CHAPTER 6

6.0 STUB-GIRDER FLOOR CONSTRUCTION

6.1 INTRODUCTION

About 1970, a special composite girder was introduced in the U.S. construction market. This unique steel-concrete composite structural system was dubbed the "stub-girder" by its principal proponent, Colaco(6.1). The structural arrangement, Fig. 6.1, offered mechanical-structural integration through "natural" openings, and a saving in steel mass due to both the efficiency of the composite girder and the combination cantilever (or Gerber) design and composite design of the beams. The stub-girder system has since seen use by other consultants in the U.S.. A limited number of project oriented load tests were also carried out in the U.S. to supplement theoretical analyses.

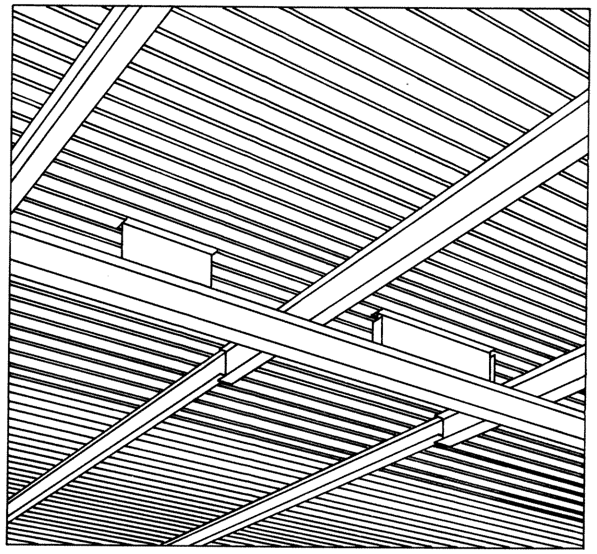


Figure 6.1
Stub-Girder Floor System

In Canada, this structural system has been the subject of several research projects, including comprehensive full-scale tests, and the Canadian research has resulted in several significant changes to the original concept. These changes include steel girder section depths, stiffening of stubs, and slab reinforcement, all of which will be discussed in this chapter. Several projects have now been designed by Canadian consulting engineers and built incorporating some of the results from this Canadian research.

The Stub-Girder System

The stub-girder floor system is basically a gravity-load-carrying floor framing system, although some adaptations to include provision for lateral forces will be discussed later. Stub-girders are vierendeel-girder type assemblies, consisting of a steel W-shape bottom flange or chord, and a

TABLE 6.1 A PARTIAL LIST OF STUB-GIRDER STRUCTURES IN NORTH AMERICA

Project Name	No. of Storeys	Approximate Floor Area (m^2)	Ref. No.
First International Building Dallas	51	176 000	6.8
Mercantile Center St. Louis	35	70 000	6.9
101 Marietta Building Atlanta	35		6.9
Town Center Tower Southfield	32	48 000	6.9
Cullen Center, Dresser Tower Houston	40	93 000	6.1
One Allen Center Building Houston	34	88 000	6.10
Pennzoil Place (twin towers) Houston	37	167 000	6.11
Georgia Power Company Headquarters Atlanta	24	71 000	6.16
One Houston Center Houston	48	100 000	6.12
First City Bank Building Houston	50	130 000	6.13
Nova Corporation Head Office Calgary	37	70 000	6.7
101 California Building San Francisco	48		6.14
ManuLife Place Edmonton	33	112 000	6.15
NRC Building Boucherville, Quebec	2	7 800	
401 West Georgia Vancouver	22	28 000	6.20

concrete deck-slab top flange or chord, with intermittent connections consisting of short lengths of W-shape (known as stubs) connected to both chords to transfer the shear between the two elements. Secondary framing passes through the vierendeel openings and these members are also connected to both top and bottom chords. Ideally, stub-girders span about 12 metres (usually core to exterior wall in a conventional office building) with the secondary framing or floor beams spanning about 9 metres. The system is very versatile, particularly with respect to secondary framing spans with beam depths being adjusted to the required structural configuration and mechanical requirements. Overall girder depths vary only slightly, by virtue of the beam depth (thus stub depth) variation. Traditionally, Canadian research and construction have concentrated on a 310 mm deep bottom chord while most U.S. projects have used 360 mm sections. For a span of greater than 13.5 metres, stub-girders tend to become impractical, with the slab design becoming critical. Girder spans down to 8 metres are worthy of consideration if openings are necessary, or if continuous beam spans are beneficial.

The floor beams, ranging from about 310 to 460 mm in depth, are placed over girders between stubs at about 2.5 to 3.5 metre centres depending upon the structural module and the spanning capability of the selected deck-slab system. The deck-slab system usually incorporates a composite wide-rib profile deck, 51 to 76 mm deep, covered by approximately 85 mm of semi-low density concrete or 65 to 75 mm of normal density concrete, usually no less than 25 MPa in strength.

This somewhat unique floor framing system has generally been used for office floors with live loads ranging from 2.4 kPa to 4.8 kPa, plus partitions. It has also seen use in "special purpose" buildings, such as laboratories, and has received serious consideration for hospital construction.

Structurally, the floor beams are designed based on cantilever and suspended span construction (also known as Gerber construction) where the floor beams are continuous over girders and cut off near the points of inflection to pick up the drop-in suspended spans. The positive moment regions of the floor beams are usually designed compositely with the deck-slab system, to produce savings in structural steel as well as to provide stiffness. The cantilever segments are bolted to the top flange of the steel bottom chord of the stub-girder, while two shear studs are usually specified on each floor beam, over the beam-girder connection, for anchorage to the deck-slab system. The drop-in or suspended span segments are frequently shallower in depth, permitting additional plenum service depth in those areas. Composite design of the drop-in segments is also often found to be beneficial.

The stub-girder is analysed as a vierendeel girder, with the deck-slab acting as a compression top-chord, the full length steel girder as a tensile bottom-chord and the steel stubs as vertical web members or shear panels. It is important to note that, using stub-girder construction, shoring is required for the fresh concrete condition since the top chord has virtually no strength at this stage. Retention of the shoring for a specific period of time is critical and will be discussed later.

This structural system permits the use of steel and concrete at their optimum strengths, resulting in overall efficiency. The natural openings between vierendeel "posts" allow structural-mechanical-sprinkler integration in two directions, permitting storey-height reduction when compared with some other structural framing systems. See Fig. 6.2.

6.2 PROPOSED DESIGN CRITERIA

Since the early seventies more than forty stub-girder framed buildings have been built in North America, totalling more than two million square metres, some of which are listed in Table 6.1. Yet, understanding of an appropriate design technique has not been widespread in the structural engineering community, due primarily to the involvement of a very small number of consulting firms mainly in the United States, and more recently in Canada.

This chapter is intended to provide an overview of the system, along with practical design criteria, for layout, analysis, structural design, detailing and construction techniques for the stub-girder floor system.

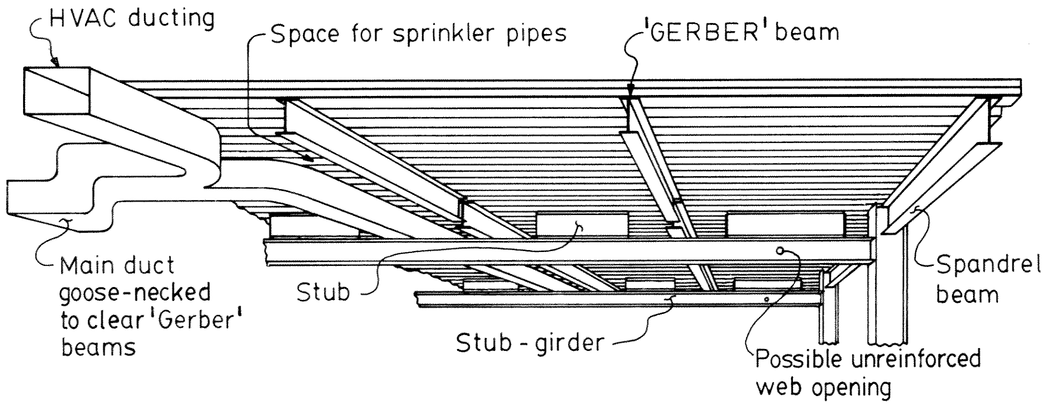


Figure 6.2
Structural-Mechanical-Sprinkler Integration
of a Typical Stub-Girder Floor

The following proposed design criteria have been prepared by the authors based on a detailed study of this structural system over a number of years. This study has included in-depth discussions with designers of the bulk of North American projects, viewing of a good number of projects during construction, and participation in both initial design and laboratory testing of several Canadian full-scale girder tests. Further information has been gleaned from some U.S. full-scale tests, and technical journals.

The proposed guidelines for the design and construction of stub-girder floor system cover the following topics:

- Deck-slab considerations
- Stub and beam layout
- Cantilever and suspended span beams (Gerber Beams)
- Depth control and design checks for Gerber Beams
- Structural properties of reinforced concrete top chord (deck-slab)
- Structural modelling of stub-girders for preliminary manual analysis
- Structural modelling of stub-girders for detailed computer analysis
- Stub-girder member strength checks
- Design of transverse slab reinforcement
- Stud shear connection design
- Shear capacity of stubs and stub stiffener design
- Stub-girder deflection checks
- Floor vibration checks
- Shoring checks for stub-girders
- Special design and construction considerations.

6.3 DECK-SLAB CONSIDERATIONS FOR STUB-GIRDER FLOOR SYSTEM

Selection of a suitable deck-slab system for a stub-girder framed floor involves more than just consideration of the load carrying capacity of the deck-slab. The following important points should be noted early in the selection process.

a) A large deck-slab total depth is preferred to produce a large effective slab design width. Steel decks 50 mm or greater in depth are suitable. A stiffer top chord can provide more efficient vierendeel action, which in turn enables more economical sizing of the steel bottom chord.

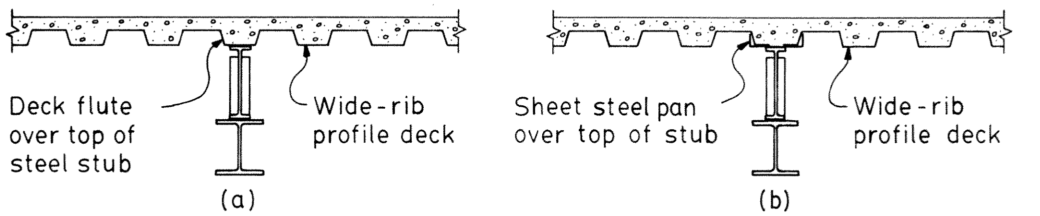


Figure 6.3
Steel Deck Arrangement in Stub-Girder Floors

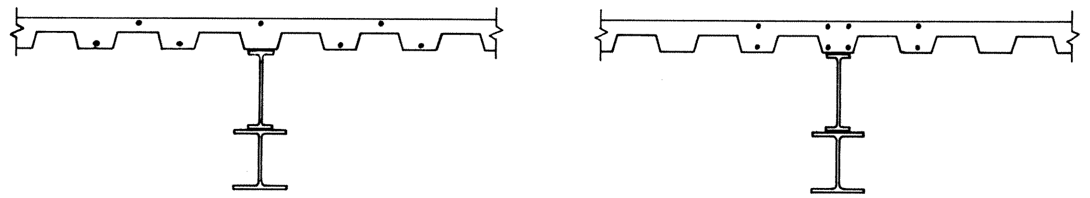
b) An 85 mm thick semi-low density concrete cover slab on a steel deck with underside unsprayed is often chosen to provide a two-hour fire resistance rating.

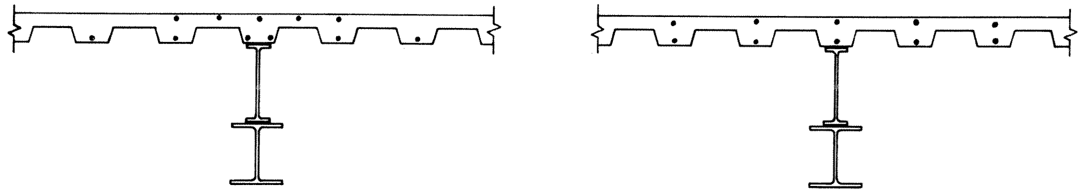
c) In locales where semi-low density concrete aggregates are either not normally available or not economical, normal density concrete cover slabs 65 to 75 mm thick may be used. Deck-slab systems of this type have been tested using full-scale assemblies, as will be noted later. If a fire resistance rating is required in such instances, sprayed-on fire protective materials must be applied to the underside of deck.

d) Since the slab will be subjected to both high compression and high shear stresses, concrete strengths are generally recommended to be not less than 25 MPa.

e) A wide-rib profile deck is chosen for the deck-slab to provide adequate concrete area directly above the stub locations, and sufficient width of concrete rib to admit stud connectors. See Fig. 6.3a and Table 1.1.

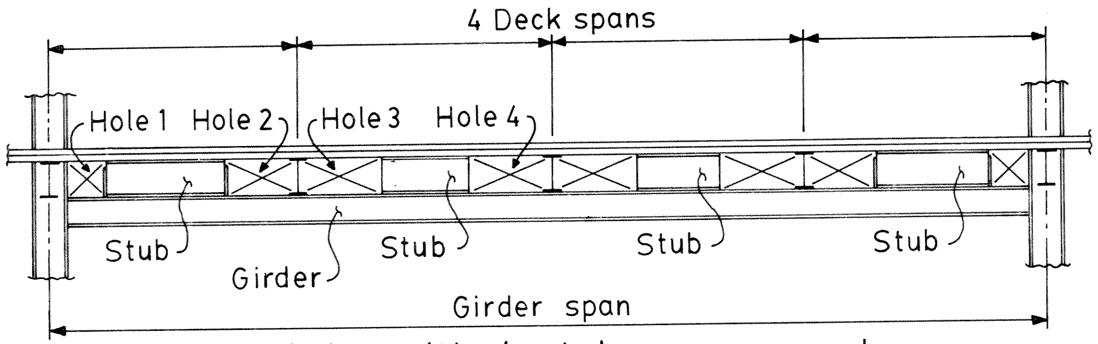
f) The location of deck flutes in stub-girder floor bays must be planned, so that a concrete rib coincides with a girder module, and it may be necessary to create a special rib coinciding with the


(a) 7-bar arrangement (b) 8-bar arrangement

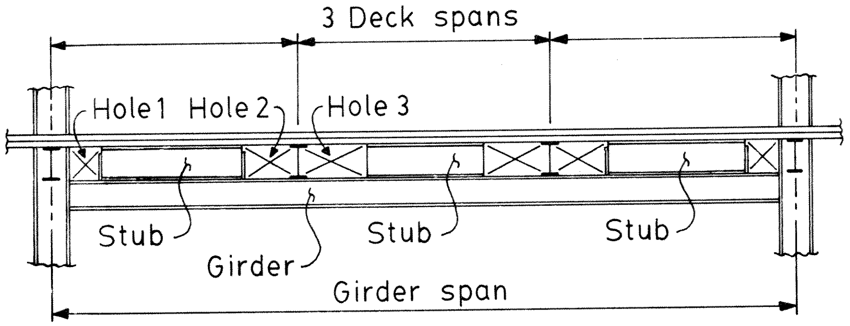

(c) 11-bar arrangement (d) 10-bar arrangement

Note: all longitudinal slab reinforcing occur within effective slab width

Figure 6.4
Continuous Longitudinal Reinforcing
in Deck-Slabs atop Stub-Girders



(a) Stub-girder with 4-stub arrangement



(b) Stub-girder with 3-stub arrangement

WEB openings suitable for preliminary manual design of typical stub-girders (as shown above):

Opening Reference Number	Width of opening as percent of girder span	
	Stub-girder with 3-stub arrangement	Stub-girder with 4-stub arrangement
1	*	*
2	7.5 to 8.5	6 to 7
3	9.5	8
4	—	8

* Computed based on bottom chord bending resistance and stub length required for the development of longitudinal slab shear and stub web shear resistance.

Figure 6.5
Typical Stub-Girders
and Proposed Width of Web Openings
Suitable for Preliminary Manual Design

girder using a continuous sheet steel pan. See Fig. 6.3b. The continuous sheet steel pans may only be required on some stub-girder modules, depending on the module of the steel deck selected.

g) Continuous full span longitudinal slab reinforcing, arranged within the effective slab design width, is required at both top and bottom of the deck-slab. This system of slab reinforcement provides added flexural strength, shear strength and ductility to the top chord of the stub-girder. See Fig. 6.4.

6.4 STUB AND BEAM LAYOUT

The majority of stub-girders built to date are in the span range of 11.5 to 13.5 metres, with four deck spans, and thus three intermediate beams, and four stubs between girder end supports. Occasionally, 3-deck spans with 3-stub arrangements or 5-deck spans with 5-stub arrangements have been used. Recommendations for width and position of web openings of typical stub-girders, illustrated in Fig. 6.5 for preliminary design purposes, assume 'optimum' use of structural material, whilst maintaining maximum natural web openings for mechanical ducting and sprinkler pipe layouts.

6.5 CANTILEVER AND SUSPENDED SPAN BEAMS (GERBER BEAMS)

To achieve more efficient distribution of moments, and to enable more economical use of structural materials both at centre span and near the supports, the century old Gerber construction, coupled with the relatively new hollow-composite construction, is used for the design of floor beams in the stub-girder floor system. See Fig. 6.6. The cantilever segments are designed on the assumption that negative moment regions at supports (i.e. at a beam-stub-girder intersection) are non-composite, and that positive moment regions are either composite or non-composite, depending upon beam span, member size and floor loading. The drop-in (or suspended) segments are designed as simply supported beams of either composite or non-composite construction.

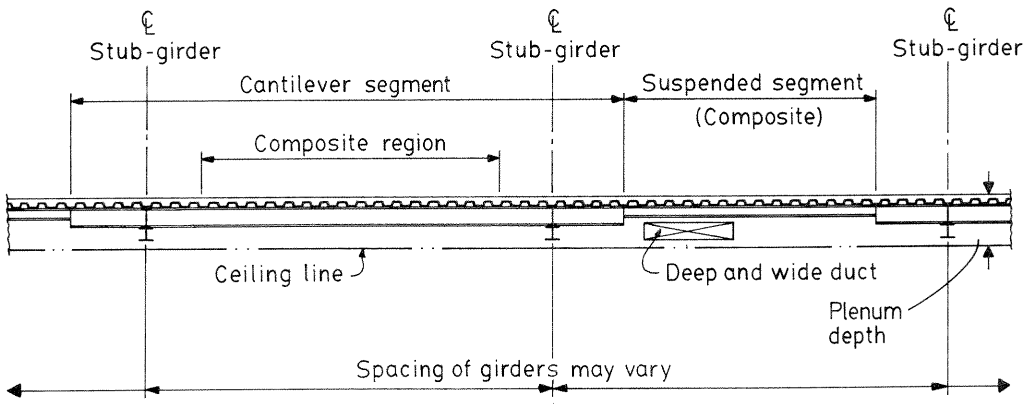


Figure 6.6
Cantilever and Suspended Span Beams (Gerber)
Construction with Optional Composite Design at
Positive Moment Regions

Considerations when selecting the depth of cantilever segments should include strength of stub-girder, depth of duct openings, storey height, total floor steel mass, etc. Since the tensile component of the stub-girder is separated from its top chord by the depth of floor beams forming the cantilever segments, a change in the depth of these beams can significantly influence the governing design forces at several critical design locations for both the deck-slab top chord and the steel bottom chord.

Suspended segment locations of the beam system are often selected to coincide with the occurrence of main air supply ducts feeding out of a building core. See Fig. 6.6. Using shallow beam sections at these locations, large supply ducts can easily be accommodated within a relatively shallow plenum.

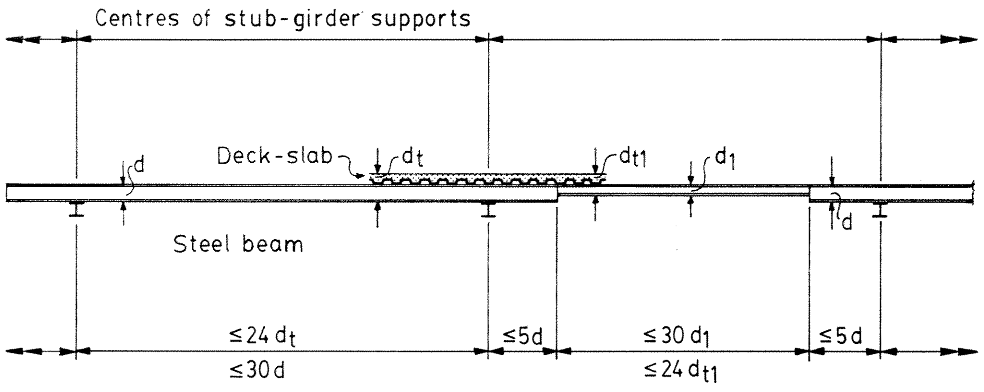


Figure 6.7
Depth Control for
Cantilever and Suspended Span Beams

6.6 DEPTH CONTROL AND DESIGN CHECKS FOR GERBER BEAMS

During preliminary design of a Gerber beam, it is convenient to know how to proportion the beam in relation to its span and where and what design checks are required. The following is a list of proposed design considerations for Gerber member selection.

– Cantilever segments (See Fig. 6.7)

a) Clear span/depth of steel shape to be ≤ 30.
   Clear span/depth of composite section to be ≤ 24.
b) Cantilever arm length/depth of steel shape to be ≤ 5.
   (See Fig. 6.8 for shear stud connection at end of cantilever arm).
c) Cantilever arm length ≤ unsupported length, L_u, for maximum M_r of steel section.

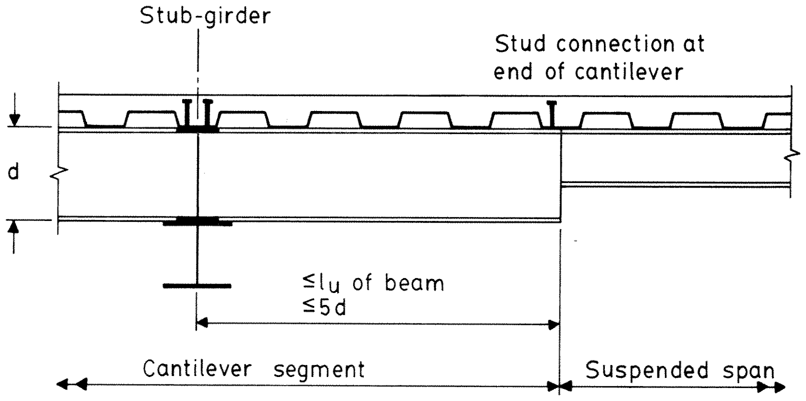


Figure 6.8
Cantilever Arm Proportioning

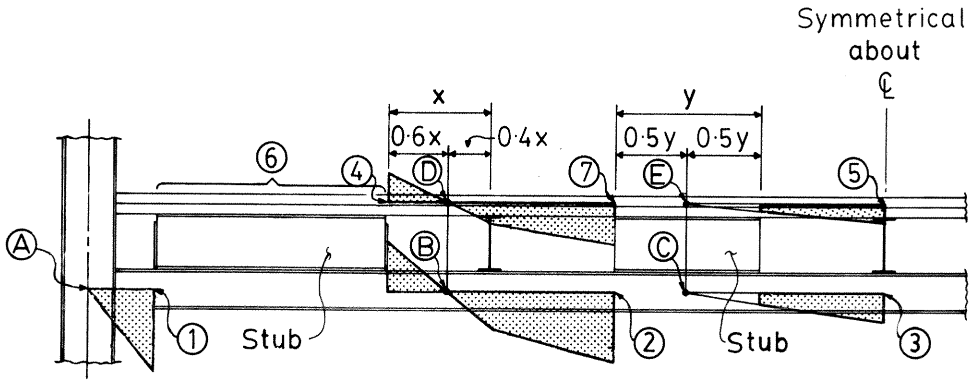
d) Check maximum negative bending and shear at the support of cantilevers.
e) Check mid-span positive bending (composite section) with zero live load on both cantilever arms and adjacent suspended spans.
f) When designed compositely, possible yielding of bottom steel fibre at positive moment area should be checked for maximum combined fresh-concrete condition loading and superimposed dead and live loads when the beam is unshored.
g) Check deflections at mid-span and at ends of cantilever arms.
h) Determine whether cambering for wet concrete loads is required.

– Suspended segments (See Fig. 6.7)

a) Suspended span/depth of steel shape to be ≤ 30.
   Suspended span/depth of composite section to be ≤ 24.
b) Check bending at mid-span and shear at supports.
c) When designed compositely, check possible yielding of bottom steel fibre under maximum combined fresh-concrete condition loading and superimposed dead and live loads, if unshored.
d) Check deflections at mid-span.
e) Determine whether cambering for wet concrete loads is required.

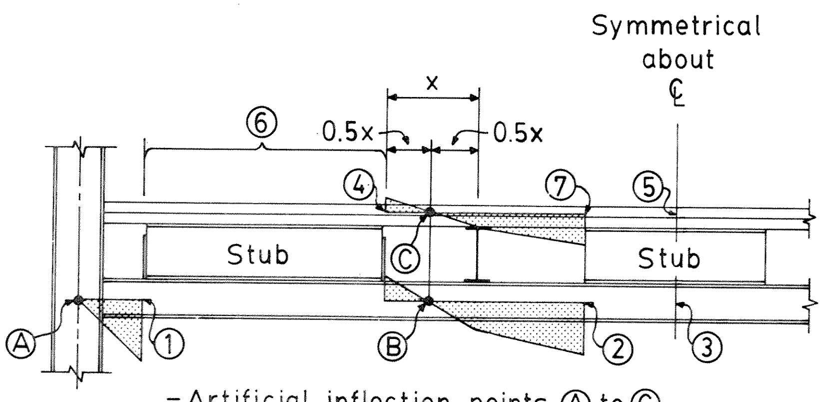
6.7 STRUCTURAL PROPERTIES OF REINFORCED CONCRETE TOP CHORD (DECK-SLAB)

The width of reinforced concrete deck-slab, deemed to be effective for stub-girder analysis and design, may be calculated using S16.1 rules, as illustrated in Section 1.4 and Figure 1.13. However, the effective concrete compression area of the top chord of a stub-girder also includes the cross-sectional area of the concrete ribs below the cover slab thickness. In addition to the concrete area, cross sectional areas provided by longitudinal reinforcing bars and deck steel should also be included during the computation of top chord structural properties. For more details see calculations in the worked example 6.19.



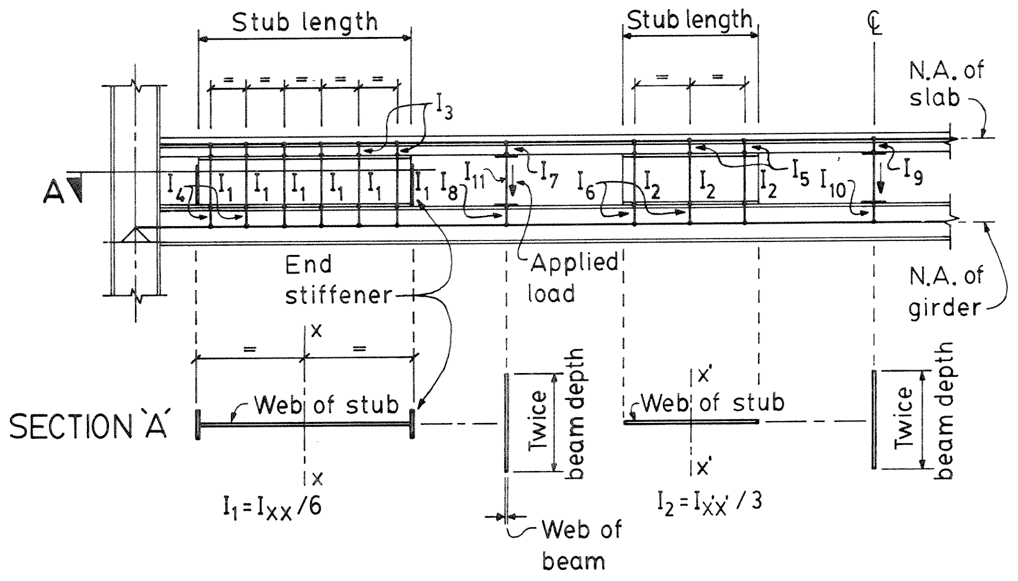
-Artifical inflection points Ⓐ to Ⓔ
-Axial, flexural forces to be computed at locations ① to ⑤, and ⑦. Longitudinal shear at ⑥.

Figure 6.9
Simplified Stub-Girder Analysis Model
(Four-Stub Arrangement)



-Artificial inflection points Ⓐ to Ⓒ
-Axial, flexural forces to be computed at locations ① to ⑤, and ⑦. Longitudinal shear at ⑥.

Figure 6.10
Simplified Stub-Girder Analysis Model
(Three-Stub Arrangement)



Moment of Inertia I_3 to I_{10} = very large fictitious values

Support conditions : near side : pinned to position
far side : pinned but on horizontal roller

Figure 6.11
Structural Modelling of a Typical Stub-Girder
for Detailed Analysis Using a Computer

6.8 STRUCTURAL MODELLING OF STUB-GIRDERS FOR PRELIMINARY MANUAL ANALYSIS

For preliminary analysis, a stub-girder can be modelled as a symmetrical "Vierendeel" girder with artificial "hinges" as indicated in Figures 6.9 and 6.10 for four-stub and three-stub arrangements respectively. Introduction of the hinges makes the structural model statically determinate, and greatly simplifies the preliminary design. Shear forces at hinge locations in top and bottom chords are proportioned according to the calculated member stiffness of the top chord and the stiffness of a trial bottom chord section. Girder deflection can be calculated by summing the flexural deflections of all subcomponents and the computed girder deflection due to axial deformation of top and bottom chord members. For detailed manual calculations and comparison of their accuracy with computer analysis results, see worked example 6.19.

6.9 STRUCTURAL MODELLING OF STUB-GIRDER FOR COMPUTER ANALYSIS

Computerized structural analysis of stub-girders, through finite element modelling and vierendeel-girder modelling, was illustrated by Colaco(6.1) in 1972. Both structural models were found to provide varying degrees of success in the prediction of mid-span deflection, concrete stresses, and steel stresses, when compared to test results of a full-scale girder specimen. The finite element model was not found to be suitable for practical design use due to its excessive demand on computer and human resources. However, it did serve its purpose for research studies by verifying the suitability of the vierendeel-girder model.

A vierendeel-girder model of a typical four-stub arrangement stub-girder is shown in Fig. 6.11. Note that the stub pieces between top and bottom chords have been 'transformed' into a series of vertical posts. A 'plane frame' type of stiffness analysis computer program can be used to obtain member forces. This analysis method was used to provide design forces for five full-scale stub-girder test specimens which were tested at two Canadian universities(6.2,6.3,6.4). Correlation between calculated forces and girder performances was found to be excellent. With the aid of a micro-computer, a designer can economically analyse and design such a girder. A step by step illustration of this modelling technique is included in the worked example in Section 6.19.

