)

a. After ascertaining the accuracy of the software, simplicity, safety and economy of design procedure it was established to base the design tables on existing AASHTO Standard Specifications 1996.

b. For the development of design tables a total of 405 bridge girders were modeled, analyzed and designed with four types of strand patterns, six types of girder cross sections and five types of girder spacing covering span lengths of 35 to 145 feet.

8.3.1 Shear Capacity Tables

a. Shear capacities tables [Table 8.3.1.1(a-e) to Table 8.3.1.6(a-e)], are developed for six type of girders with girder spacing ranging between 5 to 9 feet, 5 tables for each girder (one for each girder spacing) and a total of 30 tables are developed.

b. These tables are developed, considering above stated variables, giving nominal shear resistance required (obtained from shear investigation) and provided/actual at the section (as part of the design) at tenth points along the span. Considering # 3 U legged stirrups with Av = 0.22 in^2 using Grade 40 steel and AASHTO/ACI equations, area of shear reinforcement required and/or stirrup spacing at the section or number of stirrups is calculated.

c. Where Vs has a negative values, implies that no shear reinforcement is required and concrete can withstand shear at the section. However, keeping code restriction of minimum spacing of 24 in, stirrups are provided. The data given in these tables can be used to determine spacing, area of steel and consequently the number of stirrups required, using different bar size and steel grade.

8.3.2 Stirrup Design / Detailing Tables

a. Stirrup design tables [Table 8.3.2.1 to Table 8.3.2.6] are the outcome of shear capacity tables. One table for each girder type and a total of six tables are developed. Keeping in view the economy in the design the figures representing the number of stirrups are rounded to next number instead of rounding up the spacing in the shear capacity tables.
b. All possible strand patterns for girder lengths of 35 to145 feet are covered with girder spacing varying from 5 to 9 feet.
c. Noting of “FAILED” implies that the girder cross-sections with the specified strand pattern, girder spacing and span length have failed at initial stress level.
d. In order to investigate shear between the two given sections (e.g. 0.1 L and 0.2 L) necessary interpolation can be done.

Chapter 9

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

9.1 DISCUSSION ON RESULTS (DESIGN TABLES)

a. Development of design tables is based on the variables stated earlier with the specified material strength. Shear capacity tables can be used to alter the material i.e. the bar size and grade of stirrups so as to increase or decrease the stirrup spacing at section under consideration.

b. Stirrup design/detailing tables, based on the girder spacing range of 5 to 9 feet and four different strand patterns, presenting number of stirrups in five zones along the span. The detail investigation of the data presented in the tables' gives the following outcome:

    1) For any girder spacing, it is more economical (in terms of number of stirrups), to use parabolic/draped (D) or one point draped (D-1) strand pattern.

    2) With the increase in girder spacing, span length reduces and the number of stirrups increases, indicating increase in shear. For example, 5 feet of girder spacing and 12D strand pattern gives 51.5 feet of span with 22 stirrups whereas with 7 feet of the girder spacing and same strand pattern gives 47.5 feet of span with 26 stirrups.

3) Considering same strand pattern, for every one foot increase in the girder spacing, there is a span reduction of about 2 to 5 feet.

4) Assessment of the effect of girder depth (H) in providing shear resistance can be noted by a significant decrease in the number of the stirrups with increase in the girder depth while keeping other variables (girder spacing and strand pattern) as constant. The details are as under:

Girder Spacing(ft)	Girder Type	Girder depth H(in)	Strand Pattern	Span Length(ft)	Stirrups (Nos)	Variations
5	G 36-I	36	14 D-1	61	33	Span=6feet Stirrups=2
5	G 42-I	42	14 D-1	67	35	
5	G 42-I	42	18 D	79.5	30	Span=7feet Stirrups=1
5	G 48-I	48	18 D	86.5	31	
5	G 48-I	48	18 D	86.5	31	Span=0 Stirrups=0
5	G 54-I	54	18 D	86.5	31	
5	G 54-I	54	18 D	86.5	31	Span=8.5feet Stirrups=0
5	G 63-TB	63	18 D	95	31	
5	G 63TB	63	30 D	118	38	Span=9feet Stirrups=4
5	G 72TB	72	30 D	127	42	

5) It is clear from the above data that by keeping girder spacing and the strand pattern constant, the effect of girder depth is insignificant in reducing shear, from which inference can be drawn that the shear controlling parameter is girder spacing.

9.2 CONCLUSIONS

a. ACI code 318-95 and AASHTO standard design procedure in predicting shear capacity of prestressed girders/beams is less conservative.

b. Shear span to depth ratio effects the shear strength of the concrete. More is the ratio lesser is the strength.

c. The girder spacing predominantly influences shear capacity of the prestressed bridge girders, which is the shear controlling parameter. More the girder spacing lesser is the shear capacity and vice versa.

d. Vertical component of prestressing force contributes only 10 percent of shear capacity.

e. LRFD approach for shear based on MCFT is more realistic and more conservative. This is because of measuring actual crack angle at the section under investigation (to be intercepted by shear reinforcement) rather than empirical equations assuming angle of crack as 45 degree, which actually is a remote possibility.lesser angle of crack means lesser concrete contribution resulting in more stirrup steel requirement.

f. It is more practical and economical to use parabolic/draped and one point draped prestressing strand than other configurations.

g. For girder spacing greater than 7 feet, the girder concrete strength and cross sectional properties contributes only 5 percent of shear capacity.

h. For prestressed bridge girders, shear strength is influenced by the percentage of prestressing reinforcement so as to resist tensile stresses developed at the crack parallel to the longitudinal axis of the member.

9.3 RECOMMENDATIONS

9.3.1 RECOMMENDED DESIGN CONSIDERATIONS

9.3.1.1 Shear **Cracking in Pre-Stressed Concrete [8]**

a. The designer may elect do make a more detailed analysis for the shear design of pre-stressed concrete flexural members in conformance with ACI 318, by determining the amount of shear reinforcement required to guard against failure as the result of flexural shear or web shear cracking. Two separately analysis is required because flexural shear cracking is a function of moment and shear while web shear cracking is not a function of moment. In the case of member designed for moving loads because maximum moment and maximum shear do not necessarily occur at any one section under the same loading condition, more effort is required to make a complete analysis than is the case of a member subjected to non moving loads.

b. Due to the compression reduced by pre-stressing, the diagonal tension is smaller in pre-stressed concrete than is reinforcement concrete. Further more its angle of inclination with respect to beam axis is reduced. This implies that if cracking occurs and if, for safe design, the inclined cracked is assumed to cross at least one stirrup, the stirrup spacing is pre-stressed concrete is larger and their required area smaller than in reinforced concrete. Thus a more economical solution (for shear) is obtained.

c. For most commonly used simple span bridges, the webs thickness of post tensioned I and T girders are increased gradually towards the end, for a distance of 0.15L to 0.2L from the girder ends, to enhanced shear capacity and to provide post tensional anchorage in these regions.

9.3.1.2 Straight and Draped Tendons [8]

It should be clear that, for each characteristic load arrangement that there is a “best” tendon profile in the sense, that it produces a pre-stress moment diagram that corresponds to that of the applied load. It is of further interest to note that if the pre-stress counter moment should be made exactly equal and opposite to the moment from the loads all along the span, the result is a beam that is subject only to uniform axial compressive stress throughout for the particular loading. The beam would not only be free of cracking but also (neglecting the influence of concrete shrinkage and creep) would deflect neither up nor down when that load is in place, compared to its unstressed position. This condition is referred to as the balanced load stage.

9.3.1.3 Limitation of Section Prestressed with Straight Tendons [8]

a. It should be apparent that fully bonded straight pre-tensioned tendons can only be used in prismatic beams is which maximum flexural stresses at the bottom fibers, due to total load does not exceed the arithmetic sum of either the allowable compressive stress.

b. In a similar manner the top fiber stress may limit the capacity of a prismatic beam section if the maximum flexural stress in the top fiber, due to the total dead load is greater than the arithmetic sum of allowable compressive stress in the completed member and the top fiber tensile stress due to final pre-stressing.

c. As the result of these limitations the designer can normally determine if the specific concrete section can be used with straight tendons without calculating the magnitude and eccentricity of the prestressing force. It is only necessary to determine the stresses in the section due to the total load and compare these values with sum of the appropriate allowable stresses.

9.3.1.4 Curved or Draped Tendons

a. When a beam is pre-stressed by a straight tendon, it deflects upward or cambers. It is apparent, that the dead weight of the beam itself is acting at the time of the pre-stressing since, as the beam cambers, the soffit of the beam is no longer in contact with the soffit form, except at the extremities of beam. From this consideration, it is concluded that actual stress existing in concrete at any point in the beam at the time of pre-stressing is equal to the algebraic sum of stressed caused by the pre-stressing and the dead weight of the beam itself.

b. If the tendons more placed in the member on a parabolic curve such that the eccentricity were maximum at mid span of the beam and minimum at the ends of the beam, the stress in the top and bottom fibers would very along span / length of the beam. By careful selection of the magnitude and eccentricity of the pre-stressing force it is possible to eliminate reduction is the capacity of the beam to withstand a super imposed load due to the dead weight of the beam itself.

c. It is axiomatic in structural engineering that the dead load of structures become progressively important and greater in respect to the total load as the span length is increased. It is important consideration influencing the normal practice of using straight tendons for short members and using tendons with variable eccentricity either pre-stressed or post-tensioned for longer members.

d. It should be recognized that deflected or draped pre-tensioned tendons couldn’t be placed on smooth curves. They are often placed on trajectories consisting of a series straight lines that approximate a parabolic or other curve form.

e. Another beneficial effect of curving of pre-stressing tendons is the reduction of the shear force that must be carried by the concrete section. This can be illustrated by considering a beam having curved prestressing tendon that is sloped at an angle “α” to the horizontal at the point under consideration.

f. It will reveal that prestressing force can be resolved is to the components “psin α”, acting vertically upward and “pcos α” acting horizontally. If total shear due to external loads is (V) the concrete must resist the amount V-psin α, since the tendon is exerting an upward force equal to psin α, between center of the span and the end. If the tendon were not curved, the concrete section would carry the entire shear force (V).

9.3.1.5 Limitations of Sections Prestressed with Curved Tendons [8]

a. In considering the stress is the bottom fiber at any specific section of a simple beam pre-stressed with curved tendon, it should be apparent that the maximum stress due to external loads must not exceed the arithmetic sum of the stresses due to effective pre-stressing force and allowable tensile stress in the completed structure.

b. The initial tensile stress in the top fibers of the beam prestressed with curved tendon is not normally critical at the section of maximum moment in the beam of good proportions. If the top fiber stresses limit the design of beam with curved tendon it is usually due to excessive compressive stress under maximum loading conditions. Top fiber stresses are much more apt to be a problem as a beam with a narrow top flange that is a beam with a wide top flange.

9.3.1.6 Short Span and Moderate Span Bridges [8]

a. Short span bridges are made using composite girder construction. There is a little advantage in using composite construction for short spans (up to 450 ft) from the standpoint of flexural stresses, since the flexural stresses are not normally critical.

b. The shear stresses in short span bridges of composite construction are frequently very high and large quantities of web reinforcement may be required in order to ensure that adequate factor of safety against ultimate shear failure is provided in the structure.

c. When composite construction is used for spans between 30 and 45 ft, it is generally considered better practice to use girders with web thickness of from 7 to 10 inches, in order to reduce unit shear stresses and the required amount of web reinforcing. In addition the girder spacing used in this type of construction generally restricted to from 4 to 6 ft, for short spans. When larger spacing is used the shear stresses become excessive.

d. Moderate span as defined from 45 to 80ft, for which normally AASHTO type II and type III girders are used. These girders are used at spacing of from 5 to 6 ft.

e. A large girder depth does result in a small pre-stressing force being required for a specific girder spacing and in some instance girders with wide/larger flanges can be used at spacing of from 6 to 8 ft, with significantly larger depth of construction.

f. Another important consideration is the size of the top flange. The dead weight of a structure as well as the girder alone becomes greater as the span is increased. The significance of this can be best understood if a girder with a smaller top flange then bottom flange is analyzed for various girder spacing on a span of 70 to 80ft with composite construction.

g. It will be found that bottom flange is adequate and that the capacity and spacing of the member is limited by the compressive stresses is the smaller top flange. If the span was only 50 ft and the same procedure is followed it would be found that the bottom flange limits the design. The difference is due to the difference in the ratio of dead load to live load, which occurs as the span is increased. This restriction can be avoided by selecting girder shapes that are well proportioned.

9.3.1.7 Tendon Layout for Simply Supported Girder [6]

a. Whenever possible, tendons in simply supported girder should extend from one of the girder to the other. Provided both ends are accessible for jacking, it is preferable to alternate stressing and dead-end anchors. If the girder extends only a short distance past the supports, the tendons should be anchored in the lower portions of the section. This result is a direct flow of forces and good protection against diagonal cracking immediately above the support since the tendons are horizontal at the critical section for shear, increased shear reinforcement will often be required.

b. When the girder extends a sufficient distance beyond the support, the tendon can be anchored at the centriod of the section. The inclined tendons then contribute to the shear resistance at the critical section.

c. Tendon should be anchored away from the supports only if the girder ends are not accessible for stressing. In such cases, stressing anchored can be located at the intersection of web and top flange.

9.3.1.8 Effect of Concrete Strength [32]

a. For concrete strength in the 6000-14000 psi ranges for AASHTO type IV girders using 0.5 in diameter strands commonly used for bridges in the 100 ft range. It shows that for the span of 110 ft, a 6000 psi concrete would required a girder spacing of 6 ft. However for the same span, an 8000 psi concrete would require a girder spacing of 10 ft. Effectively this means that, for a typical 40 ft wide bridge (two 12 ft traffic lanes plus two 8ft wide shoulders) designed for HS 20-44 loading (with an impact factor of 1.25 and a distribution factor of S/5.5). The number of girders is reduced from seven to four by using 8000 psi concrete instead of 6000 psi concrete.

b. Use of high strength concrete for the same girder spacing also increases the span capabilities. For example an AASHTO type IV girder, which has a span capabilities of 112 ft at 6 ft spacing when made from 6000 psi concrete, can span 129 ft if made from 8000 psi concrete-an increase of over 15 percent.

c. The cost savings that accrue from using high strength concrete can be attributed to several factors. The increased flexural capacity of high strength concrete girders lends then to lager girder spacing (and hence a smaller number of girder) for a bridge superstructure for a given span, leading to economical construction.

d. Although the basic with cost of concrete is higher for high strength concrete it may be partially or fully offset by the reduced quantities of concrete as a result of smaller number of girder used. Although high strength concrete girders have more pre-stressing stands per girder, the total number of stands for all the girders is less then that required for the larger number of normal strength concrete girders.

9.3.1.9 Important Parameter Influencing Shear [9]

a. Hundreds of analyses on bridges of different types, geometric end stiffness using various computer programs and experimental result were performed. The programs that yielded the most accurate result were selected for further analyses in developing the AASHTO LRFD formulas.

b. Database of actual bridges was used to determine “an average bridge” for each type. Within each type the parametric studies were made to establish the distribution factor equation. For slab Girder Bridge type shown the most sensitive parameter is girder spacing. It is important to note that the span length and girder stiffness effect the load distribution but to a lesser extent.

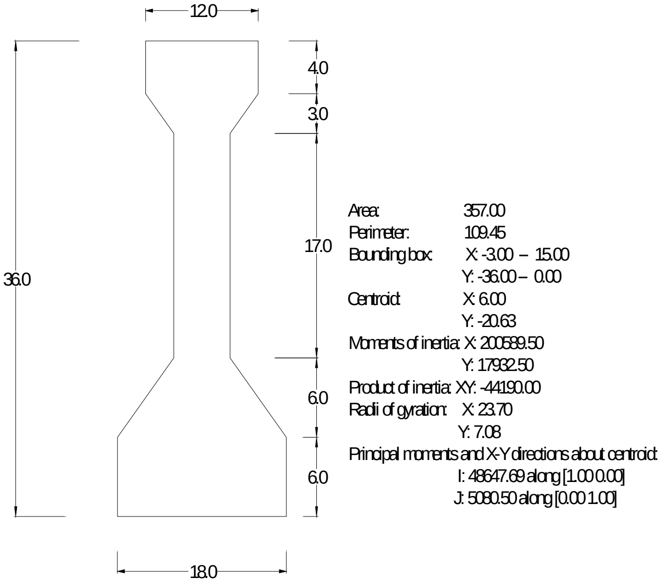
c. For a particular span and loading there is always a limiting girder spacing beyond which the material and geometrical properties of various components of bridge superstructure have insignificant effect in providing resistance against external loads.

9.3.2 Recommendations for Future Work

a. In order to determine the overall economic effect of employing LRFD procedure for design of prestressed bridges it is imperative to conduct parametric study by incorporating the entire bridge substructure and superstructure components.

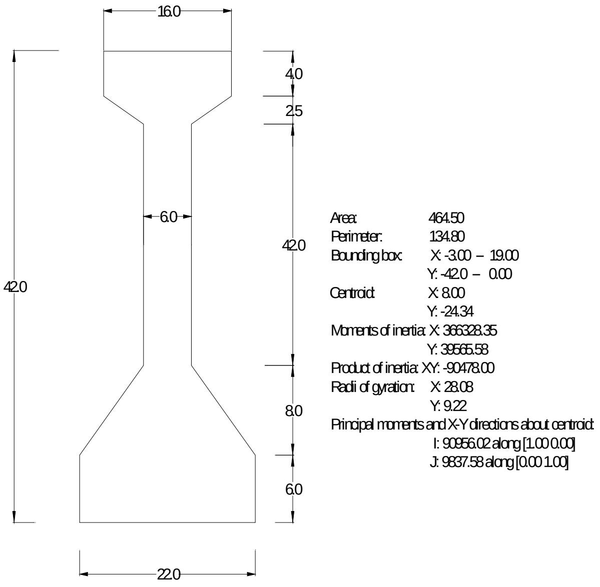
b. Standard design details of other superstructure and substructure bridge components should also be developed which would save cost and time involve in the design process.

c. Torsion and stability analysis of these bridge girders should be carryout.



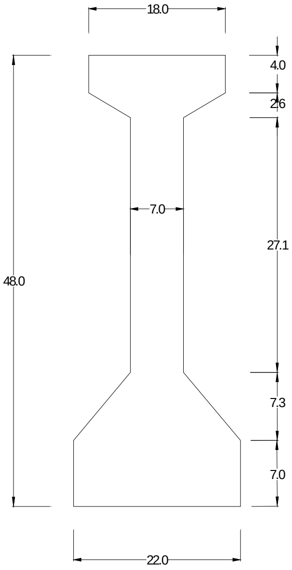
```
Area:                357.00
Perimeter:           109.45
Bounding box:         X: -3.00  –  15.00
                     Y: -36.00 –  0.00
Centroid:            X: 6.00
                     Y: -20.63
Moments of inertia: X: 200589.50
                     Y: 17932.50
Product of inertia: XY: -44190.00
Radii of gyration:   X: 23.70
                    Y: 7.08
Principal moments and X-Y directions about centroid:
                    I: 48647.69 along [1.00 0.00]
                   J: 5080.50 along [0.00 1.00]
```

Figure 1.1: Cross Section of G36- I Girder



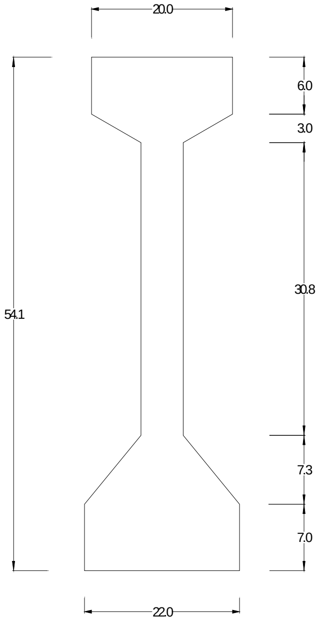
```
Area:                464.50
Perimeter:           134.80
Bounding box:         X: -3.00  –  19.00
                     Y: -42.0  –   0.00
Centroid:            X: 8.00
                     Y: -24.34
Moments of inertia: X: 366328.35
                     Y: 39565.58
Product of inertia: XY: -90478.00
Radii of gyration:    X: 28.08
                      Y: 9.22
Principal moments and X-Y directions about centroid:
                      I: 90956.02 along [1.00 0.00]
                     J: 9837.58 along [0.00 1.00]
```

Figure 1.2: Cross Section of G42- I Girder



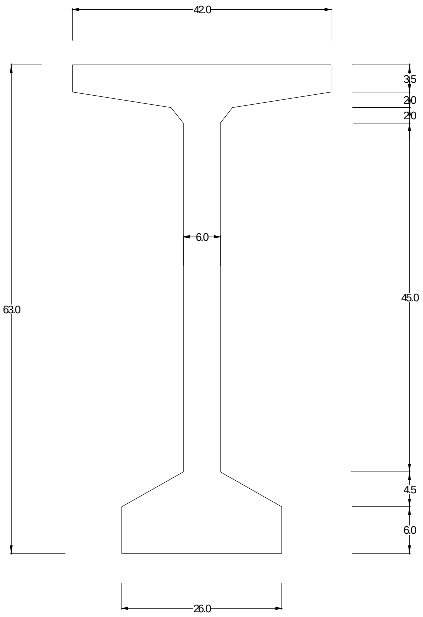
```
Area:                554.14
Perimeter:           149.29
Bounding box:         X: -2.00  --  20.00
                     Y: -48.00  --  0.00
Centroid:            X: 9.00
                     Y: -27.07
Moments of inertia: X: 548512.79
                     Y: 56678.61
Product of inertia: XY: -135037.97
Radii of gyration:   X: 31.46
                     Y: 10.11
Principal moments and X-Y directions about centroid:
                      I: 142249.76 along [1.00 0.00]
                     J: 11793.27 along [0.00 1.00]
```

Figure 1.3: Cross Section of G 48- I Girder



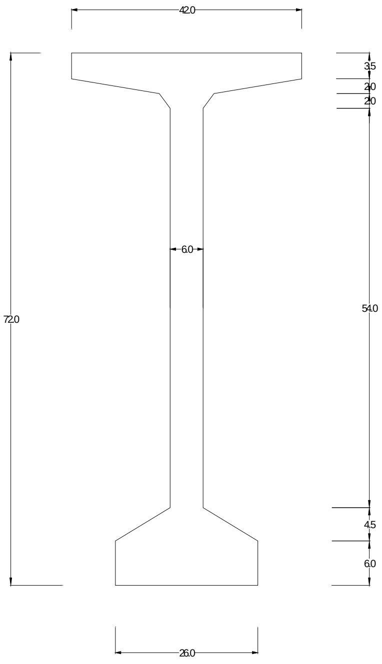
```
Area:                 599.30
Perimeter:            166.42
Bounding box:          X: -1.00  –  21.00
                      Y: -54.05 –  0.00
Centroid:             X: 10.00
                      Y: -29.05
Moments of inertia: X: 720215.48
                      Y: 73603.40
Product of inertia: XY: -174135.40
Radii of gyration:    X: 34.66
                       Y: 11.08
Principal moments and X-Y directions about centroid:
                        I: 214239.51 along [1.00 0.00]
                       J: 13673.40 along [0.00 1.00]
```

Figure 1.4: Cross Section of G 58- I Girder



```
Area:                  713.00
Perimeter:             236.83
Bounding box:          X:   0.00  -- 42.00
                       Y: -63.00  -- 0.00
Centroid:              X: 21.00
                       Y: -30.88
Moments of inertia: X: 1072510.70
                       Y: 351905.33
Product of inertia: XY: -462399.00
Radii of gyration:     X: 38.78
                      Y: 22.21
Principal moments and X-Y directions about centroid:
                       I: 392515.81 along [1.00 0.00]
                      J: 37472.33 along [0.00 1.00]
```

Figure 1.5: Cross Section of G 63-T Girder



```
Area:                  767.00
Perimeter:             254.83
Bounding box:          X: 0.00 --  42.00
                      Y: -72.00  --  0.00
Centroid:             X: 21.00
                      Y: -35.39
Moments of inertia: X: 1506832.70
                      Y: 375881.33
Product of inertia: XY: -570129.00
Radii of gyration:     X: 44.32
                      Y: 22.13
Principal moments and X-Y directions about centroid:
                       I: 545857.21 along [1.00 0.00]
                      J: 37634.33 along [0.00 1.00]
```

Figure 1.6: Cross Section of G 72-T Girder

SHEAR CAPACITY TABLES FOR G 36-I GIRDER

Table 8.3.1.1a: Girder Spacing = 5 feet

			8D			
x (ft) =	0.00	4.35	8.70	13.05	17.40	21.75
Vs.req =	-106.5	-42.8	3.0	9.7	8.2	3.3
Vs.act =	9.57	19.14	19.14	19.14	19.14	9.57
s =	24	24	24	24	24	24
stirrups=	2.175	2.175	2.175	2.175	2.175	2.175
			8S			
x (ft) =	0	4.3	8.6	12.9	17.2	21.5
Vs.req =	58.84826	30.45284	4.75105755	5.91457	8.136503	3.9819
Vs.act =	60.544	33.61319	18.92	18.92	18.92	9.46
s =	3.75	9.4	24	24	24	24
stirrups=	13.76	5.489362	2.15	2.15	2.15	2.15
			10 D-1			
x (ft) =	0	5	10	15	20	25
Vs.req =	-131.13	-37.23504	7.878382152	14.35397	12.06316	5.898383
Vs.act =	11	22	24.64341085	24.64341	22	11
s =	24	24	24	18.04	22.52	24
stirrups=	2.5	2.5	2.5	3.325942	2.664298	2.5
			10 D-2			
x (ft) =	0	5	10	15	20	25
Vs.req =	-128.3276	-36.15094	8.869190373	15.23886	12.79609	6.214418
Vs.act =	11	22	25.63414634	26.35706	22.72291	11
s =	24	24	11.74	11.15	11.99	24
stirrups=	2.5	2.5	5.110732538	5.381166	5.00417	2.5
			12D			
x (ft) =	0	5.6	11.2	16.8	22.4	28
Vs.req =	-151.2595	-32.42261	12.45492165	18.85406	15.7559	7.213451
Vs.act =	12.32	26.84973	34.74025605	36.3151	28.42458	12.32
s =	24	24	20.35	14.63	18.36	24
stirrups=	2.8	2.8	3.302211302	4.593301	3.660131	2.8
			12S			
x (ft) =	0	5.45	10.9	16.35	21.8	27.25
Vs.req =	68.94048	32.23084	-0.262489617	14.72957	15.785	8.281813
Vs.act =	71.94	45.21864	27.17522427	31.46124	28.26602	11.99
s =	4	8.66	24	18.95	17.68	24
stirrups=	16.35	7.551963	2.725	3.451187	3.699095	2.725
			14 D-1			
x (ft) =	0	6.1	12.2	18.3	24.4	30.5
Vs.req =	-98.43502	-13.53856	27.41220793	29.95719	22.1017	8.536561
Vs.act =	13.42	52.50738	77.98592937	65.25534	39.77679	13.42
s =	24	24	8.24	8.28	12.22	24
stirrups=	3.05	3.05	8.883495146	8.84058	5.99018	3.05
			14 D-2			
x (ft) =	0	6.05	12.1	18.15	24.2	30.25
Vs.req =	-97.21589	-14.6997	26.7824866	29.53721	26.9608	11.89609
Vs.act =	13.31	51.33857	76.28485885	73.20596	50.36666	15.41699
s =	24	24	8.4	8.35	9.14	20.72
stirrups=	3.025	3.025	8.642857143	8.694611	7.943107	3.503861

continued

Table 8.3.1.1a: page 2

			16 D-1			
x (ft) =	0	6.4	12.8	19.2	25.6	32
Vs.req =	-111.6017	-16.80044	26.52999144	29.76199	22.07878	9.446176
Vs.act =	14.08	53.9761	80.80651552	68.60877	41.77836	14.08
s =	24	24	8.47	8.26	12.2	24
stirrups=	3.2	3.2	9.06729634	9.297821	6.295082	3.2
			16 D-2			
x (ft) =	0	6.35	12.7	19.05	25.4	31.75
Vs.req =	-110.4546	-17.97709	25.88585025	29.33182	27.0981	12.507
Vs.act =	13.97	52.77556	79.0069944	77.33101	54.27067	17.1411
s =	24	24	8.64	8.34	9.03	19.56
stirrups=	3.175	3.175	8.819444444	9.136691	8.438538	3.895706
			16 S			
x (ft) =	0	6.1	12.2	18.3	24.4	30.5
Vs.req =	70.89547	29.24284	-6.564811891	15.1368	16.77815	10.42724
Vs.act =	84.31414	48.16434	31.41329609	37.93633	33.36303	13.42
s =	3.82	9.27	24	17.9	16.15	24
stirrups=	19.1623	7.89644	3.05	4.089385	4.532508	3.05
			18 D-1			
x (ft) =	0	6.6	13.2	19.8	26.4	33
Vs.req =	-121.8204	-21.91889	24.61429807	28.87045	21.68582	10.37678
Vs.act =	14.52	53.15415	80.21887188	70.43241	43.36768	14.52
s =	24	24	9.02	8.38	12.08	24
stirrups=	3.3	3.3	8.780487805	9.451074	6.556291	3.3
			18 D-2			
x (ft) =	0	6.55	13.1	19.65	26.2	32.75
Vs.req =	-118.1571	-22.662	24.40587278	28.85275	26.93957	12.87669
Vs.act =	14.41	52.709	79.91633184	80.51947	57.48569	18.58356
s =	24	24	9.03	8.31	8.89	18.61
stirrups=	3.275	3.275	8.704318937	9.458484	8.841395	4.223536