6.10 STUB-GIRDER MEMBER STRENGTH CHECKS

During both preliminary and detailed structural analysis, a designer should check strengths of top and bottom chord members at several critical locations. For a typical three- or four-stub arrangement stub-girder (see Figs. 6.9 and 6.10), up to 7 locations are generally considered critical. The appropriate design checks required for each of the locations shown are specified below:

Location 1 – check bending
– check shear
Location 2 – check combined bending and axial tension
Location 3 – check combined bending and axial tension
Location 4, 5, 7 – check axial compression plus flexural compression or tension
(for full effective slab width)
Location 6 – check local compression and longitudinal slab shear adjacent to stubs
(see Section 6.11 below)

6.11 DESIGN OF TRANSVERSE SLAB REINFORCEMENT

Failure to provide adequate longitudinal shear resistance may cause a stub-girder to exhibit non-ductile behaviour at ultimate failure load. Figure 6.12 illustrates a cut-away view of a stub-girder at the end stub location. The total shear force delivered by the end stub to the deck-slab can be represented by two planes of longitudinal slab shear plus an area of local concrete

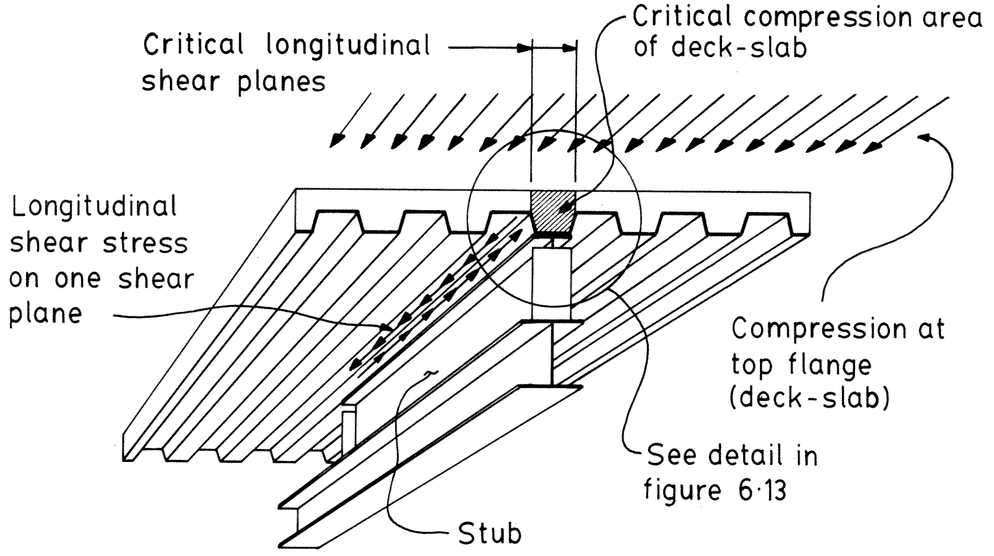


Figure 6.12
Cut-Away View of a Stub-Girder
(at End-Stub Location)

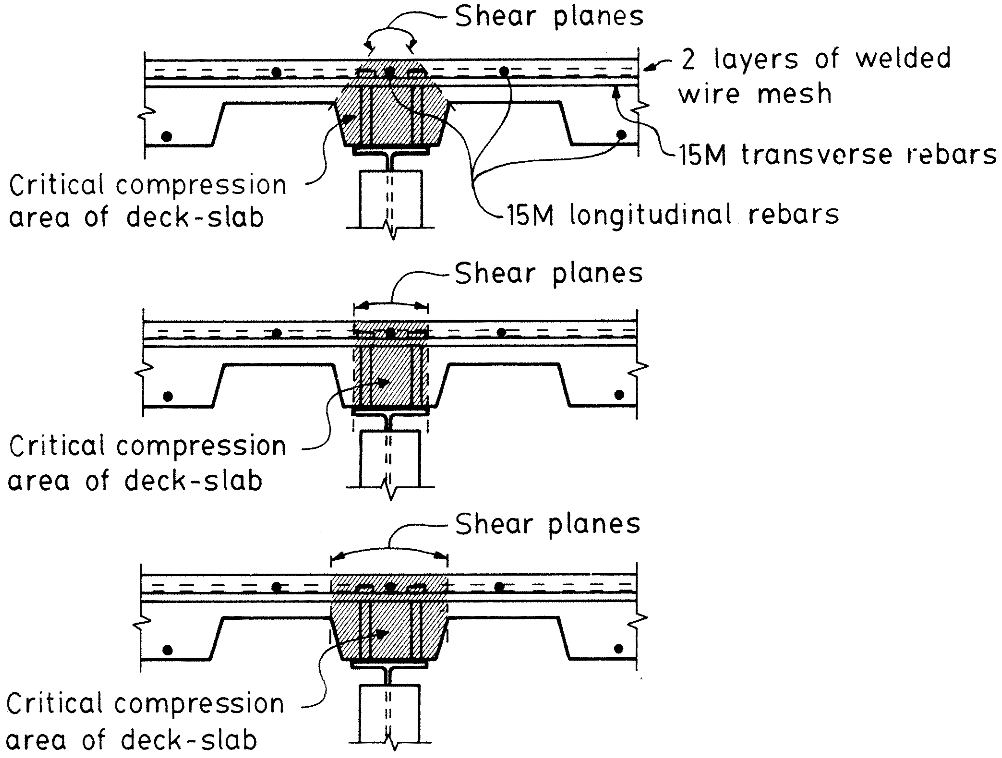


Figure 6.13
Idealized Failure Modes under
Longitudinal Slab Shear and
End-Stub Slab Compression

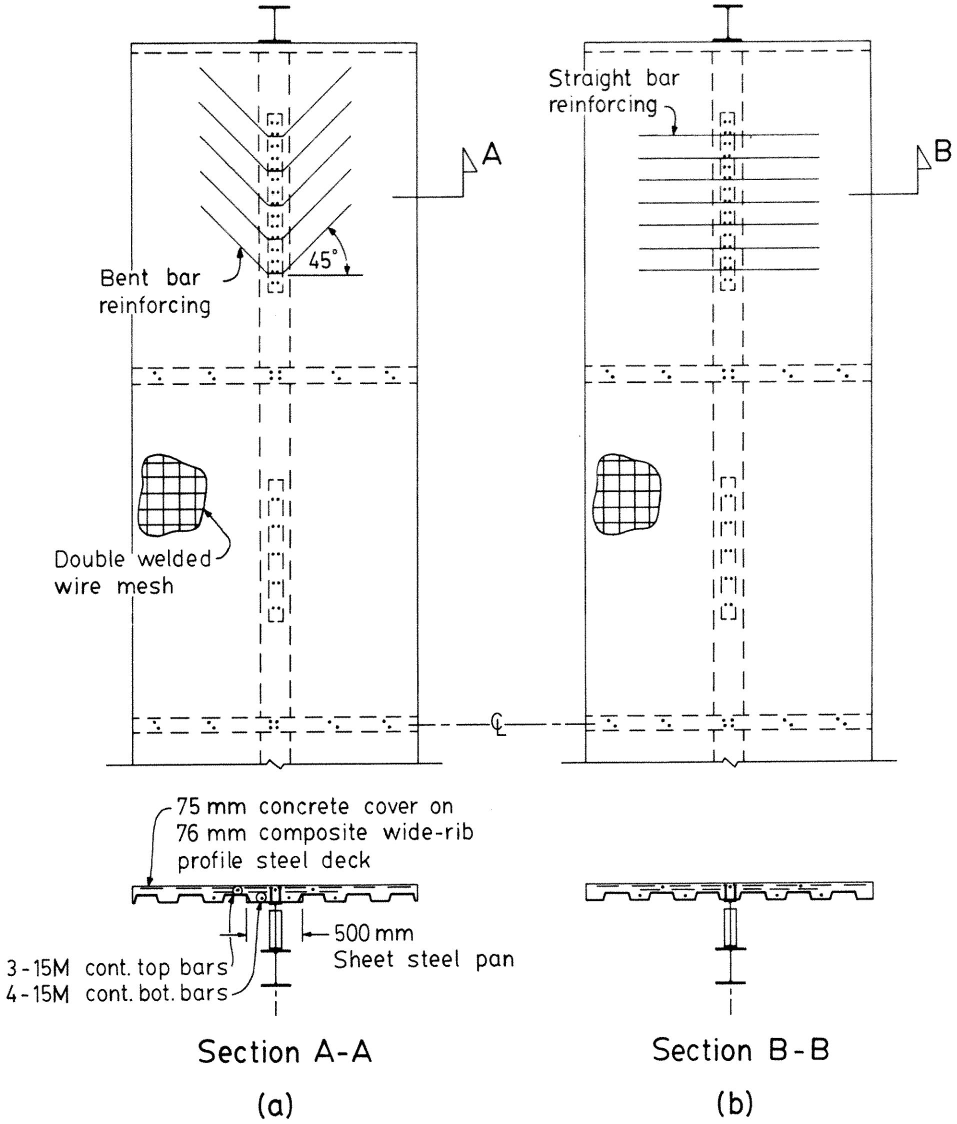


Figure 6.14
University of Saskatchewan Test Specimens

compression at the concrete rib directly in front of the end stub. (See typical detail in Fig. 6.13). A rational design method permitting evaluation of the longitudinal shear capacity of deck-slabs, with or without transverse reinforcement, was proposed by Buckner, et al(6.5). The details of this design method are presented in Section 4.9.

Three full-scale lab-tests were conducted at the University of Saskatchewan(6.4) on stub-girders spanning 12 metres. Three different deck-slab transverse reinforcing details were chosen for the same stub-girder steel and stub sections, i.e. using two layers of welded wire mesh, two layers of welded wire mesh plus straight transverse bars, and two layers of welded wire mesh plus bent bars in a herring-bone pattern (Fig. 6.14). In addition, the third specimen also incorporated a wide centre rib formed by a sheet steel pan. Ultimate failure of each specimen was caused by crushing of the concrete rib at the inside end of an end-stub accompanied by a splitting/shear failure on a horizontal plane just below the heads of shear studs, at the level of transverse reinforcement. (See Fig. 6.15). It was suggested by the researchers that when compared with results of the specimen incorporating straight bars, initial slab cracking can be delayed by using a wide centre rib along with the herring-bone transverse reinforcing. Delay of the crushing failure mechanism for the herring-bone specimen permitted increased deformation in the steel components and greatly improved the ductility of the stub-girder. Also, the ultimate capacity of the herring-bone reinforced girder was increased by 15%. In the opinion of the authors, use of the herring-bone pattern transverse reinforcement, resulting in a direct link from the stud shear connectors to the lines of principal tensile stress in the concrete, distributes the concentrated shear force from the studs to a wider section of slab, thus lowering the critical compressive slab stress. Further testing should be carried out to verify this opinion.

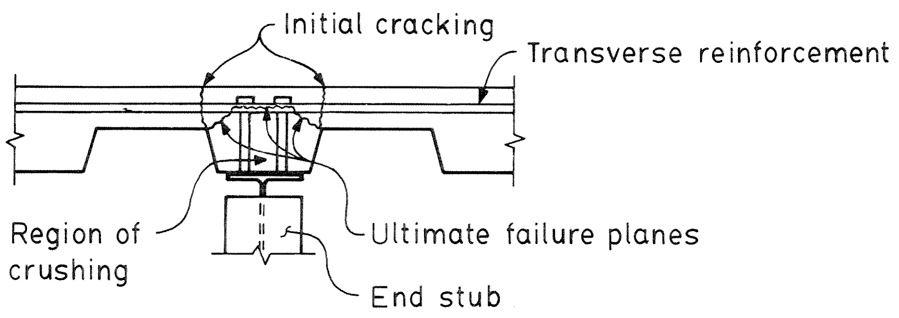


Figure 6.15
Slab Failure Mechanism

6.12 STUD SHEAR CONNECTION DESIGN

Stud shear connectors are commonly used to provide shear transfer at interfaces between slabs and stubs. The combined effect of two types of forces, namely shear forces and direct tensile forces, is considered in the stub-to-slab connections. A conservative approach is adopted, so that each stud installed provides either shear or tensile resistance, but not both. The factored shear resistance of studs can be computed using equation 2.3. The factored pull-out resistance of stud connectors may be computed(6.6), taking into account the stud embedment lengths and the amount of shear cone overlap.

Having calculated the number of stud connectors per stub based on the above-stated design assumptions, the total number is arbitrarily increased by 50% to prevent a failure mechanism occurring at the stub-to-slab interface. It is believed that this design provision, coupled with the proper transverse reinforcing design of deck-slab system, can force the failure mechanism into a combined stub-web shear yielding and concrete slab compression shear failure, (see Fig. 6.16) at ultimate load.

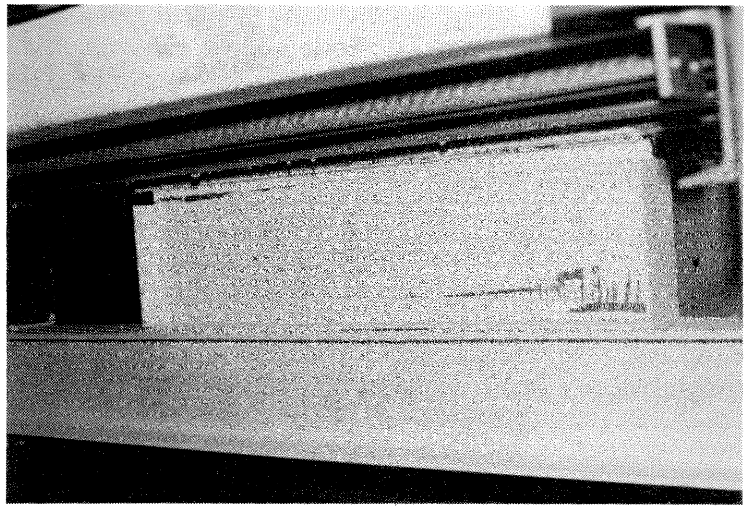


Figure 6.16
Shear Yielding of Stub-Web

6.13 SHEAR CAPACITY OF STUBS AND STUB STIFFENER DETAILS

In stub-girder design, the depth of both stubs and beams must be the same to provide a level support for the steel deck. Therefore, when light wide-flange beams, with thin slender webs, are selected for beams and stubs, some stiffening of the webs of stubs can be expected. Structural analysis of stub-girders generally shows larger horizontal shear forces and overturning moments in the outer stubs, with the interior stubs subjected to only moderate amounts of shear and overturning. Hence, web stiffeners are usually required only on the outer stubs to develop the required stub-web shear and overturning resistances.

Full scale sub-assemblage specimens of stiffened and unstiffened end-stubs, with slabs, were tested by Zimmerman and Bjorhovde(6.2,6.3). Capacities of stubs, stiffened with fitted web stiffeners, partial end-plate stiffeners, and no stiffeners, were compared. Details of several feasible stub-web stiffening configurations are shown in Figure 6.17. The partial end-plate stiffened stubs proved to provide adequate load capacity with the simplest fabrication. Also, full scale stub-girder tests were conducted to verify the analytical evaluation and the sub-assemblage tests.

6.14 DESIGN OF WELDMENTS AT STUB TO GIRDER INTERFACE

During the design of a stub-girder, it is desirable to select compatible stub and girder sections for the purpose of welding the stub bottom flange to the girder top flange. A stub to girder flange width difference of at least 17 mm should be allowed to permit the use of 8 mm fillet welds, although 10 mm fillet welds can also be used where the difference of flange width at stub to girder interface is greater than about 22 mm. A rational analysis and design of weldments (as shown in the example problem 6.19) for effects of horizontal shear and overturning-induced tension can easily be adopted by a designer. In the case of short girder spans and long beam spans, the stub flange width may exceed the girder flange width. In such cases the stub to girder welds can be made with the girder in the up-side-down position, or other suitable details, such as trimming the stub bottom flange to a suitable width, can be considered.

6.15 STUB-GIRDER DEFLECTION CHECKS

With the deep out-to-out structural depth, a stub-girder should not deflect significantly due to axial strains in top and bottom chord members. However, due to the effect of web openings, a stub-girder behaves like a vierendeel girder. Additional deflection due to "web action" must be accounted for in the total girder deflection. Also, since the composite section relies totally on a reinforced concrete top flange, concrete creep and shrinkage will have an impact on deflection.

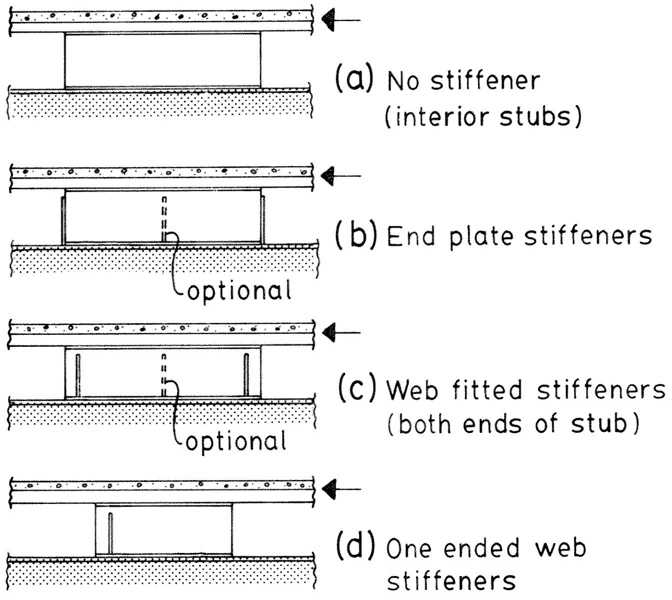


Figure 6.17
Stub-Web Stiffener Details

When designing a stub-girder, deflection of the girder under several loading conditions must be checked:

- Deflection of the stub-girder under steel deck and beam loading is small. However, this deflection should be recognized during the shoring operation, when the girder can be returned to its theoretical elevation using the shores as jacks.

- Deflection of the stub-girder at time of shore-removal is calculated to determine whether girder camber is required. If cambering is chosen, inclusion of steel dead load deflection should be considered. Also, cambering with shoring jacks, in lieu of shop cambering, may be considered. Flexural strains induced in the girder by jacking will be small compared to the axial tensile strains imposed on the steel bottom chord in the fully loaded girder assembly.

- Deflection of the stub-girder under long term dead plus live loading is computed so that comparison can be made with acceptable deflection limitations to ensure the integrity of non-structural building elements.

Elastic deflections of a typical stub-girder with equally spaced beams and symmetrical loading can be manually computed with good accuracy through a process of summing the deflections due to "chord action" and "web action" of the stub-girder structural elements (see worked example calculations Section 6.19). For the computation of more "exact" elastic deflections of stub-girders with symmetric or asymmetric geometry and loading, a plane-frame stiffness analysis computer program can be used to analyse the vierendeel equivalence of the actual stub-girder structure. An estimate of long term loaded girder deflection is also possible by reducing the concrete modulus, E_c. A reduction factor of 2.5 to the value of E_c as computed by equation 2.4 is considered satisfactory.

6.16 FLOOR VIBRATION CHECKS

Field measurements of dynamic response of a typical stub-girder floor to the heel-drop test were carried out by Matthews et al(6.18). It was determined that, under the bare floor condition (i.e. no ceiling, ducts, carpet, etc.), the interaction of floor beams and stub-girders results in a complex dynamic response with four modes of vibration occurring in frequency range of 5 to 7 Hz. The average value of damping of the bare floor alone was 2.5 percent of critical, significantly better than would be expected from a purely composite system. It was concluded that the floor system in the evaluated structure is stiff and presents no vibration problems. It should be noted that the use of W460 beams, selected to maximize mechanical openings, deepened the stub-girder on the 12.5 metre span and provided a stiffer beam assembly on the 9 metre span than might be chosen if using only structural considerations.

The procedure for manual calculation of vibration characteristics of stub-girder floor bays is only marginally more complicated than that for a hollow-composite floor bay. See Chapter 7 for example calculations. It involves the selection of an "equivalent" composite girder, having the same force to deflection relationship as that of the stub-girder incorporating the same deck-slab system. As a result, the natural frequency of a floor bay may be computed, to be followed by the computation of peak acceleration due to the specified impulse floor load simulating the effects of "typical" heel drops. Rules given by Appendix G of S16.1 may be used to evaluate the required damping of stub-girder floor bays. For more information see Chapter 7.

6.17 SHORING CHECKS FOR STUB-GIRDERS

A stub-girder design is based on the assumption of shored composite construction. Careful structural evaluation of stub-girders and shoring members for effects of shoring and construction sequence, is essential. A tendency to "over shoring" can occur when too many levels of floors are left shored during construction, causing the lowest floor girder to be overloaded. On the other hand, premature removal of shores can lead to girder deflections greater than anticipated or can even cause failure if the concrete has not reached a satisfactory strength level. For multi-storey applications, a maximum of 5, and a minimum of 3, shored levels is common. Figure 6.18 illustrates an analytical procedure for the assessment of maximum load effects on shores and shored members under an assumed construction sequence. Seven analytical models are needed in this case. Each model is loaded at the top floor with an applied force, F, calculated for the fresh-concrete condition with construction load allowance due to the top-most floor. At the same time, the structural models, with shores removed at bottom-most level, are loaded at shore locations with downward forces, T, equal to the previously calculated shoring forces (see Fig. 6.18). Final forces carried by the shores are calculated based on the method of superposition.

6.18 SPECIAL DESIGN AND CONSTRUCTION CONSIDERATIONS

A stub-girder floor system is a unique floor framing system, which requires the use of a structural reinforced concrete slab to carry both axial and flexural loads. Several design and construction considerations which are essential and unique to this floor system are listed below.

Cambering of Beams and Stub-Girders

Long span Gerber beams and stub-girders often require shop camber to ensure a theoretically "flat" floor after shore removal. In general, Gerber beams should be cambered when the computed deflection under fresh-concrete condition load approaches 20 mm. Stub-girders should be cambered when the calculated deflection of girders at shore removal exceeds 15 mm. Cambering of stub-girders can best be done subsequent to the welding of stub pieces atop the girder members, otherwise part of the camber may be released during the welding process. Field cambering with shoring jacks may be considered as an alternative to shop camber.

The Use of Screed Discs

Since a stub-girder depends on the reinforced concrete deck-slab to perform as a top chord, any significant deviation in the thickness of cover slab at critical girder locations can greatly affect the overall girder strength and stiffness. Therefore screed discs, attached to the top of the stub flanges,

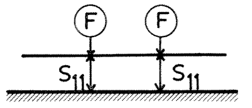
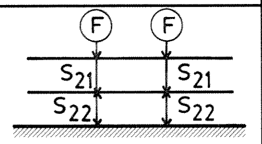
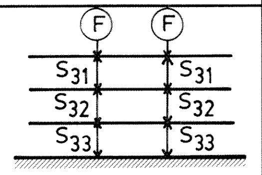
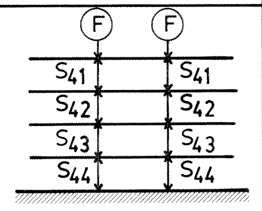
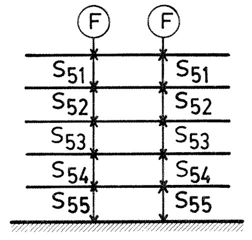
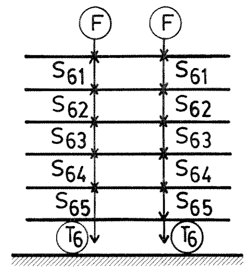
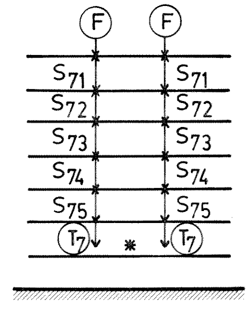
ANALYSIS MODEL	Loading Condition	Composite Girder Stiffness	Shoring forces at floor levels shown	Objective
(1)		non-composite	S_{11}	to calculate maximum shoring forces
(2)		non-composite 3-days old	S_{21} $S_{22} + S_{11}$	
(3)		non-composite 3-days old 6-days old	S_{31} $S_{32} + S_{31}$ $S_{33} + S_{22} + S_{11}$	
(4)		non-composite 3-days old 6-days old 9-days old	S_{41} $S_{42} + S_{31}$ $S_{43} + S_{32} + S_{21}$ $S_{44} + S_{33} + S_{22} + S_{11}$	
(5)		non-composite 3-days old 6-days old 9-days old 12-days old	S_{51} $S_{52} + S_{41}$ $S_{53} + S_{42} + S_{31}$ $S_{54} + S_{43} + S_{32} + S_{21}$ $S_{55} + S_{44} + S_{33} + S_{22} + S_{11}$	
(6) shore removal		non-composite 3-days old 6-days old 9-days old 12-days old 15-days old	S_{61} $S_{62} + S_{51}$ $S_{63} + S_{52} + S_{41}$ $S_{64} + S_{53} + S_{42} + S_{31}$ $S_{65} + S_{54} + S_{43} + S_{32} + S_{21}$ $T_6 = S_{55} + S_{44} + S_{33} + S_{22} + S_{11}$	to calculate maximum load on shored girders
(7) shore removal		non-composite 3-days old 6-days old 9-days old 12-days old 15-days old 18-days old	S_{71} $S_{72} + S_{61}$ $S_{73} + S_{62} + S_{51}$ $S_{74} + S_{63} + S_{52} + S_{41}$ $S_{75} + S_{64} + S_{53} + S_{42} + S_{31}$ $T_7 = S_{65} + S_{54} + S_{43} + S_{32} + S_{21}$ *compute final deflection of girder	

Figure 6.18
Analysis of Shoring Forces under an Assumed Construction Sequence

indicating the desired depth of concrete cover slab, are often used to ensure that the cover slabs are screeded to the calculated thickness. See Ref. (6.7), for details of deck-slab construction.

Installation and Inspection of Shear Studs

Field applied shear studs should be installed and inspected in accordance with the procedures recommended by the latest version of CSA Standard W59 (also see Chapter 2). In addition, all shear studs atop stubs of all stub-girders should be inspected by experienced personnel. In general, shear studs exhibiting visual weld defects or producing lower pitched sounds when struck by a hammer should be further tested by bending to approximately 15 degrees off perpendicular towards the nearest support of the girder.

Girder-to-Column Connections

A typical girder-to-column connection is shown in Figure 6.19. It should be noted that when slabs are continuous beyond columns (and thus the end of the stub-girder), final tightening of bolts at the connection is sometimes done after the removal of shoring, so that slabs at column locations are free from construction stresses induced by an otherwise fixed-end condition; as a result, the deck-slabs are less susceptible to premature cracking. Crack-control reinforcement of slabs adjacent to column locations is also recommended, see Fig. 6.20.

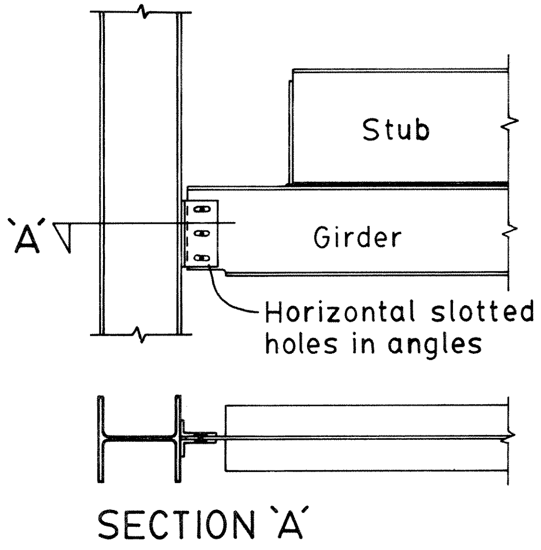


Figure 6.19
Typical Girder-Column Connection

Stub-Girder with Electrified Floor Deck

An underfloor raceway system to accommodate electrical power, as well as telephone and other communication systems, can be incorporated in a stub-girder floor framing system. Headers are thus placed in the deck-slab for cross-distribution purposes. Use of either a standard header or a trench header eliminates a portion of the concrete top chord. Removal of a portion of the concrete cover slab may require the development of an alternate means of load transfer. To minimize the problem, a header duct should be placed as close to a support as possible, with the end stub extended under the header duct. Bottom chord members near supports are often able to carry design moments without the aid of the concrete top chord. Provision must also be made for the transfer of diaphragm shears through the deck, in the case of core lateral load resisting structures. A typical detail at a trench header location on a stub-girder is shown in Fig. 6.21.

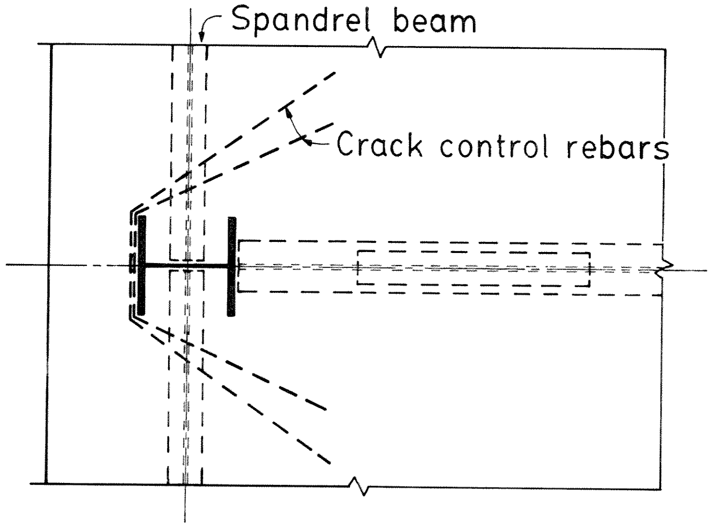


Figure 6.20
Crack Control ReBars at Column Support

Stub-Girders with One-Sided Deck-Slab Overhang

A stub-girder may be situated next to a stairwell or to an exterior wall such that a reinforced deck-slab extends only a short distance to one side of the girder member. A method of determining effective slab width as illustrated in Section 1.4 and Figure 1.13 may be used. The effective concrete compression area should be calculated in the same manner as described in Section 6.7. The stub-girder design methodology outlined in this chapter should also be followed during the design of stub-girders with one sided deck-slab overhang. Such an application might also be found around the perimeter of a building, with beams running over the girder to support a cantilevered floor system as shown in Fig. 6.22.

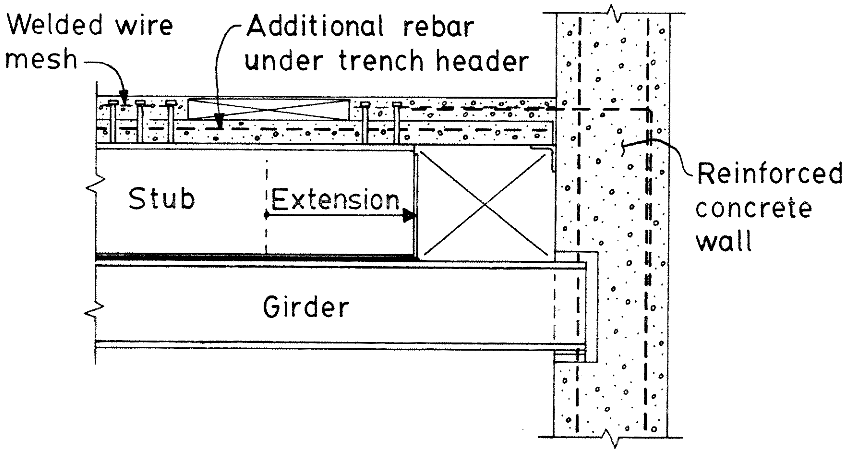
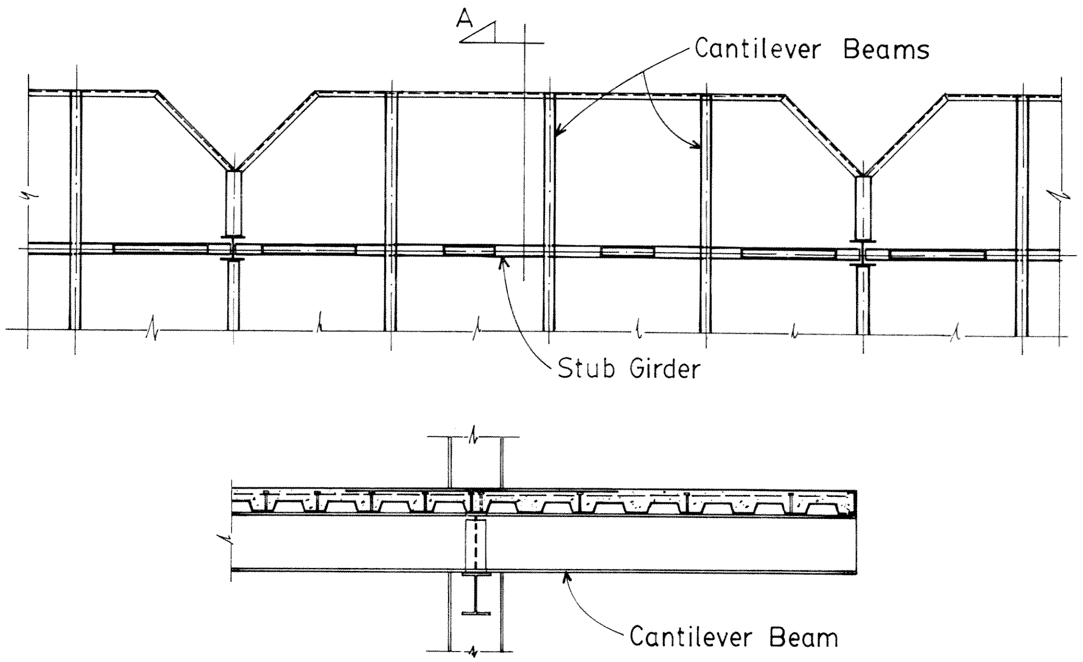


Figure 6.21
Typical Construction Detail at Trench Header Location



Section A-A

Figure 6.22
Construction of Cantilevered Floor Bays

Upgrading Existing Stub-Girders for Heavier Loading

One very important consideration in office building construction, where tenant requirements are unknown during the design and construction stages, is in the area of specified live load. Occasionally, a designer is required to upgrade a portion of a floor for heavier occupancy loading, after the completion of construction. Like other types of steel floor construction, a stub-girder framed floor can be strengthened to accommodate changes of occupancy loading. The key to stiffening of a girder lies primarily in the reduction of local moments introduced in the top compression chord due to local bending, by blocking existing web holes with plates, and, where necessary, by introducing a longitudinal plate to strengthen the bottom tension chord.