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.1b: Girder Spacing = 6 feet

			8D			
x (ft) =	0	3.95	7.9	11.85	15.8	19.75
Vs.req =	-98.22094	-47.00726	3.895086732	11.22242	9.328989	3.824456
Vs.act =	8.69	17.38	17.38	17.38	17.38	8.69
s =	24	24	24	24	24	24
stirrups=	1.975	1.975	1.975	1.975	1.975	1.975
			8 S			
x (ft) =	0	3.9	7.8	11.7	15.6	19.5
Vs.req =	76.32594	45.71656	17.79691641	6.906897	9.110649	4.463838
Vs.act =	82.368	45.69258	21.37801119	17.16	17.16	8.58
s =	2.5	6.26	16.09	24	24	24
stirrups=	18.72	7.476038	2.908638906	1.95	1.95	1.95
			10 D-1			
x (ft) =	0	4.55	9.1	13.65	18.2	22.75
Vs.req =	-121.0448	-39.3196	10.73090042	17.32514	14.69015	8.258525
Vs.act =	10.01	20.21127	25.34881487	27.39843	22.26089	10.01
s =	24	24	23.55	15.86	19.61	24
stirrups=	2.275	2.275	2.318471338	3.442623	2.784294	2.275
			10 D-2			
x (ft) =	0	4.6	9.2	13.8	18.4	23
Vs.req =	-122.1973	-38.08081	11.29212514	17.64659	14.89395	8.396435
Vs.act =	10.12	20.87642	26.18717129	27.84158	22.53083	10.12
s =	24	24	22.58	15.74	19.57	24
stirrups=	2.3	2.3	2.444641275	3.506989	2.820644	2.3
			12D			
x (ft) =	0	5.15	10.3	15.45	20.6	25.75
Vs.req =	-143.5923	-32.97063	16.28331205	22.69069	19.07922	11.51322
Vs.act =	11.33	28.79435	39.82619663	40.29852	29.75928	11.82261
s =	24	24	15.57	12.16	15.16	23
stirrups=	2.575	2.575	3.969171484	5.082237	4.076517	2.686957
			12S			
x (ft) =	0	5	10	15	20	25
Vs.req =	89.71274	50.27056	15.13621022	17.743	18.80631	12.28201
Vs.act =	94.28571	61.88427	31.0999196	34.57297	29.40948	11.61972
s =	2.8	5.55	18.44	15.73	14.84	22.72
stirrups=	21.42857	10.81081	3.253796095	3.814367	4.043127	2.640845
			14 D-1			
x (ft) =	0	5.65	11.3	16.95	22.6	28.25
Vs.req =	-89.35443	-10.58934	33.89974884	35.95646	26.87084	13.75042
Vs.act =	12.43	57.15564	87.96041979	72.91836	43.72878	14.0452
s =	24	24	6.67	6.9	10.05	21.24
stirrups=	2.825	2.825	10.16491754	9.826087	6.746269	3.19209
			14 D-2			
x (ft) =	0	5.6	11.2	16.8	22.4	28
Vs.req =	-88.22379	-12.00694	33.10715033	35.403	32.13765	17.54688
Vs.act =	12.32	55.80235	85.96511156	81.03295	59.59504	21.04484
s =	24	24	6.8	6.96	7.67	14.05
stirrups=	2.8	2.8	9.882352941	9.655172	8.761408	4.782918

continued

Table 8.3.1.1b, page 2

			16 D-1			
x (ft) =	0	5.9	11.8	17.7	23.6	29.5
Vs.req =	-103.9358	-15.32913	32.17913146	35.19199	26.42036	13.37437
Vs.act =	12.98	57.61037	89.1968961	75.34913	45.2182	14.43559
s =	24	24	6.98	6.99	10.12	21.58
stirrups=	2.95	2.95	10.14326648	10.12876	6.996047	3.280816
			16 D-2			
x (ft) =	0	5.9	11.8	17.7	23.6	29.5
Vs.req =	-101.3067	-14.80224	32.69476253	35.6789	32.69919	18.42565
Vs.act =	12.98	58.52386	90.95493837	87.05814	65.10489	23.45783
s =	24	24	6.84	6.86	7.48	13.28
stirrups=	2.95	2.95	10.35087719	10.3207	9.465241	5.331325
			16 S			
x (ft) =	0	5.7	11.4	17.1	22.8	28.5
Vs.req =	94.13825	48.6181	8.534526613	20.73993	21.8606	14.60078
Vs.act =	104.5	66.57232	35.56677888	47.29775	40.48648	16.21552
s =	2.88	5.57	24	13.07	12.4	18.56
stirrups=	23.75	12.28007	2.85	5.233359	5.516129	3.685345
			18 D-1			
x (ft) =	0	6.15	12.3	18.45	24.6	30.75
Vs.req =	-112.5234	-18.47977	31.75543714	35.56396	27.06882	14.00878
Vs.act =	13.53	59.98494	94.2078768	81.2984	49.6766	16.13115
s =	24	24	6.99	6.8	9.68	20.13
stirrups=	3.075	3.075	10.55793991	10.85294	7.623967	3.66617
			18 D-2			
x (ft) =	0	6.1	12.2	18.3	24.4	30.5
Vs.req =	-108.8098	-19.42314	31.4363523	35.46679	32.78135	18.95448
Vs.act =	13.42	59.36579	93.59076214	91.70516	69.5412	25.48101
s =	24	24	7.01	6.76	7.31	12.64
stirrups=	3.05	3.05	10.44222539	10.8284	10.01368	5.791139

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

Table 8.3.1.1c: Girder Spacing = 7 feet

			8D			
x (ft) =	0	3.7	7.4	11.1	14.8	18.5
Vs.req =	-87.16429	-46.38499	7.727826554	15.10352	12.06581	5.548831
Vs.act =	8.14	16.28	18.7921265	18.79213	16.28	8.14
s =	24	24	24	18.34	24	24
stirrups=	1.85	1.85	1.85	2.420938	1.85	1.85
			8 S			
x (ft) =	0	3.6	7.2	10.8	14.4	18
Vs.req =	92.91091	59.9848	29.75807518	8.522401	10.19901	4.951898
Vs.act =	95.04	59.60789	27.67883576	15.84	15.84	7.92
s =	2	4.77	9.62	24	24	24
stirrups=	21.6	9.056604	4.490644491	1.8	1.8	1.8
			10 D-1			
x (ft) =	0	4.2	8.4	12.6	16.8	21
Vs.req =	-112.6285	-41.485	12.9629103	19.84461	16.7555	9.535025
Vs.act =	9.24	20.61231	27.38386004	28.90458	22.13302	9.24
s =	24	24	19.5	13.85	17.2	24
stirrups=	2.1	2.1	2.584615385	3.638989	2.930233	2.1
			10 D-2			
x (ft) =	0	4.25	8.5	12.75	17	21.25
Vs.req =	-113.4959	-39.91507	13.73703657	20.33558	17.10728	9.795757
Vs.act =	9.35	21.44052	28.51804286	29.59654	22.51901	9.35
s =	24	24	18.56	13.66	17.04	24
stirrups=	2.125	2.125	2.747844828	3.733529	2.992958	2.125
			12D			
x (ft) =	0	4.75	9.5	14.25	19	23.75
Vs.req =	-136.2831	-34.86957	18.91076406	25.28352	21.36131	13.28411
Vs.act =	10.45	29.16642	41.70450224	41.51098	32.45623	13.93333
s =	24	24	13.4	10.91	13.54	18
stirrups=	2.375	2.375	4.253731343	5.224565	4.209749	3.166667
			12S			
x (ft) =	0	4.6	9.2	13.8	18.4	23
Vs.req =	108.8307	67.17884	29.8215196	19.49829	20.77612	13.84895
Vs.act =	110.4	84.47402	42.92146428	35.05763	30.13848	12.0536
s =	2.2	4.15	9.36	14.31	13.43	20.15
stirrups=	25.09091	13.3012	5.897435897	3.857442	4.110201	2.739454
			14 D-1			
x (ft) =	0	5.2	10.4	15.6	20.8	26
Vs.req =	-82.75938	-10.95779	37.86209389	39.71869	29.78807	15.65017
Vs.act =	11.44	57.42995	89.98994975	74.30464	45.99378	15.68914
s =	24	24	5.97	6.24	9.06	17.5
stirrups=	2.6	2.6	10.45226131	10	6.887417	3.565714
			14 D-2			
x (ft) =	0	5.2	10.4	15.6	20.8	26
Vs.req =	-79.99025	-10.35141	38.45572325	40.28695	36.46599	23.28229
Vs.act =	11.44	58.37333	91.79607843	85.47813	66.54173	25.92635
s =	24	24	5.85	6.12	6.76	10.59
stirrups=	2.6	2.6	10.66666667	10.19608	9.230769	5.892351

continued

Table 8.3.1.1c, page 2

			16 D-1			
x (ft) =	0	5.55	11.1	16.65	22.2	27.75
Vs.req =	-93.79792	-10.79815	39.62893785	41.87343	31.71012	16.92082
Vs.act =	12.21	63.89254	101.6041751	84.6832	51.93859	17.17702
s =	24	24	5.67	5.87	8.43	17.06
stirrups=	2.775	2.775	11.74603175	11.34583	7.900356	3.903869
			16 D-2			
x (ft) =	0	5.5	11	16.5	22	27.5
Vs.req =	-92.83795	-12.49369	38.65263477	41.16989	37.5541	24.03503
Vs.act =	12.1	62.25544	99.0443293	93.49718	73.13482	28.52652
s =	24	24	5.79	5.94	6.51	10.18
stirrups=	2.75	2.75	11.39896373	11.11111	10.13825	6.483301
			16 S			
x (ft) =	0	5.3	10.6	15.9	21.2	26.5
Vs.req =	115.3753	67.03949	24.23974492	24.40065	25.39863	17.34034
Vs.act =	119.0809	94.29774	50.21853026	51.41492	44.13083	17.90403
s =	2.35	4.04	11.18	11.11	10.67	15.63
stirrups=	27.06383	15.74257	5.688729875	5.724572	5.960637	4.069098
			18 D-1			
x (ft) =	0	5.75	11.5	17.25	23	28.75
Vs.req =	-103.852	-15.7758	38.1398441	41.49339	31.79134	17.08048
Vs.act =	12.65	64.81495	52.68570317	37.36541	55.23352	18.38886
s =	24	24	5.82	583	8.24	16.51
stirrups=	2.875	2.875	11.8556701	0.118353	8.373786	4.179285
			18 D-2			
x (ft) =	0	5.7	11.4	17.1	22.8	28.5
Vs.req =	-100.1181	-16.94237	37.69283131	41.29923	37.93796	24.61982
Vs.act =	12.54	63.98615	103.335809	99.50991	78.55139	30.93114
s =	24	24	5.85	5.8	6.32	9.73
stirrups=	2.85	2.85	11.69230769	11.7931	10.82278	7.029805

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

Table 8.3.1.1d: Girder Spacing = 8 feet

			8D			
x (ft) =	0	3.45	6.9	10.35	13.8	17.25
Vs.req =	-77.52125	-48.3652	9.539293267	17.31767	13.28417	5.931019
Vs.act =	7.59	15.18	18.975	19.71041	15.91541	7.59
s =	24	24	24	16	21.88	24
stirrups=	1.725	1.725	1.725	2.5875	1.892139	1.725
			8 S			
x (ft) =	0	3.4	6.8	10.2	13.6	17
Vs.req =	109.4454	73.82712	41.41669825	13.19083	12.79037	6.396325
Vs.act =	119.68	81.7437	42.14069857	16.28687	15.49787	7.48
s =	1.5	3.75	5.3	21.71	22.39	24
stirrups=	27.2	10.88	7.698113208	1.879318	1.822242	1.7
			10 D-1			
x (ft) =	0	3.95	7.9	11.85	15.8	19.75
Vs.req =	-101.5444	-40.08501	17.46308262	24.09609	20.04308	11.69464
Vs.act =	8.69	23.10327	32.69197172	32.78218	26.09014	11.58667
s =	24	24	14.47	11.41	14.38	18
stirrups=	1.975	1.975	3.275742916	4.154251	3.296245	2.633333
			10 D-2			
x (ft) =	0	4.15	8.3	12.45	16.6	20.75
Vs.req =	-97.40337	-29.27315	24.48583324	29.48344	24.42383	15.19328
Vs.act =	9.13	30.17899	44.31013785	41.61291	34.00319	15.65143
s =	24	24	10.41	9.42	11.94	14
stirrups=	2.075	2.075	4.783861671	5.286624	4.170854	3.557143
			12D			
x (ft) =	0	4.4	8.8	13.2	17.6	22
Vs.req =	-129.0383	-37.71347	20.63179001	27.28738	23.08879	14.37227
Vs.act =	9.68	28.58317	41.8824018	41.52033	33.0611	14.52
s =	24	24	12.29	10.11	12.53	16
stirrups=	2.2	2.2	4.296175753	5.222552	4.213887	3.3
			12S			
x (ft) =	0	4.3	8.6	12.9	17.2	21.5
Vs.req =	127.3622	83.25561	43.47212574	22.4802	23.52166	15.73599
Vs.act =	129.7371	103.1376	53.65940943	37.43826	31.94875	12.80541
s =	1.75	3.35	6.42	12.41	11.86	17.73
stirrups=	29.48571	15.40299	8.037383178	4.157937	4.350759	2.910321
			14 D-1			
x (ft) =	0	4.85	9.7	14.55	19.4	24.25
Vs.req =	-75.02539	-10.01339	42.46311698	43.77871	32.88761	17.73252
Vs.act =	10.67	58.80534	93.3791546	76.02266	48.43954	17.66069
s =	24	24	5.32	5.66	8.32	14.5
stirrups=	2.425	2.425	10.93984962	10.28269	6.995192	4.013793
			14 D-2			
x (ft) =	0	4.85	9.7	14.55	19.4	24.25
Vs.req =	-72.17523	-9.356501	43.10619392	44.39971	40.11147	28.64387
Vs.act =	10.67	59.72747	95.1980118	95.86481	79.46643	29.74216
s =	24	24	5.22	5.55	5.15	8.61
stirrups=	2.425	2.425	11.14942529	10.48649	11.30097	6.759582

continued

Table 8.3.1.1d, page 2

			16 D-1			
x (ft) =	0	5.2	10.4	15.6	20.8	26
Vs.req =	-85.5308	-8.689962	45.20494197	46.8876	35.61304	19.61385
Vs.act =	11.44	66.68346	107.5406036	88.90514	55.27285	18.66485
s =	24	24	4.97	5.25	7.5	14.71
stirrups=	2.6	2.6	12.55533199	11.88571	8.32	4.242012
			16 D-2			
x (ft) =	0	5.2	10.4	15.6	20.8	26
Vs.req =	-82.72137	-8.076022	45.80622194	47.4635	42.92938	29.85898
Vs.act =	11.44	67.7023	109.5749164	101.481	81.69223	33.52381
s =	24	24	4.88	5.15	5.7	8.19
stirrups=	2.6	2.6	12.78688525	12.1165	10.94737	7.619048
			16 S			
x (ft) =	0	5	10	15	20	25
Vs.req =	136.0441	84.65411	38.94029677	29.00271	29.55474	20.59411
Vs.act =	138.9474	120.431	66.19655911	57.05506	48.85032	20.06079
s =	1.9	3.2	6.96	9.34	9.17	13.16
stirrups=	31.57895	18.75	8.620689655	6.423983	6.543075	4.559271
			18 D-1			
FAILED IN FLEXURE						
			18 D-2			
x (ft) =	0	5.35	10.7	16.05	21.4	26.75
Vs.req =	-91.7318	-14.84899	43.45150468	46.56494	42.5769	30.30406
Vs.act =	11.77	67.48598	110.5664618	105.0246	85.88582	35.71176
s =	24	24	5.07	5.15	5.63	7.91
stirrups=	2.675	2.675	12.66272189	12.46602	11.4032	8.116308

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.1e: Girder Spacing = 9 feet

			8D			
x (ft) =	0	3.25	6.5	9.75	13	16.25
Vs.req =	-67.44698	-47.61392	12.82401856	20.39919	15.39862	6.632893
Vs.act =	7.15	15.79919	21.2854233	21.72521	16.23898	7.15
s =	24	24	19.84	13.58	18.88	24
stirrups=	1.625	1.625	1.965725806	2.87187	2.065678	1.625
			8 S			
x (ft) =	0	3.2	6.4	9.6	12.8	16
Vs.req =	122.5482	85.12945	51.9343727	21.92214	14.77639	7.013201
Vs.act =	135.168	92.52571	55.17721286	21.65548	15.75827	7.04
s =	1.25	3.36	4	13.06	19.38	24
stirrups=	30.72	11.42857	9.6	2.940276	1.981424	1.6
			10 D-1			
x (ft) =	0	3.7	7.4	11.1	14.8	18.5
Vs.req =	-93.29721	-41.68516	19.28446272	26.33176	21.32425	12.24663
Vs.act =	8.14	23.0416	33.61424551	33.17304	22.63788	8.17748
s =	24	24	13.11	10.44	13.51	23.89
stirrups=	1.85	1.85	3.386727689	4.252874	3.286454	1.858518
			10 D-2			
x (ft) =	0	3.7	7.4	11.1	14.8	18.5
Vs.req =	-95.63738	-43.20588	17.91675856	25.10885	20.27706	11.40338
Vs.act =	8.14	21.86874	31.3923949	31.24919	25.0773	11.49176
s =	24	24	14.23	11.06	14.38	17
stirrups=	1.85	1.85	3.120168658	4.014467	3.087622	2.611765
			12D			
x (ft) =	0	4.15	8.3	12.45	16.6	20.75
Vs.req =	-119.4233	-36.3861	24.81227591	31.16492	26.16704	16.40115
Vs.act =	9.13	30.57031	46.19963515	44.58919	36.68525	16.85538
s =	24	24	10.22	8.85	11.05	13
stirrups=	2.075	2.075	4.872798434	5.627119	4.506787	3.830769
			12S			
x (ft) =	0	4.05	8.1	12.15	16.2	20.25
Vs.req =	143.8451	97.72015	55.84831642	25.79463	26.37803	17.64081
Vs.act =	147.4759	117.5372	62.53140111	39.97512	38.03172	17.82
s =	1.45	2.86	5	10.82	10.58	12
stirrups=	33.51724	16.99301	9.72	4.491682	4.593573	4.05
			14 D-1			
x (ft) =	0	4.55	9.1	13.65	18.2	22.75
Vs.req =	-67.27967	-8.380787	47.12990732	47.78899	35.94445	19.66732
Vs.act =	10.01	60.16449	96.44350586	78.27836	52.00935	20.02
s =	24	24	4.79	5.19	7.51	12
stirrups=	2.275	2.275	11.39874739	10.52023	7.270306	4.55
			14 D-2			
x (ft) =	0	4.55	9.1	13.65	18.2	22.75
Vs.req =	-64.3654	-7.679211	47.81656731	48.45536	43.68404	31.38797
Vs.act =	10.01	61.12489	98.31332191	89.79417	74.62774	32.032
s =	24	24	4.7	5.09	5.64	7.5
stirrups=	2.275	2.275	11.61702128	10.72692	9.680851	7.28

Continued

Table 8.3.1.1e, page 2

			16 D-1			
x (ft) =	0	4.9	9.8	14.7	19.6	24.5
Vs.req =	-77.15784	-5.724909	50.96921757	51.82739	39.39858	22.2522
Vs.act =	10.78	69.44667	113.1340351	92.62666	58.10686	19.94757
s =	24	24	4.41	4.75	6.78	12.97
stirrups=	2.45	2.45	13.33333333	12.37895	8.672566	4.533539
			16 D-2			
x (ft) =	0	4.9	9.8	14.7	19.6	24.5
Vs.req =	-74.27277	-5.071517	51.60911987	52.44482	47.18718	34.02686
Vs.act =	10.78	70.53058	115.2698907	105.4653	85.92926	35.98331
s =	24	24	4.33	4.66	5.18	7.19
stirrups=	2.45	2.45	13.57967667	12.61803	11.35135	8.178025
			16 S			
x (ft) =	0	4.75	9.5	14.25	19	23.75
Vs.req =	154.506	100.6626	52.50051415	34.06409	33.93828	24.01549
Vs.act =	156.75	141.8389	80.11218885	62.93611	53.66261	22.23404
s =	1.6	2.69	5.16	7.96	7.98	11.28
stirrups=	35.625	21.18959	11.04651163	7.160804	7.142857	5.053191
			18 D-1			
FAILED IN FLEXURE						
			18 D-2			
FAILED IN FLEXURE						

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

SHEAR CAPACITY TABLES FOR G 42-I GIRDER

Table 8.3.1.2a: Girder Spacing = 5 feet

			10 D			
x (ft) =	0	5.4	10.8	16.2	21.6	27
Vs.req =	-134.5482	-53.12453	2.161787492	11.69458	10.17143	1.894296
Vs.act =	11.88	23.76	23.76	23.76	23.76	11.88
s =	24	24	24	24	24	24
stirrups=	2.7	2.7	2.7	2.7	2.7	2.7
			12 D-1			
x (ft) =	0	6.1	12.2	18.3	24.4	30.5
Vs.req =	-91.59258	-28.34223	20.87046575	25.9579	18.81536	3.348758
Vs.act =	13.42	38.40681	53.23944306	47.02186	32.18923	13.42
s =	24	24	12.89	11.4	17.16	24
stirrups=	3.05	3.05	5.678820791	6.421053	4.265734	3.05
			12 D-2			
x (ft) =	0	6.05	12.1	18.15	24.2	30.25
Vs.req =	-90.61673	-29.69946	20.12015242	25.45394	23.71305	8.10366
Vs.act =	13.31	37.31	51.63321799	53.39451	39.07129	13.31
s =	24	24	13.31	11.56	12.4	24
stirrups=	3.025	3.025	5.454545455	6.280277	5.854839	3.025
			12 S			
x (ft) =	0	5.9	11.8	17.7	23.6	29.5
Vs.req =	61.3282	26.02731	-5.710661989	12.12002	13.93437	4.48825
Vs.act =	62.304	37.39379	25.96	26.04711	26.04711	12.98
s =	5	12.76	24	24	23.84	24
stirrups=	14.16	5.548589	2.95	2.95	2.969799	2.95
			14 D-1			
x (ft) =	0	6.7	13.4	20.1	26.8	33.5
Vs.req =	-101.2646	-22.52414	25.90326704	30.26704	22.21705	4.669292
Vs.act =	14.74	48.91971	70.50003869	60.78506	39.20473	14.74
s =	24	24	10.35	9.74	14.46	24
stirrups=	3.35	3.35	7.768115942	8.25462	5.560166	3.35
			14 D-2			
x (ft) =	0	6.65	13.3	19.95	26.6	33.25
Vs.req =	-100.3514	-23.80522	25.18535005	29.78275	27.27481	9.258914
Vs.act =	14.63	47.72331	68.77623503	68.34525	47.29233	14.63
s =	24	24	10.61	9.84	10.75	24
stirrups=	3.325	3.325	7.521206409	8.109756	7.423256	3.325
			16 D			
x (ft) =	0	7.1	14.2	21.3	28.4	35.5
Vs.req =	-199.1576	-41.86736	12.91559835	21.77482	18.30805	5.437796
Vs.act =	15.62	31.81352	41.30269667	45.24237	35.75319	15.62
s =	24	24	23.15	14.93	18.62	24
stirrups=	3.55	3.55	3.680345572	5.706631	4.575725	3.55
			16 S			
x (ft) =	0	6.8	13.6	20.4	27.2	34
Vs.req =	65.5884	24.23266	-6.766418459	16.51323	17.85566	6.951931
Vs.act =	79.78667	41.79408	33.25037188	38.07219	34.74182	14.96
s =	4.5	13.38	24	19.63	18.15	24
stirrups=	18.13333	6.098655	3.4	4.156903	4.495868	3.4

continued

Table 8.3.1.2a: page 2

			18 D			
x (ft) =	0	7.5	15	22.5	30	37.5
Vs.req =	-220.6136	-43.10748	13.47651111	22.42678	18.92215	6.091029
Vs.act =	16.5	34.39426	45.29910547	49.46613	38.56128	16.5
s =	24	24	22.13	14.45	17.95	24
stirrups=	3.75	3.75	4.066877542	6.228374	5.013928	3.75
			20 D			
x (ft) =	0	7.8	15.6	23.4	31.2	39
Vs.req =	-243.8311	-47.29866	11.92913415	21.52768	18.33531	6.540117
Vs.act =	17.16	34.32	44.57944075	49.70516	39.44571	17.16
s =	24	24	24	15.02	18.48	24
stirrups=	3.9	3.9	3.9	6.231691	5.064935	3.9
			20 S			
x (ft) =	0	7.35	14.7	22.05	29.4	36.75
Vs.req =	65.09338	20.06272	-9.438956953	15.98622	17.98684	8.512024
Vs.act =	80.85	40.82565	35.81962025	41.74985	38.27023	16.17
s =	4.8	15.74	24	19.75	17.56	24
stirrups=	18.375	5.603558	3.675	4.465823	5.022779	3.675
			24 D-1			
x (ft) =	0	8.35	16.7	25.05	33.4	41.75
Vs.req =	-166.5687	-32.0319	25.83528578	31.26747	23.05365	7.511509
Vs.act =	18.37	61.38268	90.57255348	79.85877	50.6689	18.37
s =	24	24	10.25	9.27	13.65	24
stirrups=	4.175	4.175	9.775609756	10.80906	7.340659	4.175
			24 D-2			
x (ft) =	0	8.25	16.5	24.75	33	41.25
Vs.req =	-161.3721	-33.92696	24.96503117	30.86386	23.06086	7.941185
Vs.act =	18.15	59.59624	88.43653294	79.40101	50.56071	18.15
s =	24	24	10.51	9.27	13.44	24
stirrups=	4.125	4.125	9.419600381	10.67961	7.366071	4.125
			26 D-1			
x (ft) =	0	8.5	17	25.5	34	42.5
Vs.req =	-173.5899	-37.05225	24.0656442	30.38359	22.70353	8.298102
Vs.act =	18.7	59.91212	89.00764837	80.77128	51.67575	18.7
s =	24	24	10.89	9.39	13.61	24
stirrups=	4.25	4.25	9.366391185	10.86262	7.494489	4.25
			26 D-2			
x (ft) =	0	8.5	17	25.5	34	42.5
Vs.req =	-171.7207	-36.74528	24.35856258	30.65738	29.23355	11.59156
Vs.act =	18.7	60.52665	90.136665	94.38804	64.77803	18.7
s =	24	24	10.73	9.29	9.74	24
stirrups=	4.25	4.25	9.506057782	10.97955	10.47228	4.25

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.2b: Girder Spacing = 6 feet