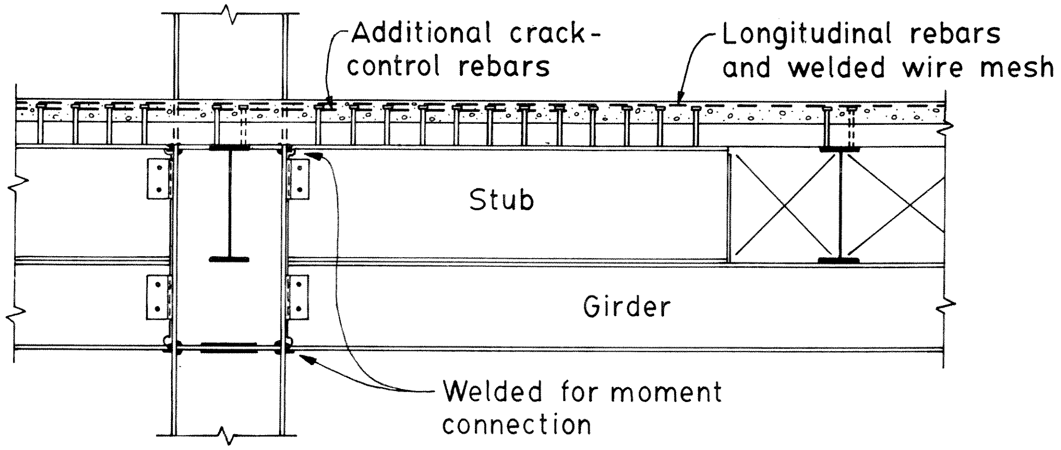


Figure 6.23
Typical Moment Joint
(for Large End Moments)

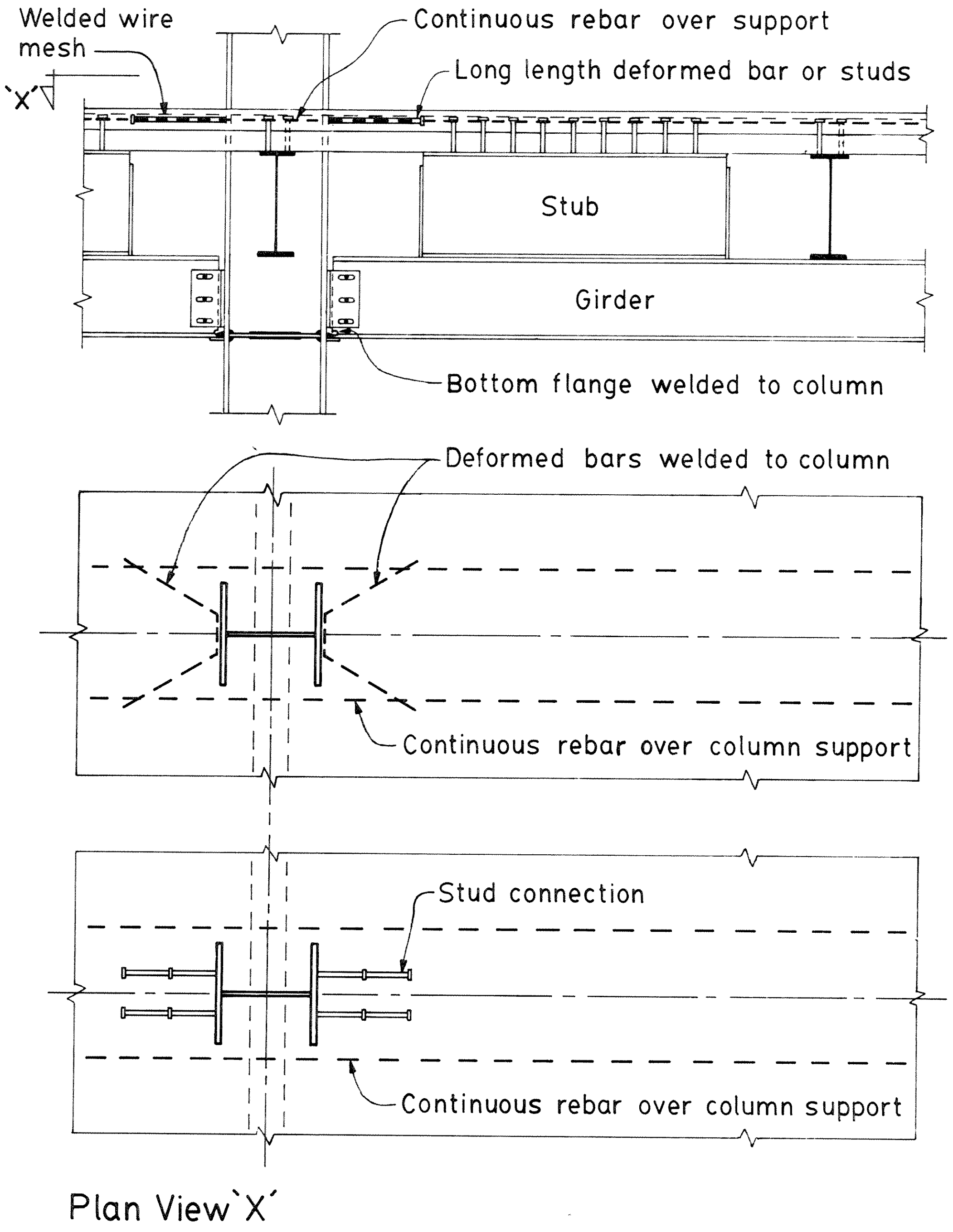


Figure 6.24
Typical Moment Joint
(for Moderate End Moments)

Rigid-Ended Stub-Girders for Participation in Lateral Load Resistance

The deep effective girder depth of a stub-girder provides a large moment of inertia which is effective for inter-storey drift control in a rigid framework, and a number of lowrise stub-girder framed buildings have been built with stub-girders connected to columns to take advantage of this capacity. The most obvious problem during the design of such a building frame involves the moment transfer at the column-girder interface. Figure 6.23 illustrates the extension of an exterior stub to a column face to provide a large moment connection. The girder system must be checked along its full length for critical load combinations under gravity and lateral forces. Bottom chord lateral bracing may also be required. This system will not likely be satisfactory beyond 5 to 10 storeys because moments due to lateral forces may override the gravity designed girders, reducing their efficiency to the point where other systems should be considered.

When wind moments are small, details such as shown in Fig. 6.24 may be used. In this case, the deck-slab is attached to the column either by long deformed bars or shear studs welded to the steel column. In addition, the bottom flange of the stub-girder is field welded or bolted to the column face to complete the moment transfer.

6.19 FLOOR DESIGN EXAMPLE

The following example illustrates the design of some typical members in a stub-girder floor layout. One line of composite Gerber beams will be selected using design tables provided in Chapter 4. In addition, a typical stub-girder will be analysed manually as well as by a computer. Detailed design checks, required for various critical locations in the stub-girder assembly, will also be illustrated.

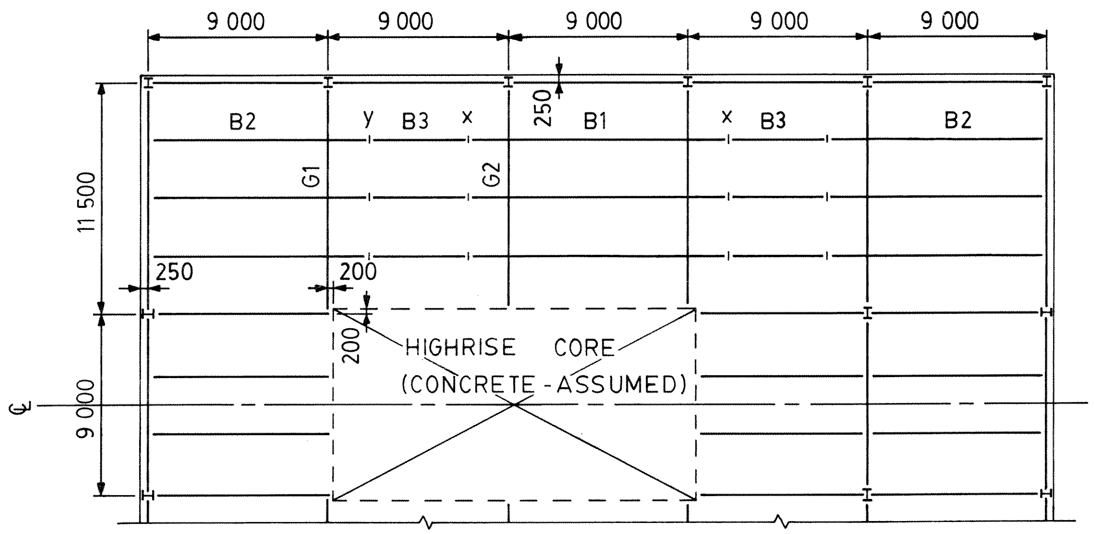


Figure 6.E1
Floor Design Example Key Plan
(Stub-Girder Floor)

The half floor plan of a typical floor in a multistorey office building is shown in Fig. 6.E1. Select Gerber beams B1, B2, B3 and stub-girder G1 using loadings and design criteria given in the floor design example 4.14, with exceptions as listed below:

Storey heights given:
floor to floor height = 3 560 mm

floor to ceiling height = 2 590 mm
plenum depth = 970 mm
maximum longitudinal duct depth = 370 mm
(see Fig. 6.E2)

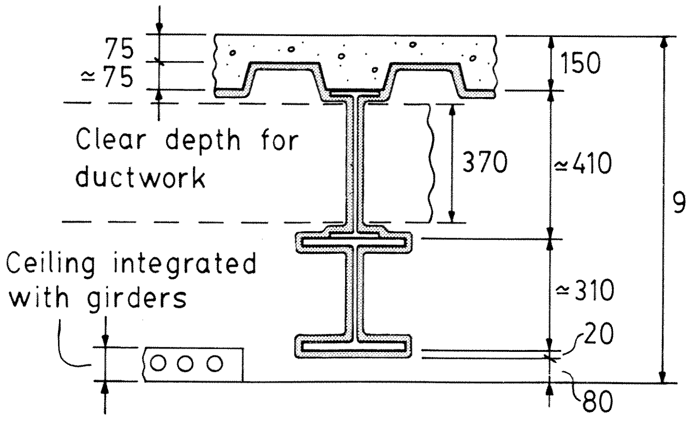


Figure 6.E2
Plenum Depth Computation

Materials: Same as specified in section 4.14 except concrete strength, $f'_c = 25$ MPa.

Solution

A 76 mm deep wide-rib profile composite steel deck is selected to span approximately 3 metres using the same criteria shown in Section 4.14. In this example, 76 mm wide-rib composite steel deck of 0.91 mm nominal thickness and a cover slab thickness of 75 mm satisfy all deck-slab design criteria; and the design parameters as listed in the manufacturer's catalogue are as follows:

Load due to steel deck, q_d = 0.10 kPa
Moment of inertia of deck, I_d = 1.10×10^6 mm^4/m
Dead load due to deck-slab, q = 2.60 kPa

Composite Gerber beams B1, B2, B3

It should be pointed out that ultimate strength design of beams B1 and B2 for positive moment effects (as illustrated below) may seem conservative, since no account is taken of the negative moment relieving effect caused by the overhanging cantilevers. However it does provide a more convenient method of calculation. In addition, this design approach permits possible future alterations of floor framing in suspended span areas, independent of adjacent floor bay framing.

Trial Member Selection, Beams B1, B2

– live load:

Tributary area, $A = 11.5(9.0)/4 = 25.9$ m^2
Reduction factor, $RF_2 = 0.3 + \sqrt{9.8/25.9} = 0.92$
Total live load for beam, $W_L = 0.92(2.4)(25.9) = 57.2$ kN

– Fresh-concrete condition dead load including concrete ponding:

$w = (1 + 0.2\ w_c\ s^4/I_d)\ s\ q$ (Table 3.1, triple span)
$= (1 + 0.2\ (2\ 300)(3)^4/1.10 \times 10^6)\ s\ q$
$= 1.034\ (3)(2.6)$
$= 8.07$ kN/m (Note, conservative deck span of 3 000 mm is used)

Total fresh-concrete condition load support to support,
$W_c = (8.07 + 0.4)(9.0) = 76.2$ kN (Beam steel assumed 0.4 kN/m)

– Superimposed dead loads between supports:

$W_p = 1.2\ (25.9) = 31.1$ kN
$W_{OD} = (0.5 + 0.2)(25.9) = 18.1$ kN

– Factored maximum positive moment, M_f

$W_f = 1.25\ (76.2 + 31.1 + 18.1) + 1.5\ (57.2) = 243$ kN
$M_f = 243 \times 9/8 = 273$ kN·m
$V_f = 243/2 = 122$ kN

– Composite factored moment resistance of beams B1 and B2, using trial section **W410×39**

$t_o = t_c + t_d = 75 + 76 = 151$ mm

$16\ t_o + b = 16(151) + 140 = 2\ 556$ mm
$L/4 = 9\ 000/4 = 2\ 250$ mm (governs)
beam spacing $= 11\ 500/4 = 2\ 875$ mm

Therefore effective slab width, $b_1 = 2\ 250$ mm

From Table 4.6 , for W410×39,
M_{rc} for 50% shear connection may be interpolated,
$M_{rc50\%} = 360$ kN·m > 273 kN·m OK
$Q_{rc50\%} = 1\ 350 \times 50\% = 675$ kN $q_r = 87.8$ kN using 19 mm studs (Table 2.1)

Therefore use 16 studs per beam (B1 and B2)

– Unshored beam requirement

Moment due to specified fresh-concrete condition load acting on bare steel beam,

$M_b = W_c\ L/8 = 76.2\ (9.0)/8 = 85.7$ kN·m

Moment due to all specified superimposed loads acting on composite beam
(i.e. after concrete attained 75% of f'_c),
$M_t = (W_L + W_p + W_{OD})\ L/8 = (52.7 + 31.1 + 18.1)(9.0)/8.0 = 115$ kN·m

From Table 4.6, $S_x = 0.634 \times 10^6$ mm^3, $S_t = 1.17 \times 10^6$ mm^3 by interpolation.

Combined stresses in bottom flange under specified loads become,

$$\frac{M_b}{S_x} + \frac{M_t}{S_t} = \frac{85.7}{0.634} + \frac{115}{1.17} = 233 \text{ MPa} < 0.9\ F_y$$

Therefore shoring is not required.

Before we proceed to design check beams B1 and B2, cantilever lengths (and hence span of suspended segment B3) must be determined.

– Compute Cantilever Lengths

Using the trial sections of beams B1 and B2 as W410×39, and using the maximum factored cantilever moment resistance under a fully laterally supported condition, the suspended floor bay framing may be modelled as shown in Figure 6.E3.

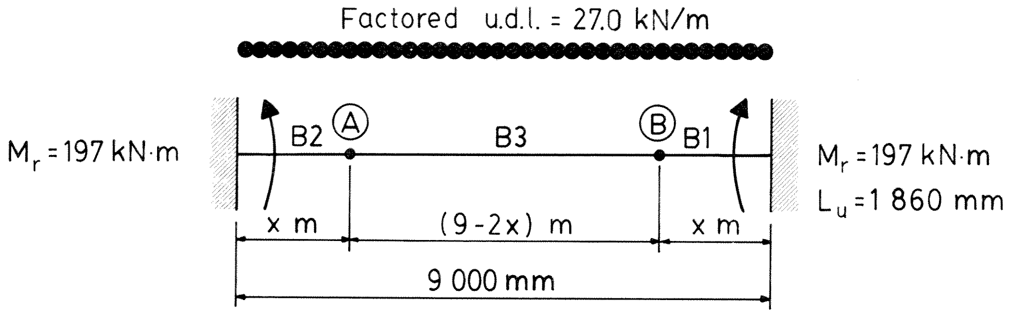


Figure 6.E3
Simplified Structural Model for Cantilever Length Computation

Factored total u.d.l. for the 9 metre framing

$$= [1.25\,(W_c + W_p + W_{OD}) + 1.5\,W_L]/9$$
$$= [1.25\,(76.2 + 31.1 + 18.1) + 1.5\,(57.2)\,]/9$$
$$= 27.0 \text{ kN/m}$$

Factored end shear at reaction A,

$$V_f = 27.0\,(9 - 2x\,)\,/\,2 = 121.5 - 27.0x \quad \text{kN}$$

where x = cantilever lengths in metres

Cantilever end moment due to V_f calculated above

$$= (121.5 - 27.0x\,)\,x$$
$$= 121.5x - 27.0x^2 \qquad \text{kN·m}$$

Cantilever end moment due to factored u.d.l. acting directly on the overhanging segment

$$= 27.0x^2/\,2 = 13.5x^2 \qquad \text{kN·m}$$

Equating cantilever-end factored applied moment to factored moment resistance,

$$197 = 121.5x - 27.0x^2 + 13.5x^2$$

and simplifying, we obtain,

$$13.5x^2 - 121.5x + 197 = 0$$

Solving for value of x,

$$x = \frac{121.5 - \sqrt{(-121.5)^2 - 4(13.5)(197)}}{2(13.5)}$$

$$x = 2.12 \text{ m} > L_u\,(\,= 1\,860 \text{ mm})$$

Use x value = 1 850 mm. Therefore the length of beam B3 can be conveniently calculated as 5 300 mm.

– Compute factored cantilever moment using "hinge" locations determined above.

$$M_f = 121.5x - 27.0x^2 + 13.5x^2$$
$$= 179 \text{ kN·m} < M_r\,(\,= 197 \text{ kN·m})$$

– Deflection estimates – beam B1:

a) Camber requirement
Deflection of unshored beam under fresh-concrete condition load,
Δ_c = deflection due to loading between supports minus the deflection due to cantilever end moments caused by loading on cantilever overhangs.

$$= \frac{5W_cL^3}{384EI_x} - \frac{M_cL^2}{8EI_x}$$

$$\text{where } M_c = \left(\frac{76.2}{9}\right)\left(\frac{5.3}{2}\right)(1.85) + \left(\frac{76.2}{9}\right)\left(\frac{1.85^2}{2}\right) = 56.0 \text{ kN·m;}$$

$$W_c = 76.2 \text{ kN}$$

$$\Delta_c = \frac{5}{384}\,\frac{(76.2)(9)^3}{(200)(127)} \times 10^3 - \frac{(56)(9)^2}{8(200)(127)} \times 10^3$$

$$= 6.2 \text{ mm}$$ Therefore **camber not required.**

b) Shrinkage deflection and creep deflection
Since beam B1 is continuous over stub-girders, the amount of shrinkage deflection is minimal. Also creep deflection is found to be not critical due to the fact that beam B1 does not require shoring. Use the following deflection calculations.

c) Deflection of composite beam due to live load and partition including long term effects

Total loading support to support = $W_L + W_p = 57.2 + 31.1 = 88.3$ kN

$$\Delta = \frac{5}{384}\,\frac{88.3\,(9)^3\,10^3}{(200)\,I_e}\,(1.15)$$

$$= 11.7 \text{ mm} < L/300 \text{ OK}$$

$$\text{where } I_e = I_s + 0.85\,(p)^{0.25}\,(I_t - I_s)$$
$$= [127 + 0.85\,(0.5)^{0.25}\,(527 - 127)]$$
$$= 413\,(\,\times 10^6 \text{ mm}^4)$$

Note: I_t for W410×39 (composite section, b_1 = 2 250 mm)= 527×10^6 mm^4

– Deflection estimate – beam B2:

a) Camber requirement

$$\Delta_c \simeq \frac{5}{384}\,\frac{W_cL^3}{EI_x} - \frac{M_cL^2}{16EI_x}$$

$$= \left\{\frac{5}{384}\,\frac{(76.2)(9)^3}{(200)(127)} - \frac{(56.0)(9^2)}{16(200)(127)}\right\} 10^3$$

$= 17.3 \text{ mm} < 20 \text{ mm}$

Therefore **camber not required.**

b) Shrinkage and creep deflections
Detailed calculation ignored for same reason as given for B1.

c) Deflection of composite beam due to live and partition loads including long term effects

Total loading support to support $= W_L + W_p = 88.3$ kN

$$\Delta = \frac{5}{384}\,\frac{(88.3)(9)^3}{(200)(413)}\,10^3 \times 1.15$$

$= 11.7 \text{ mm} < L/300$ OK

Final size selected for beams B1 and B2 and other construction details:

B1 length = 9 000 + 2(1 850) = 12 700 mm
section = W410×39
studs* = 24 − 19 mm diameter (per beam)
camber = None
B2 length = 9 000 + 1 850 = 10 850 mm
section = W410×39
studs* = 22 − 19 mm diameter (per beam)
camber = None

*including 2 studs at each beam to girder joint, and 2 studs at each cantilever end.

Trial Member Selection, B3

Span = 5 300 mm

– live load:

$$A = \frac{11.5}{4}(5.3) = 15.2 \text{ m}^2 < 20 \text{ m}^2,\ RF_2 = 1.0$$

Total live load per beam, $W_L = 1.0\,(2.4)(15.2) = 36.5$ kN

– Dead loads:

$W_c = (8.07 + 0.3)(5.3) = 44.4$ kN Assuming beam steel = 0.3 kN/m
$W_p = 1.2(15.2) = 18.2$ kN
$W_{OD} = 0.7(15.2) = 10.6$ kN

– Factored maximum positive moment, M_f

$W_f = 1.25(44.4 + 18.2 + 10.6) + 1.5(36.5) = 146$ kN

$M_f = 146 \times 5.3/8 = 96.7$ kN·m
$V_f = 146/2 = 73$ kN

– Composite factored moment resistance of beam B3 using trial section **W200×27**

$16\,t_o + b$ = 16(151)+133 = 2 549 mm
$L/4$ = 5 300/4 = 1 325 mm (governs b_1)
beam spacing = 11 500/4 = 2 875 mm

From Table 4.6 , for W200×27, by interpolation,
$M_{rc50\%} = 156 \text{ kN·m} > 96.7 \text{ kN·m}$

$$Q_{r50\%} = \frac{915}{2} = 458 \text{ kN} \qquad q_r = 87.8 \text{ kN}$$

Therefore use **12 studs** per beam. (19 mm diameter)

– Unshored beam requirement

Moment due to specified fresh-concrete condition load action on bare steel beam,
$M_b = W_cL/8 = 44.4\,(5.3)/8 = 29.4$ kN·m

Moment due to all specified superimposed loads acting on composite beam
(i.e after concrete attained 75% of f'_c),
$M_t = (W_L + W_p + W_{OD})L/8 = (36.5+18.2+10.6)(5.3)/8 = 43.3$ kN·m

From Table 4.6, $S_x = 0.249\times10^6 \text{ mm}^3$; $S_t = 0.570\times10^6 \text{ mm}^3$ by interpolation.
Combined stresses in bottom flange under specified loads become,

$$\frac{M_b}{S_x} + \frac{M_t}{S_t} = \frac{29.4}{0.249} + \frac{43.3}{0.57} = 194 \text{ MPa} < 0.9\,F_y$$

Therefore shoring is not required.

– Deflection estimates:

a) Camber requirement

$$\Delta_c = \frac{5\,W_cL^3}{384EI_x} = \frac{5}{384}\,\frac{(44.4)(5.3)^3}{(200)(25.8)} \times 10^3$$

$= 16.7$ mm (between beam supports)

Deflection at cantilever ends (x) of beam B1, due to u.d.l. on B1,
(see Figure 6.E4a),

$$\Delta_{x1} = -\frac{wL^3N}{24\,EI_x}\left(1 - 6\frac{N^2}{L^2} - 3\frac{N^3}{L^3}\right)$$

$$= -\frac{8.37(9)^3(1.85)}{24(200)(127)}\left[1 - \frac{6(1.85)^2}{9^2} - \frac{3(1.85)^3}{9^3}\right] \times 10^3$$

$= -\ 13.3$ mm (-ve sign means upward deflection)

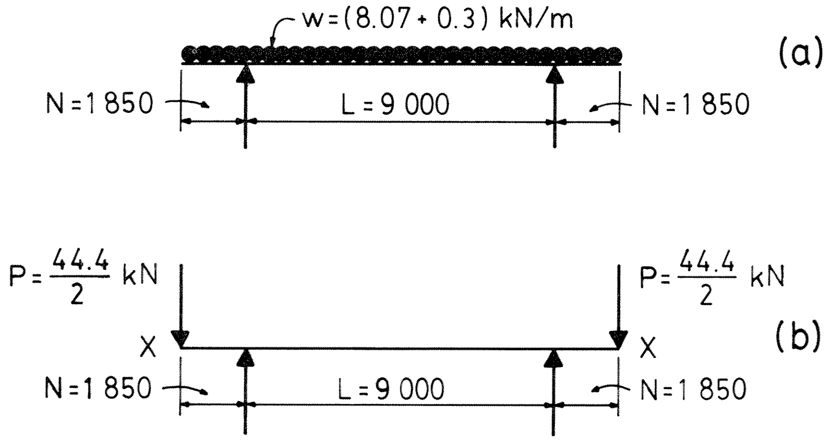


Figure 6.E4
Cantilever Segment – Beam 'B1'

Deflection at cantilever ends (x) of beam B1, due to point load at cantilever ends, (see Figure 6.E4b),

$$\Delta_{x2} = \frac{PN^2}{EI}\left(\frac{L}{2} + \frac{N}{3}\right)$$

$$= \frac{(22.2)(1.85)^2}{(200)(127)}\left(\frac{9}{2} + \frac{1.85}{3}\right) \times 10^3$$

$$= 15.3 \text{ mm} \quad \text{(downward)}$$

Therefore total downward support deflection at x,
$\Delta_x = \Delta_{x1} + \Delta_{x2} = 15.3 - 13.3 = 2$ mm

Deflection at cantilever end y of beam B2, due to u.d.l. on B2, (See Figure 6.E5a),

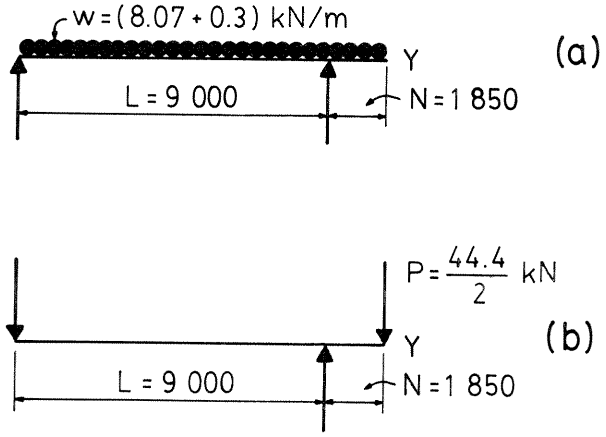


Figure 6.E5
Cantilever Segment – Beam 'B2'

$$\Delta_{y1} = \frac{wL^3N}{24EI}\left[3\,\frac{N^3}{L^3} + 4\,\frac{N^2}{L^2} - 1\right]$$

$$= \frac{8.37(9)^3(1.85)}{24(200)(127)}\left[\frac{3(1.85)^3}{9^3} + \frac{4(1.85)^2}{9^2} - 1\right] \times 10^3$$

$$= -\ 14.9 \text{ mm} \qquad \text{(-ve sign means upward)}$$

Deflection at cantilever end y of beam B2, due to point load on B2, (See Figure 6.E5b),

$$\Delta_{y2} = \frac{PN^2}{3EI}\left(N + L\right)$$

$$= \frac{22.2\,(1.85)^2}{3(200)(127)}\left(1.85 + 9\right) \times 10^3$$

$$= 10.8 \text{ mm} \qquad \text{(downward)}$$

Total downward support deflection at y,
$\Delta_y = \Delta_{y1} + \Delta_{y2} = -14.9 + 10.8$

$= -4.1$ mm (upward)

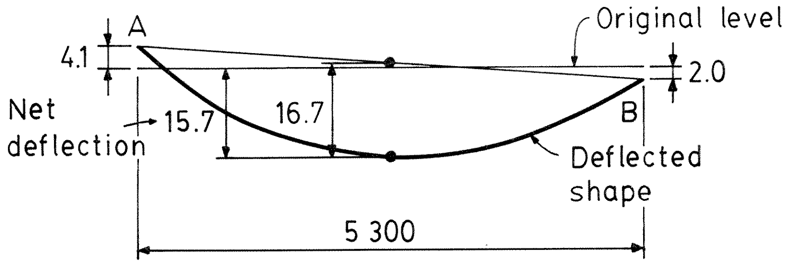


Figure 6.E6
Deflection of Suspended Segment
Beam 'B3' (under Fresh-Concrete Loading)

From Figure 6.E6, net deflection at midspan of beam B3 under fresh-concrete condition load, taking account of support movements,

$$\Delta_{c1} = 16.7 + (-4.1 + 2.0)/2 = 15.7 \text{ mm}$$

Camber not required. (Amount too small to achieve accuracy, and dead load accumulation due to level screeding of concrete will have minimal impact on total cantilever system.)

b) Deflection due to live load and partition including long term effects using composite section for B3 and steel section only for beams B1 and B2 (conservatively),

$$\Delta \simeq \Delta_c \left(\frac{I_x}{I_e}\right)\left(\frac{W_L + W_p}{W_c}\right)(1.15) + \left(\frac{\Delta_x + \Delta_y}{2}\right)\left(\frac{W_L + W_p}{W_c}\right)$$

$$= (16.7)\left(\frac{25.8}{I_e}\right)\left(\frac{36.5 + 18.2}{44.4}\right)(1.15) + \left(\frac{2 - 4.1}{2}\right)\left(\frac{36.5 + 18.2}{44.4}\right)$$

$$= 3.8 \text{ mm} < (9\,000/300) \qquad \text{OK.}$$

where $I_e = I_s + 0.85\,(p)^{0.25}\,(I_t - I_s)$
$= [25.8 + 0.85\,(0.5)^{0.25}\,(158 - 25.8)]$
$= 120\ (\times 10^6 \text{ mm}^4)$

Final size selected for beams B3 and other details:

B3 length = 5 300 mm
section = W200×27
studs = 12 studs per beam (19 mm diameter)
camber = None

Notes for Design Checks on Beams B1, B2, and B3:

a) V_f of beams B1, B2, B3 are checked with V_r of selected sections and are found to be satisfactory (see illustrated example in Chapter 4).

b) Web crippling of beams B1 and B2 at girder supports due to shoring forces is to be design checked following the analysis of maximum shoring forces. See section 6.17.

c) Additional stud connectors are to be installed for Beams B1 and B2 at beam/girder joints and at the free ends of cantilevers. See Figure 6.8.

d) Safety at construction stages such as deck placement and concrete placement is assumed to be checked using loadings as illustrated in Chapter 4 (also see example calculation in section 4.14).

Stub Girders G1 (and G2, similar)

– Live load:

Tributary area of member B2 carried by girder G1 is calculated in Fig. 6.E7, and is equal to 28.0 m².

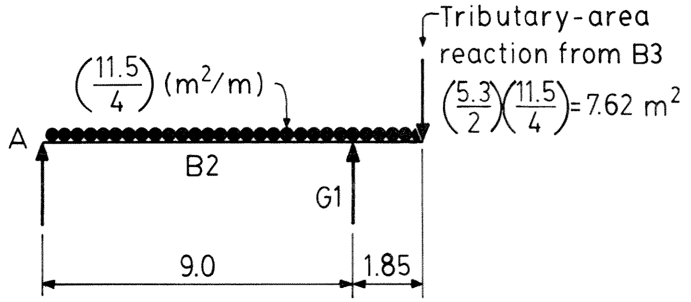
$A = 28 \times 3 = 84 \text{ m}^2$
$RF_2 = 0.3 + \sqrt{9.8/84} = 0.64$
$P_L = 0.64\,(2.4)(28.0) = 43.0 \text{ kN}$

– Dead Load:

$$P_c = \left(\frac{8.07 + 0.4}{3}\right)(28.0) + \left(\frac{11.5}{4}\right)(1.0)$$

$= 81.9$ kN Assuming girder steel = 1 kN/m

$P_p = 1.2\,(28.0) = 33.6 \text{ kN}$
$P_{OD} = (0.5 + 0.2)\,(28.0) = 19.6 \text{ kN}$



Taking moment about A, the tributary-area reaction at G1

$$= \left\{\left(\frac{11.5}{4}\right)(9 + 1.85)^2/2 + 7.62\,(9 + 1.85)\right\}/9$$

$$= 28 \text{ m}^2$$

Figure 6.E7
Tributary Area for Reaction at Point 'G1'

– Factored maximum positive moment, M_f

$P_f = 1.25(81.9 + 33.6 + 19.6) + 1.5(43) = 233 \text{ kN}$

$$M_f = 233\left(\frac{11.5}{2}\right) = 1\,340 \text{ kN·m}$$

$$V_f = 233\left(\frac{3}{2}\right) = 350 \text{ kN}$$

– Elastic properties of deck-slab system (top chord)

Using **W410×39 stubs**, $b = 140$ mm

$16t_o + b = 16(151) + 140 = 2\,556$ mm, (governs b_l)
girder spacing = 9 000 mm
$L/4 = 11\,500/4 = 2\,875$ mm

Figure 6.E8 shows the cross section of the deck-slab system within the effective width b_l.

Longitudinal reinforcing bars of size 15M are assumed. Five 15M bars near the top surface, and five 15M bars near the bottom of deck-slab, are placed in continuous lengths for the span of the girder.

In addition, two layers of welded wire mesh of size 152×152 MW18.7×MW18.7 are assumed to be placed near the top of the slab.

$E_c = w_c^{1.5} \times 0.043\,\sqrt{f'_c}$
$= (2\,300)^{1.5}\,(0.043)\,\sqrt{25} = 23\,700 \text{ MPa}$
$n = E/E_c = 200\,000/23\,700 = 8.44$

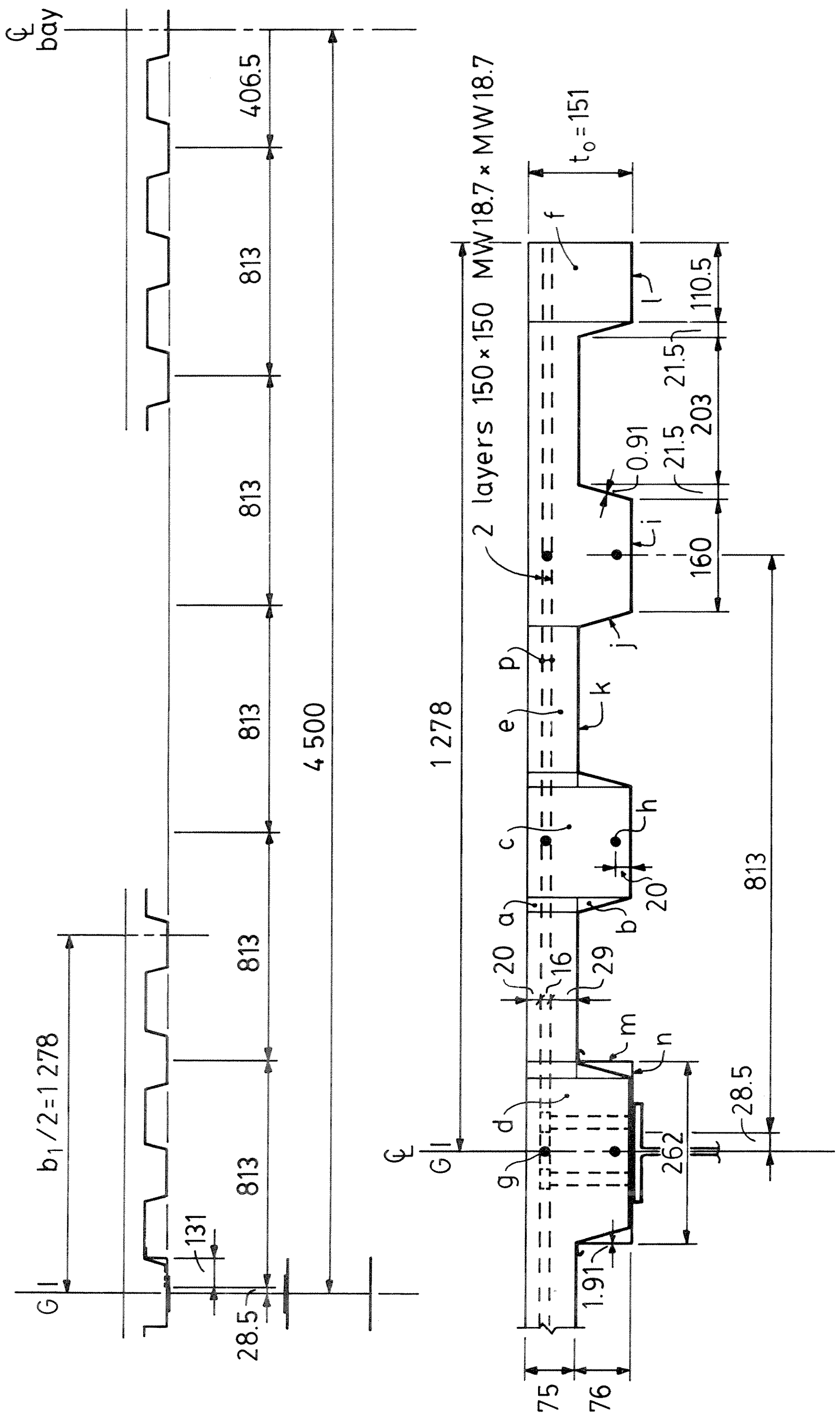


Figure 6.E8
Cross Section of Reinforced Deck-Slab within Effective Slab Width

The following table is prepared for the calculation of the neutral axis and the moment of inertia of the composite deck-slab (within the design effective width b_1).

Element I/D	No. of pieces	Total transformed area, A (mm²)	Distance from top of slab, y (mm)	Product A y (mm³)	Product A y² (mm⁴)	I_{local} in steel unit (mm⁴)
a	12	2 293	37.5	85 988	3.2×10^6	1.1×10^6
b	12	1 162	100.3	116 549	11.7×10^6	0.3×10^6
c	4	11 450	75.5	864 475	65.3×10^6	21.8×10^6
d	1	3 918	75.5	295 809	22.3×10^6	7.4×10^6
e	6	10 823	37.5	405 863	15.2×10^6	5.1×10^6
f	2	3 954	75.5	298 527	22.5×10^6	7.5×10^6
g	5	1 000	28	28 000	0.8×10^6	
h	5	1 000	123	123 000	15.1×10^6	
i	4	582	151	87 882	13.3×10^6	
j	12	862	113	97 406	11.0×10^6	0.4×10^6
k	6	1 108	75	83 100	6.2×10^6	
l	2	201	151	30 351	4.6×10^6	
m	2	290	113	32 770	3.7×10^6	0.1×10^6
n	1	500	151	75 500	11.4×10^6	
p	2	≃ 560	28	15 680	0.4×10^6	
TOTAL		39 703		2 640 900	206.7×10^6	43.7×10^6

$\overline{y}$ (Neutral axis) $= \Sigma\,(A\,y)\,/\,\Sigma\,A = 66.5$ mm (from top of slab)

I_t = Transformed moment of inertia (steel unit)
$= \Sigma\, I_{local} + \Sigma\,(A\,y^2) - y^2\Sigma A$
$= (43.7 + 206.7) \times 10^6 - (66.5)^2(39\,703) = 74.8\times10^6\ \text{mm}^4$

Note: value of I_t represents the uncracked deck-slab top chord.

- Approximate girder size selection

Assuming depth of girder section used ≃ 310 mm. Estimated effective depth of girder section, as illustrated in Figure 6.E9, is shown as 638 mm.

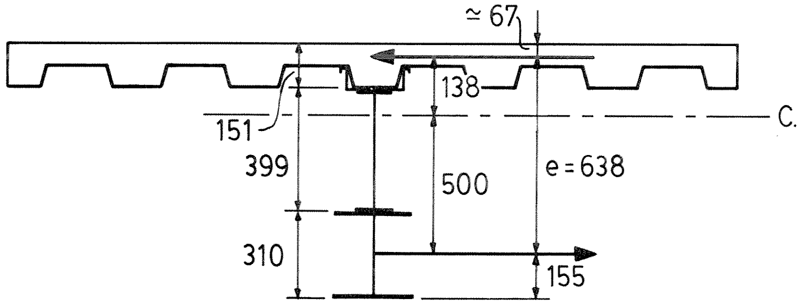


Figure 6.E9
Approximate Lever Arm Length for Bottom Chord Force Computation

Maximum bottom chord factored axial tension $\simeq M_f/e = 1\,340(10^3)/638 = 2\,100$ kN

Allowing for effects of local bending (say about 35%), factored bottom chord tension $\simeq 2\,100(1+0.35)$ is used for trial selection.

$$\text{Estimated bottom chord area} = \frac{2\,100(1+0.35)}{0.9\,F_y}$$

$$= \frac{2\,100(1+0.35)}{0.9(300)} \times 10^3$$

$$= 10\,500 \text{ mm}^2$$

Check trial section **W310×86**. $A_s = 11\,000$ mm²
$I_x = 199\times10^6$ mm⁴ $Z_x = 1\,420\times10^3$ mm³ $d = 310$ mm
$b = 254$ mm $t = 16.3$ mm $w = 9.1$ mm
(from Handbook of Steel Construction - 1984, p.6-48)

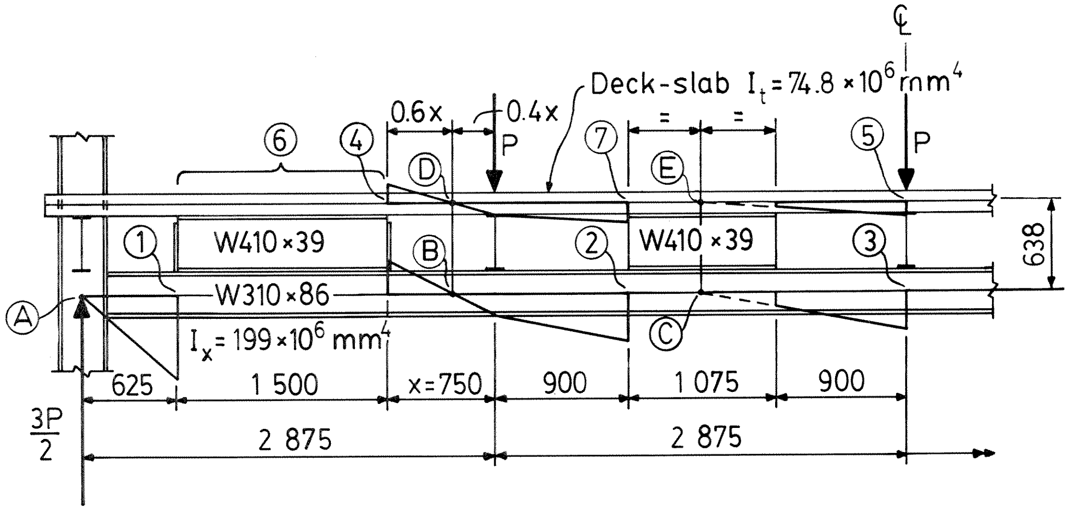


Figure 6.E10
Simplified Vierendeel Girder Model

– Approximate 'statically-determinate' model analysis

Figure 6.E10 illustrates the vierendeel girder model of the stub-girder similar to the girder shown in Figure 6.9.

Moment of inertia of top chord $= 74.8\times10^6$ mm⁴ (or 27%)
Moment of inertia of bottom chord $= 199\times10^6$ mm⁴ (or 73%)

Shear at location A $= 3P_f/2 = 350$ kN
B $= (3P_f/2)(0.73) = 255$ kN
C $= (P_f/2)(0.73) = 85$ kN
D $= (3P_f/2)(0.27) = 94.4$ kN
E $= (P_f/2)(0.27) = 31.5$ kN
where $P_f = 233$ kN

Bending moment at points:
1 $350\,(0.625) = 219$ kN·m
2 $255\,(0.4)(0.75)+85(0.9) = 153$ kN·m
3 $85(1.075/2+0.9) = 122$ kN·m
4 $94.4\,(0.6)(0.75) = 42.5$ kN·m
5 $31.5(1.075/2+0.9) = 45.3$ kN·m
7 $94.4(0.4)(0.75)+31.5(0.9) = 56.7$ kN·m

Axial forces at points:
B and D $= (3P_f/2)(2.875\text{-}0.4\times0.75)/0.638 = 1\,411$ kN
C and E $= [(3P_f/2)(2.875)(1.5)-P_f(2.875/2)]/0.638 = 1\,837$ kN

– Design checks to critical locations of stub-girder model

Location 1

Check bending in steel member:
Factored bending moment, $M_f = 219$ kN·m
Factored moment resistance,
M_r for unbraced length of 625 mm $= 383$ kN·m ($L_u = 4\,250$ mm)

Therefore, utilization of moment resistance can be calculated as

$(M_f/M_r) = 57\%$ OK, not greater than 100%

Check shear in steel member:
Factored shear force, $V_f = 350$ kN
Factored shear resistance, $V_r = 503$ kN

$$\text{Therefore, utilization of shear resistance} = \frac{V_f}{V_r} = 70\%$$

OK, not greater than 100%

Location 2

Check combined bending and axial tension of steel member:

Factored bending moment, $M_f = 153$ kN·m
Factored tension, $T_f = 1\,411$ kN
Factored moment resistance, $M_r = 383$ kN·m
Factored tensile resistance, $T_r = \phi\, F_y\, A_s$
$= 0.9(300)(11\,000)/10^3$
$= 2\,970$ kN

Therefore, utilization of combined moment and tensile resistance,

$$\frac{M_f}{M_r} + \frac{T_f}{T_r} = 87\% \qquad \text{OK, not greater than 100\%}$$

Location 3

Check combined bending and axial tension of steel member:

$M_f = 122$ kN·m $M_r = 383$ kN·m

$T_f = 1\ 837$ kN $\qquad T_r = 2\ 970$ kN

Utilization of combined moment and tensile resistance,

$$\frac{M_f}{M_r} + \frac{T_f}{T_r} = 94\% \qquad \text{OK, not greater than } 100\%$$

Locations 4, 5 and 7

In computing the top chord's resistance to combined compression and bending, it is assumed that shear bond capacity is exceeded in the ultimate state and thus no steel deck contribution can be credited. The ribbed concrete slab reinforced by top and bottom re-bars must then resist the combined forces at each critical location along the top chord. $\phi_c = 0.60$ is suggested(6.19) for members with nominal axial compression greater than the balanced nominal load of the reinforced concrete section. This condition usually applies to a stub-girder top chord since the eccentricity (i.e. the ratio of M_f to C_f) is normally quite small. A design using this ϕ_c value also satisfies the CAN3-A23.3-M77 Code as

$$0.60 \leq 0.70 \frac{1.25\ \text{D.L} + 1.5\ \text{L.L}}{1.4\ \text{D.L} + 1.7\ \text{L.L}} \text{ for all positive ratios of } \frac{\text{L.L}}{\text{D.L}}$$

Location 7

Check combined axial compression and positive bending

$M_f = 56.7$ kN·m $\qquad C_f = 1\ 411$ kN

$$e = \frac{M_f}{C_f} = 40.2 \text{ mm}$$

$$r = \sqrt{\frac{74.8 \times 10^6}{39\ 703}} = 43.4 \text{ mm}$$

$$\frac{Kl}{r} = \frac{1.0(900)}{43.4} = 20.7 < 34 - 12(M_1/M_2)$$

where $M_1 = 28.3$ and $M_2 = 56.7$

Hence neglect slenderness effect (Clause 8.12.5.1 of CAN3-A23.3-M77)

Find ultimate resistance by successive approximation

Try a = 75 mm

From Fig. 6.E11(a)

$$\epsilon_s = \frac{0.85d\epsilon_u}{a} - \epsilon_u = \frac{0.85(123)0.003}{75} - 0.003 = 0.00118 < \frac{f_y}{E_s} \text{ of rebar}$$

i.e. $f_s = E_s\, \epsilon_s = 200\ 000\ (0.00118) = 236$ MPa

$$\epsilon_s' = \frac{a - 0.85d'}{a} \epsilon_u = \frac{75 - 0.85(28)}{75}(0.003) = 0.00205 > \frac{f_y}{E_s} \text{ of rebar}$$

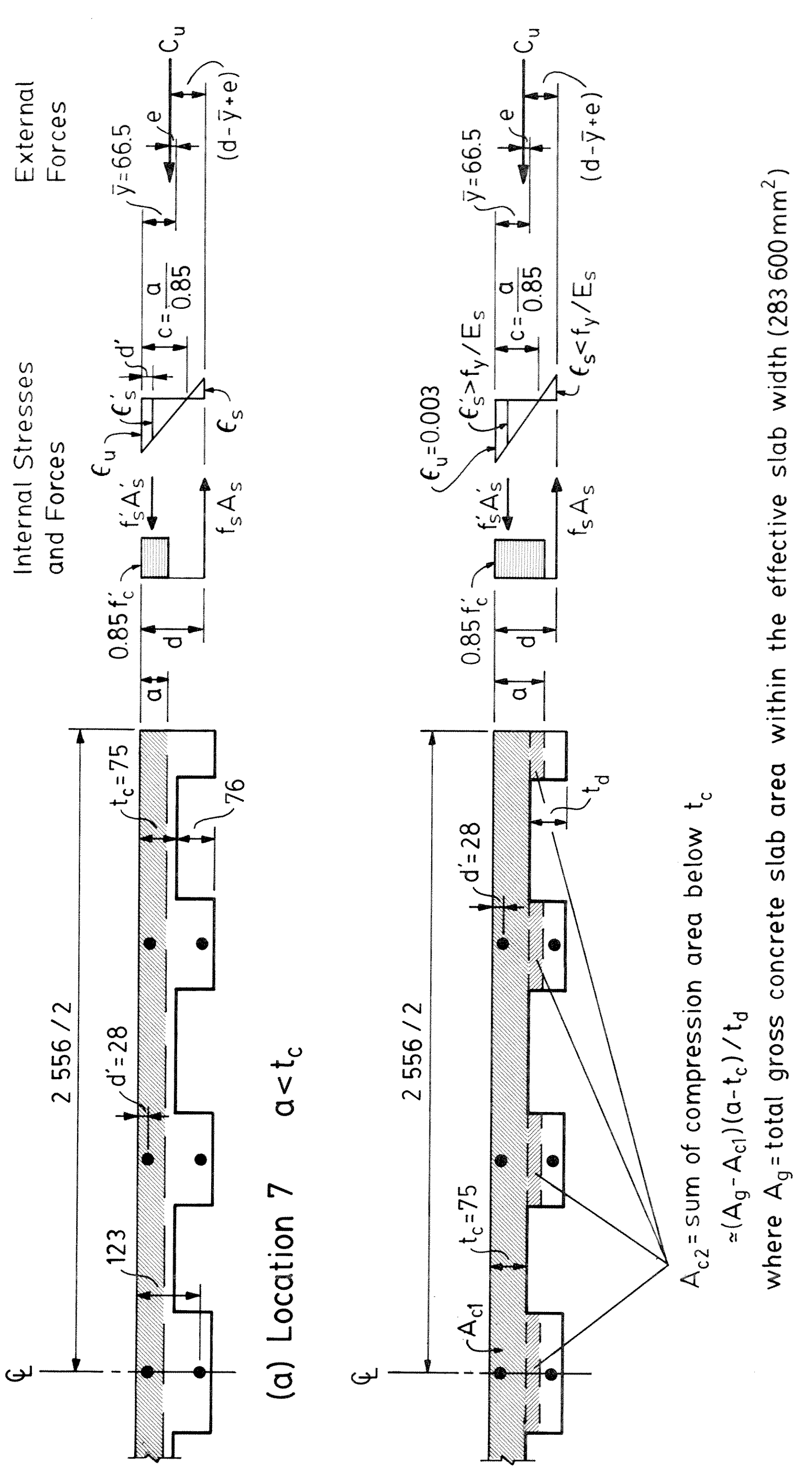


Figure 6.E11
Idealized Top Chord Cross Section Showing Internal Forces and Strains under Combined Compression and Positive Bending

$f'_s \;=\; f_y = 400$ MPa (used for rebar)

$$C_u = 0.85\, f'_c\, a\, b_l + f_y\, A'_s - f_s\, A_s$$

$$= 0.85(0.025)(75)(2\ 556) + 0.400(1\ 000) - 0.236(1\ 000)$$

$$= 4\ 074 + 400 - 236 = 4\ 238 \text{ kN}$$

Taking moment about centroid of tension bars,

$$(e + d - \overline{y})\, C_u = 0.85\, f'_c\, a\, b_l \left(d - \frac{a}{2}\right) + f_y\, A'_s\, (d - d')$$

i.e. $(e + 56.5)4\ 238 = 4\ 074(85.5) + 400(95)$

Solving for e,

$e \;=\; 34.7$ mm < 40.2 mm (Therefore, new 'a' value should be tried)

Try $a = 70$ mm , thus $e = 38.9$ mm < 40.2 mm
Try $a = 69$ mm , thus $e = 39.8$ mm $\simeq 40.2$ mm (accepted)
$C_u = 3\ 840$ kN
$f_s = 309$ MPa $< f_y$; therefore $\phi_c = 0.60$
$C_r = \phi_c\, C_u = 2\ 300$ kN
$M_r = e\, C_r = 92.6$ kN·m

$$\text{Utilization ratio} = \frac{C_f}{C_r} = \frac{M_f}{M_r} = \frac{1\ 411}{2\ 300} = 0.61 < 1.0 \qquad \text{OK}$$

Location 5

Check combined axial compression and bending,

$M_f = 45.3$ kN·m $\qquad C_f = 1\ 837$ kN

$$e = \frac{M_f}{C_f} = 24.7 \text{ mm}$$

By successive approximation,
Try $(a = 90) > t_c$

From Fig. 6.E11(b),

$$f_s = \frac{0.85(123)\epsilon_u E_s}{90} - \epsilon_u E_s = 97.0 \text{ MPa (Where } \epsilon_u E_s = 600 \text{ MPa)}$$

$$A_{cl} = 75(2\ 556) = 191\ 700 \text{ mm}^2$$

$$A_{c2} = \frac{a - t_c}{t_d}(A_g - A_{cl}) = \frac{90 - 75}{76}(283\ 600 - 191\ 700) = 18\ 140 \text{ mm}^2$$

$$C_u = 0.85 f'_c A_{cl} + 0.85 f'_c A_{c2} + f_y A'_s - f_s A_s$$
$$= 4\ 074 + 385 + 400 - 0.097(1\ 000)$$
$$= 4\ 762 \text{ kN}$$

Taking moment about centroid of tension bars,

$$(e + d - \overline{y})C_u = 0.85 f'_c A_{cl}\left(d - \frac{t_c}{2}\right) + 0.85 f'_c A_{c2}\left(d - \frac{t_c}{2} - \frac{a}{2}\right) + f_y A'_s(d - d')$$

$$\text{Thus, } e = \frac{4\ 074\ (123 - 37.5) + 385\ (123 - 37.5 - 45) + 400\ (123 - 28)}{4\ 762} - 56.5$$

$$= 27.9 \text{ mm} > 24.7 \text{ mm}$$

Try $a = 100$ mm, thus $e = 23.9$ mm < 24.7 mm
Try $a = 98$ mm, thus $e = 24.7$ mm $= 24.7$ mm (value 'a' OK)
$C_u = 5\ 020$ mm
$f_s = 40.1$ MPa $< f_y$; therefore $\phi_c = 0.60$

$C_r = 0.6\, C_u = 3\ 010$ kN
$M_r = e\, C_r = 74.3$ kN·m

$$\text{Utilization ratio} = \frac{1\ 837}{3\ 010} = 0.61 < 1.0 \qquad \text{OK}$$

Location 4

Check combined axial compression and bending (negative)

$M_f = 42.5$ kN·m $\qquad C_f = 1\ 411$ kN

$$e = \frac{M_f}{C_f} = 30.1 \text{ mm}$$

Try $a = 100$ mm

From Fig. 6.E12,

$$f_s = \frac{0.85(123)600}{100} - 600 = 27.3 \text{ MPa}$$

$A_{cl} = A_g - b_l t_c = 283\ 600 - 2\ 556(75) = 91\ 900$ mm^2
$A_{c2} = b_l(a - t_d) = 2\ 556(100 - 76) = 61\ 340$ mm^2

$$C_u = 0.85 f'_c A_{cl} + 0.85 f'_c A_{c2} + f_y A'_s - f_s A_s$$
$$= 1\ 953 + 1\ 303 + 400 - 27.3$$
$$= 3\ 629 \text{ kN}$$

Taking moment about centroid of tension bars,

$$(e + \overline{y} - t_o + d)C_u = 0.85 f'_c A_{cl}(d - t_d/2) + 0.85 f'_c A_{c2}\left(d - \frac{t_d}{2} - \frac{a}{2}\right) + f_y A'_s(d - d')$$

$$e = \frac{1\ 953(123 - 38) + 1\ 304(123 - 38 - 50) + 400(123 - 28)}{3\ 629} - 38.5$$

$$= 30.3 \text{ mm} \simeq 30.1 \text{ mm (accepted)}$$

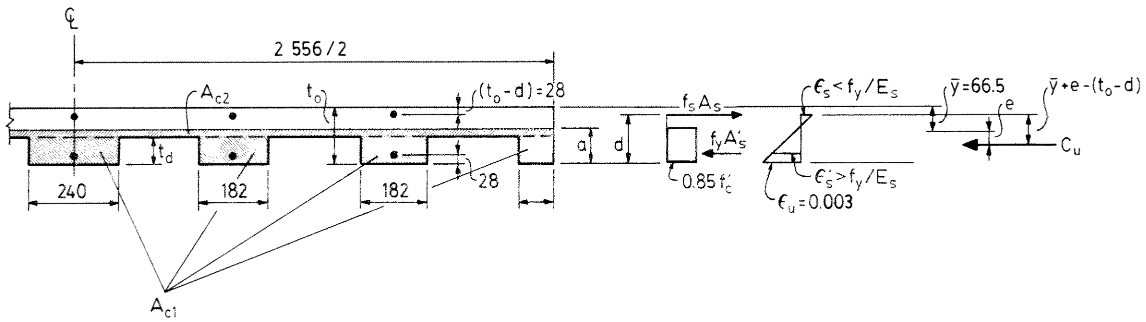


Figure 6.E12
Idealized Top Chord Section Showing
Internal Forces and Strains under
Combined Compression and Negative Bending ($a > t_d$)

$f_s = 27.3$ MPa $< f_y$; therefore $\phi_c = 0.60$
$C_r = 0.6\ (3\ 629) = 2\ 180$ kN
$M_r = e\ C_r = 65.5$ kN·m

$$\text{Utilization ratio} = \frac{1\ 411}{2\ 180} = 0.65 < 1.0 \qquad \text{OK}$$

Check shear at Location 4

In the calculation below, steel deck contribution to shear resistance is ignored and the ribbed concrete slab is replaced by a number of tee sections such that each concrete rib becomes a stem of a tee section. Shear resistance can now be computed in accordance with Clause 9.5 of CAN3-A23.3-M77. The total web area, $b_w d$, (shown as shaded parts in Fig. 6.E13) can be computed:

$$b_w d = 283\ 600 - 28(2\ 556) - 6(75-28)(203) = 155\ 000\ \text{mm}^2$$

The axial compression in the top chord is usually very high and therefore the value of M_m as defined by Eq. (32) of Clause 9.5.4 (CAN3-A23·3-M77) is negative.
Hence Eq. (34) can be used to compute v_c.

$$v_c = 0.3\ \sqrt{f'_c}\ \sqrt{1 + 0.3\ \frac{C_f}{A_g}}$$

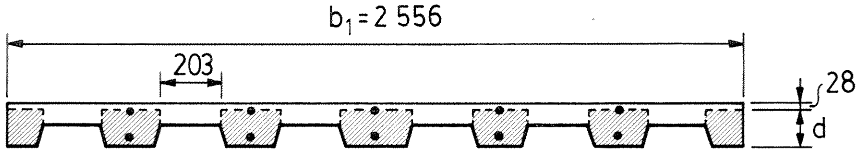


Figure 6.E13
Effective Web Area for Shear Resistance Calculation

$$= 0.3\ \sqrt{25}\ \sqrt{1 + 0.3(1\ 411\ 000)/283\ 600} = 2.37\ \text{MPa}$$

$$V_n = v_c b_w d = 2.37(155) = 367\ \text{kN}$$

$\phi_v = 0.60$ for concrete in shear, as explained at the end of Section 4.9

$V_r = \phi_v\ V_n = 0.6(367) = 220$ kN
$V_f = 94.4$ kN < 220 kN OK

- Stud shear connector design

Studs in Exterior Stub Figure 6.E14 illustrates the interface between the exterior stub and the deck-slab system.

Horizontal factored shear at A-A is represented by the axial force computed for point D and is equal to 1 411 kN.

Factored overturning moment of the deck-slab at level A-A may be calculated as,

$$\frac{1\ 411\ (151-67)}{10^3} - 42.5 = 76\ \text{kN·m}$$

The factored shear resistance of a 19 mm shear stud in a 25 MPa-2 300 kg/m^3 concrete slab can be found from Table 2.1 as 87.8 kN, (q_r).

Studs assumed in tension are shown at location ‘x’ of Fig. 6.E14. The amount of shear cone overlap is indicated by the measure of stud distance to “free” edges. Reference 2.10 is used to determine stud ultimate tension capacity P_{uc}. The P_{uc} values obtained are by means of interpolation after deducting for effects of shear cone overlap.

$q_t = \phi_{sc}\ (P_{uc})$
$\simeq 0.8\ (39.3) = 31$ kN (or 62 kN for 2 studs)

$$\text{Total number of studs for shear action} = \frac{1\ 411}{q_r} = 16.1$$

$$\text{Total number of studs for overturning} = \frac{76.0}{31 \times 1.45} = 1.7$$

Total for all effects = 17.8

Allowing for 50% extra, use **26 studs** for each exterior stub.

Studs in Interior Stub Figure 6.E15 illustrates the interface between the interior stub and the deck-slab system.

Horizontal factored shear at A-A can be calculated as (1 837 − 1 411) = 426 kN.

Factored overturning moment of the deck-slab at level A-A may be calculated as,

$$\frac{426\ (151-67)}{10^3} - 56.7 + 16.9 = -4.0\ \text{kN·m}$$

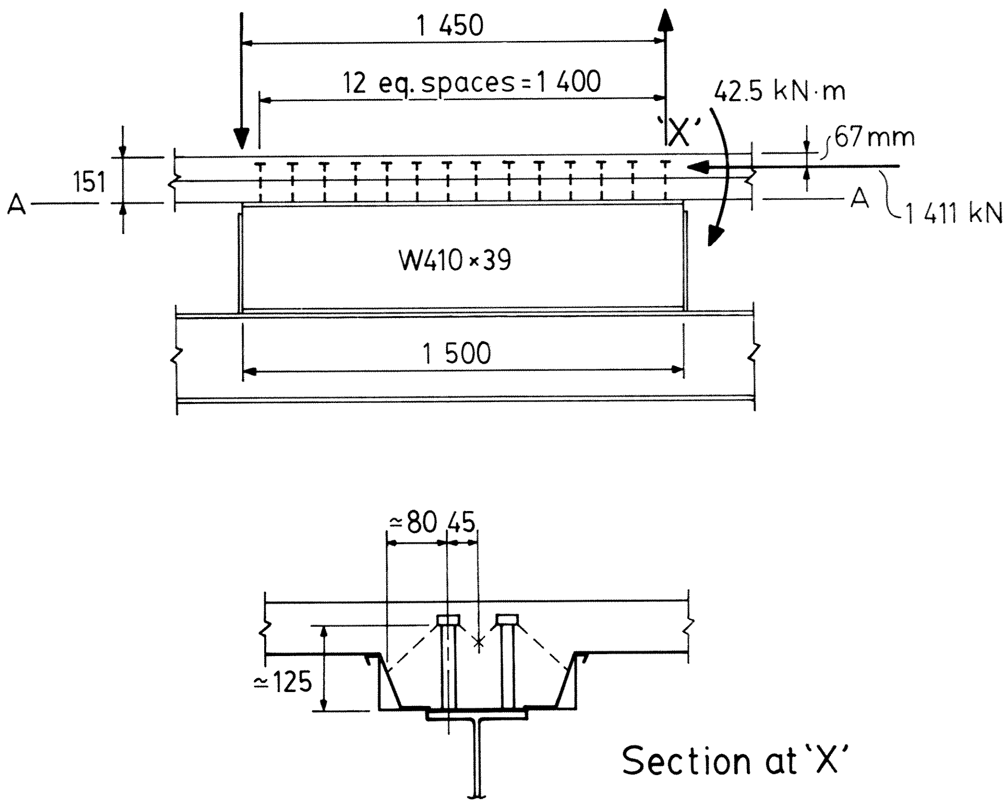


Figure 6.E14
Stud Distribution in Exterior Stubs

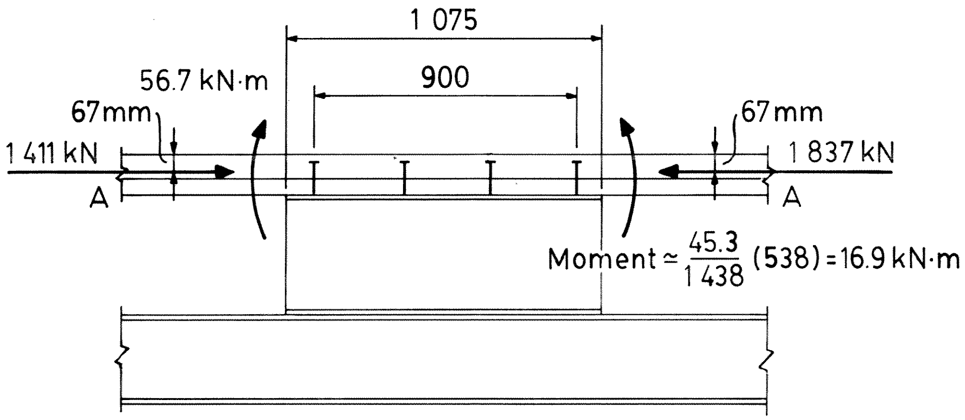


Figure 6.E15
Stud Distribution in Interior Stubs

$$\text{Total number of studs for shear action} = \frac{426}{q_r} \qquad = 4.9$$

$$\text{Total number of studs for overturning} = \frac{4.0}{31 \times 0.9} \qquad = 0.14$$

$$\underline{\text{Total for all effects} = 5.04}$$

Allowing for 50% extra, use **8 studs** for each interior stub.

- Design of transverse slab reinforcement to provide adequate deck-slab longitudinal shear resistance (Location 6, Fig. 6.E10).

The results of 5 Canadian and 2 U.S. full scale stub-girder tests, using concrete slabs of normal density and semi-low density of strengths 22 to 33 MPa, transversely reinforced with rebars of various configurations, were analysed during the preparation of the following design method. Up to four components of horizontal resisting forces are considered in the idealized failure mechanism, which include,

a) Axial resistance due to concrete in compression,
b) Axial resistance due to longitudinal steel in compression,
c) Longitudinal shear resistance of slab, reinforced by transverse rebars, and
d) Additional longitudinal shear resistance due to the longitudinal component of transverse reinforcement in tension, when "herring-bone" patterned transverse reinforcing is used.

The mean value of the computed ratios of total ultimate horizontal resistance tested to that predicted, for the seven full scale models, is found to be 1.03. An overall ϕ factor of 0.60 is used for the following example calculation.