			10 D			
x (ft) =	0	4.95	9.9	14.85	19.8	24.75
Vs.req =	-125.6861	-57.46947	3.766856847	13.80868	12.23101	5.922492
Vs.act =	10.89	21.78	21.89926706	21.89927	21.78	10.89
s =	24	24	24	23.74	24	24
stirrups=	2.475	2.475	2.475	2.502106	2.475	2.475
			12 D-1			
x (ft) =	0	5.55	11.1	16.65	22.2	27.75
Vs.req =	-85.38637	-32.06526	23.18770756	28.78585	21.1578	8.795737
Vs.act =	12.21	37.47207	53.76790554	47.70898	31.41315	12.21
s =	24	24	11.6	10.28	15.26	24
stirrups=	2.775	2.775	5.74137931	6.478599	4.364351	2.775
			12 D-2			
x (ft) =	0	5.56	11.12	16.68	22.24	27.8
Vs.req =	-82.69933	-31.11903	23.97442071	29.49426	27.55118	13.67709
Vs.act =	12.232	38.51383	55.72696173	56.93278	41.13562	13.64798
s =	24	24	11.17	9.97	10.68	21.51
stirrups=	2.78	2.78	5.973142346	6.692076	6.247191	3.101813
			12 S			
x (ft) =	0	5.4	10.8	16.2	21.6	27
Vs.req =	81.49647	43.69143	9.509744213	14.09397	16.29274	9.852802
Vs.act =	81.46286	49.39579	23.97673314	26.08006	25.86333	11.88
s =	3.5	7.6	24	23.57	20.39	24
stirrups=	18.51429	8.526316	2.7	2.749258	3.178028	2.7
			14 D-1			
x (ft) =	0	6.1	12.2	18.3	24.4	30.5
Vs.req =	-95.6916	-25.81633	28.65428466	33.63658	25.02014	10.48751
Vs.act =	13.42	47.83026	71.1773797	61.85124	38.50411	13.42
s =	24	24	9.36	8.76	12.84	24
stirrups=	3.05	3.05	7.820512821	8.356164	5.700935	3.05
			14 D-2			
x (ft) =	0	6.1	12.2	18.3	24.4	30.5
Vs.req =	-109.0437	-28.60541	25.9283887	30.82005	22.25242	9.134092
Vs.act =	13.42	43.89114	63.16962191	54.19914	34.92067	13.42
s =	24	24	10.57	9.85	14.98	24
stirrups=	3.05	3.05	6.92526017	7.431472	4.886515	3.05
			16 D			
x (ft) =	0	6.65	13.3	19.95	26.6	33.25
Vs.req =	-190.0488	-39.99742	18.99691126	28.04843	23.71042	11.88777
Vs.act =	14.63	37.08013	52.74520984	54.71233	39.04725	14.63
s =	24	24	15.64	11.59	14.38	24
stirrups=	3.325	3.325	5.10230179	6.885246	5.549374	3.325
			16 S			
x (ft) =	0	6.35	12.7	19.05	25.4	31.75
Vs.req =	88.50333	43.48746	3.360256061	21.80069	22.8044	13.20979
Vs.act =	95.79429	58.97403	36.51741089	46.14206	37.56465	13.97
s =	3.5	7.45	24	14.87	14.21	24
stirrups=	21.77143	10.22819	3.175	5.124412	5.362421	3.175

continued

Table 8.3.1.2b, page 2

			18 D			
x (ft) =	0	7	14	21	28	35
Vs.req =	-213.3591	-42.44876	18.51165951	28.26238	24.02039	12.67319
Vs.act =	15.4	38.34227	55.16546281	58.3618	41.53861	15.4
s =	24	24	16.11	11.47	14.14	24
stirrups=	3.5	3.5	5.2141527	7.323452	5.940594	3.5
			20 D			
x (ft) =	0	7.25	14.5	21.75	29	36.25
Vs.req =	-238.7673	-48.37304	15.92257045	26.62891	22.89268	13.19398
Vs.act =	15.95	36.43154	52.01366614	57.39699	41.81486	15.95
s =	24	24	18.69	12.14	14.8	24
stirrups=	3.625	3.625	4.654895666	7.166392	5.878378	3.625
			20 S			
x (ft) =	0	6.85	13.7	20.55	27.4	34.25
Vs.req =	88.80274	40.04266	-3.175289776	20.89503	22.73457	15.01015
Vs.act =	103.3371	60.9103	39.00646592	49.97534	43.22899	17.19011
s =	3.5	7.89	24	15.11	13.89	21.04
stirrups=	23.48571	10.41825	3.425	5.440106	5.917927	3.906844
			24 D-1			
x (ft) =	0	7.8	15.6	23.4	31.2	39
Vs.req =	-158.8729	-30.33214	32.27420231	38.01666	28.60932	14.1981
Vs.act =	17.16	67.32322	104.2104597	91.48724	54.65739	17.21739
s =	24	24	8.21	7.62	11	23.92
stirrups=	3.9	3.9	11.40073082	12.28346	8.509091	3.913043
			24 D-2			
x (ft) =	0	7.7	15.4	23.1	30.8	38.5
Vs.req =	-153.6537	-32.62686	31.15530211	37.4533	28.50418	14.34033
Vs.act =	16.94	65.16776	101.4424177	90.61668	54.87345	17.47142
s =	24	24	8.43	7.64	10.87	23.27
stirrups=	3.85	3.85	10.96085409	12.09424	8.50046	3.970778
			26 D-1			
x (ft) =	0	7.95	15.9	23.85	31.8	39.75
Vs.req =	-165.8112	-35.51651	30.54786589	37.21295	28.34513	14.12684
Vs.act =	17.49	66.41308	103.6505867	93.2376	56.34945	17.83935
s =	24	24	8.58	7.67	10.9	23.53
stirrups=	3.975	3.975	11.11888112	12.43807	8.752294	4.054399
			26 D-2			
x (ft) =	0	7.9	15.8	23.7	31.6	39.5
Vs.req =	-165.4596	-37.07682	29.60117541	36.57137	34.82446	18.49445
Vs.act =	17.38	64.61896	100.853354	104.6695	78.15839	27.10331
s =	24	24	8.83	7.78	8.17	15.39
stirrups=	3.95	3.95	10.73612684	12.18509	11.60343	6.159844

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

Table 8.3.1.3c: Girder Spacing = 7 feet

			10 D			
x (ft) =	0	4.6	9.2	13.8	18.4	23
Vs.req =	-115.5945	-60.31949	6.072729449	16.2842	14.46719	7.576893
Vs.act =	10.12	20.24	22.18557377	22.2835	20.33792	10.12
s =	24	24	24	20.13	23.77	24
stirrups=	2.3	2.3	2.3	2.742176	2.322255	2.3
			12 D-1			
x (ft) =	0	5.15	10.3	15.45	20.6	25.75
Vs.req =	-77.10119	-33.15298	26.96213675	32.5025	24.13655	10.93517
Vs.act =	11.33	38.60382	57.15514015	50.20419	31.65287	11.33
s =	24	24	9.97	9.1	13.38	24
stirrups=	2.575	2.575	6.198595787	6.791209	4.618834	2.575
			12 D-2			
x (ft) =	0	5.1	10.2	15.3	20.4	25.5
Vs.req =	-76.40169	-35.16548	25.80553514	31.6576	29.86993	19.21449
Vs.act =	11.22	37.1622	54.92820299	56.32408	44.92658	17.5885
s =	24	24	10.38	9.29	9.85	15.31
stirrups=	2.55	2.55	5.895953757	6.587729	6.213198	3.997387
			12 S			
x (ft) =	0	5	10	15	20	25
Vs.req =	100.8107	60.58047	24.01013143	16.04117	18.53241	11.67414
Vs.act =	105.6	67.25033	31.8226095	27.47139	25.72393	11
s =	2.5	5.48	13.84	20.71	17.93	24
stirrups=	24	10.94891	4.335260116	2.897151	3.346347	2.5
			14 D-1			
x (ft) =	0	5.7	11.4	17.1	22.8	28.5
Vs.req =	-86.58444	-24.6578	34.08978142	38.87615	29.24114	14.58926
Vs.act =	12.54	50.83008	77.99456182	67.11432	40.034	12.62416
s =	24	24	7.86	7.58	10.98	23.84
stirrups=	2.85	2.85	8.702290076	9.023747	6.229508	2.869128
			14 D-2			
x (ft) =	0	5.65	11.3	16.95	22.6	28.25
Vs.req =	-101.978	-30.09723	29.51296025	34.52898	25.22393	10.90561
Vs.act =	12.43	44.54195	66.01194833	56.48289	35.01289	12.43
s =	24	24	9.29	8.8	13.21	24
stirrups=	2.825	2.825	7.298170075	7.704545	5.132475	2.825
			16 D			
x (ft) =	0	6.2	12.4	18.6	24.8	31
Vs.req =	-182.6285	-40.9377	23.04086565	32.5078	27.65089	17.55551
Vs.act =	13.64	38.87978	57.97578412	59.28588	43.15028	16.60041
s =	24	24	12.97	10	12.33	19.72
stirrups=	3.1	3.1	5.736314572	7.44	6.034063	3.772819
			16 S			
x (ft) =	0	5.95	11.9	17.85	23.8	29.75
Vs.req =	110.1702	62.00157	18.88976265	26.43154	27.17759	18.2544
Vs.act =	116.3556	78.37653	43.93248839	51.95841	44.81361	18.48
s =	2.7	5.23	17.16	12.26	11.93	17
stirrups=	26.44444	13.65201	4.160839161	5.823817	5.984912	4.2

continued

Table 8.3.1.2c, page 2

			18 D			
x (ft) =	0	6.55	13.1	19.65	26.2	32.75
Vs.req =	-206.2489	-42.64566	23.16783208	33.298	28.44	18.26562
Vs.act =	14.41	41.28179	62.41547421	64.48427	47.25838	18.3178
s =	24	24	12.87	9.73	11.95	18.88
stirrups=	3.275	3.275	6.107226107	8.078109	6.577406	4.163136
			20 D			
x (ft) =	0	6.8	13.6	20.4	27.2	34
Vs.req =	-232.17	-48.42454	20.49529393	31.88492	27.50754	17.6374
Vs.act =	14.96	39.68727	60.13555675	64.55114	47.55516	18.41231
s =	24	24	14.52	10.14	12.32	19.5
stirrups=	3.4	3.4	5.619834711	8.047337	6.623377	4.184615
			20 S			
x (ft) =	0	6.45	12.9	19.35	25.8	32.25
Vs.req =	111.6822	59.34192	12.79086035	26.24665	27.72872	18.98753
Vs.act =	121.6286	78.20504	42.49922693	58.20914	50.37857	20.47865
s =	2.8	5.32	24	12.03	11.39	16.63
stirrups=	27.64286	14.54887	3.225	6.433915	6.795435	4.654239
			24 D-1			
x (ft) =	0	7.3	14.6	21.9	29.2	36.5
Vs.req =	-152.0459	-29.70879	37.61357303	43.87856	33.4204	17.43783
Vs.act =	16.06	70.81	113.15	99.3172	60.71381	19.79661
s =	24	24	7.04	6.6	9.42	19.47
stirrups=	3.65	3.65	12.44318182	13.27273	9.299363	4.49923
			24 D-2			
x (ft) =	0	7.25	14.5	21.75	29	36.25
Vs.req =	-145.0632	-30.26978	37.69367709	44.23142	34.05586	18.17861
Vs.act =	15.95	70.95	114.1653787	101.2313	62.91561	20.84967
s =	24	24	6.96	6.47	9.1	18.36
stirrups=	3.625	3.625	12.5	13.44668	9.56044	4.738562
			26 D-1			
FAILED IN FLEXURE						
			26 D-2			
x (ft) =	0	7.45	14.9	22.35	29.8	37.25
Vs.req =	-156.8493	-34.62792	36.33493467	43.52393	41.10313	25.24829
Vs.act =	16.39	71.02333	114.7801223	116.9087	91.66519	34.90328
s =	24	24	7.2	6.54	6.93	11.27
stirrups=	3.725	3.725	12.41666667	13.66972	12.90043	7.932564

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.2d: Girder Spacing = 8 feet

			10 D			
x (ft) =	0	4.25	8.5	12.75	17	21.25
Vs.req =	-107.0332	-66.71627	5.753502091	16.92322	15.04608	7.711707
Vs.act =	9.35	20.43148	22.66640662	21.40549	19.17057	9.35
s =	24	24	20.25	19.37	22.85	24
stirrups=	2.125	2.125	2.518518519	2.632938	2.231947	2.125
			12 D-1			
x (ft) =	0	4.8	9.6	14.4	19.2	24
Vs.req =	-69.09117	-34.84834	30.07867286	35.45294	26.45218	12.41019
Vs.act =	10.56	38.90899	58.7010891	51.10885	31.31676	10.56
s =	24	24	8.94	8.35	12.21	24
stirrups=	2.4	2.4	6.44295302	6.898204	4.717445	2.4
			12 D-2			
x (ft) =	0	4.8	9.6	14.4	19.2	24
Vs.req =	-66.62838	-34.24252	30.67121844	36.03244	33.75792	23.44671
Vs.act =	10.56	39.59093	60.08975136	60.15641	49.29201	20.19442
s =	24	24	8.73	8.16	8.71	12.55
stirrups=	2.4	2.4	6.597938144	7.058824	6.613088	4.589641
			12 S			
x (ft) =	0	4.65	9.3	13.95	18.6	23.25
Vs.req =	119.0166	76.59969	37.83084607	17.16483	20.06779	12.92839
Vs.act =	122.76	84.53498	40.64537171	27.50791	27.74819	12.92211
s =	2	4.34	8.78	19.36	16.56	19
stirrups=	27.9	12.85714	6.355353075	2.882231	3.369565	2.936842
			14 D-1			
x (ft) =	0	5.3	10.6	15.9	21.2	26.5
Vs.req =	-79.52036	-26.53856	37.26204312	42.11791	31.81983	16.20594
Vs.act =	11.66	50.52667	78.84380952	67.71153	40.77447	13.04007
s =	24	24	7.2	7	10.09	21.46
stirrups=	2.65	2.65	8.833333333	9.085714	6.303271	2.963653
			14 D-2			
x (ft) =	0	5.25	10.5	15.75	21	26.25
Vs.req =	-95.36006	-32.62978	32.16095039	37.26319	27.36796	12.15543
Vs.act =	11.55	44.08521	66.54748121	56.77089	34.30862	11.55
s =	24	24	8.52	8.15	12.18	24
stirrups=	2.625	2.625	7.394366197	7.730061	5.172414	2.625
			16 D			
x (ft) =	0	5.75	11.5	17.25	23	28.75
Vs.req =	-177.0127	-45.3678	24.51340945	34.75553	29.81767	18.98695
Vs.act =	12.65	37.53525	57.32114334	58.99758	43.21555	16.65387
s =	24	24	12.2	9.36	11.43	18.23
stirrups=	2.875	2.875	5.655737705	7.371795	6.036745	3.78497
			16 S			
x (ft) =	0	5.55	11.1	16.65	22.2	27.75
Vs.req =	130.168	79.65812	34.21897445	29.08765	29.99407	20.27913
Vs.act =	146.52	102.944	57.24924025	53.41344	48.03966	20.93143
s =	2	4.07	9.47	11.14	10.81	14
stirrups=	33.3	16.36364	7.032734952	5.978456	6.160962	4.757143

continued

Table 8.3.1.2d, page 2

			18 D			
x (ft) =	0	6.2	12.4	18.6	24.8	31
Vs.req =	-196.9965	-40.7112	29.04878012	39.11324	33.40445	21.89226
Vs.act =	13.64	45.54643	71.39497316	71.67733	52.96036	20.77157
s =	24	24	10.26	8.29	10.17	15.76
stirrups=	3.1	3.1	7.251461988	8.974668	7.315634	4.720812
			20 D			
x (ft) =	0	6.45	12.9	19.35	25.8	32.25
Vs.req =	-223.274	-46.23435	26.64864942	37.98363	32.71949	21.47955
Vs.act =	14.19	44.67881	70.50761072	72.92315	54.17605	21.27171
s =	24	24	11.17	8.51	10.35	16.01
stirrups=	3.225	3.225	6.929274843	9.095182	7.478261	4.834478
			20 S			
x (ft) =	0	6.1	12.2	18.3	24.4	30.5
Vs.req =	133.5788	77.991	28.3706955	31.32486	32.44601	22.48776
Vs.act =	136.4746	108.4639	60.89038634	65.05413	56.04192	22.94017
s =	2.36	4.05	11.13	10.08	9.73	14.04
stirrups=	31.01695	18.07407	6.576819407	7.261905	7.523124	5.213675
			24 D-1			
x (ft) =	0	6.9	13.8	20.7	27.6	34.5
Vs.req =	-143.7955	-27.47212	43.84168766	50.25452	38.60131	20.94964
Vs.act =	15.18	75.49788	123.4582621	107.8422	67.17686	22.47502
s =	24	24	6.04	5.77	8.15	16.21
stirrups=	3.45	3.45	13.70860927	14.35009	10.15951	5.107958
			24 D-2			
x (ft) =	0	6.85	13.7	20.55	27.4	34.25
Vs.req =	-136.6943	-28.1959	43.89707996	50.56572	39.21723	21.68588
Vs.act =	15.07	75.55161	124.3826654	109.6833	69.28325	23.50097
s =	24	24	5.98	5.66	7.9	15.39
stirrups=	3.425	3.425	13.7458194	14.52297	10.40506	5.341131
			26 D-1			
FAILED IN FLEXURE						
			26 D-2			
FAILED IN FLEXURE						

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.2e: Girder Spacing = 9 feet

			10 D			
x (ft) =	0	4	8	12	16	20
Vs.req =	-96.47954	-69.05961	7.823988217	19.27349	16.82968	8.733358
Vs.act =	8.8	17.6	21.21622575	22.75396	19.13774	8.8
s =	24	24	24	17.01	20.43	24
stirrups=	2	2	2	2.821869	2.349486	2
			12 D-1			
x (ft) =	0	4.5	9	13.5	18	22.5
Vs.req =	-60.97329	-36.23856	33.09770351	38.33675	28.67748	13.63704
Vs.act =	9.9	39.12509	60.00229432	51.87845	31.00124	9.9
s =	24	24	8.13	7.72	11.26	24
stirrups=	2.25	2.25	6.642066421	6.994819	4.795737	2.25
			12 D-2			
x (ft) =	0	4.5	9	13.5	18	22.5
Vs.req =	-58.49378	-35.58834	33.73357313	38.96031	36.5299	25.51289
Vs.act =	9.9	39.82443	61.39463192	60.98573	50.12264	20.60711
s =	24	24	7.94	7.55	8.05	11.53
stirrups=	2.25	2.25	6.801007557	7.152318	6.708075	4.683435
			12 S			
x (ft) =	0	4.4	8.8	13.2	17.6	22
Vs.req =	136.8983	92.03285	50.83933308	20.59079	23.12526	15.07836
Vs.act =	145.2	99.93191	49.9803112	30.56999	31.65501	15.488
s =	1.6	3.61	6.53	16.13	14.37	15
stirrups=	33	14.62604	8.08575804	3.273404	3.674322	3.52
			14 D-1			
x (ft) =	0	4.95	9.9	14.85	19.8	24.75
Vs.req =	-72.62533	-28.63851	39.99657534	44.75982	33.86584	17.48496
Vs.act =	10.89	49.89896	78.72931997	67.28998	40.70989	13.14027
s =	24	24	6.7	6.58	9.48	19.89
stirrups=	2.475	2.475	8.865671642	9.027356	6.265823	2.986425
			14 D-2			
x (ft) =	0	4.95	9.9	14.85	19.8	24.75
Vs.req =	-86.67392	-32.19847	36.51252746	41.15156	30.3832	14.12396
Vs.act =	10.89	45.6916	70.21623202	59.23961	34.71498	10.89
s =	24	24	7.51	7.38	10.97	24
stirrups=	2.475	2.475	7.909454061	8.04878	5.414768	2.475
			16 D			
x (ft) =	0	5.4	10.8	16.2	21.6	27
Vs.req =	-169.2309	-47.28108	27.4097368	37.87537	32.58977	21.01796
Vs.act =	11.88	38.01382	59.325906	60.45021	44.5696	17.31148
s =	24	24	10.91	8.59	10.46	16.47
stirrups=	2.7	2.7	5.939505041	7.543655	6.195029	3.934426
			16 S			
x (ft) =	0	5.2	10.4	15.6	20.8	26
Vs.req =	148.7885	96.31375	48.84301931	31.2871	32.37762	22.23424
Vs.act =	156.8914	122.8212	67.85132809	53.9305	50.30857	22.88
s =	1.75	3.37	6.64	10.36	10.01	12
stirrups=	35.65714	18.51632	9.397590361	6.023166	6.233766	5.2

continued

Table 8.3.1.2e, page 2

			18 D			
x (ft) =	0	5.8	11.6	17.4	23.2	29
Vs.req =	-191.1934	-43.83816	31.2535026	41.87174	35.9393	23.59127
Vs.act =	12.76	44.86063	71.6665204	71.97224	53.353	20.94665
s =	24	24	9.54	7.74	9.45	14.62
stirrups=	2.9	2.9	7.295597484	8.992248	7.365079	4.760602
			20 D			
x (ft) =	0	6.1	12.2	18.3	24.4	30.5
Vs.req =	-215.7267	-45.97266	31.24815145	42.71192	36.81355	24.41479
Vs.act =	13.42	47.25193	76.37882841	77.55559	57.86746	22.85877
s =	24	24	9.52	7.57	9.2	14.09
stirrups=	3.05	3.05	7.68907563	9.669749	7.956522	5.195174
			20 S			
x (ft) =	0	5.75	11.5	17.25	23	28.75
Vs.req =	153.5213	95.62126	43.68203808	34.87774	35.93962	24.99386
Vs.act =	159.7895	133.9917	75.53866257	68.08621	59.83925	25.3
s =	1.9	3.3	7.23	9.05	8.79	12
stirrups=	36.31579	20.90909	9.543568465	7.624309	7.849829	5.75
			24 D-1			
FAILED IN FLEXURE						
			24 D-2			
x (ft) =	0	6.45	12.9	19.35	25.8	32.25
Vs.req =	-130.3364	-28.39992	48.56586828	55.35802	43.10827	24.15496
Vs.act =	14.19	77.25667	128.9390071	113.2381	72.02618	24.66039
s =	24	24	5.4	5.17	7.19	13.81
stirrups=	3.225	3.225	14.33333333	14.97099	10.76495	5.604634
			26 D-1			
FAILED IN FLEXURE						
			26 D-2			
FAILED IN FLEXURE						

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

SHEAR CAPACITY TABLES FOR G 48-I GIRDER

Table 8.3.1.3a: Girder Spacing = 5 feet

			12 D			
x (ft) =	0	6.45	12.9	19.35	25.8	32.25
Vs.req =	-183.2261	-54.78632	4.007735494	13.93497	11.20166	-6.746385
Vs.act =	14.19	28.38	28.38	28.38	28.38	14.19
s =	24	24	24	24	24	24
stirrups=	3.225	3.225	3.225	3.225	3.225	3.225
			14 D			
x (ft) =	0	7.1	14.2	21.3	28.4	35.5
Vs.req =	-206.7658	-47.92252	9.545944326	18.54644	14.81018	-5.626662
Vs.act =	15.62	31.24	34.0960966	34.0961	31.24	15.62
s =	24	24	24	20.29	24	24
stirrups=	3.55	3.55	3.55	4.199113	3.55	3.55
			14 S			
x (ft) =	0	6.85	13.7	20.55	27.4	34.25
Vs.req =	48.69615	7.449948	-11.80301026	12.77929	14.31673	-3.635675
Vs.act =	51.66857	30.14	30.14	30.14	30.14	15.07
s =	7	24	24	24	24	24
stirrups=	11.74286	3.425	3.425	3.425	3.425	3.425
			16 D			
x (ft) =	0	7.6	15.2	22.8	30.4	38
Vs.req =	-231.0184	-46.08145	12.16080433	20.66282	16.52522	-4.792786
Vs.act =	16.72	33.44	38.82909091	38.9272	33.53811	16.72
s =	24	24	24	18.15	23.86	24
stirrups=	3.8	3.8	3.8	5.024793	3.822297	3.8
			16 S			
x (ft) =	0	7.2	14.4	21.6	28.8	36
Vs.req =	49.59386	6.166577	-11.28738917	13.9111	15.46707	-2.321948
Vs.act =	50.688	31.68	31.68	31.68	31.68	15.84
s =	7.5	24	24	24	24	24
stirrups=	11.52	3.6	3.6	3.6	3.6	3.6
			18 D			
x (ft) =	0	7.95	15.9	23.85	31.8	39.75
Vs.req =	-257.8614	-49.15535	11.31521355	20.25095	16.29812	-4.260251
Vs.act =	17.49	34.98	40.22889491	40.22889	34.98	17.49
s =	24	24	24	18.46	24	24
stirrups=	3.975	3.975	3.975	5.167931	3.975	3.975
			20 D			
x (ft) =	0	8.3	16.6	24.9	33.2	41.5
Vs.req =	-290.5935	-53.7364	8.888820378	18.4401	14.86868	-4.461097
Vs.act =	18.26	36.52	39.61672515	39.61673	36.52	18.26
s =	24	24	24	20.52	24	24
stirrups=	4.15	4.15	4.15	4.853801	4.15	4.15
			20 S			
x (ft) =	0	7.9	15.8	23.7	31.6	39.5
Vs.req =	51.32484	2.580799	-13.70021413	13.57641	15.76595	-1.263207
Vs.act =	57.93333	34.76	34.76	35.13734	35.13734	17.38
s =	7.2	24	24	24	23.49	24
stirrups=	13.16667	3.95	3.95	3.95	4.03576	3.95

continued

Table 8.3.1.3a: page 2

			22 D			
x (ft) =	0	8.6	17.2	25.8	34.4	43
Vs.req =	-307.0976	-54.88557	9.882126662	19.65382	16.02104	-3.267288
Vs.act =	18.92	37.84	42.97084746	42.97085	37.84	18.92
s =	24	24	24	18.88	24	24
stirrups=	4.3	4.3	4.3	5.466102	4.3	4.3
			24 D			
x (ft) =	0	8.95	17.9	26.85	35.8	44.75
Vs.req =	-328.0353	-55.91499	10.38750887	20.26806	16.5784	-2.764392
Vs.act =	19.69	39.38	45.61210642	46.11698	39.88487	19.69
s =	24	24	24	18.23	23.4	24
stirrups=	4.475	4.475	4.475	5.891388	4.589744	4.475
			24 S			
x (ft) =	0	8.65	17.3	25.95	34.6	43.25
Vs.req =	54.26711	-1.10761	-16.49573897	12.95179	15.77851	-1.016652
Vs.act =	66.1913	38.06	38.06	38.24414	38.24414	19.03
s =	6.9	24	24	24	23.77	24
stirrups=	15.04348	4.325	4.325	4.325	4.366849	4.325
			26 D			
x (ft) =	0	9.2	18.4	27.6	36.8	46
Vs.req =	-351.403	-60.09131	8.705518191	19.2774	15.9074	-2.39789
Vs.act =	20.24	40.48	45.68578313	45.68578	40.48	20.24
s =	24	24	24	19.09	24	24
stirrups=	4.6	4.6	4.6	5.783133	4.6	4.6
			28 D			
x (ft) =	0	9.5	19	28.5	38	47.5
Vs.req =	-372.0428	-62.13361	8.403023839	19.30495	16.00387	-2.032419
Vs.act =	20.9	41.8	47.3	47.3	41.8	20.9
s =	24	24	24	19	24	24
stirrups=	4.75	4.75	4.75	6	4.75	4.75
			30 D			
x (ft) =	0	9.6	19.2	28.8	38.4	48
Vs.req =	-379.1074	-66.43017	7.329841557	19.38599	16.37872	-0.728028
Vs.act =	21.12	42.24	48.65286257	49.7547	43.34183	21.12
s =	24	24	24	18.41	22.81	24
stirrups=	4.8	4.8	4.8	6.257469	5.050416	4.8

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.3b: Girder Spacing = 6 feet