(I) Try transverse reinforcing configuration type (I) .
Use 2 layers of mesh over stub-girder; see Fig. 6.E16, case (A)

(a) Axial ultimate resistance due to concrete in compression,
$0.85\, f'_c\, A_{cs} = 0.85\,(0.025)(109)(151) = 350 \text{ kN}$

(b) Axial ultimate resistance due to longitudinal steel in compression,
$f_y A_s = (0.4)(200)(2) = 160 \text{ kN}$

(c) Longitudinal shear ultimate resistance of the reinforced slab (credit one layer of mesh only; mesh size - 152×152 MW18.7×MW18.7).

$$\begin{aligned}
\rho &= \frac{18.7}{152(75+76)} = 0.000\,815 \\
v_u &= 0.8\,\rho\, f_y + 2.76 \qquad\qquad \text{(from Eq. 4.20)} \\
&= 0.8\,(0.000\,815)(400) + 2.76 \\
&= 3.02 \text{ MPa} < 0.3 f'_c \\
V_u &= 2\, l_{sh}(t_c + t_d) v_u \\
&= 2(1\,500)(75+76)(3.02)10^{-3} \\
&= 1\,368 \text{ kN}
\end{aligned}$$

Total factored resistance of the failure mechanism,
$0.6\,(350 + 160 + 1\,368) = 1\,127 \text{ kN} < 1\,411 \text{ kN}$

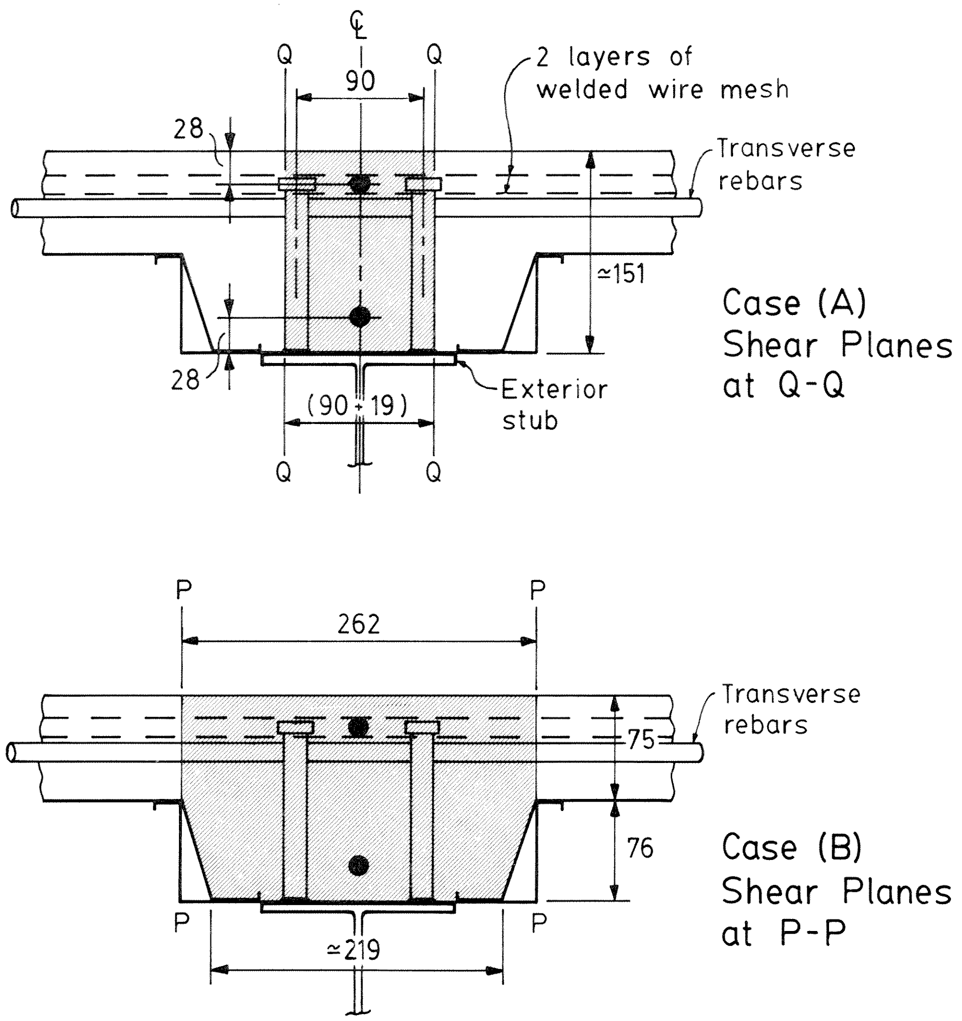


Figure 6.E16
Idealized Failure Mechanisms Used for Transverse Reinforcing Design

Therefore, transverse reinforcing configuration type (I) is not satisfactory for use in this example girder. No need to check case (B).

(II) Try transverse reinforcing configuration type (II) (same as in type (I) except add 5-15M straight bars transversely to girder span, over the exterior stub).

For Case (A), Calculations (a) and (b) are same as above; calculation (c) is to be modified as,

$$\rho = \frac{18.7}{152(75+76)} + \frac{5(200)}{1\,500(75+76)} = 0.00523$$

$$\begin{aligned} v_u &= 0.8\,(0.00523)(400) + 2.76 \\ &= 4.43 \text{ MPa} < 0.3\, f'_c \\ V_u &= 2\, l_{sh}\,(t_c + t_d)\, v_u \\ &= 2\,(1\,500)(75+76)(4.43)\, 10^{-3} \\ &= 2\,007 \text{ kN} \end{aligned}$$

Total factored resistance of the failure mechanism, for Case (A) shear planes,
$0.6\,(350 + 160 + 2\,007) = 1\,510 \text{ kN} > 1\,411 \text{ kN}$

For Case (B), shear planes are assumed to occur at P-P

(a) Axial ultimate resistance due to concrete in compression,

$$\begin{aligned} 0.85\, f'_c\, A_{cs} &= 0.85\,(0.025)\,[(75)(262) + (76)(262 + 219)/2] \\ &= 806 \text{ kN} \end{aligned}$$

(b) Axial ultimate resistance due to longitudinal steel in compression,
$f_y\, A_s = (0.4)(200)(2) = 160 \text{ kN}$

(c) Longitudinal shear ultimate resistance of the reinforced slab (one layer of mesh plus 5-15M straight bars)

$$\rho = \frac{18.7}{152(75)} + \frac{5(200)}{1\,500(75)} = 0.0105$$

$$\begin{aligned} v_u &= 0.8\, \rho\, f_y + 2.76 \\ &= 0.8(0.0105)(400) + 2.76 \\ &= 6.12 \text{ MPa} < 0.3\, f'_c \end{aligned}$$

$$\begin{aligned} V_u &= 2\, l_{sh}\,(t_c)\, v_u \\ &= 2(1\,500)(75)(6.12)\, 10^{-3} \\ &= 1\,377 \text{ kN} \end{aligned}$$

Total factored resistance of the failure mechanism, for Case (B) shear planes,
$0.6(806 + 160 + 1\,377) = 1\,406$ kN (more critical than Case (A))

(III) Try transverse reinforcing configuration type (III) (same as in type (I) except add 4-15M bent bars to be arranged in a "herring-bone" pattern over the exterior stub). See similar detail in Fig. 6.14.

For Case (A), shear planes are assumed to occur at Q-Q
Axial ultimate resistance due to concrete and longitudinal steel reinforcing,
$(350 + 160) = 510$ kN.

Longitudinal shear ultimate resistance of the reinforced slab (one layer of mesh plus rebar at a 45 degree angle),

$$\rho = \frac{18.7}{152(75+76)} + \frac{4(200)/\sqrt{2}}{1\,500(75+76)} = 0.00331$$

$$\begin{aligned} v_u &= 0.8(0.00331)(400) + 2.76 \\ &= 3.82 \text{ MPa} < 0.3\, f'_c \end{aligned}$$

$$\begin{aligned} V_u &= 2\, l_{sh}\,(t_c + t_d)\, v_u \\ &= 2\,(1\,500)(75+76)(3.82)\, 10^{-3} \\ &= 1\,730 \text{ kN} \end{aligned}$$

Additional longitudinal shear resistance due to bent bars in tension,
$2\, f_y\, A_s/\sqrt{2} = 2(0.4)(200)(4)/\sqrt{2} = 453 \text{ kN}$

Total factored resistance of the failure mechanism for Case (A) shear planes,
$0.6 (510 + 1\,730 + 453) = 1\,616$ kN

For Case (B), the total factored resistance of the failure mechanism in type (III) transverse reinforcing configuration can be shown as,
$0.6 (966 + 1\,101 + 453) = 1\,512$ kN (more critical than Case (A))

The following table summarizes the factored resistance* of slabs with 3 types of transverse reinforcing configurations, under two types of failure mechanisms:

Failure Mechanisms	Double Mesh (I)	Double Mesh plus 5-15M straight bars (II)	Double Mesh plus 4-15M bent bars at 45° angle (III)
Case (A)	1 127	1 510	1 616
Case (B)	1 023 (governs)	1 406 (governs)	1 512 (governs)

*values shown, in the above table, are in (kN) unit.

It is therefore concluded that either type (II) or type (III) transverse reinforcing configuration is satisfactory for use over the exterior stubs, since the governing factored ultimate resistance of the failure mechanism is, in each case, greater than (or very closely equal to) the factored applied load of 1 411 kN.

Also, it can be shown that transverse rebars are not required for the deck-slab over the interior stubs. Double mesh is assumed throughout the full length of the girder.

- Stiffener design at exterior stubs (see Fig. 6.E17)

Area of 'T' section in compression $= (140)(10) + (54)(6.4) = 1\,746$ mm^2

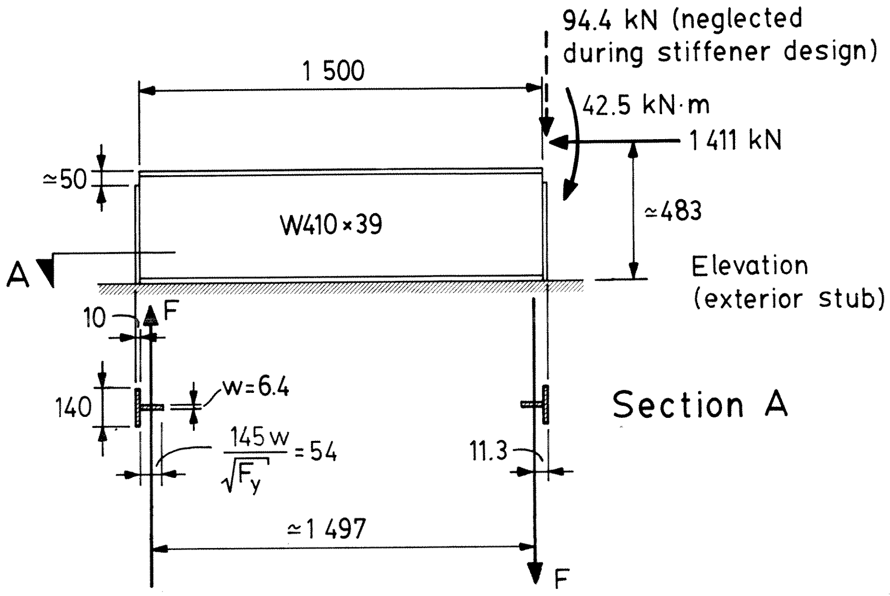


Figure 6.E17
End Stiffener Design – Exterior Stubs

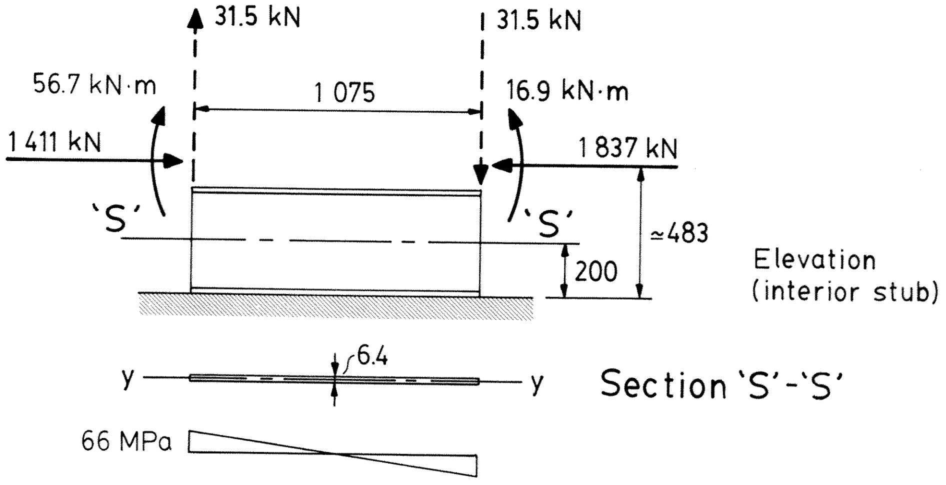


Figure 6.E18
Overturning on Interior Stubs
(Slab Shear Neglected During Design Checks)

C.G. of 'T' section from ends of stiffened stub,

$$\frac{140(10)(5) + (54)(6.4)(10 + 54/2)}{(1\,746)} = 11.3 \text{ mm}$$

Total factored overturning moment $= 1\,411(0.483) - 42.5 = 639$ kN·m

Total factored resisting moment $= F[1\,520 - 2(11.3)]\,10^{-3} = (1.497)F$

Equating moments,
$1.497\,F = 639$
$F = 639/1.497 = 427$ kN

Factored axial resistance of the 'T' section,
$\phi\, A_s\, F_y = 0.9\,(1\,746)(0.3)$
$= 471 \text{ kN} > 427 \text{ kN}$ OK

Use end stiffeners (size 10 × 140 × 350 long)

- Check stiffener requirement at interior stubs (see Fig. 6.E18)

Total factored overturning moment acting on the interior stub about level 'S'-'S',
$(1\,837 - 1\,411)(0.483 - 0.200) + 16.9 - 56.7$
$= 81.0$ kN·m (say)

$$\text{Section modulus of web section} = \frac{6.4 \times 1\,075^2}{6} = 1\,233 \times 10^3 \text{ mm}^3$$

$$\text{Compressive stress due to bending} = \frac{(81)\,10^6}{(1\,233)\,10^3} = 66 \text{ MPa}$$

r_{yy} of web plate $= \dfrac{6.4}{\sqrt{3}} = 3.69$ mm

$\dfrac{Kl}{r}$ of web plate acting as a small column with both ends fixed

$$= \frac{0.65\,(d - 2k)}{r}$$

$$= \frac{0.65\,[399 - 2(26)]}{3.69}$$

$$= 61$$

Unit factored compressive resistance, C_r/A for the small column = 205 MPa. This is greater than 66 MPa; OK. (See Handbook of Steel Construction P. 4-11).

- Check shear in web of exterior stub (horizontal shear) (Cl. 13.4.1 of S16.1)

$$a/h = (399)/1\,500 = 0.266 < 1.0$$
$$h/w = 1\,500/6.4 = 234$$
$$k_v = 4 + 5.34/(a/h)^2 = 79.5$$

$$h/w > 439\sqrt{\frac{k_v}{F_y}} \quad \text{or} \quad 234 > 226$$

$$h/w < 502\sqrt{\frac{k_v}{F_y}} \quad \text{or} \quad 234 < 258$$

$$F_s = \frac{290\sqrt{F_y\,k_v}}{(h/w)} = 191 \text{ MPa}$$

Factored shear resistance of the web,
(0.9)(1 500)(6.4)(0.191) = 1 650 kN > 1 411 kN (OK)

- Check shear in web of interior stub (horizontal shear)

Factored shear acting on the web of interior stub
= 1 837 − 1411 = 426 kN

Factored shear resistance of the web of interior stub
$= 0.5\,\phi\,A_s\,F_y = 0.5(0.9)(1\,075)(6.4)(0.3)$
= 929 kN > 426 kN (OK)

Note: Cl.13.4.4 of S16.1, factored shear resistance for gusset plate is assumed.

- Design of stub-to-girder welding (exterior stub)

Factored overturning moment at base of exterior stub = 639 kN·m (as shown before)
Factored shear at base of exterior stub = 1 411 kN (see Fig. 6.E19)

Try weld configuration as shown in Fig. 6.E19, assuming the overturning moment is resisted by couple forces, F.

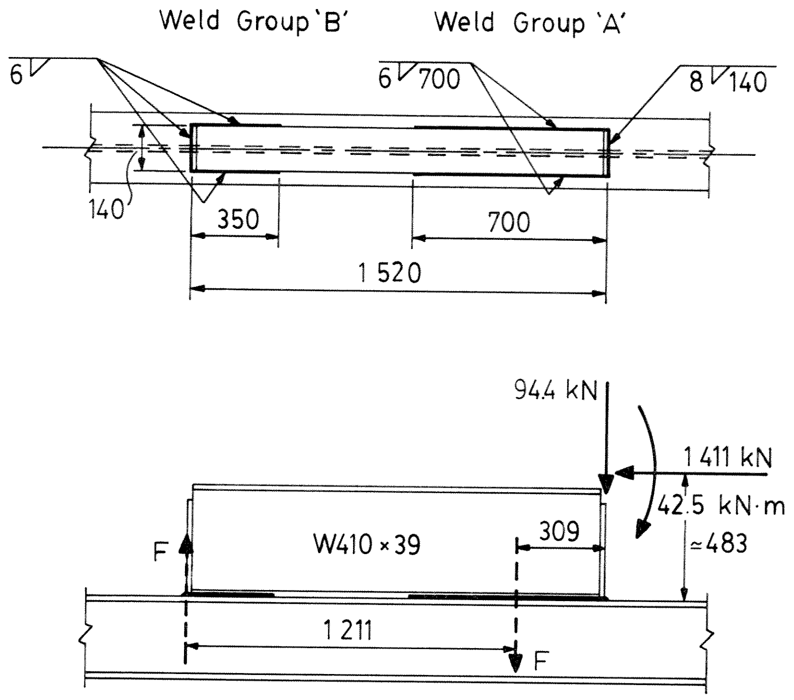


Figure 6.E19
Design of Exterior Stub to Girder Welding

C.G. of weld group 'A' from right end of stub

$$= \frac{140(1.22)(0) + 2(700)(0.918)(700/2)}{140(1.22) + 2(700)(0.918)} = 309 \text{ mm}$$

where, values 1.22 and 0.918 represent the factored shear resistance (kN) per millimetre length of 8 mm and 6 mm fillet welds respectively (see Handbook of Steel Construction P3-37).

Lever arm for overturning resistance = 1 211 mm

Factored tensile force, $F = \dfrac{639}{1.211} = 528$ kN

Reduction of tensile force due to factored slab shear of 94.4 kN
= 94.4(1 520)/(1 211) = 118 kN

Factored tensile resistance of weld group 'A'
= 140(1.22) + 2(700)(0.918) = 1 456 kN

Factored shear resistance of weld group 'A' and 'B'
= (350 + 350 + 140 + 700 + 700)(0.918) + (140)(1.22) = 2 227 kN

Percentage of utilization of weld group 'A'
= 100 [(528 − 118)/1 456 + 1 411/2 227]
= 91.5 < 100 OK

– Design of stub-to-girder welding (interior stub)

Factored O.T.M. at base of interior stub
$= (426)\ (0.483) = 206$ kN·m

Factored shear at base of interior stub
$= 426$ kN

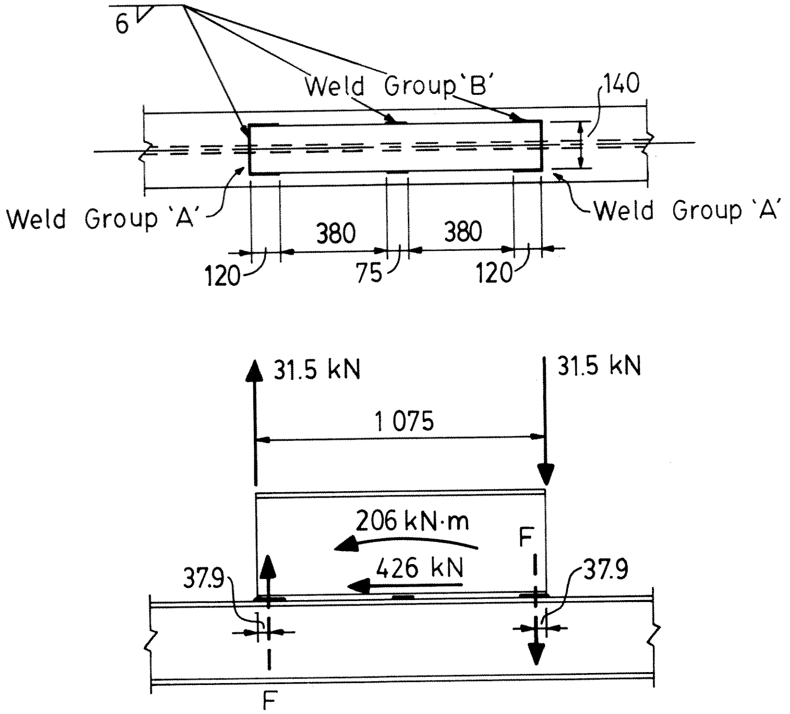


Figure 6.E20
Design of Interior Stub to Girder Welding

Try weld configuration as shown in Fig. 6.E20, assuming the overturning is resisted by couple forces, F.

C.G. of weld group 'A' from end of stub
$= 240\ (120/2)/(240 + 140)$
$= 37.9$ mm

Factored tension force F due to the factored O.T.M. plus the effects of slab shear,
$= [(206) - 31.5(1.075)]/[1.075 - 2(0.0379)]$
$= 172$ kN

Factored tensile resistance of weld group 'A'
$= (120 + 140 + 120)(0.918) = 349$ kN

Factored shear resistance of all welds
$= (2)(120 + 140 + 120 + 75)(0.918) = 835$ kN

Percentage of utilization of weld group 'A'
$= 100\ (172/349 + 426/835)$
$= 100.3 \simeq 100$ OK

– Check elastic deflection with no consideration of creep of concrete, (in terms of equally spaced point load, P kN)

a) Mid span deflection due to "chord action"

Transformed area of top chord, $A_c = 39\ 703\ \text{mm}^2$
Area of steel bottom chord, $A_s = 11\ 000\ \text{mm}^2$

Moment of inertia of transformed concrete top chord,
$I_c = 74.8 \times 10^6\ \text{mm}^4$ (same as I_t as computed from Fig. 6.E8)

Moment of inertia of steel bottom chord,
$I_s = 199 \times 10^6\ \text{mm}^4$

From Figure 6.E9, moment of inertia of top and bottom chord,
$I = A_c(138)^2 + A_s(500)^2 + I_c + I_s$
$= 3\ 780 \times 10^6\ \text{mm}^4$

$$\Delta_a = \frac{19}{384}\frac{Pl^3}{EI}$$

$$= \frac{19}{384}\frac{P\,(11\ 500)^3}{200\ 000(3\ 780)}\ 10^{-3} = 0.0995\ P\ (\text{mm})$$

b) Deflection due to bending of end cantilevers

Cantilever length $(l_c) = 625$ mm
End reaction $= (3)P/2$

$$\Delta_b = \frac{\left(\frac{3P}{2}\right) l_c^3}{3\ E\ I_s}$$

$$\frac{P\ (625)^3}{2\ E\ (199)}\ 10^{-3} = 0.0031\ P\ (\text{mm})$$

c) Deflection due to bending of chords between points F and H, Fig. 6.E21

Since shear forces at top and bottom chords are proportioned on the basis of their relative stiffnesses, additional flexural deflection computed using the bottom chord should be equal to that computed based on the top chord.

Shear at hinge B $= 1.095$ P (bottom chord)
Shear at location G $= 0.365$ P

Flexural deflection in segment FG,

$$= \frac{(1.095P)(0.6x)^3}{3\ E\ I_s} + \frac{(1.095P)(0.4x)^3}{3\ E\ I_s} + \frac{2(1.095P)(0.4x) + (0.365P)(y)}{2\ E\ I_s}\ (y)(0.4x)$$

$$= \frac{(1.095P)(450)^3}{3\ E\ (199)(10^3)} + \frac{(1.095P)(300)^3}{3\ E\ (199)(10^3)} + \frac{2(1.095P)(300) + (0.365P)(900)}{2\ E\ (199)(10^3)}\ (900)(300)$$

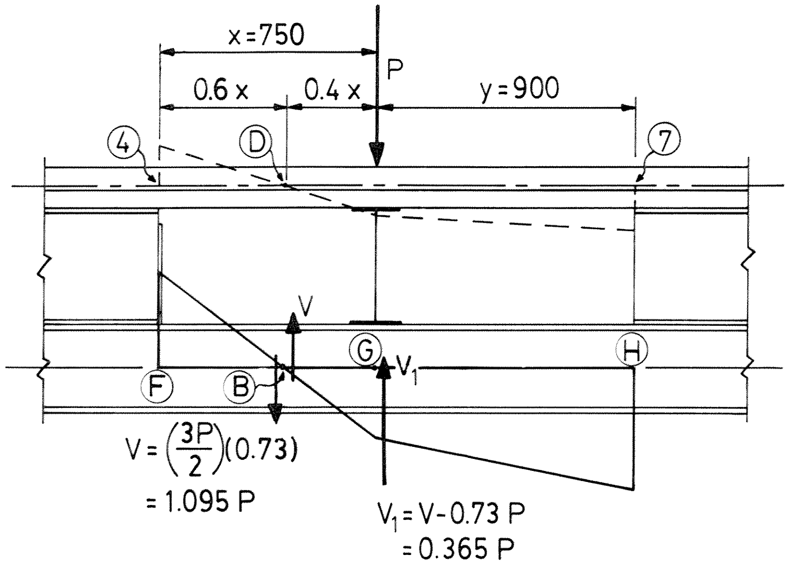


Figure 6.E21
Bending in Bottom Chord Member Between Points F and H

$$= \frac{10^6}{E\,(199)(10^3)}\,(33.26 + 9.86 + 133)\ P = 0.0044\ P\ (\text{mm})$$

Flexural deflection in segment GH,

$$= \frac{(0.365P)(900)^3}{3\ E(199)(10^3)} + \frac{(1.095P)(300)(900)^2}{2\ E\,(199)(10^3)} = 0.0056\ P\ (\text{mm})$$

Therefore, the flexural deflection of chord members between points F and H,
$\Delta_c = (0.0044 + 0.0056)\ P$
$= 0.0100\ P\ (\text{mm})$

d) Deflection due to bending of chords at central openings, Fig. 6.E22.
Shear at bottom chord = 0.365 P

$$\Delta_d = \frac{(0.365P)(900)^3}{3\ E\,(199)(10^3)} + \frac{(0.365P)(900)^2(537.5)}{2\ E\,(199)(10^3)} = 0.0042\ P\ (\text{mm})$$

Total deflection of stub-girder (chord + flexural)
$= \Delta_a + \Delta_b + \Delta_c + \Delta_d$
$= (0.0995 + 0.0031 + 0.0100 + 0.0042)\ P$
$= 0.1168\ P\ (\text{mm})$

Since $P_c = 81.9$ kN
$P_L + P_p + P_{OD} = 43 + 33.6 + 19.6 = 96.2$ kN

Deflection due to fresh-concrete condition load
$= 0.1168(81.9) = 9.6$ mm (girder not cambered)

Deflection due to live load plus superimposed dead loads (96.2 kN)
$= 0.1168(96.2) = 11.2$ mm

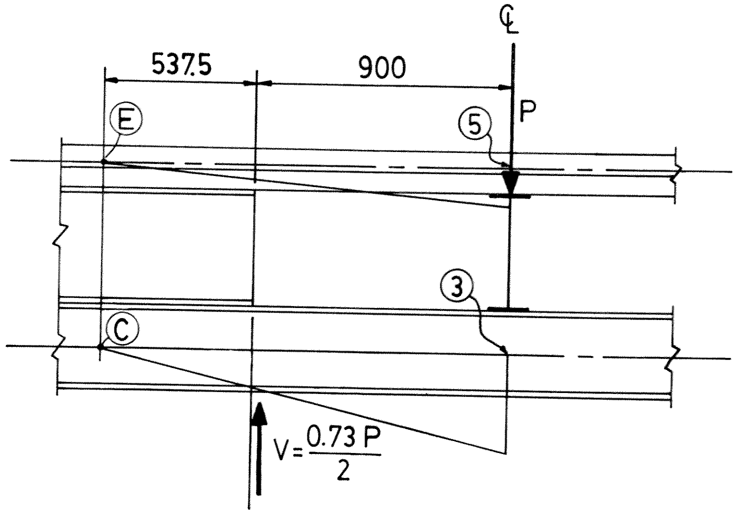


Figure 6.E22
Bending in Bottom Chord Member at Central Opening

Since there is no camber, total deflection of girder
$= 9.6 + 11.2 \simeq 21$ mm; $< L/300$.
Therefore OK

- Check girder deflection with consideration of concrete creep using $n = E_s/(E_c/2.5) = 21.1$

$A_c = 19\,543\ \text{mm}^2$ $\quad I_c = 39.9 \times 10^6\ \text{mm}^4$
$A_s = 11\,000\ \text{mm}^2$ $\quad I_s = 199 \times 10^6\ \text{mm}^4$

Effective depth: top-bottom chord = 633 mm

Shear shared by bottom chord = 83%, instead of 73% computed in the previous case.

Moment of inertia of combined top and bottom chords (spaced 633 mm apart)
$= 3\,060 \times 10^6\ \text{mm}^4$

$\Delta_a = 0.1230\ P\ (\text{mm})$
$\Delta_b = 0.0031\ P\ (83)/(73) = 0.0035\ P\ (\text{mm})$
$\Delta_c = 0.0100\ P\ (83)/(73) = 0.0114\ P\ (\text{mm})$
$\Delta_d = 0.0042\ P\ (83)/(73) = 0.0048\ P\ (\text{mm})$

Total deflection of stub-girder (chord + flexural) including concrete creep effect, under live load plus partition plus other dead load, plus fresh concrete condition load,

$$\Delta = \Delta_a + \Delta_b + \Delta_c + \Delta_d = 0.1427\ P \simeq 25.4\ \text{mm}$$

This is less than L/300 OK

- Structural modelling of stub-girder for detailed analysis using a stiffness analysis computer program (Colaco method), see Fig. 6.11 and Fig. 6.E23

$I_1 = I_{xx}/6 = 566 \times 10^6\ \text{mm}^4$

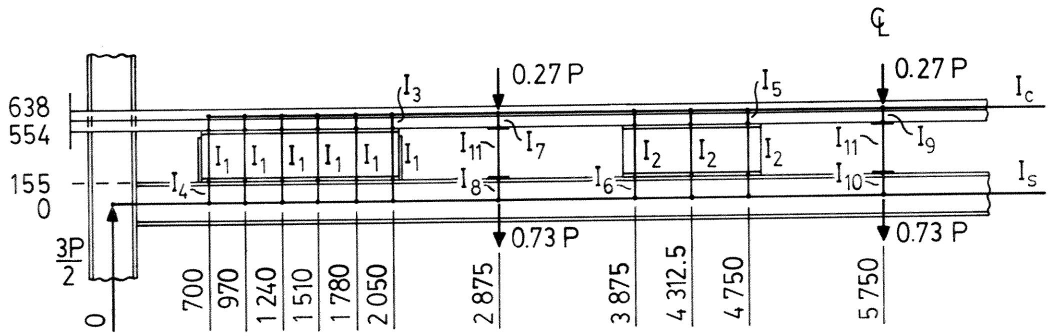


Figure 6.E23
Structural Modelling – Colaco Method

where $I_{xx} = 2(140)(10)(755)^2 + \dfrac{6.4\ (1\ 500)^3}{12} = 3\ 396 \times 10^6\ \text{mm}^4$

$I_2 = I_{x'x'}\ /3 = 221 \times 10^6\ \text{mm}^4$

where $I_{x'x'} = \dfrac{6.4(1\ 075)^3}{12} = 662.6 \times 10^6\ \text{mm}^4$

I_3 to I_{10} are very large fictitious values, say
$= 5$ times $I_1 \simeq 2\ 800 \times 10^6\ \text{mm}^4$

$I_{11} = \dfrac{2(399)(6.4)^3}{12} \simeq 0.02 \times 10^6\ \text{mm}^4$

$I_c = 74.8 \times 10^6\ \text{mm}^4$

$I_s = 199 \times 10^6\ \text{mm}^4$

$A_1 = [2(10)(140) + (6.4)(1\ 500)]/6 = 2\ 067\ \text{mm}^2$

$A_2 = 6.4(1\ 075)/3 = 2\ 293\ \text{mm}^2$

A_3, A_5, A_7, A_9 assume $8\ 000\ \text{mm}^2$

A_4, A_6, A_8, A_{10} assume $2\ 300\ \text{mm}^2$

$A_{11} = 6.4(399) = 2\ 550\ \text{mm}^2$

$A_c = 39\ 703\ \text{mm}^2$

$A_s = 11\ 000\ \text{mm}^2$

The result of the stiffness analysis run is compared to the forces computed based on the "statically-determinate" model, see Table 6.E1.

- Structural modelling of stub-girder using a stiffness analysis computer program (simplified method), see Fig. 6.E24.

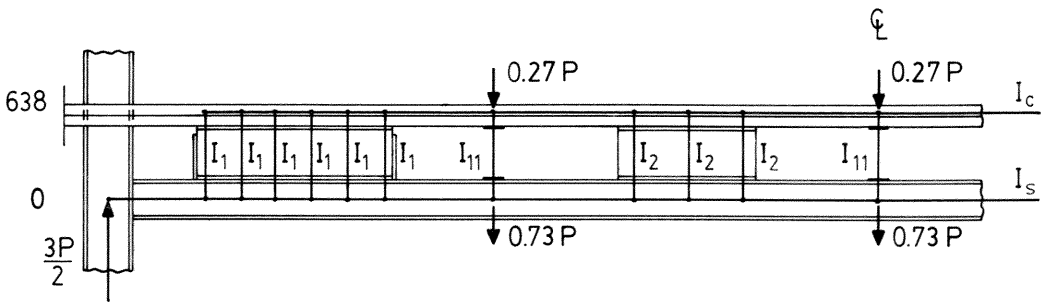


Figure 6.E24
Structural Modelling – Simplified Method

The values of A and I are as computed above. The results of the stiffness analysis run are also compared to the "statically determinate" model; see table below.

COMPARISON OF ANALYSIS METHODS

Location on the stub-girders	Structural Actions*		Analysis Methods		
			Statically determinate Model	Calaco Model	Simplified Vierendeel Model
1	Axial	(kN)	0	0	0
	Bending	(kN·m)	219	219	219
2	Axial	(kN)	1 411	1 413	1 415
	Bending	(kN·m)	153	147	143
3	Axial	(kN)	1 837	1 860	1 855
	Bending	(kN·m)	122	110	111
	Deflection	(mm)	21	20.4	20.8
4	Axial	(kN)	1 411	1 413	1 415
	Bending	(kN·m)	42.5	49.5	53.1
5	Axial	(kN)	1 837	1 860	1 855
	Bending	(kN·m)	45.3	43.4	45.2
7	Axial	(kN)	1 411	1 413	1 415
	Bending	(kN·m)	56.7	61.8	63.9

*Note: 1. Floor load for deflection calculation includes total structural plus superimposed loads.
2. All axial and bending forces listed are based on factored loads in accordance with S16.1.

6.20 TRIAL SELECTION TABLES FOR STUB-GIRDER FLOOR BAY DESIGN

The Trial Selection Tables for stub-girder floor bay design in the following pages provide typical preliminary interior stub-girder floor-bay designs suitable for more detailed structural analysis.

The information provided within the selection tables was computed based on design rules similar to the design procedures shown in section 6.19. However, certain procedures of design checks have been further simplified to provide tabulated output suitable only for trial selection purposes.

Two sets of trial selection tables are provided:
- stub-girder floor bays with stub-girders each containing four stubs and three equally spaced Gerber beams.
- stub-girder floor bays with stub-girders each containing three stubs and two equally spaced Gerber beams.

Two live load cases (2.4 kPa and 3.6 kPa) are included for each set of trial selection tables. Live load reduction as defined by equation 3.2 is assumed for all floor bay designs. Partition loading of 1.2 kPa is included in the dead load.

Two cover slab thicknesses and two concrete densities are available for each combination of stub-girder configuration and live load case:
- 75 mm thick, normal density concrete (2 300 kg/m^3)
- 85 mm thick, semi-low density concrete (1 850 kg/m^3)

To summarize, trial selection tables for stub-girder floor bays occur in the order shown below:

Description	Live Load (2.4 kPa)		Live Load (3.6 kPa)	
	75 mm ND Concrete	85 mm SLD Concrete	75 mm ND Concrete	85 mm SLD Concrete
four-stub configuration	Table 6.2	Table 6.3	Table 6.4	Table 6.5
three-stub configuration	Table 6.6	Table 6.7	Table 6.8	Table 6.9

In addition to the items discussed above, design criteria common to all floor bay designs are listed below:

a) Superimposed dead load = 1.9 kPa
b) Steel deck profile: 76 mm deep, wide-rib profile deck (T-30-V assumed)
c) Concrete strength: 25 MPa
d) Longitudinal bars:
   3-15M bars at 25 mm from top of slab (with one 15M bar occurring within mid-flute)
   4-15M bars at 120 mm from top of slab
e) Transverse bars: 5-15M 'straight' bars over exterior stub
f) Welded wire mesh:

One layer 152×152 MW9.1×MW9.1 mesh over all floor areas.
One additional layer over girder locations.

g) Shear stud diameter: 19 mm
h) Steel Costing Method:
   Use costing method as described in Ref.(17).
   Cost Index used = 1 000

For each typical floor bay, the following design data are provided in the trial selection table:

a) Cantilever segment member size selected along with the number of stud shear connectors required for each cantilever segment member.
b) Length of the cantilever segment member and the computed mid-span deflections of the cantilever segment under the conditions of:
   - during slab pour (fresh-concrete loading)
   - superimposed dead load
   - live loads

c) Percentage of member resistance utilization at:
   - mid span of the cantilever segment
   - cantilever support of the cantilever segment
d) Suspended segment member size selected; required number of stud shear connectors.
e) Same as in b) except for suspended segment.
f) Percentage of member resistance utilization at mid span of the suspended member.
g) Selected stub-girder bottom chord size; required total number of stud shear connectors per girder.
h) Width of hole No. 1 (see Fig. 6.5),
   Length of exterior stub,
   Number of shear studs atop exterior stub.
i) Width of hole No. 3 (see Fig. 6.5),
   Length of interior stub,
   Number of shear studs atop interior stub.
j) Percentage of resistance utilization at bottom chord locations 1, 2 and 3. (see Figs. 6.9-10)
k) Percentage of resistance utilization at top chord locations 4, 5, and 6. (see Figs. 6.9-10).
l) Mid span deflection of stub-girder under the conditions of:
   - shore removal (fresh concrete loading on composite girder)
   - superimposed dead load
   - live load
   - total load
m) Steel mass and cost per typical bay.

All length dimensions and deflection values provided are expressed in millimetres. The steel mass presented in each floor bay is expressed in kilograms; and the cost per typical bay of girder plus average Gerber beam system (structural steel only) is shown in dollars.

To illustrate the use of the trial selection tables, the floor design example as presented in Section 6.19 is reused here and results compared.

Basic design data for table selection:

a) Stub-girder configuration 4 stubs/girder.
b) Live load = 2.4 kPa.
c) Cover Slab: 75 mm, ND Concrete
d) Superimposed Dead Load = 1.9 kPa. (Partition = 1.2, Mechanical/Ceiling = 0.5, Fire Protection and Floor Finish = 0.2).
e) Other design criteria (similar to the design criteria as shown in the explanations above)
f) Girder span = 11 500 mm
g) Beam spans for beam selection = 9 000 mm
   Beam span for girder selection = 10 000 mm
   (since the tributary area for each beam reaction at the typical girder designed = 28 m^2)

Description	Results by Hand-computation	Results by Trial Selection Table
Cantilever Segment Size (studs)	W410×39(16)	W410×39(16)
B1 length (mm)	12 700	12 720
Utilization B1 (%)	90	86
Suspended Segment Size (studs)	W200×27(12)	W200×27(12)
B3 length (mm)	5 300	5 280
Utilization B3 (%)	62	55
Stub-girder size (studs)	W310×86(68)	W310×79(72)
Utilization (%) at 1 / 2 / 3	70/87/94	81/94/99
Utilization (%) at 4 / 5 / 6	65/61/84	80/67/75
Total deflection (mm)	21	22

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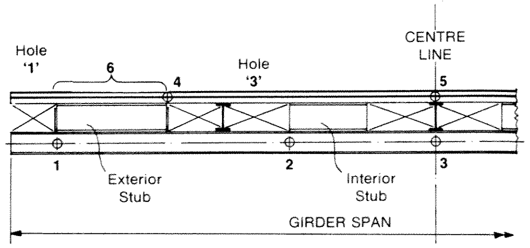
Table 6.2
STUB-GIRDER FLOOR BAY^{+}
Trial Selection Table

4-STUB CONFIGURATION



Live Load: 2.4 kPa
Cover Slab: 75 mm N.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
10000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 5/1/5	13720 9/2/7	14720 16/4/10	15860 20/5/11	17660 9/3/9
	% Utilization: Mid span/Support	35 / 67	45 / 77	56 / 86	69 / 96	68 / 90	50 / 80
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W200X31 (14)	W250X33 (14)	W360X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 13/1/1	5280 14/2/2	6280 21/3/3	7280 22/3/4	8140 19/4/5	7340 27/4/5
	% Utilization: Mid span	47	48	57	66	67	67
	S-G bottom chord size (Studs)	W310X67 (48)	W310X67 (52)	W310X74 (60)	W310X74 (64)	W310X74 (64)	W310X79 (64)
	Length: Hole 1/Ext stub, (Studs)	710/1140 (18)	710/1140 (20)	710/1140 (24)	710/1140 (26)	710/1140 (26)	690/1160 (26)
	Length: Hole 3/Int stub, (Studs)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)
	% Utilization at: 1/2/3	61 / 68 / 73	68 / 76 / 81	66 / 76 / 81	72 / 83 / 88	78 / 89 / 95	73 / 84 / 89
	% Utilization at: 4/5/6	86 / 49 / 50	95 / 55 / 56	64 / 58 / 61	69 / 63 / 67	78 / 68 / 72	85 / 66 / 66
	Defl:Shore removed+SD+LL=Total	5+4+3=12	5+4+4=13	5+4+4=13	6+5+4=15	6+5+4=15	6+4+3=13
	Steel mass / Cost per bay	2036 / 2565	2219 / 2782	2484 / 3080	2662 / 3289	3079 / 3744	3876 / 4294
10500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 5/1/5	13720 10/2/7	14720 17/4/10	15860 21/5/12	17660 9/3/9
	% Utilization: Mid span/Support	37 / 70	47 / 80	59 / 90	72 / 100	71 / 93	52 / 83
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W200X31 (14)	W250X33 (14)	W360X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 14/1/1	5280 14/2/2	6280 22/3/3	7280 23/4/5	8140 20/4/5	7340 28/4/5
	% Utilization: Mid span	49	50	60	69	70	70
	S-G bottom chord size (Studs)	W310X67 (52)	W310X74 (56)	W310X74 (64)	W310X74 (68)	W310X79 (72)	W310X86 (68)
	Length: Hole 1/Ext stub, (Studs)	750/1195 (20)	750/1195 (22)	750/1195 (26)	740/1205 (28)	660/1285 (30)	740/1205 (28)
	Length: Hole 3/Int stub, (Studs)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)
	% Utilization at: 1/2/3	67 / 75 / 80	67 / 76 / 80	73 / 83 / 88	79 / 90 / 96	71 / 92 / 98	74 / 85 / 89
	% Utilization at: 4/5/6	100 / 53 / 54	70 / 57 / 60	77 / 62 / 66	84 / 68 / 71	70 / 72 / 75	66 / 68 / 71
	Defl:Shore removed+SD+LL=Total	6+4+4=14	6+5+4=15	7+5+4=16	7+6+4=17	7+6+4=17	6+5+4=15
	Steel mass / Cost per bay	2079 / 2601	2340 / 2894	2531 / 3119	2710 / 3328	3192 / 3838	4007 / 4413
11000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W410X54 (22)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 5/1/5	13720 10/2/7	14860 13/3/9	16960 11/3/10	17660 10/3/9
	% Utilization: Mid span/Support	38 / 73	49 / 83	61 / 93	61 / 88	61 / 100	54 / 87
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W200X31 (14)	W250X33 (14)	W250X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 15/1/2	5280 15/2/2	6280 23/3/4	7140 23/4/4	7040 26/3/4	7340 29/4/5
	% Utilization: Mid span	51	52	63	70	68	74
	S-G bottom chord size (Studs)	W310X74 (56)	W310X74 (60)	W310X74 (68)	W310X79 (72)	W310X86 (76)	W310X86 (72)
	Length: Hole 1/Ext stub, (Studs)	780/1260 (22)	780/1260 (24)	780/1260 (28)	760/1280 (30)	680/1360 (32)	760/1280 (30)
	Length: Hole 3/Int stub, (Studs)	880/990 (6)	880/990 (6)	880/990 (6)	880/990 (6)	880/990 (6)	880/990 (6)
	% Utilization at: 1/2/3	65 / 74 / 79	72 / 83 / 88	79 / 91 / 97	79 / 93 / 99	69 / 93 / 99	80 / 93 / 98
	% Utilization at: 4/5/6	67 / 56 / 57	75 / 62 / 64	83 / 68 / 70	71 / 72 / 76	72 / 75 / 76	73 / 74 / 76
	Defl:Shore removed+SD+LL=Total	6+5+4=15	7+6+5=18	8+6+5=19	8+6+5=19	8+6+5=19	8+6+5=19
	Steel mass / Cost per bay	2205 / 2717	2388 / 2933	2580 / 3158	3072 / 3684	3683 / 4073	4068 / 4458

$^{+}$ See Section 6.20 for explanation.

4-STUB CONFIGURATION

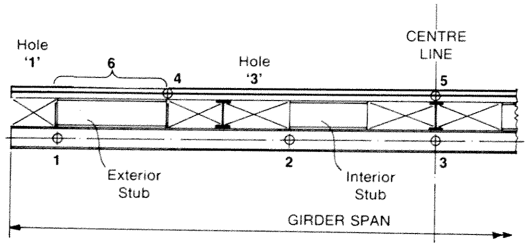


Table 6.2 (continued)
STUB-GIRDER FLOOR BAY^{+}
Trial Selection Table

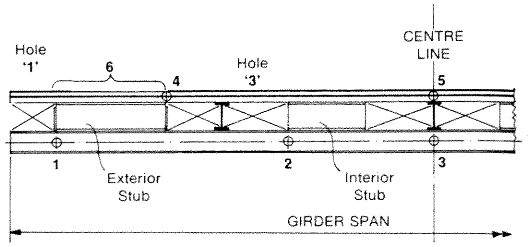
Live Load: 2.4 kPa
Cover Slab: 75 mm N.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
11500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W410X54 (22)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 5/1/5	13720 10/3/7	14860 14/3/9	16700 13/4/11	17660 10/3/9
	% Utilization: Mid span/Support	40 / 75	51 / 86	63 / 97	64 / 92	64 / 100	56 / 90
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W200X31 (14)	W250X33 (14)	W250X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 15/1/2	5280 16/2/2	6280 23/3/4	7140 24/4/5	7300 29/4/5	7340 31/4/5
	% Utilization: Mid span	53	55	66	73	76	77
	S-G bottom chord size (Studs)	W310X74 (60)	W310X74 (64)	W310X79 (72)	W310X86 (76)	W310X97 (80)	W310X97 (76)
	Length: Hole 1/Ext stub, (Studs)	820/1315 (24)	820/1315 (26)	820/1315 (30)	770/1365 (32)	690/1445 (34)	690/1445 (32)
	Length: Hole 3/Int stub, (Studs)	920/1035 (6)	920/1035 (6)	920/1035 (6)	920/1035 (6)	920/1035 (6)	920/1035 (6)
	% Utilization at: 1/2/3	71 / 81 / 86	79 / 90 / 96	81 / 94 / 99	75 / 94 / 100	65 / 92 / 97	67 / 92 / 97
	% Utilization at: 4/5/6	72 / 61 / 61	80 / 67 / 68	71 / 73 / 75	74 / 76 / 80	75 / 79 / 81	76 / 78 / 78
	Defl:Shore removed+SD+LL=Total	8+6+5=19	9+7+5=21	9+7+6=22	9+7+5=21	9+7+5=21	8+6+5=19
	Steel mass / Cost per bay	2252 / 2756	2436 / 2972	2688 / 3257	3211 / 3810	3865 / 4238	4274 / 4636
12000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W460X61 (24)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 6/2/5	13680 11/3/8	14860 15/3/9	17160 8/2/8	17660 10/3/10
	% Utilization: Mid span/Support	41 / 78	52 / 89	66 / 100	66 / 95	53 / 89	57 / 93
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W250X33 (14)	W250X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 16/1/2	5280 16/2/2	6320 16/2/3	7140 25/4/5	6840 25/3/4	7340 32/4/5
	% Utilization: Mid span	56	57	60	76	70	80
	S-G bottom chord size (Studs)	W310X74 (64)	W310X79 (68)	W310X86 (76)	W310X97 (80)	W310X107 (80)	W310X107 (84)
	Length: Hole 1/Ext stub, (Studs)	850/1370 (26)	850/1370 (28)	850/1370 (32)	780/1440 (34)	780/1440 (34)	700/1520 (36)
	Length: Hole 3/Int stub, (Studs)	960/1080 (6)	960/1080 (6)	960/1080 (6)	960/1080 (6)	960/1080 (6)	960/1080 (6)
	% Utilization at: 1/2/3	77 / 88 / 94	79 / 93 / 98	79 / 94 / 100	71 / 93 / 98	69 / 88 / 92	64 / 92 / 96
	% Utilization at: 4/5/6	84 / 66 / 65	70 / 72 / 73	74 / 76 / 80	77 / 80 / 85	76 / 79 / 82	79 / 82 / 83
	Defl:Shore removed+SD+LL=Total	9+7+6=22	10+7+6=23	10+8+6=24	10+8+6=24	9+7+5=21	9+7+5=21
	Steel mass / Cost per bay	2300 / 2794	2546 / 3073	2852 / 3417	3407 / 3994	4358 / 4707	4468 / 4813
12500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W460X61 (24)	W460X61 (24)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/4	12720 6/2/5	13520 13/3/8	16160 4/2/6	17160 8/3/8	17660 11/3/10
	% Utilization: Mid span/Support	42 / 81	54 / 93	69 / 100	45 / 83	54 / 92	59 / 97
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W200X27 (12)	W250X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 17/1/2	5280 17/2/2	6480 18/3/4	5840 27/3/4	6840 26/3/4	7340 33/4/6
	% Utilization: Mid span	58	60	65	73	73	83
	S-G bottom chord size (Studs)	W310X79 (68)	W310X86 (76)	W310X97 (80)	W310X107 (80)	W310X107 (84)	W310X118 (100)
	Length: Hole 1/Ext stub, (Studs)	890/1425 (28)	890/1425 (32)	870/1445 (34)	870/1445 (34)	710/1605 (36)	630/1685 (38)
	Length: Hole 3/Int stub, (Studs)	1000/1125 (6)	1000/1125 (6)	1000/1125 (6)	1000/1125 (6)	1000/1125 (6)	1000/1125 (12)
	% Utilization at: 1/2/3	78 / 90 / 96	78 / 93 / 98	75 / 92 / 98	74 / 88 / 92	65 / 95 / 100	55 / 91 / 95
	% Utilization at: 4/5/6	68 / 70 / 69	72 / 75 / 77	76 / 79 / 84	76 / 79 / 82	82 / 85 / 84	82 / 86 / 85
	Defl:Shore removed+SD+LL=Total	10+8+7=25	11+8+7=26	11+8+7=26	10+7+6=23	10+8+6=24	10+7+6=23
	Steel mass / Cost per bay	2413 / 2899	2688 / 3207	3049 / 3604	4150 / 4473	4442 / 4763	4696 / 5013

$^{+}$ See Section 6.20 for explanation.

Table 6.3
STUB-GIRDER FLOOR BAY^{+}
Trial Selection Table

4-STUB CONFIGURATION



Live Load: 2.4 kPa
Cover Slab: 85 mm S.L.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
10000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 4/1/5	13720 8/2/7	14720 14/4/9	15860 18/5/11	17660 8/3/9
	% Utilization: Mid span/Support	33 / 64	42 / 73	53 / 83	64 / 92	66 / 86	46 / 77
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W200X31 (16)	W250X33 (16)	W360X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 12/1/1	5280 12/2/2	6280 18/3/3	7280 19/3/4	8140 17/4/5	7340 24/4/5
	% Utilization: Mid span	43	45	54	62	64	63
	S-G bottom chord size (Studs)	W310X45 (52)	W310X52 (56)	W310X60 (64)	W310X67 (68)	W310X67 (72)	W310X67 (68)
	Length: Hole 1/Ext stub, (Studs)	710/1200 (20)	710/1200 (22)	710/1200 (26)	710/1200 (28)	630/1280 (30)	710/1200 (28)
	Length: Hole 3/Int stub, (Studs)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)
	% Utilization at: 1/2/3	86 / 91 / 98	81 / 88 / 95	80 / 87 / 94	77 / 86 / 92	74 / 93 / 99	86 / 93 / 98
	% Utilization at: 4/5/6	91 / 44 / 53	61 / 46 / 59	46 / 50 / 66	48 / 52 / 72	52 / 56 / 75	53 / 56 / 71
	Defl:Shore removed+SD+LL=Total	6+5+5=16	6+5+4=15	6+5+4=15	6+5+4=15	6+6+4=16	6+5+4=15
	Steel mass / Cost per bay	1810 / 2382	2067 / 2624	2342 / 2933	2593 / 3216	3020 / 3670	3756 / 4168
10500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 4/1/5	13720 8/2/7	14720 15/4/10	15860 19/5/12	17660 8/3/9
	% Utilization: Mid span/Support	34 / 67	44 / 77	55 / 86	67 / 95	68 / 89	48 / 80
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W200X31 (16)	W250X33 (16)	W360X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 12/1/1	5280 13/2/2	6280 19/3/3	7280 20/4/5	8140 17/4/5	7340 25/4/5
	% Utilization: Mid span	45	47	56	65	67	66
	S-G bottom chord size (Studs)	W310X52 (56)	W310X60 (60)	W310X67 (68)	W310X74 (72)	W310X74 (76)	W310X74 (72)
	Length: Hole 1/Ext stub, (Studs)	750/1255 (22)	750/1255 (24)	750/1255 (28)	720/1285 (30)	640/1365 (32)	640/1365 (30)
	Length: Hole 3/Int stub, (Studs)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)
	% Utilization at: 1/2/3	81 / 86 / 93	80 / 86 / 93	78 / 86 / 92	73 / 85 / 91	70 / 92 / 98	73 / 92 / 97
	% Utilization at: 4/5/6	72 / 44 / 57	55 / 48 / 65	47 / 51 / 71	49 / 53 / 77	52 / 57 / 80	53 / 57 / 74
	Defl:Shore removed+SD+LL=Total	6+5+5=16	6+6+5=17	6+6+5=17	6+6+5=17	7+6+5=18	6+6+4=16
	Steel mass / Cost per bay	1919 / 2435	2191 / 2740	2459 / 3042	2717 / 3328	3145 / 3783	3896 / 4280
11000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 5/1/5	13720 9/2/7	14720 15/4/10	15860 19/5/12	17660 9/3/9
	% Utilization: Mid span/Support	36 / 70	46 / 80	57 / 90	69 / 99	71 / 93	50 / 83
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W200X31 (16)	W250X33 (16)	W360X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 13/1/2	5280 13/2/2	6280 20/3/4	7280 21/4/5	8140 18/4/5	7340 26/4/5
	% Utilization: Mid span	47	49	59	68	70	69
	S-G bottom chord size (Studs)	W310X60 (60)	W310X67 (68)	W310X74 (72)	W310X74 (76)	W310X86 (80)	W310X86 (80)
	Length: Hole 1/Ext stub, (Studs)	780/1320 (24)	780/1320 (28)	780/1320 (30)	740/1360 (32)	580/1520 (34)	660/1440 (34)
	Length: Hole 3/Int stub, (Studs)	880/990 (6)	880/990 (6)	880/990 (6)	880/990 (6)	880/990 (6)	880/990 (6)
	% Utilization at: 1/2/3	78 / 85 / 91	77 / 85 / 92	76 / 85 / 91	78 / 93 / 100	56 / 88 / 94	66 / 87 / 93
	% Utilization at: 4/5/6	58 / 46 / 62	46 / 50 / 69	48 / 52 / 76	52 / 57 / 82	53 / 58 / 84	53 / 57 / 79
	Defl:Shore removed+SD+LL=Total	7+6+5=18	7+6+5=18	7+6+5=18	8+7+5=20	7+6+5=18	7+6+5=18
	Steel mass / Cost per bay	2048 / 2555	2313 / 2852	2585 / 3158	2766 / 3367	3343 / 3960	4090 / 4458

+ See Section 6.20 for explanation.

4-STUB CONFIGURATION

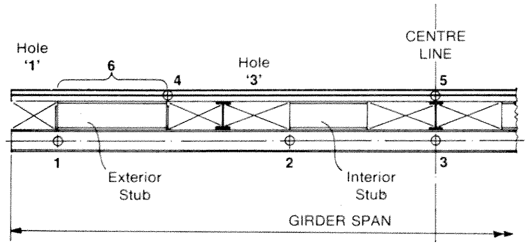


Table 6.3 (continued)
STUB-GIRDER FLOOR BAY^{+}
Trial Selection Table

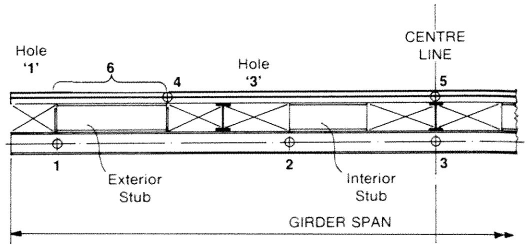
Live Load: 2.4 kPa
Cover Slab: 85 mm S.L.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
11500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 5/1/5	13720 9/3/7	14560 17/4/10	15860 20/5/12	17660 9/3/10
	% Utilization: Mid span/Support	37 / 72	47 / 83	59 / 93	73 / 100	74 / 97	52 / 86
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W200X31 (16)	W250X33 (16)	W360X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 13/1/2	5280 14/2/2	6280 21/3/4	7440 24/4/5	8140 19/4/5	7340 27/4/5
	% Utilization: Mid span	49	51	62	74	73	73
	S-G bottom chord size (Studs)	W310X60 (64)	W310X67 (72)	W310X74 (76)	W310X86 (80)	W310X97 (96)	W310X97 (84)
	Length: Hole 1/Ext stub, (Studs)	820/1385 (26)	820/1385 (30)	820/1385 (32)	680/1525 (34)	600/1605 (38)	680/1525 (36)
	Length: Hole 3/Int stub, (Studs)	920/1035 (6)	920/1035 (6)	920/1035 (6)	920/1035 (6)	920/1035 (10)	920/1035 (6)
	% Utilization at: 1/2/3	85 / 92 / 100	85 / 93 / 100	83 / 93 / 100	63 / 88 / 95	54 / 86 / 92	63 / 86 / 92
	% Utilization at: 4/5/6	57 / 51 / 67	50 / 54 / 74	52 / 57 / 81	53 / 59 / 85	55 / 61 / 90	55 / 60 / 85
	Defl:Shore removed+SD+LL=Total	8+7+6=21	8+7+6=21	8+7+6=21	8+7+6=21	8+7+5=20	7+6+5=18
	Steel mass / Cost per bay	2089 / 2586	2357 / 2887	2633 / 3197	2966 / 3548	3534 / 4138	4285 / 4636
12000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/4	12720 5/2/5	13720 10/3/8	14860 13/3/9	17160 7/3/8	17660 9/3/10
	% Utilization: Mid span/Support	38 / 75	49 / 86	61 / 96	63 / 91	49 / 85	54 / 89
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W200X31 (16)	W250X33 (16)	W250X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 14/1/2	5280 14/2/2	6280 22/3/4	7140 22/4/5	6840 22/3/4	7340 28/4/5
	% Utilization: Mid span	51	53	64	72	66	76
	S-G bottom chord size (Studs)	W310X67 (68)	W310X74 (76)	W310X86 (80)	W310X97 (96)	W310X97 (88)	W310X97 (88)
	Length: Hole 1/Ext stub, (Studs)	850/1450 (28)	850/1450 (32)	780/1520 (34)	700/1600 (38)	700/1600 (38)	620/1680 (38)
	Length: Hole 3/Int stub, (Studs)	960/1080 (6)	960/1080 (6)	960/1080 (6)	960/1080 (10)	960/1080 (6)	960/1080 (6)
	% Utilization at: 1/2/3	82 / 91 / 98	81 / 92 / 98	69 / 88 / 94	60 / 87 / 93	65 / 90 / 96	60 / 94 /99
	% Utilization at: 4/5/6	49 / 53 / 71	51 / 56 / 79	53 / 58 / 85	55 / 61 / 90	57 / 63 / 87	60 / 66 / 88
	Defl:Shore removed+SD+LL=Total	9+8+7=24	9+8+6=23	9+8+6=23	9+8+6=23	8+7+6=21	9+8+6=23
	Steel mass / Cost per bay	2218 / 2706	2490 / 3010	2839 / 3387	3423 / 3994	4254 / 4581	4363 / 4687
12500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W460X61 (30)	W460X61 (30)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/4	12720 5/2/5	13720 10/3/8	16160 4/2/6	17160 7/3/9	17660 10/3/10
	% Utilization: Mid span/Support	40 / 77	51 / 89	63 / 100	42 / 80	51 / 88	56 / 93
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W200X31 (16)	W200X27 (14)	W250X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 15/1/2	5280 15/2/2	6280 22/3/4	5840 24/3/4	6840 23/3/4	7340 29/4/6
	% Utilization: Mid span	53	56	67	68	69	79
	S-G bottom chord size (Studs)	W310X74 (72)	W310X86 (80)	W310X97 (96)	W310X97 (88)	W310X107 (104)	W310X107 (108)
	Length: Hole 1/Ext stub, (Studs)	890/1505 (30)	890/1505 (34)	790/1605 (38)	790/1605 (38)	630/1765 (40)	630/1765 (42)
	Length: Hole 3/Int stub, (Studs)	1000/1125 (6)	1000/1125 (6)	1000/1125 (10)	1000/1125 (6)	1000/1125 (12)	1000/1125 (12)
	% Utilization at: 1/2/3	80 / 89 / 96	74 / 87 / 93	65 / 87 / 93	71 / 90 / 96	55 / 89 / 95	57 / 93 / 98
	% Utilization at: 4/5/6	50 / 55 / 75	52 / 57 / 84	55 / 61 / 90	57 / 63 / 87	60 / 66 / 90	62 / 68 / 94
	Defl:Shore removed+SD+LL=Total	9+8+7=24	9+8+7=24	9+8+7=24	9+8+6=23	9+8+6=23	9+8+6=23
	Steel mass / Cost per bay	2354 / 2833	2695 / 3207	3039 / 3576	4040 / 4342	4464 / 4763	4563 / 4869

+ See Section 6.20 for explanation.

Table 6.4
STUB-GIRDER FLOOR BAY$^+$
Trial Selection Table

4-STUB CONFIGURATION



Live Load: 3.6 kPa
Cover Slab: 75 mm N.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
10000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12720 5/1/7	13600 10/2/10	14200 20/4/14	15600 22/5/17	17660 9/3/13
	% Utilization: Mid span/Support	45 / 80	57 / 91	71 / 100	88 / 100	85 / 100	62 / 94
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W360X33 (14)	W360X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 13/1/2	5280 14/2/3	6400 14/2/4	7800 15/3/6	8400 21/4/8	7340 27/4/7
	% Utilization: Mid span	56	57	61	74	86	80
	S-G bottom chord size (Studs)	W310X60 (56)	W310X67 (60)	W310X74 (64)	W310X79 (68)	W310X86 (72)	W310X86 (72)
	Length: Hole 1/Ext stub, (Studs)	710/1200 (22)	710/1200 (24)	710/1200 (26)	630/1280 (28)	550/1360 (30)	630/1280 (30)
	Length: Hole 3/Int stub, (Studs)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)
	% Utilization at: 1/2/3	79 / 86 / 93	78 / 86 / 93	76 / 86 / 92	68 / 88 / 95	58 / 88 / 94	69 / 88 / 93
	% Utilization at: 4/5/6	84 / 58 / 57	59 / 62 / 63	61 / 65 / 69	65 / 69 / 73	67 / 71 / 76	67 / 71 / 73
	Defl:Shore removed+SD+LL=Total	5+4+5=14	5+4+5=14	5+4+5=14	6+4+5=15	6+4+5=15	5+4+5=14
	Steel mass / Cost per bay	1967 / 2492	2224 / 2782	2514 / 3110	2720 / 3334	3220 / 3861	3966 / 4367
10500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12720 5/1/7	13420 11/3/10	14040 22/5/15	15440 25/5/17	17660 9/3/14
	% Utilization: Mid span/Support	47 / 83	59 / 95	75 / 100	92 / 100	90 / 100	64 / 98
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W360X33 (14)	W360X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 14/1/2	5280 14/2/3	6580 15/2/5	7960 16/4/7	8560 23/5/9	7340 28/4/7
	% Utilization: Mid span	58	60	68	81	93	84
	S-G bottom chord size (Studs)	W310X67 (60)	W310X74 (64)	W310X79 (72)	W310X86 (76)	W310X97 (80)	W310X97 (76)
	Length: Hole 1/Ext stub, (Studs)	750/1255 (24)	750/1255 (26)	720/1285 (30)	640/1365 (32)	560/1445 (34)	640/1365 (32)
	Length: Hole 3/Int stub, (Studs)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)
	% Utilization at: 1/2/3	77 / 85 / 92	77 / 86 / 92	75 / 89 / 95	66 / 89 / 96	55 / 87 / 93	66 / 87 / 92
	% Utilization at: 4/5/6	65 / 60 / 61	60 / 64 / 68	64 / 69 / 74	67 / 72 / 78	69 / 75 / 82	68 / 73 / 78
	Defl:Shore removed+SD+LL=Total	6+4+6=16	6+5+6=17	6+5+6=17	6+5+6=17	6+5+6=17	6+4+5=15
	Steel mass / Cost per bay	2085 / 2601	2345 / 2894	2617 / 3201	2847 / 3450	3396 / 4023	4150 / 4534
11000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W410X54 (22)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12720 5/1/7	13260 13/3/11	14660 15/3/13	16020 17/4/16	17540 10/3/14
	% Utilization: Mid span/Support	49 / 86	62 / 99	78 / 100	77 / 100	79 / 100	67 / 100
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W250X33 (14)	W360X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 15/1/2	5280 15/2/3	6740 17/3/5	7340 25/4/7	7980 20/4/7	7460 31/4/8
	% Utilization: Mid span	61	63	74	88	85	91
	S-G bottom chord size (Studs)	W310X67 (64)	W310X79 (68)	W310X86 (76)	W310X97 (80)	W310X107 (92)	W310X107 (80)
	Length: Hole 1/Ext stub, (Studs)	780/1320 (26)	780/1320 (28)	740/1360 (32)	660/1440 (34)	500/1600 (36)	580/1520 (34)
	Length: Hole 3/Int stub, (Studs)	880/990 (6)	880/990 (6)	880/990 (6)	880/990 (6)	880/990 (10)	880/990 (6)
	% Utilization at: 1/2/3	84 / 93 / 100	77 / 89 / 95	73 / 90 / 96	63 / 88 / 94	46 / 87 / 93	56 / 87 / 92
	% Utilization at: 4/5/6	71 / 66 / 65	64 / 68 / 73	67 / 72 / 78	70 / 75 / 83	71 / 78 / 81	71 / 77 / 81
	Defl:Shore removed+SD+LL=Total	7+5+7=19	7+5+7=19	7+5+7=19	7+5+6=18	7+5+6=18	6+5+6=17
	Steel mass / Cost per bay	2129 / 2636	2451 / 2990	2748 / 3321	3291 / 3885	3913 / 4271	4336 / 4693

$^+$ See Section 6.20 for explanation.