			12 D			
x (ft) =	0	5.95	11.9	17.85	23.8	29.75
Vs.req =	-174.2281	-59.25076	5.915146627	16.81072	13.9715	-0.879874
Vs.act =	13.09	26.18	27.10874163	27.10874	26.18	13.09
s =	24	24	24	22.41	24	24
stirrups=	2.975	2.975	2.975	3.186078	2.975	2.975
			14 D			
x (ft) =	0	6.55	13.1	19.65	26.2	32.75
Vs.req =	-199.2059	-52.06361	11.67095678	21.85642	17.96114	0.613738
Vs.act =	14.41	28.82	34.49362369	35.77509	30.10147	14.41
s =	24	24	24	17.22	22.04	24
stirrups=	3.275	3.275	3.275	4.56446	3.566243	3.275
			14 S			
x (ft) =	0	6.3	12.6	18.9	25.2	31.5
Vs.req =	70.26196	26.30208	-12.37418145	14.98759	17.01748	2.425516
Vs.act =	73.92	36.89601	27.72	28.76991	28.76991	13.86
s =	4.5	14.44	24	24	22.31	24
stirrups=	16.8	5.235457	3.15	3.15	3.388615	3.15
			16 D			
x (ft) =	0	7.1	14.2	21.3	28.4	35.5
Vs.req =	-222.2325	-46.60596	16.50423715	26.01081	21.27607	1.842676
Vs.act =	15.62	33.6778	44.07307064	46.24624	35.85098	15.62
s =	24	24	20.76	14.41	18.53	24
stirrups=	3.55	3.55	4.104046243	5.912561	4.597949	3.55
			16 S			
x (ft) =	0	6.8	13.6	20.4	27.2	34
Vs.req =	73.5642	25.88466	-6.538252434	20.24653	21.27163	4.285125
Vs.act =	75.58737	39.92801	34.49427639	40.05085	35.47657	14.96
s =	4.75	14.38	24	18.38	17.5	24
stirrups=	17.17895	5.674548	3.4	4.439608	4.662857	3.4
			18 D			
x (ft) =	0	7.45	14.9	22.35	29.8	37.25
Vs.req =	-249.5437	-49.18838	16.16210255	25.98733	21.3706	2.546234
Vs.act =	16.39	34.98858	45.93423132	48.71391	37.76826	16.39
s =	24	24	21.15	14.39	18.4	24
stirrups=	3.725	3.725	4.226950355	6.212648	4.858696	3.725
			20 D			
x (ft) =	0	7.8	15.6	23.4	31.2	39
Vs.req =	-282.5716	-53.44438	14.06353656	24.4217	20.14228	2.495203
Vs.act =	17.16	34.32	43.74747579	47.41904	37.99156	17.16
s =	24	24	24	15.49	19.77	24
stirrups=	3.9	3.9	3.9	6.042608	4.734446	3.9
			20 S			
x (ft) =	0	7.4	14.8	22.2	29.6	37
Vs.req =	76.19011	23.3693	-11.48212164	18.53348	20.64074	5.520229
Vs.act =	80.56082	40.9311	35.82577289	41.32504	38.05926	16.28
s =	4.85	15.85	24	19.99	17.94	24
stirrups=	18.30928	5.602524	3.7	4.442221	4.949833	3.7

continued

Table 8.3.1.3b, page 2

			22 D			
x (ft) =	0	8.1	16.2	24.3	32.4	40.5
Vs.req =	-299.6257	-54.074	15.59844473	26.07058	21.65447	3.803023
Vs.act =	17.82	37.45636	49.69117741	53.81481	41.58	17.82
s =	24	24	21.78	14.23	18	24
stirrups=	4.05	4.05	4.462809917	6.830639	5.4	4.05
			24 D			
x (ft) =	0	8.35	16.7	25.05	33.4	41.75
Vs.req =	-324.5003	-58.55368	13.90075265	25.08617	21.01075	4.311379
Vs.act =	18.37	36.74	48.32108696	53.82115	42.24006	18.37
s =	24	24	24	14.72	18.47	24
stirrups=	4.175	4.175	4.175	6.807065	5.425014	4.175
			24 S			
x (ft) =	0	8.15	16.3	24.45	32.6	40.75
Vs.req =	81.52087	21.22342	-13.18407261	18.77304	21.37474	6.071502
Vs.act =	93.54783	42.28314	39.46753754	46.0572	42.44966	17.93
s =	4.6	17.67	24	19.98	17.55	24
stirrups=	21.26087	5.534805	4.075	4.894895	5.57265	4.075
			26 D			
x (ft) =	0	8.65	17.3	25.95	34.6	43.25
Vs.req =	-346.518	-60.57489	13.7993811	25.27794	21.25593	4.815486
Vs.act =	19.03	38.06	50.39813187	56.49024	44.15211	19.03
s =	24	24	24	14.56	18.18	24
stirrups=	4.325	4.325	4.325	7.129121	5.709571	4.325
			28 D			
x (ft) =	0	8.9	17.8	26.7	35.6	44.5
Vs.req =	-369.4191	-64.22438	12.53454689	24.61544	20.84115	5.221051
Vs.act =	19.58	39.16	51.11825503	56.98059	45.02234	19.58
s =	24	24	24	14.9	18.47	24
stirrups=	4.45	4.45	4.45	7.167785	5.78235	4.45
			30 D			
x (ft) =	0	9	18	27	36	45
Vs.req =	-377.2065	-68.73165	11.49486467	24.77271	21.29538	6.554367
Vs.act =	19.8	39.6	52.8	60.09236	46.89236	19.8
s =	24	24	24	14.4	17.54	24
stirrups=	4.5	4.5	4.5	7.5	6.157355	4.5

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

Table 8.3.1.3c: Girder Spacing = 7 feet

			12 D			
x (ft) =	0	5.5	11	16.5	22	27.5
Vs.req =	-165.4097	-65.22279	6.562474482	18.43889	15.71175	4.593282
Vs.act =	12.1	24.2	26.3143906	26.31439	24.2	12.1
s =	24	24	24	20.43	24	24
stirrups=	2.75	2.75	2.75	3.230543	2.75	2.75
			14 D			
x (ft) =	0	6.05	12.1	18.15	24.2	30.25
Vs.req =	-191.9167	-58.01165	12.43207489	23.8026	19.98986	6.367136
Vs.act =	13.31	26.62	33.51493359	36.33827	29.44333	13.31
s =	24	24	24	15.81	19.8	24
stirrups=	3.025	3.025	3.025	4.59203	3.666667	3.025
			14 S			
x (ft) =	0	5.85	11.7	17.55	23.4	29.25
Vs.req =	91.0075	44.50587	2.509746608	17.12075	19.56562	8.10935
Vs.act =	96.525	49.08102	26.79605951	29.83951	28.78345	12.87
s =	3.2	8.53	24	22.18	19.41	24
stirrups=	21.9375	8.229777	2.925	3.165014	3.616692	2.925
			16 D			
x (ft) =	0	6.6	13.2	19.8	26.4	33
Vs.req =	-215.0711	-50.38003	18.71223984	29.32823	24.40121	8.0293
Vs.act =	14.52	33.55222	46.29982846	48.83196	36.08436	14.52
s =	24	24	18.31	12.78	16.16	24
stirrups=	3.3	3.3	4.325505188	6.197183	4.90099	3.3
			16 S			
x (ft) =	0	6.3	12.6	18.9	25.2	31.5
Vs.req =	94.7038	44.56652	-0.449232535	22.438	23.92014	10.2484
Vs.act =	95.04	53.69713	33.91063291	41.42852	35.23789	13.86
s =	3.5	8.35	24	16.59	15.56	24
stirrups=	21.6	9.053892	3.15	4.556962	4.858612	3.15
			18 D			
x (ft) =	0	7	14	21	28	35
Vs.req =	-241.1429	-49.8701	20.18099285	31.05058	25.86698	9.066732
Vs.act =	15.4	37.21818	52.51585624	55.01346	39.71579	15.4
s =	24	24	16.94	12.04	15.2	24
stirrups=	3.5	3.5	4.958677686	6.976744	5.526316	3.5
			20 D			
x (ft) =	0	7.35	14.7	22.05	29.4	36.75
Vs.req =	-274.3837	-53.65303	18.53521497	29.82192	24.91664	9.200653
Vs.act =	16.17	37.00092	51.41247816	54.86692	40.45536	16.17
s =	24	24	18.63	12.69	15.98	24
stirrups=	3.675	3.675	4.734299517	6.950355	5.519399	3.675
			20 S			
x (ft) =	0	7	14	21	28	35
Vs.req =	100.3152	43.55653	-6.909153635	24.09359	25.8826	12.11871
Vs.act =	100.4348	58.88235	39.4468445	49.87494	41.22809	15.4
s =	3.68	8.5	24	15.37	14.31	24
stirrups=	22.82609	9.882353	3.5	5.465192	5.870021	3.5

continued

Table 8.3.1.3c, page 2

			<u>22 D</u>			
x (ft) =	0	7.65	15.3	22.95	30.6	38.25
Vs.req =	-291.9826	-53.6517	20.7059669	31.97294	26.8431	10.64831
Vs.act =	16.83	41.44426	59.40495727	62.60888	44.64818	16.83
s =	24	24	16.41	11.61	14.52	24
stirrups=	3.825	3.825	5.594149909	7.906977	6.322314	3.825
			<u>24 D</u>			
x (ft) =	0	7.9	15.8	23.7	31.6	39.5
Vs.req =	-317.3236	-57.94198	19.26435712	31.19867	26.37734	11.26182
Vs.act =	17.38	41.12047	58.97019643	63.58595	45.73622	17.38
s =	24	24	17.57	11.84	14.71	24
stirrups=	3.95	3.95	5.395560615	8.006757	6.444596	3.95
			<u>24 S</u>			
x (ft) =	0	7.65	15.3	22.95	30.6	38.25
Vs.req =	106.74	42.7897	-12.25651469	22.87109	25.62415	12.85503
Vs.act =	115.4057	62.88701	41.45926829	52.21943	44.42016	16.83
s =	3.5	8.77	24	16.4	14.64	24
stirrups=	26.22857	10.4675	3.825	5.597561	6.270492	3.825
			<u>26 D</u>			
x (ft) =	0	8.15	16.3	24.45	32.6	40.75
Vs.req =	-341.6643	-61.78243	18.05132183	30.59247	26.02887	11.80925
Vs.act =	17.93	40.95408	58.79465061	64.76788	46.9273	17.93
s =	24	24	18.69	12.03	14.84	24
stirrups=	4.075	4.075	5.232744783	8.129676	6.590296	4.075
			<u>28 D</u>			
x (ft) =	0	8.4	16.8	25.2	33.6	42
Vs.req =	-364.9778	-65.18627	17.07275945	30.15952	25.80467	12.30661
Vs.act =	18.48	40.98228	58.97596732	66.20023	48.20654	18.48
s =	24	24	19.71	12.16	14.92	24
stirrups=	4.2	4.2	5.114155251	8.289474	6.756032	4.2
			<u>30 D</u>			
x (ft) =	0	8.45	16.9	25.35	33.8	42.25
Vs.req =	-375.705	-72.17302	14.52342887	29.25685	25.46839	13.61001
Vs.act =	18.59	38.29671	56.27720558	66.98358	49.00309	18.59
s =	24	24	22.64	12.2	14.67	24
stirrups=	4.225	4.225	4.478798587	8.311475	6.912065	4.225

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

Table 8.3.1.3d: Girder Spacing = 8 feet

			12 D			
x (ft) =	0	5.15	10.3	15.45	20.6	25.75
Vs.req =	-154.9721	-69.11594	8.359966634	20.71338	17.88156	8.970776
Vs.act =	11.33	22.66	26.27887301	27.21963	23.60076	11.33
s =	24	24	24	18.19	22.16	24
stirrups=	2.575	2.575	2.575	3.397471	2.788809	2.575
			14 D			
x (ft) =	0	5.65	11.3	16.95	22.6	28.25
Vs.req =	-182.993	-62.49672	13.94964258	26.09122	22.21483	11.79708
Vs.act =	12.43	24.86	33.11793343	37.42867	29.17074	12.43
s =	24	24	24	14.42	17.82	24
stirrups=	2.825	2.825	2.825	4.701803	3.804714	2.825
			14 S			
x (ft) =	0	5.45	10.9	16.35	21.8	27.25
Vs.req =	110.6548	61.94814	17.74868763	18.35657	21.36405	12.87957
Vs.act =	110.6769	60.39592	27.36790904	30.10848	28.18358	11.99
s =	2.6	6.13	21.39	20.68	17.77	24
stirrups=	25.15385	10.66884	3.057503506	3.162476	3.68036	2.725
			16 D			
x (ft) =	0	6.15	12.3	18.45	24.6	30.75
Vs.req =	-207.8567	-55.33535	20.01938662	31.65707	26.69952	13.80186
Vs.act =	13.53	32.49729	46.3929654	49.41078	35.80298	13.81787
s =	24	24	17.12	11.84	14.77	23.5
stirrups=	3.075	3.075	4.310747664	6.233108	4.996615	3.140426
			16 S			
x (ft) =	0	5.9	11.8	17.7	23.6	29.5
Vs.req =	115.3438	62.69404	15.22171372	25.06918	26.81073	15.92486
Vs.act =	115.3778	65.42444	33.95777778	43.42158	38.41919	15.97538
s =	2.7	5.94	24	14.85	13.88	19.5
stirrups=	26.22222	11.91919	2.95	4.767677	5.100865	3.630769
			18 D			
x (ft) =	0	6.65	13.3	19.95	26.6	33.25
Vs.req =	-230.5546	-48.17737	26.06567766	37.02734	31.01283	15.43971
Vs.act =	14.63	41.3922	61.52655156	62.45521	43.29619	15.60533
s =	24	24	13.12	10.1	12.68	22.5
stirrups=	3.325	3.325	6.082317073	7.90099	6.293375	3.546667
			20 D			
x (ft) =	0	7	14	21	28	35
Vs.req =	-263.8577	-51.38603	24.42216173	36.20384	30.39835	15.77915
Vs.act =	15.4	41.53861	61.50703491	63.58216	43.61374	15.4
s =	24	24	14.14	10.45	13.1	24
stirrups=	3.5	3.5	5.940594059	8.038278	6.412214	3.5
			20 S			
x (ft) =	0	6.65	13.3	19.95	26.6	33.25
Vs.req =	123.5083	63.14414	9.326171462	29.53098	30.96535	18.4917
Vs.act =	125.4	74.44601	42.63	57.35786	47.83786	18.48
s =	2.8	5.87	24	12.54	11.96	19
stirrups=	28.5	13.59455	3.325	6.363636	6.672241	4.2

continued

Table 8.3.1.3d, page 2

			22 D			
x (ft) =	0	7.25	14.5	21.75	29	36.25
Vs.req =	-283.8701	-53.3025	25.44709618	37.54916	31.73247	17.27192
Vs.req =	-283.8701	-53.3025	25.44709618	37.54916	31.73247	17.27192
s =	24	24	13.35	9.88	12.29	22
stirrups=	3.625	3.625	6.516853933	8.805668	7.078926	3.954545
			24 D			
x (ft) =	0	7.45	14.9	22.35	29.8	37.25
Vs.req =	-311.7282	-59.92436	22.51837674	35.70533	30.46227	17.90808
Vs.act =	16.39	42.56166	64.17745379	68.88178	48.74786	17.87188
s =	24	24	15.03	10.35	12.74	22.01
stirrups=	3.725	3.725	5.948103792	8.637681	7.017268	4.06179
			24 S			
x (ft) =	0	7.25	14.5	21.75	29	36.25
Vs.req =	131.3009	63.6867	3.95179123	27.73879	30.37211	19.47864
Vs.act =	133.8462	80.94151	44.26360947	59.30956	50.87134	19.87539
s =	2.86	5.89	24	13.52	12.35	19.26
stirrups=	30.41958	14.7708	3.625	6.434911	7.044534	4.517134
			26 D			
x (ft) =	0	7.7	15.4	23.1	30.8	38.5
Vs.req =	-336.51	-63.44938	21.66036882	35.3792	30.34777	18.57736
Vs.act =	16.94	43.03499	65.18730127	71.02946	51.17805	19.24089
s =	24	24	15.58	10.4	12.73	21.13
stirrups=	3.85	3.85	5.930680359	8.884615	7.258445	4.372929
			28 D			
x (ft) =	0	7.95	15.9	23.85	31.8	39.75
Vs.req =	-360.2052	-66.51585	21.04307768	35.23031	30.35911	18.93061
Vs.act =	17.49	43.74141	66.5741737	73.42687	53.42162	20.31752
s =	24	24	15.99	10.41	12.68	20.66
stirrups=	3.975	3.975	5.966228893	9.164265	7.523659	4.617619
			30 D			
x (ft) =	0	8	16	24	32	40
Vs.req =	-371.8601	-73.90542	18.37268368	34.2885	30.01123	18.84189
Vs.act =	17.6	41.19777	64.17413424	74.50408	54.91132	20.98361
s =	24	24	17.9	10.41	12.45	20.13
stirrups=	4	4	5.363128492	9.221902	7.710843	4.769001

Notes:
1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.3e: Girder Spacing = 9 feet

			12 D			
x (ft) =	0	4.85	9.7	14.55	19.4	24.25
Vs.req =	-144.0892	-72.69682	10.15417931	22.75444	19.81519	10.4519
Vs.act =	10.67	21.34	26.14311178	28.27711	23.474	10.67
s =	24	24	24	16.55	20	24
stirrups=	2.425	2.425	2.425	3.516616	2.91	2.425
			14 D			
x (ft) =	0	5.35	10.7	16.05	21.4	26.75
Vs.req =	-171.8844	-63.83491	17.37699409	29.67936	25.38291	14.50161
Vs.act =	11.77	26.05109	36.55869454	40.39691	32.98668	14.86737
s =	24	24	19.78	12.68	15.59	19
stirrups=	2.675	2.675	3.24570273	5.063091	4.118024	3.378947
			14 S			
x (ft) =	0	5.15	10.3	15.45	20.6	25.75
Vs.req =	130.2525	78.99923	32.30764277	20.92839	24.0808	15.05147
Vs.act =	135.96	79.67435	38.13220484	32.23294	32.34953	15.10667
s =	2	4.81	11.75	18.14	15.77	18
stirrups=	30.9	12.84823	5.259574468	3.406836	3.918833	3.433333
			16 D			
x (ft) =	0	5.8	11.6	17.4	23.2	29
Vs.req =	-198.4665	-57.84087	22.78190172	34.9145	29.65585	17.7401
Vs.act =	12.76	33.1217	48.87566861	51.53953	41.03968	18.01412
s =	24	24	15.04	10.74	13.3	17
stirrups=	2.9	2.9	4.627659574	6.480447	5.233083	4.094118
			16 S			
x (ft) =	0	5.55	11.1	16.65	22.2	27.75
Vs.req =	135.1622	80.1889	30.40826144	27.28006	29.31423	18.93053
Vs.act =	139.5429	87.09635	45.42504744	44.55789	37.97941	14.90539
s =	2.1	4.64	12.24	13.64	12.7	19.66
stirrups=	31.71429	14.35345	5.441176471	4.882698	5.244094	3.387589
			18 D			
x (ft) =	0	6.25	12.5	18.75	25	31.25
Vs.req =	-223.0195	-51.71408	28.23516426	39.99567	33.78571	21.05629
Vs.act =	13.75	41.00021	62.54432409	63.64463	49.64084	21.29032
s =	24	24	12.11	9.35	11.64	15.5
stirrups=	3.125	3.125	6.193228737	8.02139	6.443299	4.83871
			20 D			
x (ft) =	0	6.6	13.2	19.8	26.4	33
Vs.req =	-256.413	-54.14282	27.16813004	39.70909	33.61348	20.97717
Vs.act =	14.52	41.93778	63.98441296	65.97423	47.46355	18.05596
s =	24	24	12.71	9.53	11.85	19.3
stirrups=	3.3	3.3	6.231313926	8.310598	6.683544	4.103627
			20 S			
x (ft) =	0	6.3	12.6	18.9	25.2	31.5
Vs.req =	145.2967	82.06191	25.48631574	33.50669	34.89541	23.54375
Vs.act =	151.2	96.64942	52.99649158	61.45472	55.11156	23.76
s =	2.2	4.51	14.53	11.05	10.61	14
stirrups=	34.36364	16.76275	5.203028217	6.841629	7.125353	5.4

continued

Table 8.3.1.3e, page 2

			22 D			
x (ft) =	0	6.85	13.7	20.55	27.4	34.25
Vs.req =	-277.1149	-55.50653	28.34270371	41.536	35.34847	22.47369
Vs.act =	15.07	45.23514	70.66681735	73.29225	55.39557	22.605
s =	24	24	11.99	8.93	11.03	16
stirrups=	3.425	3.425	6.855713094	9.204927	7.452403	5.1375
			24 D			
x (ft) =	0	7.1	14.2	21.3	28.4	35.5
Vs.req =	-303.3195	-59.13783	27.39747293	41.35721	35.38393	22.58936
Vs.act =	15.62	45.97466	72.3344991	76.18422	56.92438	22.72
s =	24	24	12.35	8.93	10.96	16.5
stirrups=	3.55	3.55	6.898785425	9.540873	7.773723	5.163636
			24 S			
x (ft) =	0	6.85	13.7	20.55	27.4	34.25
Vs.req =	154.2641	83.8936	21.4954713	30.96531	33.83788	23.02838
Vs.act =	154.5641	101.6394	50.59287382	62.50883	55.82721	23.18462
s =	2.34	4.47	17.45	12.11	11.08	15.6
stirrups=	35.12821	18.38926	4.710601719	6.787779	7.418773	5.269231
			26 D			
x (ft) =	0	7.3	14.6	21.9	29.2	36.5
Vs.req =	-330.7187	-65.18148	24.91401055	39.85891	34.38462	21.90162
Vs.act =	16.06	44.52677	70.2262451	76.05129	56.31696	22.02514
s =	24	24	13.54	9.23	11.24	17.5
stirrups=	3.65	3.65	6.46971935	9.490791	7.793594	5.005714
			28 D			
x (ft) =	0	7.5	15	22.5	30	37.5
Vs.req =	-357.1467	-70.72747	22.71037927	38.5625	33.52972	21.31416
Vs.act =	16.5	43.23869	68.37906862	76.13515	56.07515	21.58038
s =	24	24	14.81	9.51	11.48	18.35
stirrups=	3.75	3.75	6.076975017	9.463722	7.839721	4.904632
			30 D			
FAILED IN FLEXURE						

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

SHEAR CAPACITY TABLES FOR G 54-I GIRDER

Table 8.3.1.4a: Girder Spacing = 5 feet

			12 D			
x (ft) =	0	6.9	13.8	20.7	27.6	34.5
Vs.req =	-183.3695	-56.89857	3.809310026	14.41384	11.74389	-4.394993
Vs.act =	15.18	30.36	30.36	30.36	30.36	15.18
s =	24	24	24	24	24	24
stirrups=	3.45	3.45	3.45	3.45	3.45	3.45
			14 D			
x (ft) =	0	7.6	15.2	22.8	30.4	38
Vs.req =	-209.4072	-49.87496	9.715842305	18.85638	15.16897	-3.501068
Vs.act =	16.72	33.44	34.66633274	34.66633	33.44	16.72
s =	24	24	24	22.36	24	24
stirrups=	3.8	3.8	3.8	4.078712	3.8	3.8
			16 D			
x (ft) =	0	8.25	16.5	24.75	33	41.25
Vs.req =	-232.7444	-43.99533	14.94626264	22.85836	18.28701	-2.643767
Vs.act =	18.15	36.3	41.8367863	41.83679	36.3	18.15
s =	24	24	24	18.39	24	24
stirrups=	4.125	4.125	4.125	5.383361	4.125	4.125
			16 S			
x (ft) =	0	8	16	24	32	40
Vs.req =	58.79303	16.09852	-9.301561391	15.82848	17.11035	-1.123492
Vs.act =	60.34286	35.2	35.2	35.2	35.2	17.6
s =	7	24	24	24	24	24
stirrups=	13.71429	4	4	4	4	4
			18 D			
x (ft) =	0	8.65	17.3	25.95	34.6	43.25
Vs.req =	-260.757	-46.2615	14.56899276	22.7681	18.28201	-2.162489
Vs.act =	19.03	38.06	43.83825638	43.83826	38.06	19.03
s =	24	24	24	18.41	24	24
stirrups=	4.325	4.325	4.325	5.63824	4.325	4.325
			20 D			
x (ft) =	0	9	18	27	36	45
Vs.req =	-288.7973	-49.63992	13.38385503	22.08824	17.82148	-1.785616
Vs.act =	19.8	39.6	44.88975713	44.88976	39.6	19.8
s =	24	24	24	18.94	24	24
stirrups=	4.5	4.5	4.5	5.702218	4.5	4.5
			20 S			
x (ft) =	0	8.65	17.3	25.95	34.6	43.25
Vs.req =	59.85792	13.44136	-11.77421397	15.3952	17.31812	0.453494
Vs.act =	65.24571	38.06	38.06	38.06	38.06	19.03
s =	7	24	24	24	24	24
stirrups=	14.82857	4.325	4.325	4.325	4.325	4.325
			22 D			
x (ft) =	0	9.4	18.8	28.2	37.6	47
Vs.req =	-312.3841	-50.37158	14.00734022	22.81181	18.44761	-1.274893
Vs.act =	20.68	41.36	47.86072289	48.01699	41.51627	20.68
s =	24	24	24	18.26	23.82	24
stirrups=	4.7	4.7	4.7	6.177437	4.735516	4.7

continued

Table 8.3.1.4a: page 2

			24 D			
x (ft) =	0	9.7	19.4	29.1	38.8	48.5
Vs.req =	-337.8371	-53.99074	12.65766374	22.06747	17.95275	-0.896113
Vs.act =	21.34	42.68	48.59705162	48.59705	42.68	21.34
s =	24	24	24	18.79	24	24
stirrups=	4.85	4.85	4.85	6.194784	4.85	4.85
			24 S			
x (ft) =	0	9.4	18.8	28.2	37.6	47
Vs.req =	61.6072	10.04727	-13.94689614	15.13727	17.57198	1.013993
Vs.act =	72.98824	41.36	41.36	41.36862	41.36862	20.68
s =	6.8	24	24	24	23.99	24
stirrups=	16.58824	4.7	4.7	4.7	4.701959	4.7
			26 D			
x (ft) =	0	10.05	20.1	30.15	40.2	50.25
Vs.req =	-360.6216	-55.56579	12.6361547	22.28864	18.18219	-0.532649
Vs.act =	22.11	44.22	50.73135922	50.75903	44.24767	22.11
s =	24	24	24	18.54	23.97	24
stirrups=	5.025	5.025	5.025	6.504854	5.031289	5.025
			28 D			
x (ft) =	0	10.3	20.6	30.9	41.2	51.5
Vs.req =	-385.7812	-60.0571	10.64614336	21.04744	17.30063	-0.263452
Vs.act =	22.66	45.32	50.4352809	50.43528	45.32	22.66
s =	24	24	24	19.58	24	24
stirrups=	5.15	5.15	5.15	6.312564	5.15	5.15
			30 D-1			
x (ft) =	0	10.6	21.2	31.8	42.4	53
Vs.req =	-251.6312	-33.46798	30.38624968	34.5355	24.12189	0.108851
Vs.act =	23.32	74.951	104.4309963	86.31377	56.83377	23.32
s =	24	24	10.84	10.6	16.7	24
stirrups=	5.3	5.3	11.73431734	12	7.616766	5.3
			30 D-2			
x (ft) =	0	10.6	21.2	31.8	42.4	53
Vs.req =	-250.138	-33.23736	30.6016935	34.73695	24.33856	0.214722
Vs.act =	23.32	75.38326	105.2647767	87.10098	57.21945	23.32
s =	24	24	10.75	10.52	16.51	24
stirrups=	5.3	5.3	11.83255814	12.09125	7.704422	5.3

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.4b: Girder Spacing = 6 feet

			12 D			
x (ft) =	0	6.35	12.7	19.05	25.4	31.75
Vs.req =	-173.9418	-62.09817	5.271866749	17.06319	14.37419	1.703594
Vs.act =	13.97	27.94	27.94	27.94	27.94	13.97
s =	24	24	24	24	24	24
stirrups=	3.175	3.175	3.175	3.175	3.175	3.175
			14 D			
x (ft) =	0	7	14	21	28	35
Vs.req =	-201.3444	-54.5771	11.0437251	21.9894	18.21475	2.956546
Vs.act =	15.4	30.8	34.6801252	34.68013	30.8	15.4
s =	24	24	24	19.17	24	24
stirrups=	3.5	3.5	3.5	4.381847	3.5	3.5
			16 D			
x (ft) =	0	7.6	15.2	22.8	30.4	38
Vs.req =	-226.2877	-48.4918	16.69731295	26.29793	21.61124	4.077368
Vs.act =	16.72	34.29687	42.68826177	44.65742	36.26603	16.72
s =	24	24	22.83	15.98	20.53	24
stirrups=	3.8	3.8	3.994743758	5.707134	4.44228	3.8
			16 S			
x (ft) =	0	7.4	14.8	22.2	29.6	37
Vs.req =	81.28768	35.61945	-5.725573649	19.18136	20.76893	5.550965
Vs.act =	81.4	48.51762	33.63761884	36.15127	35.07365	16.28
s =	4.8	12.12	24	22.51	20.79	24
stirrups=	18.5	7.326733	3.7	3.944913	4.271284	3.7
			18 D			
x (ft) =	0	8.1	16.2	24.3	32.4	40.5
Vs.req =	-251.9647	-46.15841	19.62398781	28.64122	23.48875	4.863902
Vs.act =	17.82	39.88811	51.28122621	51.91375	40.52064	17.82
s =	24	24	19.38	14.64	18.84	24
stirrups=	4.05	4.05	5.015479876	6.639344	5.159236	4.05
			20 D			
x (ft) =	0	8.45	16.9	25.35	33.8	42.25
Vs.req =	-280.5147	-49.15595	18.8228607	28.25976	23.27248	5.363841
Vs.act =	18.59	40.69902	52.23460965	53.63244	42.09685	18.59
s =	24	24	20.18	14.81	18.98	24
stirrups=	4.225	4.225	5.024777007	6.846725	5.342466	4.225
			20 S			
x (ft) =	0	8.15	16.3	24.45	32.6	40.75
Vs.req =	84.82785	34.22447	-7.80674711	21.53108	23.10027	7.541648
Vs.act =	89.65	52.88695	39.93	45.60505	41.53505	17.93
s =	4.8	12.31	24	19.56	18.23	24
stirrups=	20.375	7.94476	4.075	5	5.364783	4.075
			22 D			
x (ft) =	0	8.8	17.6	26.4	35.2	44
Vs.req =	-306.1162	-51.0923	18.77190716	28.50615	23.55599	5.948677
Vs.act =	19.36	42.41906	54.86193182	56.71655	44.27367	19.36
s =	24	24	20.15	14.61	18.65	24
stirrups=	4.4	4.4	5.240694789	7.227926	5.662198	4.4

continued

Table 8.3.1.4b, page 2

			24 D			
x (ft) =	0	9.1	18.2	27.3	36.4	45.5
Vs.req =	-332.1462	-54.47405	17.69521863	27.98016	23.24011	6.414269
Vs.act =	20.02	42.57775	54.97879911	57.95134	45.55029	20.02
s =	24	24	21.3	14.82	18.82	24
stirrups=	4.55	4.55	5.126760563	7.368421	5.802338	4.55
			24 S			
x (ft) =	0	8.8	17.6	26.4	35.2	44
Vs.req =	87.41817	31.78818	-11.94435926	20.04514	22.52293	8.237563
Vs.act =	96.8	69.9193	41.45415121	46.92793	44.19378	19.36
s =	4.8	9.19	24	21.03	18.71	24
stirrups=	22	11.49075	4.4	5.021398	5.644041	4.4
			26 D			
x (ft) =	0	9.4	18.8	28.2	37.6	47
Vs.req =	-357.1032	-57.42422	16.86885109	27.6244	23.04605	6.827471
Vs.act =	20.68	42.95648	55.45295174	59.4229	46.92643	20.68
s =	24	24	22.28	14.96	18.91	24
stirrups=	4.7	4.7	5.062836625	7.540107	5.965098	4.7
			28 D			
x (ft) =	0	9.7	19.4	29.1	38.8	48.5
Vs.req =	-381.0422	-59.98025	16.26950351	27.42472	22.96428	7.197152
Vs.act =	21.34	43.55952	56.29537108	61.14562	48.40977	21.34
s =	24	24	23.05	15.03	18.92	24
stirrups=	4.85	4.85	5.04989154	7.744511	6.15222	4.85
			30 D-1			
x (ft) =	0	9.95	19.9	29.85	39.8	49.75
Vs.req =	-246.3256	-32.23766	37.11727368	41.54203	29.9284	7.599315
Vs.act =	21.89	81.11886	118.8610974	98.66344	60.9212	21.89
s =	24	24	8.87	8.81	13.46	24
stirrups=	4.975	4.975	13.46110485	13.55278	8.870728	4.975
			30 D-2			
x (ft) =	0	9.95	19.9	29.85	39.8	49.75
Vs.req =	-244.7768	-31.98552	37.35433967	41.76411	30.16524	7.705187
Vs.act =	21.89	81.52224	119.673379	99.48258	61.33144	21.89
s =	24	24	8.81	8.75	13.32	24
stirrups=	4.975	4.975	13.55278093	13.64571	8.963964	4.975

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.4c: Girder Spacing = 7 feet

			12 D			
x (ft) =	0	5.85	11.7	17.55	23.4	29.25
Vs.req =	-164.7653	-69.24234	5.213633493	18.28082	15.83747	7.27112
Vs.act =	12.87	25.74	26.28789748	26.2879	25.74	12.87
s =	24	24	24	23.02	24	24
stirrups=	2.925	2.925	2.925	3.049522	2.925	2.925
			14 D			
x (ft) =	0	6.5	13	19.5	26	32.5
Vs.req =	-192.1546	-58.9515	12.89806967	24.89264	21.01202	9.071889
Vs.act =	14.3	28.6	34.55974026	36.45606	30.49632	14.3
s =	24	24	24	16.94	21.19	24
stirrups=	3.25	3.25	3.25	4.604486	3.680982	3.25
			16 D			
x (ft) =	0	7.05	14.1	21.15	28.2	35.25
Vs.req =	-218.7351	-53.03664	17.9733157	29.33646	24.5537	10.47642
Vs.act =	15.51	33.06021	43.52648572	46.57616	36.10989	15.51
s =	24	24	21.21	14.33	18.07	24
stirrups=	3.525	3.525	3.988684583	5.903699	4.681793	3.525
			16 S			
x (ft) =	0	6.9	13.8	20.7	27.6	34.5
Vs.req =	102.994	54.58237	10.59898703	22.44347	24.27167	11.93439
Vs.act =	104.0914	61.23815	34.11555094	39.41447	35.65892	15.18
s =	3.5	7.91	24	19.24	17.79	24
stirrups=	23.65714	10.46776	3.45	4.303534	4.6543	3.45
			18 D			
x (ft) =	0	7.6	15.2	22.8	30.4	38
Vs.req =	-243.159	-46.9894	23.69765775	33.73199	28.0397	11.6242
Vs.act =	16.72	41.72187	57.285055	57.71284	42.14966	16.72
s =	24	24	16.05	12.43	15.78	24
stirrups=	3.8	3.8	5.682242991	7.337088	5.779468	3.8
			20 D			
x (ft) =	0	7.95	15.9	23.85	31.8	39.75
Vs.req =	-272.1695	-49.47131	23.39251053	33.73059	28.13568	12.27807
Vs.act =	17.49	43.33729	59.67162585	60.56064	44.22631	17.49
s =	24	24	16.24	12.41	15.7	24
stirrups=	3.975	3.975	5.874384236	7.687349	6.076433	3.975
			20 S			
x (ft) =	0	7.7	15.4	23.1	30.8	38.5
Vs.req =	108.6433	54.37193	5.480279851	27.19291	28.46399	14.40875
Vs.act =	109.8811	69.39935	43.18661072	53.71688	44.41027	16.94
s =	3.7	7.75	24	15.49	14.8	24
stirrups=	24.97297	11.92258	3.85	5.965139	6.243243	3.85
			22 D			
x (ft) =	0	8.3	16.6	24.9	33.2	41.5
Vs.req =	-298.2138	-50.8309	23.87726411	34.38988	28.75633	12.99848
Vs.act =	18.26	45.92667	63.85494082	64.8689	46.94063	18.26
s =	24	24	15.84	12.11	15.28	24
stirrups=	4.15	4.15	6.287878788	8.224608	6.518325	4.15

continued

Table 8.3.1.4c, page 2

			24 D			
x (ft) =	0	8.6	17.2	25.8	34.4	43
Vs.req =	-324.7202	-53.87608	23.14823744	34.13832	28.66624	13.56772
Vs.act =	18.92	46.79477	65.2476093	67.12906	48.67623	18.92
s =	24	24	16.29	12.15	15.26	24
stirrups=	4.3	4.3	6.335174954	8.493827	6.762779	4.3
			24 S			
x (ft) =	0	8.3	16.6	24.9	33.2	41.5
Vs.req =	112.3276	52.9296	-0.213714675	25.19377	27.57733	15.28737
Vs.act =	118.4432	73.31528	44.45485953	54.87549	46.94063	18.26
s =	3.7	7.96	24	16.73	15.28	24
stirrups=	26.91892	12.51256	4.15	5.953377	6.518325	4.15
			26 D			
x (ft) =	0	8.9	17.8	26.7	35.6	44.5
Vs.req =	-350.0948	-56.46769	22.67686784	34.06192	28.70039	14.07447
Vs.act =	19.58	47.92258	67.0828947	69.69684	50.53652	19.58
s =	24	24	16.58	12.13	15.18	24
stirrups=	4.45	4.45	6.441495778	8.804617	7.035573	4.45
			28 D			
x (ft) =	0	9.15	18.3	27.45	36.6	45.75
Vs.req =	-376.3538	-60.77319	21.00337246	33.08516	28.03782	14.47683
Vs.act =	20.13	47.19555	65.83922198	69.96283	51.31915	20.13
s =	24	24	17.85	12.46	15.49	24
stirrups=	4.575	4.575	6.151260504	8.812199	7.088444	4.575
			30 D-1			
x (ft) =	0	9.4	18.8	28.2	37.6	47
Vs.req =	-240.1064	-30.319	44.00129251	48.60187	35.74611	14.94722
Vs.act =	20.68	86.94435	132.1767031	109.9514	64.71904	20.68
s =	24	24	7.49	7.53	11.27	24
stirrups=	4.7	4.7	15.06008011	14.98008	10.00887	4.7
			30 D-2			
x (ft) =	0	9.4	18.8	28.2	37.6	47
Vs.req =	-238.51	-30.04666	44.25886293	48.84334	36.00177	15.05309
Vs.act =	20.68	87.47946	133.1524028	110.8261	65.15312	20.68
s =	24	24	7.43	7.48	11.16	24
stirrups=	4.7	4.7	15.18169583	15.08021	10.10753	4.7

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

Table 8.3.1.4d: Girder Spacing = 8 feet

			12 D			
x (ft) =	0	5.5	11	16.5	22	27.5
Vs.req =	-152.8061	-71.89197	7.917819913	21.40635	18.69753	9.589056
Vs.act =	12.1	24.2	26.87110885	26.98819	24.31708	12.1
s =	24	24	24	19.66	23.77	24
stirrups=	2.75	2.75	2.75	3.35707	2.776609	2.75
			14 D			
x (ft) =	0	6.05	12.1	18.15	24.2	30.25
Vs.req =	-182.9051	-64.54486	13.73778653	26.79571	22.97865	12.92468
Vs.act =	13.31	26.62	33.61769231	36.79066	29.79297	13.31
s =	24	24	24	15.73	19.38	24
stirrups=	3.025	3.025	3.025	4.615385	3.74613	3.025
			16 D			
x (ft) =	0	6.6	13.2	19.8	26.4	33
Vs.req =	-209.6015	-56.46988	20.27877048	32.59675	27.60358	16.56917
Vs.act =	14.52	33.05617	45.571081	48.70655	38.26593	16.59429
s =	24	24	18.8	12.89	16.08	21
stirrups=	3.3	3.3	4.212765957	6.144298	4.925373	3.771429
			16 S			
x (ft) =	0	6.45	12.9	19.35	25.8	32.25
Vs.req =	123.6435	72.86063	26.53779386	24.85489	27.06632	17.53575
Vs.act =	126.1333	77.79844	39.97463867	40.95794	39.27593	17.92421
s =	2.7	5.93	16.72	17.37	15.95	19
stirrups=	28.66667	13.05228	4.629186603	4.455959	4.852665	4.073684
			18 D			
x (ft) =	0	7.15	14.3	21.45	28.6	35.75
Vs.req =	-234.1102	-48.4868	26.97699256	38.18932	32.04935	18.10792
Vs.act =	15.73	42.50447	61.15698175	61.71923	45.48671	18.15
s =	24	24	14.1	10.98	13.81	20.8
stirrups=	3.575	3.575	6.085106383	7.814208	6.212889	4.125
			20 D			
x (ft) =	0	7.55	15.1	22.65	30.2	37.75
Vs.req =	-261.7682	-47.8503	28.99954218	39.91104	33.49595	19.05012
Vs.act =	16.61	47.04053	68.46870229	68.26106	50.1549	19.932
s =	24	24	13.1	10.48	13.19	20
stirrups=	3.775	3.775	6.916030534	8.645038	6.86884	4.53
			20 S			
x (ft) =	0	7.3	14.6	21.9	29.2	36.5
Vs.req =	131.5466	73.95352	21.9337608	32.56302	33.54745	21.0583
Vs.act =	137.6571	87.69605	49.86170788	60.47461	49.9599	19.272
s =	2.8	5.7	19.2	12.94	12.56	20
stirrups=	31.28571	15.36842	4.5625	6.769706	6.974522	4.38
			22 D			
x (ft) =	0	7.85	15.7	23.55	31.4	39.25
Vs.req =	-289.9541	-50.98305	28.40766379	39.79804	33.54528	19.8344
Vs.act =	17.27	48.4105	70.76573487	71.26493	51.76008	20.12039
s =	24	24	13.31	10.46	13.1	20.6
stirrups=	3.925	3.925	7.077385424	9.005736	7.19084	4.572816

continued

Table 8.3.1.4d, page 2

			24 D			
x (ft) =	0	8.15	16.3	24.45	32.6	40.75
Vs.req =	-316.8921	-53.59534	28.10543503	39.87902	33.7293	20.52859
Vs.act =	17.93	50.01949	73.46640854	74.55503	53.66953	20.49143
s =	24	24	13.41	10.4	12.97	21
stirrups=	4.075	4.075	7.293064877	9.403846	7.540478	4.657143
			24 S			
x (ft) =	0	7.9	15.8	23.7	31.6	39.5
Vs.req =	136.762	73.58029	16.92974308	31.17319	33.18341	22.21265
Vs.act =	139.04	90.17581	48.23207101	63.69617	55.39112	22.54703
s =	3	5.73	24	13.52	12.7	18.5
stirrups=	31.6	16.5445	3.95	7.011834	7.464567	5.124324
			26 D			
x (ft) =	0	8.4	16.8	25.2	33.6	42
Vs.req =	-344.6416	-58.13743	26.42219166	38.92564	33.10674	21.01808
Vs.act =	18.48	49.64796	72.93066689	75.46484	54.78198	21.07985
s =	24	24	14.23	10.62	13.16	21.04
stirrups=	4.2	4.2	7.083626142	9.491525	7.659574	4.790875
			28 D			
x (ft) =	0	8.65	17.3	25.95	34.6	43.25
Vs.req =	-371.4109	-62.22373	25.00560139	38.15441	32.61517	20.67019
Vs.act =	19.03	49.49831	72.7572011	76.57718	55.65031	21.36202
s =	24	24	14.99	10.8	13.32	21.38
stirrups=	4.325	4.325	6.924616411	9.611111	7.792793	4.855005
			30 D-1			
x (ft) =	0	8.9	17.8	26.7	35.6	44.5
Vs.req =	-234.2158	-29.00636	50.2158877	55.10604	41.09629	20.66505
Vs.act =	19.58	91.21415	142.4052307	118.7221	70.0545	22.10348
s =	24	24	6.56	6.64	9.8	21.26
stirrups=	4.45	4.45	16.2804878	16.08434	10.89796	5.023518
			30 D-2			
x (ft) =	0	8.9	17.8	26.7	35.6	44.5
Vs.req =	-232.5763	-28.71404	50.49395707	55.36674	41.37045	20.92621
Vs.act =	19.58	91.76433	143.3843318	119.5955	70.83673	22.44126
s =	24	24	6.51	6.6	9.71	20.94
stirrups=	4.45	4.45	16.40552995	16.18182	10.99897	5.100287

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

Table 8.3.1.4e: Girder Spacing = 9 feet

			12 D			
x (ft) =	0	5.15	10.3	15.45	20.6	25.75
Vs.req =	-141.9502	-77.54059	8.438298538	22.58614	20.0125	10.61535
Vs.act =	11.33	22.66	25.91798283	26.83112	23.57313	11.33
s =	24	24	24	18.64	22.21	24
stirrups=	2.575	2.575	2.575	3.315451	2.78253	2.575
			14 D			
x (ft) =	0	5.7	11.4	17.1	22.8	28.5
Vs.req =	-171.8157	-67.69459	16.02362838	29.6144	25.59327	14.70647
Vs.act =	12.54	25.15887	33.75369939	38.43138	32.34455	15.048
s =	24	24	23.85	14.24	17.4	20
stirrups=	2.85	2.85	2.867924528	4.803371	3.931034	3.42
			16 D			
x (ft) =	0	6.2	12.4	18.6	24.8	31
Vs.req =	-200.0971	-60.4072	22.13626282	35.27658	30.15185	18.35591
Vs.act =	13.64	32.65045	46.49659906	49.72528	40.94542	18.70629
s =	24	24	17.22	11.91	14.72	17.5
stirrups=	3.1	3.1	4.320557491	6.246851	5.054348	4.251429
			16 S			
x (ft) =	0	6.05	12.1	18.15	24.2	30.25
Vs.req =	143.432	90.49614	42.00795025	26.63175	29.31874	19.17064
Vs.act =	145.2	98.04248	50.78028406	41.39271	41.04635	19.36
s =	2.2	4.77	10.28	16.21	14.73	16.5
stirrups=	33	15.22013	7.062256809	4.478717	4.928717	4.4
			18 D			
x (ft) =	0	6.7	13.4	20.1	26.8	33.5
Vs.req =	-226.3503	-53.11331	28.24236016	40.74698	34.54193	21.83083
Vs.act =	14.74	41.00281	60.64181498	61.99493	49.45296	21.83704
s =	24	24	13.47	10.29	12.81	16.2
stirrups=	3.35	3.35	5.968819599	7.813411	6.276347	4.962963
			20 D			
x (ft) =	0	7.15	14.3	21.45	28.6	35.75
Vs.req =	-252.4788	-48.55313	32.71609604	44.65733	37.70775	24.33157
Vs.act =	15.73	48.2468	72.80708402	72.5294	56.59524	24.35613
s =	24	24	11.61	9.37	11.71	15.5
stirrups=	3.575	3.575	7.390180879	9.156884	7.327071	5.535484
			20 S			
x (ft) =	0	6.9	13.8	20.7	27.6	34.5
Vs.req =	153.058	92.81695	38.21964607	36.39294	37.42511	25.68565
Vs.act =	158.4	113.3066	64.548223	63.84357	58.3781	26.02286
s =	2.3	4.54	11.02	11.57	11.26	14
stirrups=	36	18.23789	7.513611615	7.156439	7.353464	5.914286
			22 D			
x (ft) =	0	7.45	14.9	22.35	29.8	37.25
Vs.req =	-281.0824	-51.17369	32.63451552	44.9379	38.08359	24.69514
Vs.act =	16.39	50.3296	76.37326006	76.52031	58.98286	24.8962
s =	24	24	11.59	9.27	11.54	15.8
stirrups=	3.725	3.725	7.71354616	9.644013	7.746967	5.658228

continued

Table 8.3.1.4e, page 2

			24 D			
x (ft) =	0	7.7	15.4	23.1	30.8	38.5
Vs.req =	-310.4097	-55.959	30.96596289	44.03105	37.52675	24.33327
Vs.act =	16.94	50.34674	76.56597355	78.02716	59.50792	24.64
s =	24	24	12.17	9.42	11.66	16.5
stirrups=	3.85	3.85	7.592440427	9.808917	7.924528	5.6
			24 S			
x (ft) =	0	7.5	15	22.5	30	37.5
Vs.req =	159.7744	93.53975	33.9772183	35.76611	37.70687	26.13507
Vs.act =	165	119.7146	65.52604901	69.03669	61.82039	26.4
s =	2.4	4.51	12.41	11.78	11.18	15
stirrups=	37.5	19.95565	7.252215955	7.640068	8.050089	6
			26 D			
x (ft) =	0	8	16	24	32	40
Vs.req =	-336.5695	-57.53803	31.4520691	44.69289	38.16577	24.86602
Vs.act =	17.6	52.94728	81.0121452	82.65261	62.1306	25.14286
s =	24	24	11.95	9.25	11.42	16.8
stirrups=	4	4	8.033472803	10.37838	8.406305	5.714286
			28 D			
x (ft) =	0	8.2	16.4	24.6	32.8	41
Vs.req =	-365.9094	-64.00665	28.50777288	42.8116	36.83421	23.89562
Vs.act =	18.04	50.96471	77.88421639	81.68215	60.77598	24.05333
s =	24	24	13.15	9.63	11.79	18
stirrups=	4.1	4.1	7.482889734	10.21807	8.346056	5.466667
			30 D-1			
x (ft) =	0	8.4	16.8	25.2	33.6	42
Vs.req =	-230.5226	-30.4387	54.3320389	59.98639	45.12587	23.29681
Vs.act =	18.48	91.66812	145.8963155	122.4302	73.23841	23.51644
s =	24	24	6.06	6.1	8.92	18.86
stirrups=	4.2	4.2	16.63366337	16.52459	11.30045	5.344645
			30 D-2			
x (ft) =	0	8.4	16.8	25.2	33.6	42
Vs.req =	-228.8411	-30.12493	54.63241383	60.26781	45.4198	23.57687
Vs.act =	18.48	92.15442	146.8625374	123.3034	73.97324	23.85799
s =	24	24	6.02	6.06	8.85	18.59
stirrups=	4.2	4.2	16.74418605	16.63366	11.38983	5.42227

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

SHEAR CAPACITY TABLES FOR G 63-T BULB GIRDER

Table 8.3.1.5a: Girder Spacing = 5 feet

			14 S			
x (ft) =	0	8.2	16.4	24.6	32.8	41
Vs.req =	48.3249	9.38496	-17.46434412	9.8205	11.95102	-9.345239
Vs.act =	50.93647	36.08	36.08	36.08	36.08	18.04
s =	8.5	24	24	24	24	24
stirrups=	11.57647	4.1	4.1	4.1	4.1	4.1
			18 D			
x (ft) =	0	9.5	19	28.5	38	47.5
Vs.req =	-285.4163	-42.33262	17.83139802	24.701206	18.82766	-7.970287
Vs.act =	20.9	41.8	46.66271186	46.662712	41.8	20.9
s =	24	24	24	19.47	24	24
stirrups=	4.75	4.75	4.75	5.8551618	4.75	4.75
			18 S			
x (ft) =	0	9.5	19	28.5	38	47.5
Vs.req =	55.77353	10.00696	-9.984220019	16.396982	17.28688	-7.970287
Vs.act =	59.01176	41.8	41.8	41.8	41.8	20.9
s =	8.5	24	24	24	24	24
stirrups=	13.41176	4.75	4.75	4.75	4.75	4.75
			20 D			
x (ft) =	0	10	20	30	40	50
Vs.req =	-313.8026	-41.29027	19.42773657	26.03727	19.85435	-7.55141
Vs.act =	22	45.95644	52.60538477	50.648942	44	22
s =	24	24	22.04	18.43	24	24
stirrups=	5	5	5.444646098	6.5111232	5	5
			22 D			
x (ft) =	0	10.4	20.8	31.2	41.6	52
Vs.req =	-343.4633	-42.93591	19.20250074	26.029065	19.86455	-7.243847
Vs.act =	22.88	47.53739	54.50086488	52.723478	45.76	22.88
s =	24	24	22.27	18.4	24	24
stirrups=	5.2	5.2	5.603951504	6.7826087	5.2	5.2
			22 S			
x (ft) =	0	10.2	20.4	30.6	40.8	51
Vs.req =	57.8922	8.78161	-10.83244318	17.064537	18.26924	-6.030822
Vs.act =	71.808	44.88	44.88	44.88	44.88	22.44
s =	7.5	24	24	24	24	24
stirrups=	16.32	5.1	5.1	5.1	5.1	5.1
			24 D			
x (ft) =	0	10.8	21.6	32.4	43.2	54
Vs.req =	-371.9408	-44.15817	19.23618677	26.207999	20.01175	-6.975429
Vs.act =	23.76	49.43492	56.9209486	55.006027	47.52	23.76
s =	24	24	22.21	18.25	24	24
stirrups=	5.4	5.4	5.835209365	7.1013699	5.4	5.4
			26 D			
x (ft) =	0	11.1	22.2	33.3	44.4	55.5
Vs.req =	-401.0855	-47.70701	17.75967837	25.32559	19.38431	-6.658528
Vs.act =	24.42	48.86037	55.58170597	55.561339	48.84	24.42
s =	24	24	23.98	18.82	24	24
stirrups=	5.55	5.55	5.554628857	7.077577	5.55	5.55

continued

Table 8.3.1.5a: page 2

			28 D			
x (ft) =	0	11.5	23	34.5	46	57.5
Vs.req =	-426.1472	-47.8484	18.52303627	26.08973	19.98684	-6.339041
Vs.act =	25.3	51.78059	59.82490942	58.644316	50.6	25.3
s =	24	24	22.93	18.21	24	24
stirrups=	5.75	5.75	6.018316616	7.5782537	5.75	5.75
			30 D			
x (ft) =	0	11.8	23.6	35.4	47.2	59
Vs.req =	-453.4016	-50.72352	17.45198069	25.488417	19.56305	-6.09257
Vs.act =	25.96	51.92	59.4747929	59.474793	51.92	25.96
s =	24	24	24	18.59	24	24
stirrups=	5.9	5.9	5.9	7.6169984	5.9	5.9
			32 D-1			
x (ft) =	0	12.1	24.2	36.3	48.4	60.5
Vs.req =	-307.7585	-21.24111	38.77988858	39.752035	26.84502	-5.871152
Vs.act =	26.62	94.87641	129.7463044	98.547899	63.678	26.62
s =	24	24	9.36	10.39	17.24	24
stirrups=	6.05	6.05	15.51282051	13.974976	8.422274	6.05
			32 D-2			
x (ft) =	0	12.1	24.2	36.3	48.4	60.5
Vs.req =	-306.5601	-21.06454	38.94305966	39.904155	27.01276	-5.772391
Vs.act =	26.62	95.24299	130.4700335	99.208451	63.9814	26.62
s =	24	24	9.31	10.33	17.1	24
stirrups=	6.05	6.05	15.59613319	14.056147	8.491228	6.05
			34 D-1			
x (ft) =	0	12.35	24.7	37.05	49.4	61.75
Vs.req =	-322.6593	-23.56587	38.13624098	39.391118	26.57778	-5.500591
Vs.act =	27.17	95.95481	131.304465	100.16862	64.81896	27.17
s =	24	24	9.48	10.43	17.32	24
stirrups=	6.175	6.175	15.63291139	14.209012	8.556582	6.175
			34 D-2			
x (ft) =	0	12.35	24.7	37.05	49.4	61.75
Vs.req =	-319.0664	-23.04699	38.61509757	39.837475	27.06658	-5.221689
Vs.act =	27.17	97.06068	133.3843461	102.05547	65.7318	27.17
s =	24	24	9.33	10.27	16.91	24
stirrups=	6.175	6.175	15.88424437	14.43038	8.764045	6.175

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.5b: Girder Spacing = 6 feet