4-STUB CONFIGURATION

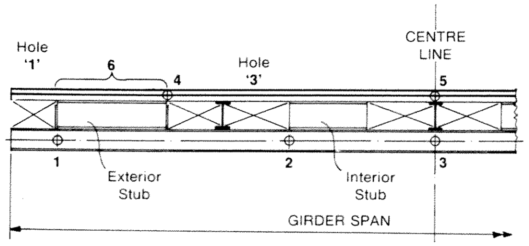


Table 6.4 (continued)
STUB-GIRDER FLOOR BAY$^+$
Trial Selection Table

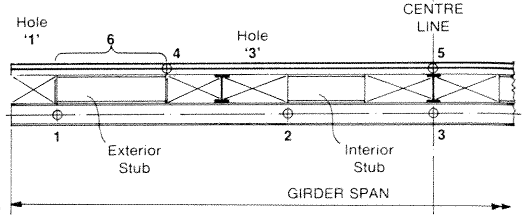
Live Load: 3.6 kPa
Cover Slab: 75 mm N.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
11500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W410X54 (22)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12600 6/2/8	13120 14/3/11	14500 16/4/13	15840 20/5/16	17300 12/3/14
	% Utilization: Mid span/Support	50 / 90	64 / 100	82 / 100	80 / 100	83 / 100	70 / 100
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W250X33 (14)	W360X33 (14)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 15/1/2	5400 16/2/4	6880 19/3/6	7500 28/4/8	8160 22/4/8	7700 35/5/9
	% Utilization: Mid span	64	69	81	96	93	96
	S-G bottom chord size (Studs)	W310X74 (68)	W310X86 (76)	W310X97 (80)	W310X107 (92)	W310X118 (108)	W310X107 (88)
	Length: Hole 1/Ext stub, (Studs)	820/1385 (28)	820/1385 (32)	760/1445 (34)	600/1605 (36)	520/1685 (38)	600/1605 (38)
	Length: Hole 3/Int stub, (Studs)	920/1035 (6)	920/1035 (6)	920/1035 (6)	920/1035 (10)	920/1035 (16)	920/1035 (6)
	% Utilization at: 1/2/3	82 / 92 / 99	76 / 89 / 95	70 / 88 / 95	54 / 88 / 94	46 / 87 / 92	60 / 94 / 100
	% Utilization at: 4/5/6	64 / 68 / 69	66 / 71 / 77	70 / 76 / 83	72 / 79 / 85	74 / 82 / 86	77 / 84 / 86
	Defl:Shore removed+SD+LL=Total	8+6+7=21	7+6+7=20	8+6+7=21	7+6+7=20	7+6+7=20	7+6+7=20
	Steel mass / Cost per bay	2258 / 2756	2584 / 3113	2935 / 3497	3479 / 4052	4109 / 4451	4396 / 4734
12000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W460X61 (24)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12440 7/2/8	12980 16/3/11	14340 18/4/13	16860 9/3/12	17080 14/4/15
	% Utilization: Mid span/Support	52 / 93	67 / 100	85 / 99	84 / 100	67 / 100	73 / 100
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W250X33 (16)	W250X33 (14)	W360X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 16/1/2	5560 19/2/4	7020 22/4/7	7660 32/5/10	7140 28/4/7	7920 23/4/7
	% Utilization: Mid span	67	76	88	99	91	91
	S-G bottom chord size (Studs)	W310X86 (72)	W310X97 (80)	W310X107 (96)	W310X118 (112)	W310X118 (100)	W310X118 (100)
	Length: Hole 1/Ext stub, (Studs)	850/1450 (30)	850/1450 (34)	700/1600 (36)	620/1680 (40)	620/1680 (40)	540/1760 (40)
	Length: Hole 3/Int stub, (Studs)	960/1080 (6)	960/1080 (6)	960/1080 (12)	960/1080 (16)	960/1080 (10)	960/1080 (10)
	% Utilization at: 1/2/3	74 / 87 / 93	74 / 88 / 94	60 / 88 / 94	53 / 87 / 93	57 / 90 / 96	51 / 94 / 99
	% Utilization at: 4/5/6	65 / 70 / 74	69 / 75 / 82	72 / 79 / 86	76 / 83 / 90	78 / 85 / 87	80 / 88 / 88
	Defl:Shore removed+SD+LL=Total	8+6+8=22	8+6+8=22	8+6+8=22	8+6+7=21	8+6+7=21	8+6+7=21
	Steel mass / Cost per bay	2458 / 2946	2773 / 3292	3127 / 3672	3682 / 4242	4511 / 4827	4604 / 4915
12500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W460X61 (24)	W460X61 (24)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12280 8/2/8	12860 17/4/12	16160 4/2/9	16640 11/3/13	16880 16/4/15
	% Utilization: Mid span/Support	54 / 96	70 / 100	89 / 99	57 / 98	69 / 100	77 / 100
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W200X27 (12)	W250X33 (16)	W360X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 17/1/3	5720 21/3/5	7140 24/4/8	5840 27/3/5	7360 32/5/9	8120 26/5/9
	% Utilization: Mid span	69	83	95	87	96	100
	S-G bottom chord size (Studs)	W310X97 (76)	W310X107 (96)	W310X118 (112)	W310X118 (100)	W310X129 (120)	W310X129 (124)
	Length: Hole 1/Ext stub, (Studs)	890/1505 (32)	870/1525 (36)	710/1685 (40)	710/1685 (40)	550/1845 (42)	550/1845 (44)
	Length: Hole 3/Int stub, (Studs)	1000/1125 (6)	1000/1125 (12)	1000/1125 (16)	1000/1125 (10)	1000/1125 (18)	1000/1125 (18)
	% Utilization at: 1/2/3	72 / 85 / 92	70 / 86 / 93	57 / 87 / 93	62 / 91 / 96	47 / 90 / 95	49 / 93 / 98
	% Utilization at: 4/5/6	67 / 73 / 79	71 / 78 / 86	75 / 83 / 90	78 / 85 / 87	80 / 89 / 90	83 / 92 / 93
	Defl:Shore removed+SD+LL=Total	9+7+8=24	9+7+8=24	9+7+8=24	9+7+8=24	8+7+7=22	9+7+8=24
	Steel mass / Cost per bay	2656 / 3135	2961 / 3469	3337 / 3870	4327 / 4618	4733 / 5019	4816 / 5108

$^+$ See Section 6.20 for explanation.

Table 6.5
STUB-GIRDER FLOOR BAY+
Trial Selection Table

4-STUB CONFIGURATION



Live Load: 3.6 kPa
Cover Slab: 85 mm S.L.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
10000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12720 4/1/7	13720 8/2/10	14340 17/4/14	15780 18/5/17	17660 8/3/13
	% Utilization: Mid span/Support	43 / 77	54 / 88	66 / 99	82 / 100	82 / 100	58 / 91
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W200X31 (16)	W250X33 (16)	W360X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 12/1/2	5280 12/2/3	6280 18/3/5	7660 23/4/8	8220 17/4/7	7340 24/4/7
	% Utilization: Mid span	52	54	65	83	78	76
	S-G bottom chord size (Studs)	W310X52 (60)	W310X60 (64)	W310X67 (72)	W310X74 (76)	W310X79 (80)	W310X79 (76)
	Length: Hole 1/Ext stub, (Studs)	710/1200 (24)	710/1200 (26)	630/1280 (30)	550/1360 (32)	470/1440 (34)	470/1440 (32)
	Length: Hole 3/Int stub, (Studs)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)	800/900 (6)
	% Utilization at: 1/2/3	85 / 92 / 99	84 / 92 / 99	73 / 91 / 98	61 / 90 /96	53 / 92 / 98	55 / 92 / 97
	% Utilization at: 4/5/6	63 / 48 / 62	48 / 52 / 69	51 / 55 / 74	52 / 57 / 79	55 / 60 / 83	55 / 60 / 76
	Defl:Shore removed+SD+LL=Total	5+4+6=15	5+5+6=16	5+5+6=16	5+5+6=16	5+5+6=16	5+4+5=14
	Steel mass / Cost per bay	1883 / 2408	2151 / 2708	2423 / 3007	2676 / 3284	3160 / 3794	3914 / 4294
10500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12720 4/1/7	13600 9/2/10	14180 18/4/15	15580 21/5/17	17660 8/3/14
	% Utilization: Mid span/Support	44 / 80	56 / 92	69 / 100	86 / 100	86 / 100	61 / 94
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W360X33 (16)	W360X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 12/1/2	5280 13/2/3	6400 13/2/4	7820 14/3/6	8420 19/4/8	7340 25/4/7
	% Utilization: Mid span	54	56	61	74	86	80
	S-G bottom chord size (Studs)	W310X60 (64)	W310X67 (68)	W310X74 (76)	W310X79 (80)	W310X86 (84)	W310X86 (80)
	Length: Hole 1/Ext stub, (Studs)	750/1255 (26)	750/1255 (28)	640/1365 (32)	560/1445 (34)	400/1605 (36)	480/1525 (34)
	Length: Hole 3/Int stub, (Studs)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)	840/945 (6)
	% Utilization at: 1/2/3	84 / 90 / 97	82 / 91 / 97	69 / 90 / 97	61 / 93 / 99	42 / 92 / 99	53 / 92 / 98
	% Utilization at: 4/5/6	57 / 49 / 68	48 / 53 / 75	51 / 55 / 79	54 / 59 / 85	55 / 61 / 87	55 / 61 / 82
	Defl:Shore removed+SD+LL=Total	6+5+7=18	6+5+7=18	6+5+6=17	6+5+6=17	6+5+6=17	6+5+6=17
	Steel mass / Cost per bay	2007 / 2523	2268 / 2817	2571 / 3148	2779 / 3375	3294 / 3906	4050 / 4413
11000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12720 5/1/8	13420 10/3/11	14040 20/5/15	15420 23/6/18	17660 9/3/14
	% Utilization: Mid span/Support	46 / 83	58 / 95	73 / 100	90 / 100	90 / 100	63 / 98
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W360X33 (16)	W360X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 13/1/2	5280 13/2/3	6580 14/3/5	7960 15/4/7	8580 22/5/9	7340 26/4/7
	% Utilization: Mid span	57	59	67	81	93	84
	S-G bottom chord size (Studs)	W310X67 (68)	W310X74 (76)	W310X79 (80)	W310X86 (84)	W310X97 (100)	W310X97 (88)
	Length: Hole 1/Ext stub, (Studs)	780/1320 (28)	740/1360 (32)	660/1440 (34)	500/1600 (36)	420/1680 (40)	420/1680 (38)
	Length: Hole 3/Int stub, (Studs)	880/990 (6)	880/990 (6)	880/990 (6)	880/990 (6)	880/990 (10)	880/990 (6)
	% Utilization at: 1/2/3	81 / 89 / 96	76 / 90 / 96	69 / 93 / 100	51 / 93 / 100	42 / 91 / 97	43 / 91 / 96
	% Utilization at: 4/5/6	47 / 51 / 72	50 / 54 / 79	53 / 58 / 85	55 / 61 / 88	57 / 63 / 93	57 / 63 / 86
	Defl:Shore removed+SD+LL=Total	6+5+7=18	6+6+7=19	7+6+7=20	7+6+7=20	6+6+7=19	6+5+6=17
	Steel mass / Cost per bay	2129 / 2636	2397 / 2933	2676 / 3242	2917 / 3495	3474 / 4073	4249 / 4585

+ See Section 6.20 for explanation.

4-STUB CONFIGURATION

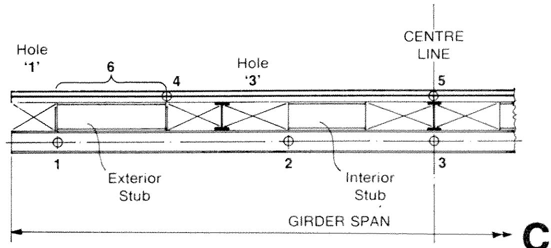


Table 6.5 (continued)
STUB-GIRDER FLOOR BAY+
Trial Selection Table

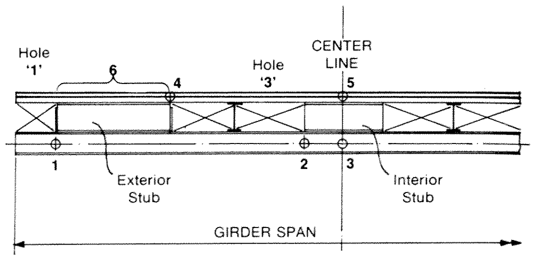
Live Load: 3.6 kPa
Cover slab: 85 mm S.L.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
11500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12720 5/1/8	13260 12/3/11	13900 22/5/15	15280 25/6/18	17540 9/3/14
	% Utilization: Mid span/Support	47 / 86	60 / 99	76 / 100	94 / 100	94 / 100	65 / 100
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W360X33 (16)	W360X33 (18)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 13/1/2	5280 14/2/3	6740 16/3/6	8100 17/4/8	8720 24/5/10	7460 28/4/8
	% Utilization: Mid span	59	62	74	87	97	90
	S-G bottom chord size (Studs)	W310X74 (72)	W310X79 (80)	W310X97 (92)	W310X97 (100)	W310X107 (116)	W310X107 (104)
	Length: Hole 1/Ext stub, (Studs)	820/1385 (30)	760/1445 (34)	600/1605 (36)	520/1685 (40)	440/1765 (42)	440/1765 (40)
	Length: Hole 3/Int stub, (Studs)	920/1035 (6)	920/1035 (6)	920/1035 (10)	920/1035 (10)	920/1035 (16)	920/1035 (12)
	% Utilization at: 1/2/3	79 / 88 / 95	75 / 92 / 99	53 / 85 / 91	50 / 92 / 99	41 / 91 / 97	42 / 90 / 96
	% Utilization at: 4/5/6	49 / 53 / 77	52 / 58 / 84	53 / 59 / 89	58 / 64 / 94	60 / 67 / 99	59 / 66 / 91
	Defl:Shore removed+SD+LL=Total	7+6+8=21	7+6+8=21	7+6+7=20	7+6+7=20	7+6+7=20	7+6+7=20
	Steel mass / Cost per bay	2258 / 2756	2507 / 3032	2950 / 3499	3104 / 3671	3655 / 4240	4431 / 4749
12000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12600 5/2/8	13120 13/3/11	14500 15/4/14	17120 7/3/13	17300 11/4/15
	% Utilization: Mid span/Support	49 / 90	62 / 100	79 / 100	81 / 100	62 / 100	68 / 100
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W250X33 (16)	W250X33 (16)	W250X33 (18)
	Length; Defl: Slab pour/SD/LL	4280 14/1/2	5400 15/2/4	6880 18/3/6	7500 26/5/9	6880 23/3/6	7700 32/5/10
	% Utilization: Mid span	62	67	80	95	80	96
	S-G bottom chord size (Studs)	W310X79 (80)	W310X86 (84)	W310X97 (100)	W310X107 (116)	W310X118 (120)	W310X118 (124)
	Length: Hole 1/Ext stub, (Studs)	850/1450 (34)	780/1520 (36)	620/1680 (40)	540/1760 (42)	460/1840 (42)	460/1840 (44)
	Length: Hole 3/Int stub, (Studs)	960/1080 (6)	960/1080 (6)	960/1080 (10)	960/1080 (16)	960/1080 (18)	960/1080 (18)
	% Utilization at: 1/2/3	79 / 90 / 97	72 / 92 / 99	56 / 92 / 98	48 / 91 / 97	40 / 87 / 92	42 / 90 / 95
	% Utilization at: 4/5/6	51 / 56 / 82	54 / 60 / 89	57 / 64 / 94	60 / 67 / 100	60 / 66 / 94	62 / 69 / 97
	Defl:Shore removed+SD+LL=Total	8+7+8=23	8+7+8=23	8+7+8=23	8+7+8=23	7+6+7=20	7+6+7=20
	Steel mass / Cost per bay	2370 / 2857	2644 / 3158	3010 / 3548	3556 / 4108	4548 / 4843	4628 / 4929
12500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W460X61 (30)	W460X61 (30)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12440 6/2/8	13000 14/3/12	16160 4/2/10	16880 9/3/13	17100 13/4/15
	% Utilization: Mid span/Support	51 / 93	65 / 100	82 / 100	54 / 94	65 / 100	71 / 100
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W200X27 (14)	W250X33 (16)	W360X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 15/1/3	5560 17/2/4	7000 20/4/7	5840 24/3/5	7120 26/4/8	7900 21/4/8
	% Utilization: Mid span	64	74	86	82	89	90
	S-G bottom chord size (Studs)	W310X86 (84)	W310X97 (100)	W310X107 (116)	W310X118 (120)	W310X118 (128)	W310X129 (144)
	Length: Hole 1/Ext stub, (Studs)	870/1525 (36)	710/1685 (40)	630/1765 (42)	550/1845 (42)	470/1925 (46)	340/2055 (48)
	Length: Hole 3/Int stub, (Studs)	1000/1125 (6)	1000/1125 (10)	1000/1125 (16)	1000/1125 (18)	1000/1125 (18)	1000/1125 (24)
	% Utilization at: 1/2/3	76 / 90 / 97	61 / 91 / 97	54 / 91 / 97	46 / 87 / 92	43 / 94 / 99	29 / 89 / 94
	% Utilization at: 4/5/6	53 / 59 / 87	57 / 63 / 93	60 / 67 / 99	60 / 67 / 94	65 / 72 / 99	64 / 72 / 100
	Defl:Shore removed+SD+LL=Total	8+7+9=24	8+7+9=24	9+8+9=26	8+7+8=23	8+7+8=23	8+7+8=23
	Steel mass / Cost per bay	2513 / 2991	2848 / 3343	3202 / 3728	4348 / 4618	4613 / 4890	4857 / 5122

+ See Section 6.20 for explanation.

Table 6.6
STUB-GIRDER FLOOR BAY⁺
Trial Selection Table

3-STUB CONFIGURATION



Live Load: 2.4 kPa
Cover Slab: 75 mm N.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
8000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 5/1/5	13720 10/2/7	14660 17/4/10	15860 21/5/12	17660 9/3/9
	% Utilization: Mid span/Support	37 / 71	48 / 81	59 / 91	73 / 100	72 / 95	52 / 84
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W200X31 (14)	W250X33 (14)	W360X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 14/1/1	5280 14/2/2	6280 22/3/3	7340 24/4/5	8140 20/4/5	7340 29/4/5
	% Utilization: Mid span	50	51	61	71	72	71
	S-G bottom chord size (Studs)	W310X45 (34)	W310X45 (38)	W310X45 (42)	W310X45 (42)	W310X45 (46)	W310X45 (46)
	Length: Hole 1/Ext stub, (Studs)	570/1456 (14)	570/1456 (16)	570/1456 (18)	570/1456 (18)	570/1456 (20)	570/1456 (20)
	Length: Hole 3/Int stub, (Studs)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)
	% Utilization at: 1/2/3	53 / 62 / 49	59 / 69 / 54	65 / 76 / 59	71 / 83 / 65	77 / 89 / 70	79 / 88 / 67
	% Utilization at: 4/5/6	43 / 20 / 34	48 / 22 / 38	52 / 24 / 41	57 / 27 / 45	62 / 29 / 48	84 / 28 / 45
	Defl:Shore removed+SD+LL=Total	3+2+2=7	3+2+2=7	3+3+2=8	4+3+2=9	4+3+3=10	4+3+2=9
	Steel mass / Cost per bay	1420 / 1812	1558 / 1974	1701 / 2143	1834 / 2299	2155 / 2641	2728 / 3014
8500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W410X54 (22)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 5/1/5	13720 10/2/7	14860 14/3/9	16780 13/3/11	17660 10/3/9
	% Utilization: Mid span/Support	39 / 74	50 / 85	62 / 96	63 / 91	63 / 100	55 / 89
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W200X31 (14)	W250X33 (14)	W250X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 15/1/2	5280 15/2/2	6280 23/3/4	7140 24/4/5	7220 28/4/5	7340 30/4/5
	% Utilization: Mid span	53	54	65	72	73	76
	S-G bottom chord size (Studs)	W310X45 (38)	W310X45 (42)	W310X45 (42)	W310X45 (46)	W310X60 (50)	W310X45 (50)
	Length: Hole 1/Ext stub, (Studs)	600/1553 (16)	600/1553 (18)	600/1553 (18)	600/1553 (20)	600/1553 (22)	600/1553 (22)
	Length: Hole 3/Int stub, (Studs)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)
	% Utilization at: 1/2/3	59 / 70 / 55	66 / 77 / 61	72 / 85 / 67	79 / 92 / 72	64 / 78 / 59	88 / 98 / 75
	% Utilization at: 4/5/6	47 / 22 / 37	53 / 24 / 41	58 / 26 / 45	63 / 28 / 48	62 / 31 / 51	100 / 30 / 49
	Defl:Shore removed+SD+LL=Total	3+3+2=8	4+3+3=10	4+3+3=10	4+3+3=10	4+3+3=10	5+4+3=12
	Steel mass / Cost per bay	1490 / 1838	1627 / 2000	1771 / 2169	2109 / 2520	2643 / 2839	2824 / 3040
9000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W410X54 (22)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 6/2/5	13680 11/3/8	14860 15/3/9	16480 16/4/11	17660 10/3/10
	% Utilization: Mid span/Support	41 / 78	52 / 89	66 / 100	66 / 95	67 / 100	57 / 93
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W250X33 (14)	W250X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 16/1/2	5280 16/2/2	6320 16/2/3	7140 25/4/5	7520 32/5/6	7340 32/4/5
	% Utilization: Mid span	56	57	60	76	84	80
	S-G bottom chord size (Studs)	W310X45 (42)	W310X45 (46)	W310X45 (46)	W310X52 (50)	W310X60 (54)	W310X52 (54)
	Length: Hole 1/Ext stub, (Studs)	640/1640 (18)	640/1640 (20)	640/1640 (20)	640/1640 (22)	640/1640 (24)	640/1640 (24)
	Length: Hole 3/Int stub, (Studs)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)
	% Utilization at: 1/2/3	67 / 77 / 61	74 / 86 / 68	81 / 94 / 74	75 / 89 / 69	72 / 86 / 66	84 / 95 / 72
	% Utilization at: 4/5/6	55 / 23 / 40	61 / 25 / 44	67 / 28 / 48	64 / 30 / 52	68 / 33 / 55	70 / 32 / 53
	Defl:Shore removed+SD+LL=Total	4+3+3=10	5+4+3=12	5+4+4=13	5+4+3=12	5+4+3=12	5+4+3=12
	Steel mass / Cost per bay	1489 / 1864	1627 / 2026	1790 / 2218	2170 / 2570	2631 / 2859	2876 / 3090

⁺ See Section 6.20 for explanation.

3-STUB CONFIGURATION

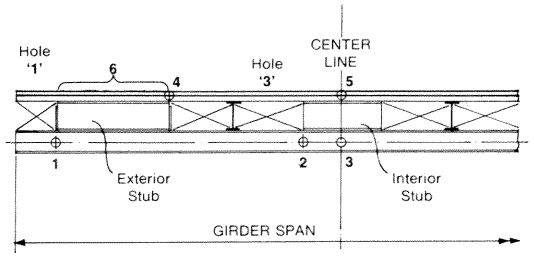


Table 6.6 (continued)
STUB-GIRDER FLOOR BAY⁺
Trial Selection Table

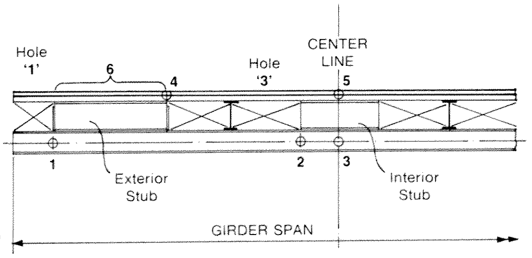
Live Load: 2.4 kPa
Cover Slab: 75 mm N.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
9500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X 46 (20)	W410X54 (22)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/4	12720 6/2/5	13460 13/3/8	14860 15/4/9	16220 18/4/11	17660 11/3/10
	% Utilization: Mid span/Support	43 / 82	55 / 94	70 / 100	69 / 100	71 / 100	60 / 98
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W250X33 (14)	W360X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 17/1/2	5280 17/2/2	6540 18/3/4	7140 26/4/5	7780 22/4/5	7340 34/5/6
	% Utilization: Mid span	59	60	67	80	78	84
	S-G bottom chord size (Studs)	W310X45 (42)	W310X45 (46)	W310X52 (50)	W310X52 (54)	W310X60 (62)	W310X60 (58)
	Length: Hole 1/Ext stub, (Studs)	670/1736 (18)	670/1736 (20)	670/1736 (22)	670/1736 (24)	670/1736 (28)	610/1796 (26)
	Length: Hole 3/Int stub, (Studs)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)
	% Utilization at: 1/2/3	73 / 85 / 68	81 / 94 / 75	76 / 90 / 70	83 / 98 / 76	80 / 95 / 73	75 / 94 / 71
	% Utilization at: 4/5/6	77 / 24 / 43	86 / 26 / 47	63 / 29 / 52	68 / 32 / 56	72 / 35 / 59	72 / 33 / 56
	Defl:Shore removed+SD+LL=Total	5+4+4=13	6+4+4=14	5+4+4=13	6+5+4=15	6+5+4=15	5+4+3=12
	Steel mass / Cost per bay	1524 / 1890	1662 / 2052	1893 / 2266	2211 / 2597	2669 / 2882	3009 / 3197
10000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W410X54 (22)	W460X61 (24)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 3/1/4	12720 6/2/6	13860 9/2/7	15540 10/3/8	17160 9/3/9	17480 13/4/10
	% Utilization: Mid span/Support	45 / 85	57 / 98	59 / 94	60 / 100	57 / 98	63 / 100
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W200X27 (22)	W250X33 (14)	W250X33 (14)	W250X33 (26)
	Length; Defl: Slab pour/SD/LL	4280 18/1/2	5280 18/2/3	6140 31/4/5	6460 22/3/4	6840 28/4/5	7520 38/5/7
	% Utilization: Mid span	62	63	67	69	77	74
	S-G bottom chord size (Studs)	W310X52 (46)	W310X52 (50)	W310X52 (54)	W310X60 (62)	W310X60 (62)	W310X67 (62)
	Length: Hole 1/Ext stub, (Studs)	710/1823 (20)	710/1823 (22)	710/1823 (24)	710/1823 (28)	600/1933 (28)	580/1953 (28)
	Length: Hole 3/Int stub, (Studs)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)
	% Utilization at: 1/2/3	69 / 81 / 64	77 / 90 / 71	84 / 98 / 77	82 / 96 / 75	75 / 99 / 76	67 / 93 / 70
	% Utilization at: 4/5/6	55 / 25 / 46	61 / 27 / 51	70 / 30 / 55	70 / 33 / 59	79 / 33 / 58	73 / 35 / 59
	Defl:Shore removed+SD+LL=Total	5+4+4=13	6+5+4=15	7+5+4=16	7+5+4=16	6+5+4=15	6+5+4=15
	Steel mass / Cost per bay	1672 / 1942	1810 / 2104	2116 / 2410	2645 / 2778	3053 / 3149	3195 / 3293
10500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W460X61 (24)	W460X61 (24)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 3/1/4	12600 7/2/6	13860 10/3/7	16160 5/2/7	17020 10/3/9	17220 15/4/10
	% Utilization: Mid span/Support	46 / 89	60 / 100	61 / 98	49 / 92	60 / 100	67 / 100
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W200X27 (22)	W200X27 (12)	W250X33 (14)	W360X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 18/2/2	5400 20/2/3	6140 32/4/5	5840 30/3/4	6980 31/4/5	7780 26/4/5
	% Utilization: Mid span	65	70	70	81	85	86
	S-G bottom chord size (Studs)	W310X52 (50)	W310X52 (54)	W310X60 (62)	W310X60 (62)	W310X67 (66)	W310X74 (66)
	Length: Hole 1/Ext stub, (Studs)	750/1910 (22)	750/1910 (24)	750/1910 (28)	740/1920 (28)	750/1910 (30)	730/1930 (30)
	Length: Hole 3/Int stub, (Studs)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)
	% Utilization at: 1/2/3	76 / 88 / 70	85 / 98 / 78	83 / 97 / 76	89 / 100 / 77	87 / 98 / 74	78 / 92 / 69
	% Utilization at: 4/5/6	68 / 26 / 49	75 / 29 / 54	69 / 32 / 60	99 / 32 / 59	74 / 35 / 64	73 / 36 / 66
	Defl:Shore removed+SD+LL=Total	6+5+5=16	7+6+5=18	7+6+5=18	7+6+5=18	7+6+4=17	7+5+4=16
	Steel mass / Cost per bay	1670 / 1970	1805 / 2129	2196 / 2525	2822 / 2963	3094 / 3251	3235 / 3393

⁺ See Section 6.20 for explanation.

Table 6.7
STUB-GIRDER FLOOR BAY+
Trial Selection Table

3-STUB CONFIGURATION



Live Load: 2.4 kPa
Cover Slab: 85 mm S.L.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
8000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 4/1/5	13720 9/2/7	14720 15/4/10	15860 19/5/12	17660 8/3/9
	% Utilization: Mid span/Support	35 / 68	45 / 78	55 / 87	68 / 97	69 / 91	49 / 81
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W200X31 (16)	W250X33 (16)	W360X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 12/1/1	5280 13/2/2	6280 19/3/3	7280 21/4/5	8140 18/4/5	7340 25/4/5
	% Utilization: Mid span	46	48	57	66	68	67
	S-G bottom chord size (Studs)	W310X45 (38)	W310X45 (42)	W310X45 (42)	W310X45 (46)	W310X45 (50)	W310X45 (50)
	Length: Hole 1/Ext stub, (Studs)	570/1456 (16)	570/1456 (18)	570/1456 (18)	570/1456 (20)	570/1456 (22)	570/1456 (22)
	Length: Hole 3/Int stub, (Studs)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)
	% Utilization at: 1/2/3	51 / 60 / 46	57 / 66 / 51	62 / 73 / 56	68 / 79 / 61	73 / 85 / 66	76 / 84 / 64
	% Utilization at: 4/5/6	33 / 17 / 38	37 / 19 / 42	41 / 20 / 46	44 / 22 / 50	48 / 24 / 54	48 / 23 / 49
	Defl:Shore removed+SD+LL=Total	2+2+2=6	3+2+2=7	3+3+2=8	3+3+3=9	3+3+3=9	3+3+2=8
	Steel mass / Cost per bay	1420 / 1812	1558 / 1974	1701 / 2143	1834 / 2300	2155 / 2641	2728 / 3014
8500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/3	12720 5/1/5	13720 9/3/7	14620 17/4/10	15860 20/5/12	17660 9/3/10
	% Utilization: Mid span/Support	37 / 71	47 / 82	58 / 92	71 / 100	73 / 95	51 / 85
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W200X31 (16)	W250X33 (16)	W360X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 13/1/2	5280 14/2/2	6280 20/3/4	7380 23/4/5	8140 19/4/5	7340 27/4/5
	% Utilization: Mid span	48	50	61	72	72	71
	S-G bottom chord size (Studs)	W310X45 (42)	W310X45 (46)	W310X45 (46)	W310X45 (50)	W310X45 (54)	W310X45 (54)
	Length: Hole 1/Ext stub, (Studs)	600/1553 (18)	600/1553 (20)	600/1553 (20)	600/1553 (22)	600/1553 (24)	600/1553 (24)
	Length: Hole 3/Int stub, (Studs)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)
	% Utilization at: 1/2/3	57 / 67 / 52	63 / 74 / 58	69 / 81 / 63	75 / 88 / 69	81 / 95 / 74	84 / 94 / 71
	% Utilization at: 4/5/6	37 / 18 / 41	41 / 20 / 45	45 / 22 / 50	49 / 24 / 54	53 / 26 / 58	53 / 25 / 54
	Defl:Shore removed+SD+LL=Total	3+3+3=9	3+3+3=9	4+3+3=10	4+4+3=11	4+4+3=11	4+4+3=11
	Steel mass / Cost per bay	1490 / 1838	1627 / 2000	1771 / 2169	1903 / 2325	2233 / 2667	2824 / 3040
9000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W410X54 (26)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/4	12720 5/2/5	13720 10/3/8	14860 13/3/9	16760 12/4/11	17660 9/3/10
	% Utilization: Mid span/Support	38 / 75	49 / 86	61 / 96	63 / 91	62 / 100	54 / 89
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W200X31 (16)	W250X33 (16)	W250X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 14/1/2	5280 14/2/2	6280 22/3/4	7140 22/4/5	7240 26/4/5	7340 28/4/5
	% Utilization: Mid span	51	53	64	72	74	76
	S-G bottom chord size (Studs)	W310X45 (42)	W310X45 (46)	W310X45 (50)	W310X45 (54)	W310X60 (62)	W310X52 (58)
	Length: Hole 1/Ext stub, (Studs)	640/1640 (18)	640/1640 (20)	640/1640 (22)	640/1640 (24)	640/1640 (28)	640/1640 (26)
	Length: Hole 3/Int stub, (Studs)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)
	% Utilization at: 1/2/3	64 / 74 / 58	71 / 82 / 64	78 / 90 / 70	84 / 98 / 76	69 / 82 / 63	80 / 91 / 68
	% Utilization at: 4/5/6	40 / 19 / 45	45 / 21 / 49	49 / 23 / 54	53 / 25 / 59	53 / 28 / 61	55 / 26 / 59
	Defl:Shore removed+SD+LL=Total	4+3+3=10	4+4+3=11	5+4+4=13	5+4+4=13	4+4+3=11	4+4+3=11
	Steel mass / Cost per bay	1489 / 1864	1627 / 2026	1771 / 2195	2104 / 2546	2640 / 2869	2876 / 3090

+ See Section 6.20 for explanation.