			14 S			
x (ft) =	0	7.55	15.1	22.65	30.2	37.75
Vs.req =	69.29517	27.89673	-10.47394861	11.76467	14.57522	-2.648361
Vs.act =	72.48	37.76924	33.22	33.22	33.22	16.61
s =	5.5	18.84	24	24	24	24
stirrups=	16.47273	4.808917	3.775	3.775	3.775	3.775
			18 D			
x (ft) =	0	8.85	17.7	26.55	35.4	44.25
Vs.req =	-276.9057	-43.98502	21.68761571	29.63588	23.35316	-0.765608
Vs.act =	19.47	43.09386	52.41499003	50.10865	40.78752	19.47
s =	24	24	19.78	16.23	21.92	24
stirrups=	4.425	4.425	5.369059656	6.543438	4.844891	4.425
			18 S			
x (ft) =	0	8.85	17.7	26.55	35.4	44.25
Vs.req =	79.2306	30.25519	-8.809954044	20.58052	21.67532	-0.765608
Vs.act =	84.96	46.543	38.94	38.94	38.94	19.47
s =	5.5	17.26	24	24	24	24
stirrups=	19.30909	6.152955	4.425	4.425	4.425	4.425
			20 D			
x (ft) =	0	9.4	18.8	28.2	37.6	47
Vs.req =	-304.329	-40.15061	25.28902947	32.46151	25.53376	-0.162323
Vs.act =	20.68	49.99601	62.8965213	58.38411	45.4836	20.68
s =	24	24	16.93	14.78	20.01	24
stirrups=	4.7	4.7	6.662728884	7.631935	5.637181	4.7
			22 D			
x (ft) =	0	9.8	19.6	29.4	39.2	49
Vs.req =	-334.4503	-41.28448	25.50067199	32.78725	25.81014	0.239139
Vs.act =	21.56	52.4151	66.27193617	61.60307	47.74623	21.56
s =	24	24	16.77	14.61	19.76	24
stirrups=	4.9	4.9	7.012522361	8.049281	5.951417	4.9
			22 S			
x (ft) =	0	9.6	19.2	28.8	38.4	48
Vs.req =	83.13233	30.06844	-7.387953304	22.87651	23.90525	1.406691
Vs.act =	84.48	51.27348	44.05574661	46.91304	45.09729	21.12
s =	6	16.81	24	22.1	21.14	24
stirrups=	19.2	6.853064	4.8	5.21267	5.449385	4.8
			24 D			
x (ft) =	0	10.1	20.2	30.3	40.4	50.5
Vs.req =	-366.4235	-45.4819	23.62805919	31.56566	24.91016	0.523401
Vs.act =	22.22	51.71558	64.67235622	61.2668	48.31002	22.22
s =	24	24	18.08	15.16	20.44	24
stirrups=	5.05	5.05	6.703539823	7.994723	5.92955	5.05
			26 D			
x (ft) =	0	10.5	21	31.5	42	52.5
Vs.req =	-393.0438	-45.36148	24.68696216	32.57169	25.71654	0.963341
Vs.act =	23.1	55.23913	70.03386728	66.00833	51.21359	23.1
s =	24	24	17.25	14.63	19.72	24
stirrups=	5.25	5.25	7.304347826	8.61244	6.389452	5.25

continued

Table 8.3.1.5b, page 2

			28 D			
x (ft) =	0	10.8	21.6	32.4	43.2	54
Vs.req =	-421.7971	-48.36515	23.62697232	31.99752	25.32248	1.294875
Vs.act =	23.76	55.47524	70.11523915	66.96914	52.32914	23.76
s =	24	24	17.98	14.85	19.96	24
stirrups=	5.4	5.4	7.208008899	8.727273	6.492986	5.4
			30 D			
x (ft) =	0	11.1	22.2	33.3	44.4	55.5
Vs.req =	-449.6433	-51.02297	22.77481718	31.56818	25.03392	1.591249
Vs.act =	24.42	55.91275	70.53871519	68.14627	53.5203	24.42
s =	24	24	18.61	15.01	20.14	24
stirrups=	5.55	5.55	7.157442235	8.874084	6.613704	5.55
			32 D-1			
x (ft) =	0	11.35	22.7	34.05	45.4	56.75
Vs.req =	-305.3274	-20.10705	45.35362742	46.55799	32.50673	1.834497
Vs.act =	24.97	99.88	142.4725705	109.6468	67.05427	24.97
s =	24	24	8	8.87	14.24	24
stirrups=	5.675	5.675	17.025	15.35513	9.564607	5.675
			32 D-2			
x (ft) =	0	11.35	22.7	34.05	45.4	56.75
Vs.req =	-304.0954	-19.91437	45.5327366	46.72552	32.68973	1.933258
Vs.act =	24.97	100.2564	143.2320104	110.3575	67.38189	24.97
s =	24	24	7.96	8.82	14.13	24
stirrups=	5.675	5.675	17.11055276	15.44218	9.639066	5.675
			34 D-1			
x (ft) =	0	11.65	23.3	34.95	46.6	58.25
Vs.req =	-318.6445	-20.7173	45.91005183	47.11474	32.95303	2.26432
Vs.act =	25.63	103.6909	148.6021981	114.5728	69.6615	25.63
s =	24	24	7.88	8.72	13.97	24
stirrups=	5.825	5.825	17.74111675	16.03211	10.00716	5.825
			34 D-2			
x (ft) =	0	11.6	23.2	34.8	46.4	58
Vs.req =	-316.7313	-21.72466	45.40298686	46.82598	32.87843	2.520807
Vs.act =	25.52	102.6585	147.2163422	114.0778	69.52	25.52
s =	24	24	7.94	8.74	13.92	24
stirrups=	5.8	5.8	17.53148615	15.92677	10	5.8

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.5c: Girder Spacing = 7 feet

			14 S			
x (ft) =	0	7.05	14.1	21.15	28.2	35.25
Vs.req =	90.22436	46.25002	5.385301848	14.62211	17.78339	3.824782
Vs.act =	93.06	48.24879	31.02	31.02	31.02	15.51
s =	4	11.37	24	24	24	24
stirrups=	21.15	7.440633	3.525	3.525	3.525	3.525
			18 D			
x (ft) =	0	8.25	16.5	24.75	33	41.25
Vs.req =	-268.5003	-47.30457	24.09443648	33.4497	26.95995	6.165992
Vs.act =	18.15	42.60817	54.75024189	53.23046	41.08839	18.15
s =	24	24	17.81	14.38	18.99	24
stirrups=	4.125	4.125	5.558674902	6.884562	5.21327	4.125
			18 S			
x (ft) =	0	8.25	16.5	24.75	33	41.25
Vs.req =	101.3957	49.79719	2.429833021	23.61897	25.14236	6.165992
Vs.act =	108.9	59.67526	37.85149254	40.67405	39.12256	18.15
s =	4	10.49	24	22.11	20.77	24
stirrups=	24.75	9.43756	4.125	4.477612	4.76649	4.125
			20 D			
x (ft) =	0	8.8	17.6	26.4	35.2	44
Vs.req =	-296.249	-42.00969	28.84930923	37.13102	29.82491	6.969956
Vs.act =	19.36	50.64889	67.25173719	63.08719	46.48434	19.36
s =	24	24	14.85	12.92	17.13	24
stirrups=	4.4	4.4	7.111111111	8.173375	6.164623	4.4
			22 D			
x (ft) =	0	9.2	18.4	27.6	36.8	46
Vs.req =	-326.8601	-42.4828	29.61759031	37.87718	30.43947	7.495563
Vs.act =	20.24	53.87989	72.0398892	67.4006	49.2406	20.24
s =	24	24	14.44	12.65	16.75	24
stirrups=	4.6	4.6	7.645429363	8.727273	6.591045	4.6
			22 S			
x (ft) =	0	9.05	18.1	27.15	36.2	45.25
Vs.req =	107.1754	50.71568	-0.816645673	27.98624	28.96096	8.657485
Vs.act =	108.6	67.83778	46.36847176	53.84185	47.29338	19.91
s =	4.4	9.97	24	18.06	17.45	24
stirrups=	24.68182	10.89268	4.525	6.013289	6.223496	4.525
			24 D			
x (ft) =	0	9.6	19.2	28.8	38.4	48
Vs.req =	-356.1989	-42.51366	30.64329773	38.812	31.19001	7.955856
Vs.act =	21.12	57.48155	77.47103855	72.16831	52.17882	21.12
s =	24	24	13.94	12.33	16.32	24
stirrups=	4.8	4.8	8.263988522	9.343066	7.058824	4.8
			26 D			
x (ft) =	0	9.9	19.8	29.7	39.6	49.5
Vs.req =	-386.4977	-45.64484	29.60757969	38.27809	30.84117	8.401778
Vs.act =	21.78	58.13049	78.33602896	73.76183	53.55629	21.78
s =	24	24	14.38	12.45	16.45	24
stirrups=	4.95	4.95	8.26147427	9.542169	7.221884	4.95

continued

Table 8.3.1.5c, page 2

			28 D			
x (ft) =	0	10.2	20.4	30.6	40.8	51
Vs.req =	-415.8064	-48.37468	28.81281099	37.91158	30.61368	8.799898
Vs.act =	22.44	58.97731	79.51895749	75.60187	55.06023	22.44
s =	24	24	14.74	12.53	16.51	24
stirrups=	5.1	5.1	8.303934871	9.768555	7.413689	5.1
			30 D			
x (ft) =	0	10.5	21	31.5	42	52.5
Vs.req =	-444.1658	-50.73861	28.23571799	37.69711	30.4966	9.157057
Vs.act =	23.1	60.03538	81.04038835	77.64403	56.63902	23.1
s =	24	24	15.01	12.57	16.53	24
stirrups=	5.25	5.25	8.394403731	10.02387	7.622505	5.25
			32 D-1			
x (ft) =	0	10.75	21.5	32.25	43	53.75
Vs.req =	-300.2225	-17.08138	52.9254882	54.06111	38.67829	9.446965
Vs.act =	23.65	106.3905	157.0337185	121.7117	71.06855	23.65
s =	24	24	6.86	7.64	11.97	24
stirrups=	5.375	5.375	18.80466472	16.88482	10.77694	5.375
			32 D-2			
x (ft) =	0	10.75	21.5	32.25	43	53.75
Vs.req =	-298.9652	-16.87415	53.11911284	54.24258	38.87501	9.545726
Vs.act =	23.65	106.754	157.7881637	122.462	71.42778	23.65
s =	24	24	6.83	7.6	11.88	24
stirrups=	5.375	5.375	18.88726208	16.97368	10.85859	5.375
			34 D-1			
x (ft) =	0	11	22	33	44	55
Vs.req =	-315.4681	-19.06638	52.6549511	54.00503	38.64844	9.897732
Vs.act =	24.2	108.7415	160.8621155	125.0864	72.96574	24.2
s =	24	24	6.87	7.61	11.91	24
stirrups=	5.5	5.5	19.2139738	17.3456	11.08312	5.5
			34 D-2			
x (ft) =	0	11	22	33	44	55
Vs.req =	-311.6864	-18.45886	53.22163579	54.5362	39.22113	10.17663
Vs.act =	24.2	109.9903	163.2302511	127.2086	73.96864	24.2
s =	24	24	6.77	7.5	11.67	24
stirrups=	5.5	5.5	19.49778434	17.6	11.31105	5.5

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.5d: Girder Spacing = 8 feet

			14 S			
x (ft) =	0	6.6	13.2	19.8	26.4	33
Vs.req =	110.2628	63.97396	20.82620641	16.71038	20.35383	9.954684
Vs.act =	116.16	64.30286	29.04	29.04	29.04	14.52
s =	3	7	24	24	24	24
stirrups=	26.4	11.31429	3.3	3.3	3.3	3.3
			18 D			
x (ft) =	0	7.75	15.5	23.25	31	38.75
Vs.req =	-258.5564	-49.72338	26.80475132	37.44397	30.64514	12.88735
Vs.act =	17.05	42.60903	57.42818449	56.35749	41.53833	17.05
s =	24	24	16.01	12.84	16.71	24
stirrups=	3.875	3.875	5.808869457	7.242991	5.56553	3.875
			18 S			
x (ft) =	0	7.75	15.5	23.25	31	38.75
Vs.req =	123.1228	68.9657	19.11195724	26.87525	28.69565	12.88735
Vs.act =	136.4	71.10548	38.11021616	43.54373	39.53352	17.05
s =	3	7.57	24	19.43	18.2	24
stirrups=	31	12.28534	3.875	4.786413	5.10989	3.875
			20 D			
x (ft) =	0	8.3	16.6	24.9	33.2	41.5
Vs.req =	-286.4959	-42.83785	32.83555191	42.0688	34.26584	13.92973
Vs.act =	18.26	51.86736	72.01577564	67.80077	47.65235	18.26
s =	24	24	13.04	11.41	14.91	24
stirrups=	4.15	4.15	7.63803681	8.729185	6.68008	4.15
			22 D			
x (ft) =	0	8.75	17.5	26.25	35	43.75
Vs.req =	-315.8573	-40.31721	35.77055553	44.42751	36.13543	14.66981
Vs.act =	19.25	57.87876	81.4859054	75.59988	51.99274	19.25
s =	24	24	11.96	10.78	14.11	24
stirrups=	4.375	4.375	8.779264214	9.74026	7.441531	4.375
			22 S			
x (ft) =	0	8.6	17.2	25.8	34.4	43
Vs.req =	130.8852	71.05341	16.34985514	33.71949	34.41391	15.78247
Vs.act =	133.5529	82.78498	49.2121948	61.20302	49.83082	18.92
s =	3.4	7.11	24	14.99	14.69	24
stirrups=	30.35294	14.51477	4.3	6.88459	7.025187	4.3
			24 D			
x (ft) =	0	9.1	18.2	27.3	36.4	45.5
Vs.req =	-347.1406	-41.8331	35.88986352	44.70226	36.3989	15.18966
Vs.act =	20.02	60.39647	85.28114349	79.2492	54.36453	20.02
s =	24	24	11.9	10.7	13.99	24
stirrups=	4.55	4.55	9.176470588	10.20561	7.805575	4.55
			26 D			
x (ft) =	0	9.4	18.8	28.2	37.6	47
Vs.req =	-377.9206	-44.64013	35.16310365	44.40988	36.24641	15.72084
Vs.act =	20.68	61.66431	87.23966929	81.73213	56.15677	20.68
s =	24	24	12.11	10.73	13.99	24
stirrups=	4.7	4.7	9.31461602	10.51258	8.062902	4.7

continued

Table 8.3.1.5d, page 2

			28 D			
x (ft) =	0	9.7	19.4	29.1	38.8	48.5
Vs.req =	-407.6773	-47.02823	34.68440394	44.28999	36.21821	16.19637
Vs.act =	21.34	63.14898	89.54057325	84.41927	58.02768	21.34
s =	24	24	12.25	10.73	13.96	24
stirrups=	4.85	4.85	9.502040816	10.84809	8.338109	4.85
			30 D			
x (ft) =	0	9.95	19.9	29.85	39.8	49.75
Vs.req =	-438.3578	-51.20066	32.96663612	43.23869	35.47251	16.57694
Vs.act =	21.89	62.77405	88.81835326	84.90545	58.86115	21.89
s =	24	24	12.85	10.96	14.21	24
stirrups=	4.975	4.975	9.291828794	10.89416	8.402533	4.975
			32 D-1			
x (ft) =	0	10.2	20.4	30.6	40.8	51
Vs.req =	-295.3751	-14.75074	59.8222807	61.00705	44.38569	16.92397
Vs.act =	22.44	111.1649	168.2758366	131.1866	74.07567	22.44
s =	24	24	6.07	6.77	10.43	24
stirrups=	5.1	5.1	20.16474465	18.07976	11.73538	5.1
			32 D-2			
x (ft) =	0	10.2	20.4	30.6	40.8	51
Vs.req =	-294.0963	-14.52902	60.03047849	61.2024	44.59595	17.02273
Vs.act =	22.44	111.6056	169.0706074	131.8896	74.42456	22.44
s =	24	24	6.04	6.74	10.36	24
stirrups=	5.1	5.1	20.26490066	18.16024	11.81467	5.1
			34 D-1			
x (ft) =	0	10.4	20.8	31.2	41.6	52
Vs.req =	-312.8394	-18.45598	58.48771452	60.15626	43.73104	17.38626
Vs.act =	22.88	111.7344	169.252612	132.5464	75.02815	22.88
s =	24	24	6.18	6.83	10.53	24
stirrups=	5.2	5.2	20.19417476	18.27233	11.85185	5.2
			34 D-2			
x (ft) =	0	10.4	20.8	31.2	41.6	52
Vs.req =	-308.9804	-17.80357	59.09940842	60.73032	44.34556	17.66516
Vs.act =	22.88	112.8997	171.4914822	134.6811	76.0893	22.88
s =	24	24	6.1	6.74	10.32	24
stirrups=	5.2	5.2	20.45901639	18.51632	12.09302	5.2

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

Table 8.3.1.5e: Girder Spacing = 9 feet

			14 S			
x (ft) =	0	6.2	12.4	18.6	24.8	31
Vs.req =	129.585	81.13085	35.8185227	18.24648	22.45101	13.23251
Vs.act =	130.944	87.77173	35.93972752	27.62377	27.62377	13.64
s =	2.5	5	14.68	24	23.41	24
stirrups=	29.76	14.88	5.068119891	3.1	3.178129	3.1
			18 D			
x (ft) =	0	7.3	14.6	21.9	29.2	36.5
Vs.req =	-248.2428	-52.76373	28.78472394	40.86724	33.84081	19.34154
Vs.act =	16.06	41.92846	58.61611993	58.22288	44.74721	19.272
s =	24	24	14.9	11.77	15.13	20
stirrups=	3.65	3.65	5.879194631	7.442651	5.789822	4.38
			18 S			
x (ft) =	0	7.3	14.6	21.9	29.2	36.5
Vs.req =	144.0464	87.57345	35.42831241	29.55586	31.75978	19.34154
Vs.act =	154.176	90.82039	47.96249652	45.24425	42.703	19.272
s =	2.5	5.96	14.74	17.67	16.45	20
stirrups=	35.04	14.69799	5.943012212	4.957555	5.325228	4.38
			20 D			
x (ft) =	0	7.8	15.6	23.4	31.2	39
Vs.req =	-277.896	-46.6705	34.48137578	45.24235	37.30321	20.56918
Vs.act =	17.16	50.31942	71.97563141	68.89948	50.67527	20.592
s =	24	24	12.42	10.61	13.69	20
stirrups=	3.9	3.9	7.536231884	8.821866	6.837107	4.68
			22 D			
x (ft) =	0	8.3	16.6	24.9	33.2	41.5
Vs.req =	-305.879	-40.45176	40.12872924	49.60895	40.74295	21.60664
Vs.act =	18.26	59.37069	86.47715381	80.36965	56.91519	21.912
s =	24	24	10.66	9.66	12.52	20
stirrups=	4.15	4.15	9.343339587	10.31056	7.955272	4.98
			22 S			
x (ft) =	0	8.15	16.3	24.45	32.6	40.75
Vs.req =	153.2192	90.64195	33.28500764	38.00528	38.74557	22.65773
Vs.act =	159.3778	105.4474	60.68405114	65.3296	56.1102	23.13548
s =	2.7	5.58	15.19	13.3	13.05	18.6
stirrups=	36.22222	17.52688	6.438446346	7.353383	7.494253	5.258065
			24 D			
x (ft) =	0	8.6	17.2	25.8	34.4	43
Vs.req =	-339.2562	-43.81766	39.08629367	49.03264	40.37012	22.17903
Vs.act =	18.92	60.46437	88.06896345	82.53411	58.71352	22.704
s =	24	24	10.93	9.76	12.61	20
stirrups=	4.3	4.3	9.441903019	10.57377	8.183981	5.16
			26 D			
x (ft) =	0	8.9	17.8	26.7	35.6	44.5
Vs.req =	-370.5407	-46.20671	38.74808448	49.03953	40.46218	22.81804
Vs.act =	19.58	62.33887	91.10455071	85.84927	60.42652	22.92293
s =	24	24	10.99	9.72	12.53	20.5
stirrups=	4.45	4.45	9.717925387	10.98765	8.523543	5.209756

continued

Table 8.3.1.5e, page 2

			28 D			
x (ft) =	0	9.2	18.4	27.6	36.8	46
Vs.req =	-400.7711	-48.16351	38.66012664	49.22063	40.67865	23.39101
Vs.act =	20.24	64.44018	94.53800582	89.41747	62.77526	23.69561
s =	24	24	10.99	9.65	12.43	20.5
stirrups=	4.6	4.6	10.04549591	11.44041	8.881738	5.385366
			30 D			
x (ft) =	0	9.5	19	28.5	38	47.5
Vs.req =	-429.9847	-49.72975	38.79571082	49.55823	41.00707	23.90688
Vs.act =	20.9	66.83407	98.40268518	93.28229	64.69938	23.88571
s =	24	24	10.92	9.56	12.29	21
stirrups=	4.75	4.75	10.43956044	11.92469	9.275834	5.428571
			32 D-1			
x (ft) =	0	9.7	19.4	29.1	38.8	48.5
Vs.req =	-290.466	-12.85209	66.23005876	67.54197	49.7417	24.26119
Vs.act =	21.34	114.7999	177.2830946	138.8351	79.40039	24.38857
s =	24	24	5.48	6.11	9.31	21
stirrups=	4.85	4.85	21.24087591	19.05074	12.50269	5.542857
			32 D-2			
x (ft) =	0	9.7	19.4	29.1	38.8	48.5
Vs.req =	-289.17	-12.61603	66.45281768	67.75108	49.96529	24.35995
Vs.act =	21.34	115.1422	177.90072	139.4672	79.74561	24.37696
s =	24	24	5.46	6.09	9.25	21.01
stirrups=	4.85	4.85	21.31868132	19.1133	12.58378	5.540219
			34 D-1			
x (ft) =	0	9.9	19.8	29.7	39.6	49.5
Vs.req =	-308.196	-16.46258	65.03241455	66.80676	49.17964	24.43789
Vs.act =	21.78	115.7944	179.0095104	140.8413	80.91666	25.0705
s =	24	24	5.56	6.15	9.36	20.85
stirrups=	4.95	4.95	21.36690647	19.31707	12.69231	5.697842
			34 D-2			
x (ft) =	0	9.9	19.8	29.7	39.6	49.5
Vs.req =	-304.2783	-15.76857	65.6861774	67.42066	49.83283	25.05334
Vs.act =	21.78	116.9931	181.328436	142.9945	82.74364	25.86442
s =	24	24	5.49	6.07	9.19	20.21
stirrups=	4.95	4.95	21.63934426	19.57166	12.92709	5.878278

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

SHEAR CAPACITY TABLES FOR G 72-T BULB GIRDER

Table 8.3.1.6a: Girder Spacing = 5 feet

			18 S			
x (ft) =	0	10.2	20.4	30.6	40.8	51
Vs.req =	47.75787	-1.756529	-15.38611339	13.42826	14.76287	-15.42757
Vs.act =	48.96	44.88	44.88	44.88	44.88	22.44
s =	11	24	24	24	24	24
stirrups=	11.12727	5.1	5.1	5.1	5.1	5.1
			20 D			
x (ft) =	0	10.7	21.4	32.1	42.8	53.5
Vs.req =	-330.8007	-47.37989	18.26493781	25.21638	18.0905	-14.1385
Vs.act =	23.54	47.08	49.39629291	49.39629	47.08	23.54
s =	24	24	24	21.85	24	24
stirrups=	5.35	5.35	5.35	5.87643	5.35	5.35
			22 D			
x (ft) =	0	11.1	22.2	33.3	44.4	55.5
Vs.req =	-362.8677	-49.65279	17.61955964	24.89296	18.41738	-13.8699
Vs.act =	24.42	48.84	50.93945701	50.93946	48.84	24.42
s =	24	24	24	22.1	24	24
stirrups=	5.55	5.55	5.55	6.027149	5.55	5.55
			22 S			
x (ft) =	0	11	22	33	44	55
Vs.req =	50.68044	-2.92776	-15.88655299	14.46133	16.09048	-13.54688
Vs.act =	52.8	48.4	48.4	48.4	48.4	24.2
s =	11	24	24	24	24	24
stirrups=	12	5.5	5.5	5.5	5.5	5.5
			24 D			
x (ft) =	0	11.55	23.1	34.65	46.2	57.75
Vs.req =	-392.4546	-49.91826	18.28277605	25.53194	18.89477	-13.61656
Vs.act =	25.41	50.82	53.74828996	53.74829	50.82	25.41
s =	24	24	24	21.52	24	24
stirrups=	5.775	5.775	5.775	6.44052	5.775	5.775
			26 D			
x (ft) =	0	11.9	23.8	35.7	47.6	59.5
Vs.req =	-422.6976	-52.56057	17.41168308	25.09334	18.5901	-13.30666
Vs.act =	26.18	52.36	54.96240953	54.96241	52.36	26.18
s =	24	24	24	21.83	24	24
stirrups=	5.95	5.95	5.95	6.541457	5.95	5.95
			26 S			
x (ft) =	0	11.75	23.5	35.25	47	58.75
Vs.req =	51.78865	-6.110834	-18.48910533	13.97496	16.15741	-12.70957
Vs.act =	56.4	51.7	51.7	51.7	51.7	25.85
s =	11	24	24	24	24	24
stirrups=	12.81818	5.875	5.875	5.875	5.875	5.875
			28 D			
x (ft) =	0	12.3	24.6	36.9	49.2	61.5
Vs.req =	-461.8877	-56.76107	14.9378233	22.87168	16.71011	-14.28319
Vs.act =	27.06	54.12	67.3978882	67.39789	54.12	27.06
s =	24	24	24	16.1	24	24
stirrups=	6.15	6.15	6.15	9.167702	6.15	6.15

continued

Table 8.3.1.6a: page 2

			30 D			
x (ft) =	0	12.7	25.4	38.1	50.8	63.5
Vs.req =	-486.4846	-56.35976	16.17096833	24.12351	17.72114	-13.69334
Vs.act =	27.94	55.88	57.14557491	57.14557	55.88	27.94
s =	24	24	24	22.96	24	24
stirrups=	6.35	6.35	6.35	6.637631	6.35	6.35
			32 D			
x (ft) =	0	13	26	39	52	65
Vs.req =	-515.2045	-59.6291	14.81871339	23.30081	17.12176	-13.49328
Vs.act =	28.6	57.2	57.5376054	57.53761	57.2	28.6
s =	24	24	24	23.72	24	24
stirrups=	6.5	6.5	6.5	6.576728	6.5	6.5
			34 D			
x (ft) =	0	13.3	26.6	39.9	53.2	66.5
Vs.req =	-540.9327	-61.46171	14.1171825	23.04467	16.9804	-13.1254
Vs.act =	29.26	58.52	58.67935484	58.67935	58.52	29.26
s =	24	24	24	23.87	24	24
stirrups=	6.65	6.65	6.65	6.686217	6.65	6.65
			36 D			
x (ft) =	0	13.6	27.2	40.8	54.4	68
Vs.req =	-565.8441	-61.96836	13.56345923	22.88569	16.90705	-12.79464
Vs.act =	29.92	59.84	59.92752194	59.92752	59.84	29.92
s =	24	24	24	23.93	24	24
stirrups=	6.8	6.8	6.8	6.819891	6.8	6.8
			38 D			
x (ft) =	0	13.9	27.8	41.7	55.6	69.5
Vs.req =	-590.0405	-62.25335	13.1340846	22.80568	16.88765	-12.50058
Vs.act =	30.58	61.16	61.26227425	61.26227	61.16	30.58
s =	24	24	24	23.92	24	24
stirrups=	6.95	6.95	6.95	6.973244	6.95	6.95
			42 D			
x (ft) =	0	14.3	28.6	42.9	57.2	71.5
Vs.req =	-637.4892	-67.59985	9.938506781	21.11847	15.80744	-11.57584
Vs.act =	31.46	62.92	62.92	62.92	62.92	31.46
s =	24	24	24	24	24	24
stirrups=	7.15	7.15	7.15	7.15	7.15	7.15

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.6b: Girder Spacing = 6 feet

			18 S			
x (ft) =	0	9.5	19	28.5	38	47.5
Vs.req =	71.66392	18.91503	-15.31711516	16.95064	18.80459	-8.069807
Vs.act =	71.65714	41.8	41.8	41.8	41.8	20.9
s =	7	24	24	24	24	24
stirrups=	16.28571	4.75	4.75	4.75	4.75	4.75
			20 D			
x (ft) =	0	10.1	20.2	30.3	40.4	50.5
Vs.req =	-319.7249	-45.98518	24.56515924	32.02199	24.67092	-6.592366
Vs.act =	22.22	48.87067	57.63731034	53.4122	44.64557	22.22
s =	24	24	20.01	17.21	23.78	24
stirrups=	5.05	5.05	6.056971514	7.042417	5.09672	5.05
			22 D			
x (ft) =	0	10.5	21	31.5	42	52.5
Vs.req =	-352.2233	-47.83278	24.28355336	31.97599	24.6497	-6.248026
Vs.act =	23.1	50.5184	59.6322268	55.53735	46.42352	23.1
s =	24	24	20.22	17.21	23.77	24
stirrups=	5.25	5.25	6.231454006	7.321325	5.300799	5.25
			22 S			
x (ft) =	0	10.4	20.8	31.2	41.6	52
Vs.req =	77.17119	19.16312	-12.04916509	20.63741	22.05696	-5.943102
Vs.act =	78.44571	45.76	45.76	45.76	45.76	22.88
s =	7	24	24	24	24	24
stirrups=	17.82857	5.2	5.2	5.2	5.2	5.2
			24 D			
x (ft) =	0	10.9	21.8	32.7	43.6	54.5
Vs.req =	-383.5899	-49.20564	24.29538381	32.14414	24.78634	-5.946595
Vs.act =	23.98	52.4852	62.16134095	58.04258	48.36644	23.98
s =	24	24	20.19	17.1	23.6	24
stirrups=	5.45	5.45	6.478454681	7.649123	5.542373	5.45
			26 D			
x (ft) =	0	11.25	22.5	33.75	45	56.25
Vs.req =	-414.3567	-51.54619	23.70008675	31.91924	24.64846	-5.582197
Vs.act =	24.75	53.52907	63.39445438	59.72105	49.85566	24.75
s =	24	24	20.64	17.16	23.66	24
stirrups=	5.625	5.625	6.540697674	7.867133	5.705833	5.625
			26 S			
x (ft) =	0	11.1	22.2	33.3	44.4	55.5
Vs.req =	79.32212	16.81708	-15.33718511	19.77131	21.89785	-5.0078
Vs.act =	83.72571	48.84	48.84	48.84	48.84	24.42
s =	7	24	24	24	24	24
stirrups=	19.02857	5.55	5.55	5.55	5.55	5.55
			28 D			
x (ft) =	0	11.6	23.2	34.8	46.4	58
Vs.req =	-455.1789	-57.25522	20.24185876	28.95165	22.1968	-6.525147
Vs.act =	25.52	51.04	57.28763485	57.28763	51.04	25.52
s =	24	24	24	19.28	24	24
stirrups=	5.8	5.8	5.8	7.219917	5.8	5.8

continued

Table 8.3.1.6b, page 2

			30 D			
x (ft) =	0	11.95	23.9	35.85	47.8	59.75
Vs.req =	-481.9187	-57.96355	20.83253983	29.74498	22.8808	-5.903391
Vs.act =	26.29	52.91278	60.50892874	60.17614	52.58	26.29
s =	24	24	23.7	18.62	24	24
stirrups=	5.975	5.975	6.050632911	7.701396	5.975	5.975
			32 D			
x (ft) =	0	12.25	24.5	36.75	49	61.25
Vs.req =	-512.2511	-61.06968	19.65279577	29.05663	22.38349	-5.666141
Vs.act =	26.95	53.9	60.95630915	60.95631	53.9	26.95
s =	24	24	24	19.02	24	24
stirrups=	6.125	6.125	6.125	7.728707	6.125	6.125
			34 D			
x (ft) =	0	12.5	25	37.5	50	62.5
Vs.req =	-541.4333	-64.96834	18.03123004	28.1285	21.74372	-5.28169
Vs.act =	27.5	55	61.25959079	61.25959	55	27.5
s =	24	24	24	19.55	24	24
stirrups=	6.25	6.25	6.25	7.672634	6.25	6.25
			36 D			
x (ft) =	0	12.8	25.6	38.4	51.2	64
Vs.req =	-567.7452	-66.85307	17.72204168	28.1623	21.82088	-4.917969
Vs.act =	28.16	56.32	62.9254321	62.92543	56.32	28.16
s =	24	24	24	19.44	24	24
stirrups=	6.4	6.4	6.4	7.901235	6.4	6.4
			38 D			
x (ft) =	0	13.1	26.2	39.3	52.4	65.5
Vs.req =	-592.3039	-68.50301	17.54421055	28.2802	21.95566	-4.593457
Vs.act =	28.82	57.64	64.67692068	64.67692	57.64	28.82
s =	24	24	24	19.29	24	24
stirrups=	6.55	6.55	6.55	8.1493	6.55	6.55
			42 D			
x (ft) =	0	13.5	27	40.5	54	67.5
Vs.req =	-640.9811	-74.26914	14.43924732	26.68485	20.94568	-3.631666
Vs.act =	29.7	59.4	65.09225422	65.09225	59.4	29.7
s =	24	24	24	20.14	24	24
stirrups=	6.75	6.75	6.75	8.043694	6.75	6.75

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

Table 8.3.1.6c: Girder Spacing = 7 feet

			18 S			
x (ft) =	0	8.9	17.8	26.7	35.6	44.5
Vs.req =	94.81897	39.15037	-11.84780045	20.30822	22.57711	-0.904925
Vs.act =	97.9	49.74175	39.16	39.16	39.16	19.58
s =	4.8	15.58	24	24	24	24
stirrups=	22.25	6.854942	4.45	4.45	4.45	4.45
			20 D			
x (ft) =	0	9.5	19	28.5	38	47.5
Vs.req =	-309.9066	-47.38779	28.73914808	37.20139	29.40473	0.747053
Vs.act =	20.9	50.23333	63.20234076	59.01186	46.04286	20.9
s =	24	24	17.1	14.81	19.95	24
stirrups=	4.75	4.75	6.666666667	7.697502	5.714286	4.75
			22 D			
x (ft) =	0	10	20	30	40	50
Vs.req =	-339.9722	-44.7094	31.58363345	39.47704	31.15798	1.273276
Vs.act =	22	55.97683	71.85344804	65.96172	50.08511	22
s =	24	24	15.54	13.94	18.8	24
stirrups=	5	5	7.722007722	8.608321	6.382979	5
			22 S			
x (ft) =	0	9.85	19.7	29.55	39.4	49.25
Vs.req =	102.4662	40.6358	-8.923960727	26.24252	27.54607	1.514679
Vs.act =	104.016	57.26754	44.66204244	47.12569	45.80364	21.67
s =	5	14.61	24	22.62	21.55	24
stirrups=	23.64	8.090349	4.925	5.225464	5.484919	4.925
			24 D			
x (ft) =	0	10.35	20.7	31.05	41.4	51.75
Vs.req =	-373.1386	-47.52176	30.71385841	39.00242	30.81898	1.61656
Vs.act =	22.77	56.98916	73.00411479	67.57737	51.56241	22.77
s =	24	24	15.97	14.09	18.98	24
stirrups=	5.175	5.175	7.777082029	8.814762	6.54373	5.175
			26 D			
x (ft) =	0	10.65	21.3	31.95	42.6	53.25
Vs.req =	-405.908	-51.44174	29.14220443	38.06384	30.14977	2.012019
Vs.act =	23.43	56.94132	72.5884599	68.15263	52.50549	23.43
s =	24	24	16.78	14.39	19.34	24
stirrups=	5.325	5.325	7.616209774	8.881167	6.608066	5.325
			26 S			
x (ft) =	0	10.5	21	31.5	42	52.5
Vs.req =	105.4887	39.0656	-13.08254082	24.86807	27.06682	2.558008
Vs.act =	110.88	59.9617	46.56170123	48.99832	48.63662	23.1
s =	5	15.04	24	23.63	21.71	24
stirrups=	25.2	8.37766	5.25	5.332205	5.803777	5.25
			28 D			
x (ft) =	0	11	22	33	44	55
Vs.req =	-446.8305	-57.02328	25.78604093	35.15731	27.73488	1.13068
Vs.act =	24.2	54.32448	66.69878863	63.65123	51.27692	24.2
s =	24	24	19.28	15.88	21.45	24
stirrups=	5.5	5.5	6.846473029	8.312343	6.153846	5.5

continued

Table 8.3.1.6c, page 2

			30 D			
x (ft) =	0	11.3	22.6	33.9	45.2	56.5
Vs.req =	-475.7787	-59.18804	25.49514997	35.31089	27.94844	1.779786
Vs.act =	24.86	55.67818	68.86920223	66.3144	53.12338	24.86
s =	24	24	19.36	15.68	21.11	24
stirrups=	5.65	5.65	7.004132231	8.647959	6.423496	5.65
			32 D			
x (ft) =	0	11.6	23.2	34.8	46.4	58
Vs.req =	-506.6391	-62.05701	24.54057254	34.79746	27.58764	2.062725
Vs.act =	25.52	56.02199	69.07126155	67.2703	54.22103	25.52
s =	24	24	20.08	15.88	21.34	24
stirrups=	5.8	5.8	6.932270916	8.765743	6.522962	5.8
			34 D			
x (ft) =	0	11.9	23.8	35.7	47.6	59.5
Vs.req =	-534.6368	-63.91452	24.34591338	34.94118	27.76019	2.506903
Vs.act =	26.18	57.34667	71.08534519	69.711	55.97232	26.18
s =	24	24	20.16	15.74	21.09	24
stirrups=	5.95	5.95	7.083333333	9.072427	6.770982	5.95
			36 D			
x (ft) =	0	12.15	24.3	36.45	48.6	60.75
Vs.req =	-563.6048	-67.42246	23.02963712	34.23705	27.28752	2.885343
Vs.act =	26.73	56.94762	70.33769163	70.15378	56.76371	26.73
s =	24	24	21.23	15.99	21.36	24
stirrups=	6.075	6.075	6.867640132	9.118199	6.825843	6.075
			38 D			
x (ft) =	0	12.4	24.8	37.2	49.6	62
Vs.req =	-591.8872	-70.67389	21.86016724	33.62816	26.8818	3.22476
Vs.act =	27.28	56.65281	69.73779442	70.69013	57.60515	27.28
s =	24	24	22.29	16.22	21.59	24
stirrups=	6.2	6.2	6.6756393	9.173859	6.89208	6.2
			42 D			
FAILED IN FLEXURE						

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi
2. Prestressing steel-0.5 in grade 270 low relaxation
3. Stirrup steel-two # 3 U legged grade 40(40ksi)
4. Slab thickness- 7.5 in

Table 8.3.1.6d: Girder Spacing = 8 feet

			18 S			
x (ft) =	0	8.35	16.7	25.05	33.4	41.75
Vs.req =	116.9066	58.76298	5.357253394	22.76337	25.61619	6.017356
Vs.act =	119.1568	60.84399	36.74	36.87882	36.87882	18.37
s =	3.7	10.38	24	24	23.82	24
stirrups=	27.08108	9.653179	4.175	4.175	4.206549	4.175
			20 D			
x (ft) =	0	8.95	17.9	26.85	35.8	44.75
Vs.req =	-299.9171	-49.81995	31.9600965	41.62849	33.51163	7.887415
Vs.act =	19.69	50.41562	66.41746059	62.67985	46.67801	19.69
s =	24	24	15.38	13.24	17.51	24
stirrups=	4.475	4.475	6.983094928	8.111782	6.133638	4.475
			22 D			
x (ft) =	0	9.45	18.9	28.35	37.8	47.25
Vs.req =	-330.2617	-45.98729	35.70811281	44.57962	35.80469	8.564622
Vs.act =	20.79	57.078	76.72235981	70.93314	51.28878	20.79
s =	24	24	13.75	12.34	16.36	24
stirrups=	4.725	4.725	8.247272727	9.189627	6.93154	4.725
			22 S			
x (ft) =	0	9.3	18.6	27.9	37.2	46.5
Vs.req =	126.131	61.30149	2.18987856	30.22831	31.79073	8.763294
Vs.act =	129.2211	71.18727	45.46203666	51.30305	46.76102	20.46
s =	3.8	9.68	24	19.64	18.67	24
stirrups=	29.36842	11.52893	4.65	5.682281	5.977504	4.65
			24 D			
x (ft) =	0	9.8	19.6	29.4	39.2	49
Vs.req =	-363.8631	-48.37343	35.21078158	44.389	35.69361	8.999982
Vs.act =	21.56	58.70573	78.94217452	73.36692	53.13047	21.56
s =	24	24	13.93	12.38	16.39	24
stirrups=	4.9	4.9	8.442211055	9.499192	7.175107	4.9
			26 D			
x (ft) =	0	10.15	20.3	30.45	40.6	50.75
Vs.req =	-395.5033	-49.86698	35.34934974	44.72993	36.00674	9.511747
Vs.act =	22.33	61.05254	82.47111478	76.85049	55.43191	22.33
s =	24	24	13.84	12.25	16.19	24
stirrups=	5.075	5.075	8.800578035	9.942857	7.523162	5.075
			26 S			
x (ft) =	0	9.95	19.9	29.85	39.8	49.75
Vs.req =	130.5246	60.70604	-2.633391213	29.37788	31.74764	9.977887
Vs.act =	131.34	76.16273	48.158	54.6505	50.2725	21.89
s =	4	9.68	24	20	18.51	24
stirrups=	29.85	12.33471	4.975	5.97	6.450567	4.975
			28 D			
x (ft) =	0	10.5	21	31.5	42	52.5
Vs.req =	-436.4399	-55.23839	32.15842091	41.93583	33.67294	8.701444
Vs.act =	23.1	58.96028	77.51317717	73.0281	54.47521	23.1
s =	24	24	15.46	13.31	17.67	24
stirrups=	5.25	5.25	8.150064683	9.466566	7.13073	5.25

continued

Table 8.3.1.6d, page 2

			30 D			
x (ft) =	0	10.8	21.6	32.4	43.2	54
Vs.req =	-465.8718	-57.06156	32.18112336	42.3377	34.08554	9.405798
Vs.act =	23.76	60.9334	80.76973314	76.53914	56.70281	23.76
s =	24	24	15.34	13.08	17.31	24
stirrups=	5.4	5.4	8.448500652	9.908257	7.487002	5.4
			32 D			
x (ft) =	0	11.05	22.1	33.15	44.2	55.25
Vs.req =	-498.9177	-61.7935	30.04543422	40.95312	33.06863	9.704706
Vs.act =	24.31	59.88561	78.79338753	75.99531	57.08753	24.31
s =	24	24	16.4	13.5	17.8	24
stirrups=	5.525	5.525	8.085365854	9.822222	7.449438	5.525
			34 D			
x (ft) =	0	11.3	22.6	33.9	45.2	56.5
Vs.req =	-529.2635	-65.44315	28.72901514	40.27289	32.62454	10.16561
Vs.act =	24.86	59.79208	78.60997596	76.91689	58.099	24.86
s =	24	24	17.08	13.66	17.95	24
stirrups=	5.65	5.65	7.93911007	9.926794	7.554318	5.65
			36 D			
x (ft) =	0	11.55	23.1	34.65	46.2	57.75
Vs.req =	-558.8008	-68.78081	27.59624741	39.71589	32.2688	10.58397
Vs.act =	25.41	59.82535	78.63870014	77.99079	59.17744	25.41
s =	24	24	17.72	13.79	18.06	24
stirrups=	5.775	5.775	7.821670429	10.05076	7.674419	5.775
			38 D			
x (ft) =	0	11.8	23.6	35.4	47.2	59
Vs.req =	-587.6187	-71.84648	26.61795325	39.25949	31.98372	10.96059
Vs.act =	25.96	59.98731	78.88259906	79.20149	60.3062	25.96
s =	24	24	18.31	13.89	18.14	24
stirrups=	5.9	5.9	7.733478973	10.19438	7.805954	5.9
			42 D			
FAILED IN FLEXURE						

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

Table 8.3.1.6e: Girder Spacing = 9 feet

			18 S			
x (ft) =	0	7.9	15.8	23.7	31.6	39.5
Vs.req =	138.8433	78.12988	22.22332385	25.90584	29.09703	12.78231
Vs.act =	139.04	70.78845	35.09210191	37.60338	37.27127	17.38
s =	3	7.81	24	23.55	20.97	24
stirrups=	31.6	12.13828	3.95	4.025478	4.520744	3.95
			20 D			
x (ft) =	0	8.45	16.9	25.35	33.8	42.25
Vs.req =	-289.5936	-52.99864	34.41706935	45.45205	37.10633	14.81855
Vs.act =	18.59	49.8337	68.05557867	65.032	46.81011	18.59
s =	24	24	14.28	12.12	15.81	24
stirrups=	4.225	4.225	7.100840336	8.366337	6.413662	4.225
			22 D			
x (ft) =	0	8.95	17.9	26.85	35.8	44.75
Vs.req =	-320.1542	-47.8607	39.19636834	49.16954	40.01272	15.67875
Vs.act =	19.69	57.43441	79.97497195	74.50925	51.96869	19.69
s =	24	24	12.52	11.19	14.64	24
stirrups=	4.475	4.475	8.57827476	9.597855	7.336066	4.475
			22 S			
x (ft) =	0	8.85	17.7	26.55	35.4	44.25
Vs.req =	149.6327	81.723	19.68219564	35.00119	36.55462	15.90009
Vs.act =	155.76	83.83364	47.02188679	56.32529	48.2434	19.47
s =	3	7.26	24	16.96	16.24	24
stirrups=	35.4	14.6281	4.425	6.261792	6.539409	4.425
			24 D			
x (ft) =	0	9.3	18.6	27.9	37.2	46.5
Vs.req =	-354.1324	-49.72698	39.1468394	49.31837	40.17563	16.22502
Vs.act =	20.46	59.64915	83.26814066	77.80427	54.18527	20.46
s =	24	24	12.53	11.14	14.56	24
stirrups=	4.65	4.65	8.906624102	10.01795	7.664835	4.65
			26 D			
x (ft) =	0	9.65	19.3	28.95	38.6	48.25
Vs.req =	-386.1699	-50.6632	39.75819217	50.02021	40.77934	16.83572
Vs.act =	21.23	62.65439	87.95589709	82.16228	56.86077	21.23
s =	24	24	12.3	10.95	14.3	24
stirrups=	4.825	4.825	9.414634146	10.57534	8.097902	4.825
			26 S			
x (ft) =	0	9.5	19	28.5	38	47.5
Vs.req =	155.3462	82.05986	15.46796085	34.75618	37.01104	17.30783
Vs.act =	167.2	90.95587	50.56292135	61.24982	52.4869	20.9
s =	3	7.16	24	16.91	15.88	24
stirrups=	38	15.92179	4.75	6.741573	7.178841	4.75
			28 D			
x (ft) =	0	10	20	30	40	50
Vs.req =	-427.1011	-55.74525	36.79182941	47.382	38.56432	16.11393
Vs.act =	22	61.08216	83.90389311	79.04079	56.21905	22
s =	24	24	13.51	11.78	15.43	24
stirrups=	5	5	8.8823094	10.18676	7.777058	5

continued

Table 8.3.1.6e, page 2

			30 D			
x (ft) =	0	10.2	20.4	30.6	40.8	51
Vs.req =	-460.6751	-61.94066	33.95514252	45.66815	37.37348	16.78901
Vs.act =	22.44	59.47989	81.43890068	78.52829	56.56928	22.44
s =	24	24	14.54	12.13	15.78	24
stirrups=	5.1	5.1	8.418156809	10.09068	7.756654	5.1
			32 D			
x (ft) =	0	10.5	21	31.5	42	52.5
Vs.req =	-492.43	-64.13007	33.60410435	45.62041	37.38305	17.19302
Vs.act =	23.1	60.89141	83.5339853	80.94257	58.3	23.1
s =	24	24	14.67	12.12	15.75	24
stirrups=	5.25	5.25	8.588957055	10.39604	8	5.25
			34 D			
x (ft) =	0	10.75	21.5	32.25	43	53.75
Vs.req =	-523.3435	-67.5698	32.50519022	45.11325	37.07854	17.70572
Vs.act =	23.65	61.2394	84.15216033	82.50956	59.5968	23.65
s =	24	24	15.1	12.19	15.79	24
stirrups=	5.375	5.375	8.543046358	10.58244	8.169728	5.375
			36 D			
x (ft) =	0	11	22	33	44	55
Vs.req =	-553.4198	-70.68096	31.59795529	44.73502	36.86628	18.17218
Vs.act =	24.2	61.74363	84.99461323	84.18722	60.93624	24.2
s =	24	24	15.47	12.24	15.81	24
stirrups=	5.5	5.5	8.532643827	10.78431	8.349146	5.5
			38 D			
FAILED IN FLEXURE						
			42 D			
FAILED IN FLEXURE						

Notes:

1. fc girder-6 ksi, fc slab-3.6 ksi

2. Prestressing steel-0.5 in grade 270 low relaxation

3. Stirrup steel-two # 3 U legged grade 40(40ksi)

4. Slab thickness- 7.5 in

STIRRUP DESIGN/ DETAILING TABLES

fc = 6ksi
fy = 40 ksi
2#3U legged stirrups
Av=0.22 in2

Table 8.3.2.1: Design Table for G 36-I Girder

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L (FT)	NUMBER OF STIRRUPS						TOTAL (L/2)
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	
5	8 D	43.5	3.0	3.0	3.0	3.0	3.0	3.0	18.0
	8 S	43	14.0	6.0	3.0	3.0	3.0	3.0	32
	10 D-1	50	3.0	3.0	3.0	4.0	3.0	3.0	19.0
	10 D-2	50	3.0	3.0	6.0	4.0	5.0	3.0	24.0
	12 D	56	3.0	3.0	4.0	5.0	4.0	3.0	22.0
	12 S	54.5	17.0	8.0	3.0	4.0	4.0	3.0	39.0
	14 D-1	61	3.0	3.0	9.0	9.0	6.0	3.0	33.0
	14 D-2	60.5	3.0	3.0	9.0	9.0	8.0	4.0	36.0
	16 D-1	64	4.0	4.0	9.0	10.0	7.0	4.0	38.0
	16 D-2	63.5	4.0	4.0	9.0	10.0	9.0	4.0	40.0
	16 S	61	20.0	8.0	3.0	4.0	5.0	3.0	43.0
	18 D-1	66	4.0	4.0	9.0	10.0	7.0	4.0	38.0
	18 D-2	65.5	4.0	4.0	9.0	10.0	9.0	5.0	41.0
6	8 D	39.5	2.0	2.0	2.0	2.0	2.0	2.0	12.0
	8 S	39	19.0	8.0	3.0	2.0	2.0	2.0	36.0
	10 D-1	45.5	3.0	3.0	3.0	4.0	3.0	3.0	19.0
	10 D-2	46	3.0	3.0	3.0	4.0	3.0	3.0	19.0
	12 D	51.5	3.0	3.0	4.0	5.0	4.0	3.0	22.0
	12 S	55.5	22.0	11.0	4.0	4.0	4.0	3.0	48.0
	14 D-1	50	2.8	2.8	10.2	9.8	6.7	3.2	35.6
	14 D-2	56.5	3.0	3.0	10.0	10.0	9.0	5.0	40.0
	16 D-1	56	3.0	3.0	11.0	11.0	7.0	4.0	39.0
	16 D-2	59	3.0	3.0	11.0	11.0	10.0	6.0	44.0
	16 S	57	24.0	13.0	3.0	6.0	6.0	4.0	56.0
	18 D-1	61.5	3.0	3.0	11.0	11.0	8.0	4.0	40.0
	18 D-2	61	3.0	3.0	11.0	11.0	10.0	6.0	44.0
7	8 D	37	2.0	2.0	2.0	3.0	2.0	2.0	13.0
	8 S	36	22.0	9.0	5.0	2.0	2.0	2.0	42.0
	10 D-1	42	3.0	3.0	3.0	4.0	3.0	2.0	18.0
	10 D-2	42.5	3.0	3.0	3.0	4.0	3.0	3.0	19.0
	12 D	47.5	3.0	3.0	5.0	6.0	5.0	4.0	26.0
	12 S	46	25.0	14.0	6.0	4.0	5.0	3.0	57.0
	14 D-1	52	3.0	3.0	11.0	10.0	7.0	4.0	38.0
	14 D-2	52	3.0	3.0	11.0	11.0	10.0	6.0	44.0
	16 D-1	55.5	3.0	3.0	12.0	12.0	8.0	4.0	42.0
	16 D-2	55	3.0	3.0	12.0	12.0	11.0	7.0	48.0
	16 S	53	27.0	16.0	6.0	6.0	6.0	4.0	65.0
	18 D-1	57.5	3.0	3.0	12.0	1.0	9.0	5.0	33.0
	18 D-2	57	3.0	3.0	12.0	12.0	11.0	7.0	48.0

Continued

Table 8.3.2.1: page 2

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L (FT)	NUMBER OF STIRRUPS						TOTAL (L/2)
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	
8	8 D	34.5	2.0	2.0	2.0	3.0	2.0	2.0	13.0
	8 S	34	28.0	11.0	8.0	2.0	2.0	2.0	53.0
	10 D-1	39.5	2.0	2.0	4.0	5.0	4.0	3.0	20.0
	10 D-2	41.5	2.0	2.0	5.0	6.0	5.0	4.0	24.0
	12 D	44	3.0	3.0	5.0	6.0	5.0	4.0	26.0
	12 S	43	30.0	16.0	8.0	5.0	5.0	3.0	67.0
	14 D-1	48.5	3.0	3.0	11.0	11.0	7.0	4.0	39.0
	14 D-2	48.5	3.0	3.0	12.0	11.0	12.0	7.0	48.0
	16 D-1	52	3.0	3.0	13.0	12.0	9.0	5.0	45.0
	16 D-2	52	3.0	3.0	13.0	13.0	11.0	8.0	51.0
	16 S	50	32.0	19.0	9.0	7.0	7.0	5.0	79.0
	18 D-1	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	18 D-2	53.5	3.0	3.0	13.0	13.0	12.0	9.0	53.0
9	8 D	32.5	2.0	2.0	2.0	3.0	2.0	2.0	13.0
	8 S	32	31.0	12.0	10.0	3.0	2.0	2.0	60.0
	10 D-1	37	2.0	2.0	4.0	5.0	4.0	2.0	19.0
	10 D-2	37	2.0	2.0	4.0	4.0	3.0	3.0	18.0
	12 D	41.5	2.0	2.0	5.0	6.0	5.0	4.0	24.0
	12 S	40.5	34.0	17.0	10.0	5.0	5.0	4.0	75.0
	14 D-1	45.5	3.0	3.0	12.0	11.0	8.0	5.0	42.0
	14 D-2	45.5	3.0	3.0	12.0	11.0	10.0	8.0	47.0
	16 D-1	49	3.0	3.0	14.0	13.0	9.0	5.0	47.0
	16 D-2	49	3.0	3.0	14.0	13.0	12.0	9.0	54.0
	16 S	47.5	36.0	22.0	12.0	8.0	8.0	5.0	91.0
	18 D-1	**FAILED**							
	18 D-2	**FAILED**							

fc = 6 ksi
fy = 40 ksi
2#3U legged stirrups
Av=0.22in2

Table 8.3.2.2: Design Table for G 42-I Girder

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L(FT)	NUMBER OF STIRRUPS						TOTAL (L/2)
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	
5	10 D	54.00	3.0	3.0	3.0	3.0	3.0	3.0	18.0
	12 D-1	61	3.0	3.0	6.0	7.0	5.0	3.0	27.0
	12 D-2	60.5	3.0	3.0	6.0	7.0	6.0	3.0	28.0
	12 S	59	15.0	6.0	3.0	3.0	3.0	3.0	33.0
	14 D-1	67	4.0	4.0	8.0	9.0	6.0	4.0	35.0
	14 D-2	66.5	4.0	4.0	8.0	9.0	8.0	4.0	37.0
	16 D	71	4.0	4.0	4.0	6.0	5.0	4.0	27.0
	16 S	68	19.0	6.0	4.0	5.0	5.0	4.0	43.0
	18 D	75	4.0	4.0	4.0	7.0	5.0	4.0	28.0
	20 D	78	4.0	4.0	4.0	7.0	5.0	4.0	28.0
	20 S	73.5	19.0	6.0	4.0	5.0	5.0	4.0	43.0
	24 D-1	83.5	5.0	5.0	10.0	11.0	8.0	5.0	44.0
	24 D-2	82.5	5.0	5.0	10.0	11.0	8.0	5.0	44.0
	26 D-1	85	5.0	5.0	10.0	11.0	8.0	5.0	44.0
	26 D-2	85	5.0	5.0	10.0	11.0	11.0	5.0	47.0
6	10 D	49.5	3.0	3.0	3.0	3.0	3.0	3.0	18.0
	12 D-1	55.5	3.0	3.0	6.0	7.0	5.0	3.0	27.0
	12 D-2	55.5	3.0	3.0	6.0	7.0	7.0	4.0	30.0
	12 S	54	19.0	9.0	3.0	3.0	4.0	3.0	41.0
	14 D-1	61	3.0	3.0	8.0	9.0	6.0	3.0	32.0
	14 D-2	61	3.0	3.0	7.0	8.0	5.0	3.0	29.0
	16 D	66.5	4.0	4.0	6.0	7.0	6.0	4.0	31.0
	16 S	63.5	22.0	11.0	4.0	6.0	6.0	4.0	53.0
	18 D	70	4.0	4.0	6.0	8.0	6.0	4.0	32.0
	20 D	72.5	4.0	4.0	5.0	7.0	6.0	4.0	30.0
	20 S	68.5	24.0	11.0	4.0	6.0	6.0	4.0	55.0
	24 D-1	78	4.0	4.0	12.0	13.0	9.0	4.0	46.0
	24 D-2	77	4.0	4.0	11.0	12.0	9.0	4.0	44.0
	26 D-1	79.5	4.0	4.0	12.0	13.0	9.0	4.0	46.0
	26 D-2	79	4.0	4.0	11.0	13.0	12.0	7.0	51.0
7	10 D	46	3.0	3.0	3.0	3.0	3.0	3.0	18.0
	12 D-1	51.5	3.0	3.0	7.0	7.0	5.0	3.0	28.0
	12 D-2	51	3.0	3.0	6.0	7.0	7.0	4.0	30.0
	12 S	50	24.0	11.0	5.0	3.0	4.0	3.0	50.0
	14 D-1	57	3.0	3.0	9.0	9.0	7.0	3.0	34.0
	14 D-2	56.5	3.0	3.0	8.0	8.0	6.0	3.0	31.0
	16 D	62	4.0	4.0	6.0	8.0	6.0	4.0	32.0
	16 S	59.5	27.0	14.0	5.0	6.0	6.0	5.0	63.0
	18 D	65.5	4.0	4.0	7.0	8.0	7.0	5.0	35.0
	20 D	68	4.0	4.0	6.0	8.0	7.0	5.0	34.0
	20 S	64.5	28.0	15.0	4.0	7.0	7.0	5.0	66.0
	24 D-1	73	4.0	4.0	13.0	14.0	10.0	5.0	50.0
	24 D-2	72.5	4.0	4.0	13.0	14.0	10.0	5.0	50.0
	26 D-1	**FAILED**							
	26 D-2	74.5	4.0	4.0	13.0	14.0	13.0	8.0	56.0

CONTINUED

Table 8.3.2.2: page 2

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L(FT)	NUMBER OF STIRRUPS						TOTAL (L/2)
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	
8	10 D	42.5	3.0	3.0	3.0	3.0	3.0	3.0	18.0
	12 D-1	48	3.0	3.0	7.0	7.0	5.0	3.0	28.0
	12 D-2	48	3.0	3.0	7.0	7.0	7.0	5.0	32.0
	12 S	46.5	28.0	13.0	7.0	3.0	4.0	3.0	58.0
	14 D-1	53	3.0	3.0	9.0	9.0	7.0	3.0	34.0
	14 D-2	52.5	3.0	3.0	8.0	8.0	6.0	3.0	31.0
	16 D	57.5	3.0	3.0	6.0	8.0	6.0	4.0	30.0
	16 S	55.5	34.0	17.0	7.0	6.0	7.0	5.0	76.0
	18 D	62	4.0	4.0	8.0	9.0	8.0	5.0	38.0
	20 D	64.5	4.0	4.0	7.0	9.0	8.0	5.0	37.0
	20 S	61	31.0	19.0	7.0	8.0	8.0	6.0	79.0
	24 D-1	69	4.0	4.0	14.0	15.0	11.0	6.0	54.0
	24 D-2	68.5	4.0	4.0	14.0	15.0	11.0	6.0	54.0
	26 D-1	**FAILED**							
	26 D-2	FAILED							
9	10 D	40	2.0	2.0	2.0	3.0	3.0	2.0	14.0
	12 D-1	45	3.0	3.0	7.0	7.0	5.0	3.0	28.0
	12 D-2	45	3.0	3.0	7.0	8.0	7.0	5.0	33.0
	12 S	44	33.0	15.0	8.0	4.0	4.0	4.0	68.0
	14 D-1	49.5	3.0	3.0	9.0	9.0	7.0	3.0	34.0
	14 D-2	49.5	3.0	3.0	8.0	8.0	6.0	3.0	31.0
	16 D	54	3.0	3.0	6.0	8.0	7.0	4.0	31.0
	16 S	52	36.0	19.0	10.0	6.0	7.0	6.0	84.0
	18 D	58	3.0	3.0	8.0	9.0	8.0	5.0	36.0
	20 D	61	3.0	3.0	8.0	10.0	8.0	6.0	38.0
	20 S	57.5	37.0	21.0	10.0	8.0	8.0	6.0	90.0
	24 D-1	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	24 D-2	64.5	4.0	4.0	15.0	15.0	11.0	6.0	55.0
	26 D-1	**FAILED**							
	26 D-2	**FAILED**							

fc = 6 ksi
fy = 40 ksi
2#3U legged stirrups
Av=0.22 in2

Table 8.3.2.3: Design Table for G 48-I Girder

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L (FT)	NUMBER OF STIRRUPS						TOTAL (L/2)
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	
5	12 D	64.5	4.0	4.0	4.0	4.0	4.0	4.0	24.0
	14 D	71	4.0	4.0	4.0	5.0	4.0	4.0	25.0
	14 S	68.5	12.0	4.0	4.0	4.0	4.0	4.0	32.0
	16 D	76	4.0	4.0	4.0	5.0	4.0	4.0	25.0
	16 S	72	12.0	4.0	4.0	4.0	4.0	4.0	32.0
	18 D	79.5	4.0	4.0	4.0	6.0	4.0	4.0	26.0
	20 D	83	5.0	5.0	5.0	5.0	5.0	5.0	30.0
	20 S	79	14.0	4.0	4.0	4.0	4.0	4.0	34.0
	22 D	86	5.0	5.0	5.0	6.0	5.0	5.0	31.0
	24 D	89.5	5.0	5.0	5.0	6.0	5.0	5.0	31.0
	24 S	86.5	15.0	5.0	5.0	5.0	5.0	5.0	40.0
	26 D	92	5.0	5.0	5.0	6.0	5.0	5.0	31.0
	28 D	95	5.0	5.0	5.0	6.0	5.0	5.0	31.0
	30 D	96	5.0	5.0	5.0	7.0	5.0	5.0	32.0
6	12 D	59.5	3.0	3.0	3.0	4.0	3.0	3.0	19.0
	14 D	65.5	4.0	4.0	4.0	5.0	4.0	4.0	25.0
	14 S	63	17.0	6.0	4.0	4.0	4.0	4.0	39.0
	16 D	71	4.0	4.0	5.0	6.0	5.0	4.0	28.0
	16 S	68	18.0	6.0	4.0	5.0	5.0	4.0	42.0
	18 D	74.5	4.0	4.0	5.0	7.0	5.0	4.0	29.0
	20 D	78	4.0	4.0	4.0	6.0	5.0	4.0	27.0
	20 S	74	19.0	6.0	4.0	5.0	5.0	4.0	43.0
	22 D	81	4.0	4.0	5.0	7.0	6.0	4.0	30.0
	24 D	83.5	5.0	5.0	5.0	7.0	6.0	5.0	33.0
	24 S	81.5	22.0	6.0	4.0	5.0	6.0	4.0	47.0
	26 D	86.5	5.0	5.0	5.0	8.0	6.0	5.0	34.0
	28 D	89	5.0	5.0	5.0	8.0	6.0	5.0	34.0
	30 D	90	5.0	5.0	5.0	8.0	7.0	5.0	35.0
7	12 D	55	3.0	3.0	3.0	4.0	3.0	3.0	19.0
	14 D	60.5	3.0	3.0	3.0	5.0	4.0	3.0	21.0
	14 S	58.5	22.0	9.0	3.0	4.0	4.0	3.0	45.0
	16 D	66	4.0	4.0	5.0	7.0	5.0	4.0	29.0
	16 S	63	22.0	9.0	4.0	5.0	5.0	4.0	49.0
	18 D	70	4.0	4.0	5.0	7.0	6.0	4.0	30.0
	20 D	73.5	4.0	4.0	5.0	7.0	6.0	4.0	30.0
	20 S	70	23.0	10.0	4.0	6.0	6.0	4.0	53.0
	22 D	76.5	4.0	4.0	6.0	8.0	7.0	4.0	33.0
	24 D	79	4.0	4.0	6.0	8.0	7.0	4.0	33.0
	24 S	76.5	27.0	11.0	4.0	6.0	7.0	4.0	59.0
	26 D	81.5	4.0	4.0	6.0	9.0	7.0	4.0	34.0
	28 D	84	5.0	5.0	6.0	9.0	7.0	5.0	37.0
	30 D	84.5	5.0	5.0	5.0	9.0	7.0	5.0	36.0

continued

Table 8.3.2.3: page 2

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L (FT)	NUMBER OF STIRRUPS						TOTAL (L/2)
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	
8	12 D	51.5	3.0	3.0	3.0	4.0	3.0	3.0	19.0
	14 D	56.5	3.0	3.0	3.0	5.0	4.0	3.0	21.0
	14 S	54.5	26.0	11.0	3.0	4.0	4.0	3.0	51.0
	16 D	61.5	3.0	3.0	5.0	7.0	5.0	4.0	27.0
	16 S	59	27.0	12.0	3.0	5.0	6.0	4.0	57.0
	18 D	66.5	4.0	4.0	6.0	8.0	7.0	4.0	33.0
	20 D	70	4.0	4.0	6.0	8.0	7.0	4.0	33.0
	20 S	66.5	29.0	14.0	4.0	7.0	7.0	5.0	66.0
	22 D	72.5	4.0	4.0	7.0	9.0	7.0	4.0	35.0
	24 D	74.5	4.0	4.0	6.0	9.0	7.0	4.0	34.0
	24 S	72.5	31.0	15.0	4.0	7.0	7.0	5.0	69.0
	26 D	77	4.0	4.0	6.0	9.0	8.0	5.0	36.0
	28 D	79.5	4.0	4.0	6.0	10.0	8.0	5.0	37.0
	30 D	80	4.0	4.0	6.0	10.0	8.0	5.0	37.0
9	12 D	48.5	3.0	3.0	3.0	4.0	3.0	3.0	19.0
	14 D	53.5	3.0	3.0	4.0	5.0	5.0	4.0	24.0
	14 S	51.5	31.0	13.0	6.0	4.0	4.0	4.0	62.0
	16 D	58	3.0	3.0	5.0	7.0	6.0	4.0	28.0
	16 S	55.5	32.0	15.0	6.0	5.0	6.0	4.0	68.0
	18 D	62.5	4.0	4.0	7.0	8.0	7.0	5.0	35.0
	20 D	66	4.0	4.0	7.0	9.0	7.0	5.0	36.0
	20 S	63	35.0	17.0	6.0	7.0	8.0	6.0	79.0
	22 D	68.5	4.0	4.0	7.0	10.0	8.0	6.0	39.0
	24 D	71	4.0	4.0	7.0	10.0	8.0	6.0	39.0
	24 S	68.5	36.0	19.0	5.0	7.0	8.0	6.0	81.0
	26 D	73	4.0	4.0	7.0	10.0	8.0	5.0	38.0
	28 D	75	4.0	4.0	6.0	10.0	8.0	5.0	37.0
	30 D	**FAILED**							

fc = 6 ksi
fy = 40 ksi
2#3U legged stirrups
Av=0.22 in2

Table 8.3.2.4: Design Table for G 54-I Girder

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L(FT)	NUMBER OF STIRRUPS						TOTAL (L/2)
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	
5	12 D	69	4.0	4.0	4.0	4.0	4.0	4.0	24.0
	14 D	76	4.0	4.0	4.0	4.0	4.0	4.0	24.0
	16 D	82.5	5.0	5.0	5.0	6.0	5.0	5.0	31.0
	16 S	80	14.0	4.0	4.0	4.0	4.0	4.0	34.0
	18 D	86.5	5.0	5.0	5.0	6.0	5.0	5.0	31.0
	20 D	90	5.0	5.0	5.0	6.0	5.0	5.0	31.0
	20 S	86.5	15.0	5.0	5.0	5.0	5.0	5.0	40.0
	22 D	94	5.0	5.0	5.0	7.0	5.0	5.0	32.0
	24 D	97	5.0	5.0	5.0	7.0	5.0	5.0	32.0
	24 S	94	17.0	5.0	5.0	5.0	5.0	5.0	42.0
	26 D	100.5	5.0	5.0	5.0	7.0	5.0	5.0	32.0
	28 D	103.5	6.0	6.0	6.0	7.0	6.0	6.0	37.0
	30 D-1	106	6.0	6.0	12.0	12.0	8.0	6.0	50.0
	30 D-2	106	6.0	6.0	12.0	12.0	8.0	6.0	50.0
6	12 D	63.5	4.0	4.0	4.0	4.0	4.0	4.0	24.0
	14 D	70	4.0	4.0	4.0	5.0	4.0	4.0	25.0
	16 D	76	4.0	4.0	4.0	6.0	5.0	4.0	27.0
	16 S	74	19.0	8.0	4.0	4.0	5.0	4.0	44.0
	18 D	81	4.0	4.0	5.0	7.0	6.0	4.0	30.0
	20 D	84.5	5.0	5.0	5.0	7.0	6.0	5.0	33.0
	20 S	81.5	21.0	8.0	4.0	5.0	6.0	4.0	48.0
	22 D	88	5.0	5.0	6.0	8.0	6.0	5.0	35.0
	24 D	91	5.0	5.0	6.0	8.0	6.0	5.0	35.0
	24 S	88	22.0	12.0	5.0	5.0	6.0	5.0	55.0
	26 D	94	5.0	5.0	5.0	8.0	6.0	5.0	34.0
	28 D	97	5.0	5.0	5.0	8.0	7.0	5.0	35.0
	30 D-1	99.5	5.0	5.0	14.0	14.0	9.0	5.0	52.0
	30 D-2	99.5	5.0	5.0	14.0	14.0	9.0	5.0	52.0
7	12 D	58.5	3.0	3.0	3.0	3.0	3.0	3.0	18.0
	14 D	65	4.0	4.0	4.0	5.0	4.0	4.0	25.0
	16 D	70.5	4.0	4.0	4.0	6.0	5.0	4.0	27.0
	16 S	69	24.0	11.0	4.0	5.0	5.0	4.0	53.0
	18 D	76	4.0	4.0	6.0	8.0	6.0	4.0	32.0
	20 D	79.5	4.0	4.0	6.0	8.0	6.0	4.0	32.0
	20 S	7	25.0	12.0	4.0	6.0	7.0	4.0	58.0
	22 D	83	5.0	5.0	7.0	9.0	7.0	5.0	38.0
	24 D	86	5.0	5.0	7.0	9.0	7.0	5.0	38.0
	24 S	83	27.0	12.0	5.0	6.0	7.0	5.0	62.0
	26 D	89	5.0	5.0	7.0	9.0	7.0	5.0	38.0
	28 D	91.5	5.0	5.0	7.0	9.0	7.0	5.0	38.0
	30 D-1	94	5.0	5.0	15.0	15.0	10.0	5.0	55.0
	30 D-2	94	5.0	5.0	16.0	15.0	11.0	5.0	57.0

continued

Table 8.3.2.4: page 2

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L(FT)	NUMBER OF STIRRUPS						TOTAL
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	(L/2)
8	12 D	55	3.0	3.0	3.0	4.0	3.0	3.0	19.0
	14 D	60.5	3.0	3.0	3.0	5.0	4.0	3.0	21.0
	16 D	66	4.0	4.0	5.0	7.0	5.0	4.0	29.0
	16 S	64.5	29.0	13.0	5.0	5.0	5.0	4.0	61.0
	18 D	71.5	4.0	3.6	6.0	8.0	7.0	5.0	33.6
	20 D	75.5	4.0	4.0	7.0	9.0	7.0	5.0	36.0
	20 S	73	32.0	16.0	5.0	7.0	7.0	5.0	72.0
	22 D	78.5	4.0	4.0	7.0	9.0	8.0	5.0	37.0
	24 D	81.5	4.0	4.0	8.0	10.0	8.0	5.0	39.0
	24 S	79	32.0	17.0	4.0	7.0	8.0	6.0	74.0
	26 D	84	5.0	5.0	7.0	10.0	8.0	5.0	40.0
	28 D	86.5	5.0	5.0	7.0	10.0	8.0	5.0	40.0
	30 D-1	89	5.0	5.0	17.0	16.0	11.0	5.0	59.0
	30 D-2	89	5.0	5.0	17.0	17.0	11.0	6.0	61.0
9	12 D	51.5	3.0	3.0	3.0	4.0	3.0	3.0	19.0
	14 D	57	3.0	3.0	3.0	5.0	4.0	4.0	22.0
	16 D	62	4.0	4.0	5.0	7.0	5.0	5.0	30.0
	16 S	60.5	33.0	16.0	7.0	5.0	5.0	5.0	71.0
	18 D	67	4.0	4.0	6.0	8.0	7.0	5.0	34.0
	20 D	71.5	4.0	4.0	8.0	10.0	8.0	6.0	40.0
	20 S	69	36.0	19.0	8.0	8.0	8.0	6.0	85.0
	22 D	74.5	4.0	4.0	8.0	10.0	8.0	6.0	40.0
	24 D	77	4.0	4.0	8.0	10.0	8.0	6.0	40.0
	24 S	75	38.0	20.0	8.0	8.0	8.0	6.0	88.0
	26 D	80	4.0	4.0	8.0	11.0	9.0	6.0	42.0
	28 D	82	5.0	5.0	8.0	11.0	9.0	6.0	44.0
	30 D-1	84	5.0	5.0	17.0	17.0	12.0	6.0	62.0
	30 D-2	84	5.0	5.0	17.0	17.0	12.0	6.0	62.0

fc = 6 ksi
fy = 40 ksi
2#3U legged stirrups
Av=0.22 in2

Table 8.3.2.5: Design Table for G 63-T Bulb Girder

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L(FT)	NUMBER OF STIRRUPS						TOTAL (L/2)
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	
5	14 S	82	12.0	5.0	5.0	5.0	5.0	5.0	37.0
	18 D	95	5.0	5.0	5.0	6.0	5.0	5.0	31.0
	18 S	95	14.0	5.0	5.0	5.0	5.0	5.0	39.0
	20 D	100	5.0	5.0	5.0	7.0	5.0	5.0	32.0
	22 D	104	6.0	6.0	6.0	7.0	6.0	6.0	37.0
	22 S	102	17.0	6.0	6.0	6.0	6.0	6.0	47.0
	24 D	108	6.0	6.0	6.0	8.0	6.0	6.0	38.0
	26 D	111	6.0	6.0	6.0	7.0	6.0	6.0	37.0
	28 D	115	6.0	6.0	6.0	8.0	6.0	6.0	38.0
	30 D	118	6.0	6.0	6.0	8.0	6.0	6.0	38.0
	32 D-1	121	6.0	6.0	16.0	14.0	9.0	6.0	57.0
	32 D-2	121	6.0	6.0	16.0	14.0	9.0	6.0	57.0
	34 D-1	123.5	7.0	7.0	16.0	15.0	9.0	7.0	61.0
	34 D-2	123.5	7.0	7.0	16.0	15.0	9.0	7.0	61.0
6	14 S	75.5	17.0	5.0	4.0	4.0	4.0	4.0	38.0
	18 D	88.5	5.0	5.0	6.0	7.0	5.0	5.0	33.0
	18 S	88.5	20.0	7.0	5.0	5.0	5.0	5.0	47.0
	20 D	94	5.0	5.0	7.0	8.0	6.0	5.0	36.0
	22 D	98	5.0	5.0	7.0	8.0	6.0	5.0	36.0
	22 S	96	20.0	7.0	5.0	6.0	6.0	5.0	49.0
	24 D	101	5.0	5.0	7.0	8.0	6.0	5.0	36.0
	26 D	105	6.0	6.0	8.0	9.0	7.0	6.0	42.0
	28 D	108	6.0	6.0	8.0	9.0	7.0	6.0	42.0
	30 D	111	6.0	6.0	8.0	9.0	7.0	6.0	42.0
	32 D-1	113.5	6.0	6.0	17.0	16.0	10.0	6.0	61.0
	32 D-2	113.5	6.0	6.0	18.0	16.0	10.0	6.0	62.0
	34 D-1	116.5	6.0	6.0	18.0	16.0	10.0	6.0	62.0
	34 D-2	116	6.0	6.0	18.0	16.0	10.0	6.0	62.0
7	14 S	70.5	22.0	8.0	4.0	4.0	4.0	4.0	46.0
	18 D	82.5	5.0	5.0	6.0	7.0	6.0	5.0	34.0
	18 S	82.5	25.0	10.0	5.0	5.0	5.0	5.0	55.0
	20 D	88	5.0	5.0	8.0	9.0	7.0	5.0	39.0
	22 D	92	5.0	5.0	8.0	9.0	7.0	5.0	39.0
	22 S	90.5	25.0	11.0	5.0	6.0	7.0	5.0	59.0
	24 D	96	5.0	5.0	9.0	10.0	7.0	5.0	41.0
	26 D	99	5.0	5.0	9.0	10.0	8.0	5.0	42.0
	28 D	102	6.0	6.0	9.0	10.0	8.0	6.0	45.0
	30 D	105	6.0	6.0	9.0	10.0	8.0	6.0	45.0
	32 D-1	107.5	6.0	6.0	19.0	17.0	11.0	6.0	65.0
	32 D-2	107.5	6.0	6.0	19.0	17.0	11.0	6.0	65.0
	34 D-1	110	6.0	6.0	20.0	18.0	11.0	6.0	67.0
	34 D-2	110	6.0	6.0	20.0	18.0	12.0	6.0	68.0

continued

Table 8.3.2.5: page 2

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L(FT)	NUMBER OF STIRRUPS						TOTAL (L/2)
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	
8	14 S	66	27.0	12.0	4.0	4.0	4.0	4.0	55.0
	18 D	77.5	4.0	4.0	6.0	8.0	6.0	4.0	32.0
	18 S	77.5	31.0	13.0	4.0	5.0	6.0	4.0	63.0
	20 D	83	5.0	5.0	8.0	9.0	7.0	5.0	39.0
	22 D	91	5.0	5.0	9.0	10.0	8.0	5.0	42.0
	22 S	86	31.0	15.0	5.0	7.0	7.0	5.0	70.0
	24 D	91	5.0	5.0	10.0	11.0	8.0	5.0	44.0
	26 D	94	5.0	5.0	10.0	11.0	8.0	5.0	44.0
	28 D	97	5.0	5.0	10.0	11.0	9.0	5.0	45.0
	30 D	99.5	5.0	5.0	10.0	11.0	9.0	5.0	45.0
	32 D-1	102	6.0	6.0	21.0	18.0	12.0	6.0	69.0
	32 D-2	102	6.0	6.0	21.0	19.0	12.0	6.0	70.0
	34 D-1	104	6.0	6.0	21.0	19.0	12.0	6.0	70.0
	34 D-2	104	6.0	6.0	21.0	19.0	12.0	6.0	70.0
9	14 S	62	30.0	15.0	5.0	4.0	4.0	4.0	62.0
	18 D	73	4.0	4.0	6.0	8.0	6.0	5.0	33.0
	18 S	73	35.0	15.0	6.0	5.0	6.0	5.0	72.0
	20 D	78	3.9	4.0	8.0	9.0	7.0	5.0	36.9
	22 D	86	5.0	5.0	10.0	11.0	8.0	5.0	44.0
	22 S	81.5	37.0	18.0	7.0	8.0	8.0	6.0	84.0
	24 D	86	5.0	5.0	10.0	11.0	9.0	6.0	46.0
	26 D	89	5.0	5.0	10.0	11.0	9.0	6.0	46.0
	28 D	92	5.0	5.0	10.0	12.0	9.0	6.0	47.0
	30 D	95	5.0	5.0	11.0	12.0	10.0	6.0	49.0
	32 D-1	97	5.0	5.0	22.0	19.0	13.0	6.0	70.0
	32 D-2	97	5.0	5.0	22.0	20.0	13.0	6.0	71.0
	34 D-1	99	5.0	5.0	22.0	20.0	13.0	6.0	71.0
	34 D-2	99	5.0	5.0	22.0	20.0	13.0	6.0	71.0

fc = 6 ksi
fy = 40 ksi
2#3U legged stirrups
Av=0.22 in2

Table 8.3.2.6: Design Table for G 72-T Bulb Girder

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L(FT)	NUMBER OF STIRRUPS						TOTAL (L/2)
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	
5	18 S	102	12.00	6.00	6.00	6.00	6.00	6.00	42.00
	20 D	101	6.00	6.00	6.00	6.00	6.00	6.00	36.00
	22 D	111	6.00	6.00	6.00	6.00	6.00	6.00	36.00
	22 S	110	12.00	6.00	6.00	6.00	6.00	6.00	42.00
	24 D	115.5	6.00	6.00	6.00	7.00	6.00	6.00	37.00
	26 D	119	6.00	6.00	6.00	7.00	6.00	6.00	37.00
	26 S	117.5	13.00	6.00	6.00	6.00	6.00	6.00	43.00
	28 D	123	7.00	7.00	7.00	8.00	7.00	7.00	43.00
	30 D	127	7.00	7.00	7.00	7.00	7.00	7.00	42.00
	32 D	130	7.00	7.00	7.00	7.00	7.00	7.00	42.00
	34 D	133	7.00	7.00	7.00	7.00	7.00	7.00	42.00
	36 D	136	7.00	7.00	7.00	7.00	7.00	7.00	42.00
	38 D	139	7.00	7.00	7.00	7.00	7.00	7.00	42.00
	42 D	143	8.00	8.00	8.00	8.00	8.00	8.00	48.00
6	18 S	95	17.00	5.00	5.00	5.00	5.00	5.00	42.00
	20 D	95	5.00	5.00	6.00	7.00	6.00	5.00	34.00
	22 D	105	6.00	6.00	7.00	8.00	6.00	6.00	39.00
	22 S	104	18.00	6.00	6.00	6.00	6.00	6.00	48.00
	24 D	109	6.00	6.00	7.00	8.00	6.00	6.00	39.00
	26 D	112.5	6.00	6.00	7.00	8.00	6.00	6.00	39.00
	26 S	111	19.00	6.00	6.00	6.00	6.00	6.00	49.00
	28 D	116	6.00	6.00	6.00	8.00	6.00	6.00	38.00
	30 D	119.5	6.00	6.00	6.00	8.00	6.00	6.00	38.00
	32 D	122.5	7.00	7.00	7.00	8.00	7.00	7.00	43.00
	34 D	125	7.00	7.00	7.00	8.00	7.00	7.00	43.00
	36 D	128	7.00	7.00	7.00	8.00	7.00	7.00	43.00
	38 D	131	7.00	7.00	7.00	9.00	7.00	7.00	44.00
	42 D	135	7.00	7.00	7.00	8.00	7.00	7.00	43.00
7	18 S	89	23.00	7.00	5.00	5.00	5.00	5.00	50.00
	20 D	89.5	5.00	5.00	7.00	8.00	6.00	5.00	36.00
	22 D	100	5.00	5.00	8.00	9.00	7.00	5.00	39.00
	22 S	98.5	24.00	8.00	5.00	6.00	6.00	5.00	54.00
	24 D	103.5	6.00	6.00	8.00	9.00	7.00	6.00	42.00
	26 D	106.5	6.00	6.00	8.00	9.00	7.00	6.00	42.00
	26 S	105	26.00	9.00	6.00	6.00	6.00	6.00	59.00
	28 D	110	6.00	6.00	7.00	9.00	7.00	6.00	41.00
	30 D	113	6.00	6.00	7.00	9.00	7.00	6.00	41.00
	32 D	116	6.00	6.00	7.00	9.00	7.00	6.00	41.00
	34 D	119	6.00	6.00	7.00	9.00	7.00	6.00	41.00
	36 D	121.5	6.00	6.00	7.00	10.00	7.00	6.00	42.00
	38 D	124	7.00	7.00	7.00	10.00	7.00	7.00	45.00
	42 D	**FAILED**							

continued

Table 8.3.2.6: page 2

GIRDER SPACING(FT)	STRAND PATTERN	SPAN L(FT)	NUMBER OF STIRRUPS						TOTAL (L/2)
			0.0L	0.1L	0.2L	0.3L	0.4L	0.5L	
8	18 S	83.5	27.00	10.00	5.00	5.00	5.00	5.00	57.00
	20 D	89.5	5.00	5.00	7.00	9.00	7.00	5.00	38.00
	22 D	94.5	5.00	5.00	9.00	10.00	7.00	5.00	41.00
	22 S	93	30.00	12.00	5.00	6.00	6.00	5.00	64.00
	24 D	98	5.00	5.00	9.00	10.00	8.00	5.00	42.00
	26 D	101.5	5.00	5.00	9.00	10.00	8.00	5.00	42.00
	26 S	99.5	30.00	13.00	5.00	6.00	7.00	5.00	66.00
	28 D	105	6.00	6.00	9.00	10.00	8.00	6.00	45.00
	30 D	108	6.00	6.00	9.00	10.00	8.00	6.00	45.00
	32 D	110.5	6.00	6.00	8.00	9.00	8.00	6.00	43.00
	34 D	113	6.00	6.00	8.00	10.00	8.00	6.00	44.00
	36 D	115.5	6.00	6.00	8.00	10.00	8.00	6.00	44.00
	38 D	118	6.00	6.00	8.00	11.00	8.00	6.00	45.00
	42 D	**FAILED**							
9	18 S	79	32.00	13.00	4.00	4.00	5.00	4.00	62.00
	20 D	84.5	5.00	5.00	8.00	9.00	7.00	5.00	39.00
	22 D	89.5	5.00	5.00	9.00	10.00	8.00	5.00	42.00
	22 S	88.5	36.00	15.00	5.00	7.00	7.00	5.00	75.00
	24 D	93	5.00	5.00	9.00	10.00	8.00	5.00	42.00
	26 D	96.5	5.00	5.00	10.00	11.00	9.00	5.00	45.00
	26 S	95	38.00	16.00	5.00	7.00	8.00	5.00	79.00
	28 D	100	5.00	5.00	9.00	11.00	8.00	5.00	43.00
	30 D	102	6.00	6.00	9.00	10.00	8.00	6.00	45.00
	32 D	105	6.00	6.00	9.00	11.00	8.00	6.00	46.00
	34 D	107.5	6.00	6.00	9.00	11.00	9.00	6.00	47.00
	36 D	110	6.00	6.00	9.00	11.00	9.00	6.00	47.00
	38 D	**FAILED**							
	42 D	**FAILED**							

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