3-STUB CONFIGURATION

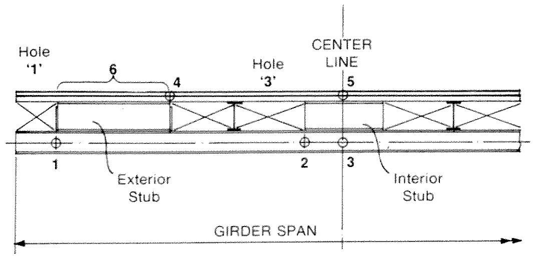


Table 6.7 (continued)
STUB-GIRDER FLOOR BAY+
Trial Selection Table

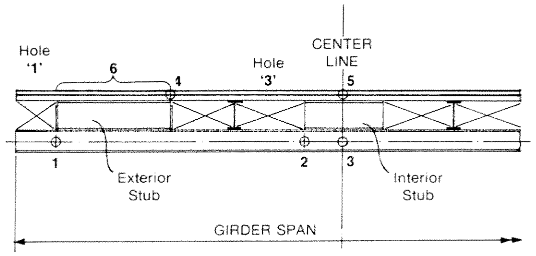
Live Load: 2.4 kPa
Cover Slab: 85 mm S.L.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
9500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W410X54 (26)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/4	12720 5/2/5	13660 10/3/8	14860 14/4/9	16480 14/4/11	17660 10/3/10
	% Utilization: Mid span/Support	40 / 78	51 / 90	64 / 100	66 / 96	66 / 100	56 / 94
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W250X33 (16)	W250X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 15/1/2	5280 15/2/2	6340 15/3/3	7140 23/4/5	7520 30/5/6	7340 30/5/6
	% Utilization: Mid span	54	56	60	76	84	80
	S-G bottom chord size (Studs)	W310X45 (46)	W310X45 (50)	W310X45 (54)	W310X52 (62)	W310X60 (66)	W310X52 (62)
	Length: Hole 1/Ext stub, (Studs)	670/1736 (20)	670/1736 (22)	670/1736 (24)	670/1736 (28)	670/1736 (30)	640/1766 (28)
	Length: Hole 3/Int stub, (Studs)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)
	% Utilization at: 1/2/3	70 / 81 / 64	78 / 90 / 71	85 / 99 / 78	79 / 93 / 72	76 / 91 / 69	84 / 100 / 75
	% Utilization at: 4/5/6	43 / 20 / 48	47 / 22 / 53	52 / 24 / 59	53 / 26 / 63	56 / 29 / 66	58 / 28 / 63
	Defl:Shore removed+SD+LL=Total	4+4+4=12	5+4+4=13	6+5+4=15	5+5+4=14	5+5+4=14	5+5+4=14
	Steel mass / Cost per bay	1524 / 1890	1662 / 2052	1825 / 2244	2211 / 2597	2678 / 2891	2925 / 3117
10000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/4	12720 5/2/6	13460 12/3/8	14860 14/4/9	17160 8/3/9	17660 10/3/10
	% Utilization: Mid span/Support	42 / 82	53 / 94	68 / 100	69 / 100	54 / 93	59 / 98
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W250X33 (16)	W250X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 15/1/2	5280 16/2/3	6540 17/3/4	7140 25/4/5	6840 25/4/5	7340 31/5/6
	% Utilization: Mid span	57	59	67	79	73	84
	S-G bottom chord size (Studs)	W310X45 (50)	W310X45 (54)	W310X52 (62)	W310X60 (66)	W310X60 (66)	W310X60 (70)
	Length: Hole 1/Ext stub, (Studs)	710/1823 (22)	710/1823 (24)	710/1823 (28)	680/1853 (30)	630/1903 (30)	610/1923 (32)
	Length: Hole 3/Int stub, (Studs)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)
	% Utilization at: 1/2/3	78 / 89 / 71	86 / 99 / 79	80 / 94 / 74	75 / 92 / 71	75 / 95 / 72	75 / 98 / 74
	% Utilization at: 4/5/6	53 / 21 / 52	59 / 23 / 58	51 / 25 / 63	54 / 28 / 69	57 / 28 / 66	59 / 29 / 68
	Defl:Shore removed+SD+LL=Total	5+5+4=14	6+5+5=16	6+5+5=16	6+5+4=15	6+5+4=15	6+5+4=15
	Steel mass / Cost per bay	1599 / 1916	1737 / 2078	1971 / 2294	2385 / 2708	3049 / 3149	3126 / 3228
10500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W460X61 (30)	W460X61 (30)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/4	12720 6/2/6	13280 14/4/8	16160 4/2/7	17160 8/3/9	17500 12/4/11
	% Utilization: Mid span/Support	43 / 85	56 / 98	72 / 100	46 / 88	56 / 97	62 / 100
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W200X27 (14)	W250X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 16/2/2	5280 17/2/3	6720 19/4/5	5840 27/3/4	6840 26/4/5	7500 35/5/7
	% Utilization: Mid span	60	62	74	76	77	92
	S-G bottom chord size (Studs)	W310X45 (54)	W310X52 (62)	W310X60 (66)	W310X60 (66)	W310X67 (70)	W310X67 (74)
	Length: Hole 1/Ext stub, (Studs)	750/1910 (24)	750/1910 (28)	750/1910 (30)	750/1910 (30)	750/1910 (32)	750/1910 (34)
	Length: Hole 3/Int stub, (Studs)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)
	% Utilization at: 1/2/3	86 / 97 / 78	81 / 94 / 74	79 / 93 / 72	86 / 96 / 73	83 / 93 / 70	86 / 97 / 73
	% Utilization at: 4/5/6	71 / 21 / 56	49 / 24 / 62	53 / 27 / 69	56 / 27 / 67	58 / 29 / 72	60 / 30 / 75
	Defl:Shore removed+SD+LL=Total	7+6+5=18	6+6+5=17	7+6+5=18	6+6+5=17	6+6+5=17	7+6+5=18
	Steel mass / Cost per bay	1593 / 1942	1808 / 2132	2055 / 2407	2820 / 2963	3101 / 3258	3168 / 3329

+ See Section 6.20 for explanation.

Table 6.8
STUB-GIRDER FLOOR BAY+
Trial Selection Table

3-STUB CONFIGURATION



Live Load: 3.6 kPa
Cover Slab: 75 mm N.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
8000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12720 5/1/7	13380 12/3/11	14000 23/5/15	15380 25/5/17	17660 9/3/14
	% Utilization: Mid span/Support	48 / 84	60 / 96	76 / 100	94 / 100	91 / 100	65 / 99
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W360X33 (14)	W360X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 14/1/2	5280 14/2/3	6620 16/3/5	8000 17/4/7	8620 24/5/9	7340 29/4/7
	% Utilization: Mid span	59	61	70	83	96	85
	S-G bottom chord size (Studs)	W310X45 (38)	W310X45 (42)	W310X45 (46)	W310X45 (50)	W310X52 (50)	W310X52 (50)
	Length: Hole 1/Ext stub, (Studs)	570/1456 (16)	570/1456 (18)	570/1456 (20)	570/1456 (22)	570/1456 (22)	570/1456 (22)
	Length: Hole 3/Int stub, (Studs)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)
	% Utilization at: 1/2/3	62 / 73 / 57	69 / 80 / 63	75 / 88 / 69	82 / 95 / 75	75 / 89 / 68	78 / 88 / 66
	% Utilization at: 4/5/6	49 / 23 / 40	55 / 25 / 44	60 / 28 / 48	65 / 30 / 52	66 / 32 / 56	66 / 31 / 52
	Defl:Shore removed+SD+LL=Total	3+2+3=8	3+2+3=8	3+3+3=9	4+3+4=11	3+3+3=9	3+2+3=8
	Steel mass / Cost per bay	1420 / 1812	1558 / 1974	1718 / 2163	1827 / 2292	2204 / 2650	2787 / 3035
8500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W410X54 (22)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12660 5/1/8	13160 14/3/11	14540 16/4/13	15900 19/4/16	17380 11/3/14
	% Utilization: Mid span/Support	50 / 89	63 / 100	81 / 100	79 / 100	82 / 100	69 / 100
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W250X33 (14)	W360X33 (14)	W250X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 15/1/2	5340 16/2/3	6840 19/3/6	7460 27/4/8	8100 22/4/8	7620 33/5/9
	% Utilization: Mid span	63	66	79	94	90	98
	S-G bottom chord size (Studs)	W310X45 (42)	W310X45 (46)	W310X45 (50)	W310X52 (54)	W310X60 (58)	W310X52 (54)
	Length: Hole 1/Ext stub, (Studs)	600/1553 (18)	600/1553 (20)	600/1553 (22)	600/1553 (24)	600/1553 (26)	580/1573 (24)
	Length: Hole 3/Int stub, (Studs)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)
	% Utilization at: 1/2/3	69 / 81 / 64	77 / 90 / 70	84 / 98 / 77	77 / 92 / 71	74 / 89 / 68	83 / 98 / 74
	% Utilization at: 4/5/6	54 / 25 / 43	60 / 27 / 47	66 / 30 / 52	67 / 32 / 56	70 / 35 / 59	73 / 34 / 56
	Defl:Shore removed+SD+LL=Total	3+3+4=10	4+3+4=11	4+3+4=11	4+3+4=11	4+3+4=11	4+3+4=11
	Steel mass / Cost per bay	1490 / 1838	1626 / 1999	1785 / 2186	2165 / 2535	2614 / 2807	2877 / 3049
9000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W410X54 (22)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12440 7/2/8	12980 16/3/11	14340 18/4/13	15680 22/5/16	17080 14/4/15
	% Utilization: Mid span/Support	52 / 93	67 / 100	85 / 99	84 / 100	86 / 100	73 / 100
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W250X33 (16)	W360X33 (16)	W360X33 (14)
	Length; Defl: Slab pour/SD/LL	4280 16/1/2	5560 19/2/4	7020 22/4/7	7660 32/5/10	8320 25/5/9	7920 23/4/7
	% Utilization: Mid span	67	76	88	99	97	91
	S-G bottom chord size (Studs)	W310X45 (46)	W310X45 (50)	W310X52 (54)	W310X60 (58)	W310X60 (62)	W310X60 (62)
	Length: Hole 1/Ext stub, (Studs)	640/1640 (20)	640/1640 (22)	640/1640 (24)	640/1640 (26)	640X1640 (28)	640/1640 (28)
	Length: Hole 3/Int stub, (Studs)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)
	% Utilization at: 1/2/3	78 / 90 / 71	86 / 99 / 78	80 / 94 / 73	77 / 92 / 70	83 / 99 / 76	86 / 98 / 73
	% Utilization at: 4/5/6	63 / 26 / 46	70 / 29 / 51	67 / 32 / 56	71 / 35 / 61	77 / 38 / 64	77 / 36 / 61
	Defl:Shore removed+SD+LL=Total	4+3+5=12	5+4+5=14	4+3+5=12	4+3+4=11	5+4+5=14	5+4+4=13
	Steel mass / Cost per bay	1489 / 1864	1622 / 2020	1850 / 2234	2235 / 2633	2605 / 2831	2926 / 3138

+ See Section 6.20 for explanation.

3-STUB CONFIGURATION

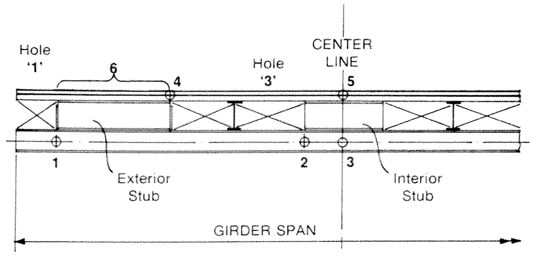


Table 6.8 (continued)
STUB-GIRDER FLOOR BAY+
Trial Selection Table

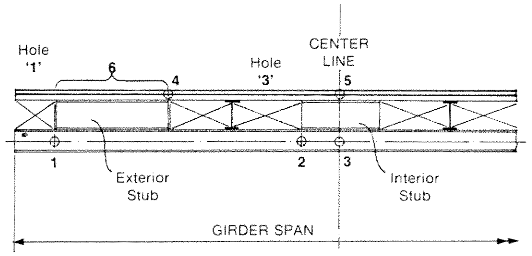
Live Load: 3.6 kPa
Cover Slab: 75 mm N.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
9500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W410X54 (22)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12240 8/2/8	12820 18/4/12	14160 21/4/14	15480 24/5/17	16820 16/4/15
	% Utilization: Mid span/Support	54 / 97	71 / 100	90 / 99	89 / 100	91 / 100	78 / 100
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W360X33 (14)	W360X33 (20)	W360X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 17/1/3	5760 22/3/5	7180 25/4/8	7840 20/4/8	8520 28/6/10	8180 27/5/9
	% Utilization: Mid span	70	86	97	94	99	99
	S-G bottom chord size (Studs)	W310X45 (50)	W310X52 (54)	W310X60 (58)	W310X67 (62)	W310X67 (70)	W310X67 (66)
	Length: Hole 1/Ext stub, (Studs)	670/1736 (22)	670/1736 (24)	640/1766 (26)	590/1816 (28)	670/1736 (32)	530/1876 (30)
	Length: Hole 3/Int stub, (Studs)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)
	% Utilization at: 1/2/3	85 / 99 / 79	80 / 95 / 74	75 / 93 / 72	66 / 91 / 70	81 / 98 / 75	67 / 97 / 73
	% Utilization at: 4/5/6	88 / 27 / 50	65 / 30 / 55	69 / 34 / 60	72 / 36 / 64	78 / 39 / 68	78 / 38 / 63
	Defl:Shore removed+SD+LL=Total	5+4+5=14	5+4+5=14	5+4+5=14	5+4+5=14	5+4+5=14	5+4+5=14
	Steel mass / Cost per bay	1524 / 1890	1723 / 2066	1969 / 2339	2354 / 2730	2715 / 2925	3053 / 3227
10000	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W410X54 (22)	W460X61 (24)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11640 3/1/6	12060 9/2/8	13380 12/3/10	14680 15/3/12	16320 13/3/13	16580 19/5/15
	% Utilization: Mid span/Support	57 / 100	75 / 99	75 / 100	79 / 100	74 / 100	82 / 100
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (12)	W250X33 (14)	W250X33 (18)	W250X33 (26)	W360X33 (22)
	Length; Defl: Slab pour/SD/LL	4360 18/2/3	5940 25/3/6	6620 20/3/6	7320 30/5/9	7680 38/6/11	8420 31/6/10
	% Utilization: Mid span	77	96	87	97	92	99
	S-G bottom chord size (Studs)	W310X52 (54)	W310X60 (58)	W310X67 (62)	W310X67 (70)	W310X74 (70)	W310X74 (70)
	Length: Hole 1/Ext stub, (Studs)	710/1823 (24)	670/1863 (26)	620/1913 (28)	710/1823 (32)	520/2013 (32)	500/2033 (32)
	Length: Hole 3/Int stub, (Studs)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)
	% Utilization at: 1/2/3	80 / 94 / 74	74 / 93 / 73	67 / 92 / 71	84 / 100 / 77	59 / 93 / 69	59 / 96 / 72
	% Utilization at: 4/5/6	62 / 28 / 53	66 / 32 / 59	69 / 34 / 63	75 / 37 / 68	75 / 38 / 65	78 / 39 / 67
	Defl:Shore removed+SD+LL=Total	5+4+6=15	5+4+6=15	5+4+5=14	6+5+6=17	5+4+5=14	5+4+5=14
	Steel mass / Cost per bay	1670 / 1940	1885 / 2174	2331 / 2624	2690 / 2821	3174 / 3256	3240 / 3324
10500	Cantilever seg. size (Studs)	W410X39 (16)	W410X39 (16)	W410X46 (20)	W460X61 (24)	W460X61 (24)	W460X61 (24)
	Length; Defl: Slab pour/SD/LL	11440 4/1/6	11920 10/2/9	13220 13/3/11	15660 7/2/10	16100 15/4/14	16380 21/5/16
	% Utilization: Mid span/Support	60 / 100	79 / 100	79 / 100	63 / 100	78 / 100	86 / 100
	Suspended seg. size (Studs)	W150X22 (20)	W200X27 (22)	W250X33 (14)	W250X33 (14)	W360X33 (18)	W410X39 (16)
	Length; Defl: Slab pour/SD/LL	4560 22/2/4	6080 29/4/7	6780 23/4/7	6340 21/3/5	7900 25/5/9	8620 21/5/9
	% Utilization: Mid span	88	83	96	84	98	97
	S-G bottom chord size (Studs)	W310X60 (58)	W310X67 (62)	W310X74 (70)	W310X74 (70)	W310X79 (74)	W310X79 (78)
	Length: Hole 1/Ext stub, (Studs)	750/1910 (26)	750/1910 (28)	750/1910 (32)	750/1910 (32)	750/1910 (34)	750/1910 (36)
	Length: Hole 3/Int stub, (Studs)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)
	% Utilization at: 1/2/3	79 / 92 / 72	77 / 92 / 71	76 / 91 / 70	82 / 94 / 71	83 / 96 / 72	86 / 100 / 74
	% Utilization at: 4/5/6	64 / 30 / 57	68 / 34 / 64	71 / 37 / 69	74 / 36 / 68	78 / 39 / 73	80 / 41 / 76
	Defl:Shore removed+SD+LL=Total	6+5+6=17	6+5+6=17	6+5+6=17	6+5+6=17	6+5+6=17	6+5+6=17
	Steel mass / Cost per bay	1751 / 2049	1958 / 2279	2396 / 2732	3008 / 3153	3186 / 3340	3332 / 3496

+ See Section 6.20 for explanation.

Table 6.9
STUB-GIRDER FLOOR BAY[+]
Trial Selection Table

3-STUB CONFIGURATION



Live Load: 3.6 kPa
Cover Slab: 85 mm S.L.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
8000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12720 4/1/7	13540 9/3/11	14120 19/4/15	15540 21/5/17	17660 8/3/14
	% Utilization: Mid span/Support	45 / 81	57 / 93	70 / 100	87 / 100	87 / 100	61 / 95
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W360X33 (16)	W360X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 12/1/2	5280 13/2/3	6460 13/2/4	7880 14/3/7	8460 20/5/9	7340 25/4/7
	% Utilization: Mid span	55	57	63	77	88	81
	S-G bottom chord size (Studs)	W310X45 (42)	W310X45 (46)	W310X45 (50)	W310X45 (54)	W310X45 (58)	W310X45 (54)
	Length: Hole 1/Ext stub, (Studs)	570/1456 (18)	570/1456 (20)	570/1456 (22)	570/1456 (24)	570/1456 (26)	570/1456 (24)
	Length: Hole 3/Int stub, (Studs)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)	760/1146 (6)
	% Utilization at: 1/2/3	60 / 70 / 54	66 / 78 / 60	73 / 85 / 66	79 / 92 / 71	85 / 99 / 77	88 / 98 / 74
	% Utilization at: 4/5/6	39 / 19 / 44	43 / 21 / 49	47 / 23 / 54	51 / 25 / 58	55 / 27 / 62	55 / 26 / 57
	Defl:Shore removed+SD+LL=Total	2+2+3=7	3+2+3=8	3+3+4=10	3+3+4=10	3+3+4=10	3+3+4=10
	Steel mass / Cost per bay	1420 / 1812	1558 / 1974	1719 / 2164	1829 / 2293	2149 / 2633	2728 / 3014
8500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12720 5/1/8	13320 11/3/11	13940 22/5/15	15320 24/6/18	17620 9/3/14
	% Utilization: Mid span/Support	47 / 85	59 / 97	75 / 100	92 / 100	93 / 100	64 / 100
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W360X33 (16)	W360X33 (16)	W250X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 13/1/2	5280 14/2/3	6680 15/3/5	8060 16/4/8	8680 23/5/10	7380 27/4/8
	% Utilization: Mid span	58	61	72	85	98	87
	S-G bottom chord size (Studs)	W310X45 (46)	W310X45 (50)	W310X45 (54)	W310X52 (58)	W310X52 (62)	W310X52 (62)
	Length: Hole 1/Ext stub, (Studs)	600/1553 (20)	600/1553 (22)	600/1553 (24)	600/1553 (26)	600/1553 (28)	600/1553 (28)
	Length: Hole 3/Int stub, (Studs)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)	800/2033 (6)
	% Utilization at: 1/2/3	66 / 78 / 61	74 / 87 / 67	80 / 95 / 74	74 / 89 / 68	80 / 96 / 73	83 / 95 / 71
	% Utilization at: 4/5/6	43 / 21 / 48	47 / 23 / 53	52 / 25 / 58	53 / 27 / 63	57 / 29 / 68	57 / 28 / 62
	Defl:Shore removed+SD+LL=Total	3+3+4=10	3+3+4=10	4+3+4=11	4+3+4=11	4+3+4=11	4+3+4=11
	Steel mass / Cost per bay	1490 / 1838	1627 / 2000	1787 / 2188	1959 / 2339	2285 / 2676	2885 / 3060
9000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W410X54 (26)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12600 5/2/8	13120 13/3/11	14500 15/4/14	15840 18/5/16	17300 11/4/15
	% Utilization: Mid span/Support	49 / 90	62 / 100	79 / 100	81 / 100	81 / 100	68 / 100
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W250X33 (16)	W360X33 (16)	W250X33 (18)
	Length; Defl: Slab pour/SD/LL	4280 14/1/2	5400 15/2/4	6880 18/3/6	7500 26/5/9	8160 21/4/8	7700 32/5/10
	% Utilization: Mid span	62	67	80	95	92	96
	S-G bottom chord size (Studs)	W310X45 (50)	W310X45 (54)	W310X52 (58)	W310X52 (62)	W310X60 (70)	W310X60 (66)
	Length: Hole 1/Ext stub, (Studs)	640/1640 (22)	640/1640 (24)	640/1640 (26)	640/1640 (28)	640/1640 (32)	640/1640 (30)
	Length: Hole 3/Int stub, (Studs)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)	850/1300 (6)
	% Utilization at: 1/2/3	75 / 87 / 68	82 / 96 / 75	77 / 91 / 70	83 / 98 / 75	80 / 95 / 72	83 / 94 / 70
	% Utilization at: 4/5/6	46 / 22 / 52	51 / 24 / 58	53 / 27 / 63	57 / 29 / 68	60 / 32 / 71	60 / 30 / 69
	Defl:Shore removed+SD+LL=Total	4+3+5=12	4+4+5=13	4+4+5=13	4+4+5=13	4+4+5=13	4+4+5=13
	Steel mass / Cost per bay	1489 / 1864	1625 / 2024	1851 / 2235	2163 / 2561	2610 / 2837	2936 / 3148

[+] See Section 6.20 for explanation.

3-STUB CONFIGURATION

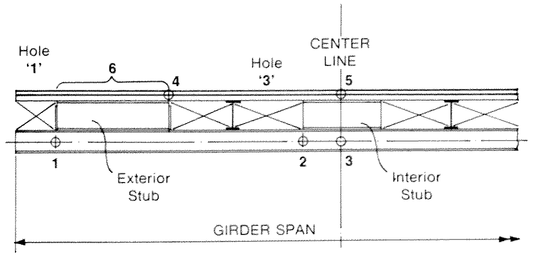


Table 6.9 (continued)
STUB-GIRDER FLOOR BAY[+]
Trial Selection Table

Live Load: 3.6 kPa
Cover Slab: 85 mm S.L.D. Concrete

Girder Span (mm)	Description	Beam Span (mm)					
		8 000	9 000	10 000	11 000	12 000	12 500
9500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W410X54 (26)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/5	12400 6/2/8	12960 15/4/12	14320 17/4/14	15640 20/5/17	17040 13/4/15
	% Utilization: Mid span/Support	51 / 94	66 / 100	84 / 100	85 / 100	86 / 100	72 / 100
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W250X33 (20)	W360X33 (18)	W360X33 (16)
	Length; Defl: Slab pour/SD/LL	4280 15/1/3	5600 18/2/5	7040 20/4/7	7680 30/5/10	8360 23/5/10	7960 22/4/8
	% Utilization: Mid span	65	76	89	97	98	93
	S-G bottom chord size (Studs)	W310X45 (54)	W310X52 (58)	W310X60 (66)	W310X60 (70)	W310X67 (74)	W310X67 (70)
	Length: Hole 1/Ext stub, (Studs)	670/1736 (24)	670/1736 (26)	670/1736 (30)	620/1786 (32)	670/1736 (34)	550/1856 (32)
	Length: Hole 3/Int stub, (Studs)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)	900/1366 (6)
	% Utilization at: 1/2/3	82 / 95 / 75	77 / 91 / 71	75 / 90 / 69	75 / 97 / 74	78 / 95 / 72	66 / 94 / 69
	% Utilization at: 4/5/6	49 / 23 / 56	51 / 25 / 62	54 / 28 / 69	59 / 30 / 74	61 / 33 / 77	61 / 32 / 72
	Defl:Shore removed+SD+LL=Total	4+4+6=14	4+4+5=13	5+4+5=14	5+4+5=14	5+4+5=14	4+4+5=13
	Steel mass / Cost per bay	1524 / 1890	1726 / 2070	1968 / 2341	2285 / 2664	2720 / 2931	3060 / 3237
10000	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W410X46 (22)	W460X61 (30)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11720 2/1/6	12220 8/2/9	12820 16/4/12	14140 19/5/14	16540 11/3/13	16800 15/4/15
	% Utilization: Mid span/Support	53 / 98	69 / 100	88 / 100	89 / 100	69 / 100	76 / 100
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (16)	W360X33 (16)	W250X33 (20)	W360X33 (18)
	Length; Defl: Slab pour/SD/LL	4280 15/1/3	5780 20/3/6	7180 23/4/8	7860 18/4/8	7460 31/5/10	8200 25/5/10
	% Utilization: Mid span	69	85	97	95	96	100
	S-G bottom chord size (Studs)	W310X52 (58)	W310X52 (62)	W310X60 (70)	W310X67 (74)	W310X67 (74)	W310X74 (78)
	Length: Hole 1/Ext stub, (Studs)	710/1823 (26)	700/1833 (28)	640/1893 (32)	590/1943 (34)	50/1983 (34)	530/2003 (36)
	Length: Hole 3/Int stub, (Studs)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)	950/2383 (6)
	% Utilization at: 1/2/3	77 / 90 / 71	84 / 100 / 78	75 / 98 / 76	67 / 96 / 73	67 / 99 / 74	60 / 93 / 68
	% Utilization at: 4/5/6	48 / 24 / 61	53 / 26 / 67	57 / 29 / 73	59 / 32 / 78	62 / 32 / 74	61 / 33 / 77
	Defl:Shore removed+SD+LL=Total	5+4+6=15	5+5+6=16	5+5+6=16	5+5+6=16	5+5+6=16	5+4+5=14
	Steel mass / Cost per bay	1672 / 1942	1801 / 2093	2055 / 2371	2453 / 2765	3106 / 3193	3246 / 3335
10500	Cantilever seg. size (Studs)	W410X39 (20)	W410X39 (20)	W410X39 (20)	W460X61 (30)	W460X61 (30)	W460X61 (30)
	Length; Defl: Slab pour/SD/LL	11620 3/1/6	12060 9/2/9	12680 18/4/13	15900 5/2/10	16300 12/4/14	16580 17/5/16
	% Utilization: Mid span/Support	56 / 100	73 / 100	92 / 100	59 / 100	73 / 100	80 / 100
	Suspended seg. size (Studs)	W150X22 (24)	W200X27 (14)	W250X33 (20)	W200X27 (14)	W250X33 (32)	W360X33 (26)
	Length; Defl: Slab pour/SD/LL	4380 17/2/3	5940 23/3/6	7320 26/5/9	6100 30/4/7	7700 36/6/11	8420 28/6/11
	% Utilization: Mid span	75	94	97	100	90	97
	S-G bottom chord size (Studs)	W310X52 (62)	W310X60 (70)	W310X67 (74)	W310X67 (78)	W310X74 (82)	W310X79 (86)
	Length: Hole 1/Ext stub, (Studs)	750/1910 (28)	750/1910 (32)	750/1910 (34)	750/1910 (36)	750/1910 (38)	750/1910 (40)
	Length: Hole 3/Int stub, (Studs)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)	990/1520 (6)
	% Utilization at: 1/2/3	85 / 98 / 77	84 / 98 / 76	81 / 97 / 75	89 / 100 / 75	85 / 98 / 73	82 / 96 / 71
	% Utilization at: 4/5/6	51 / 25 / 65	55 / 28 / 73	58 / 30 / 80	60 / 30 / 77	62 / 33 / 83	63 / 34 / 86
	Defl:Shore removed+SD+LL=Total	6+5+7=18	6+5+7=18	6+5+7=18	6+5+6=17	6+5+6=17	6+5+6=17
	Steel mass / Cost per bay	1667 / 1967	1883 / 2205	2127 / 2478	2883 / 3025	3140 / 3294	3259 / 3418

[+] See Section 6.20 for explanation.

CHAPTER 7

7.0 FLOOR VIBRATION – COMPOSITE CONSTRUCTION

7.1 INTRODUCTION

The assessment of vibration characteristics of a floor from a serviceability standpoint is a complex subject. It involves the assessment of certain dynamic properties of the floor system such as the natural frequency, mass, damping, and dynamic response in terms of acceleration. It also requires consideration of the occupants' threshold of annoyance to vibrations. The threshold of annoyance generally varies depending on the types of floor vibration and the types of occupancy.

A guide for assessing floor vibrations is outlined in Appendix G of CAN3-S16.1-M84 which provides a method of evaluating serviceability and acceptance criteria. The authors have based the following commentary and the following design examples on Appendix G, and on their experience.

There is an increasing trend toward large column-free "office landscaped" floor spaces, and an increasing trend to compositely designed floor systems, using lighter and shallower floor construction with less inherent damping. Superimposed loads are also a component of a structure's performance under vertical impact loading. This aspect is now addressed mathematically in Appendix G, in that, a designer is able to include an appropriate amount of the design loads in his calculations of acceleration and frequency. Since office occupancy space is rarely subjected to its design load, it is one of the more susceptible design cases, and one must ensure that objectionable floor vibrations will not occur during normal occupancy activity.

In estimating appropriate damping values for various types of construction, Appendix G differentiates between composite and non-composite assemblies, assigning a lesser value to compositely designed floors.

Any steel/concrete floor assembly usually has some means of positive connection between concrete deck and beams (e.g. arc spot welds through the steel deck). Since very small deflections are involved in vibrations due to normal human activity, there may indeed be sufficient interaction to prevent distinction between composite and non-composite construction in many instances. Therefore it is the authors' recommendation that in borderline cases, damping should be assumed to be equivalent to composite construction, regardless of the actual construction used. However it is also suggested that this subject is worthy of further investigation.

7.2 TYPES OF FLOOR VIBRATION

Floor vibrations can be divided into two categories, namely continuous or steady state source vibrations and transient vibrations. ***Continuous vibrations*** are usually caused by periodic forces of machinery, vehicles or human group activities. If the dynamic force frequency approaches the natural frequency of the floor, the magnitude of vibration can be considerably magnified and a resonance state is reached unless there is a large amount of damping. Human group activities, such as dancing or gymnastics, can generate periodic forces with frequencies as high as about 4 Hz. Therefore, in general, floors used for such occupancies are designed with natural frequencies of greater than 5 hertz (8 hertz for very repetitive activities such as jumping exercises). The

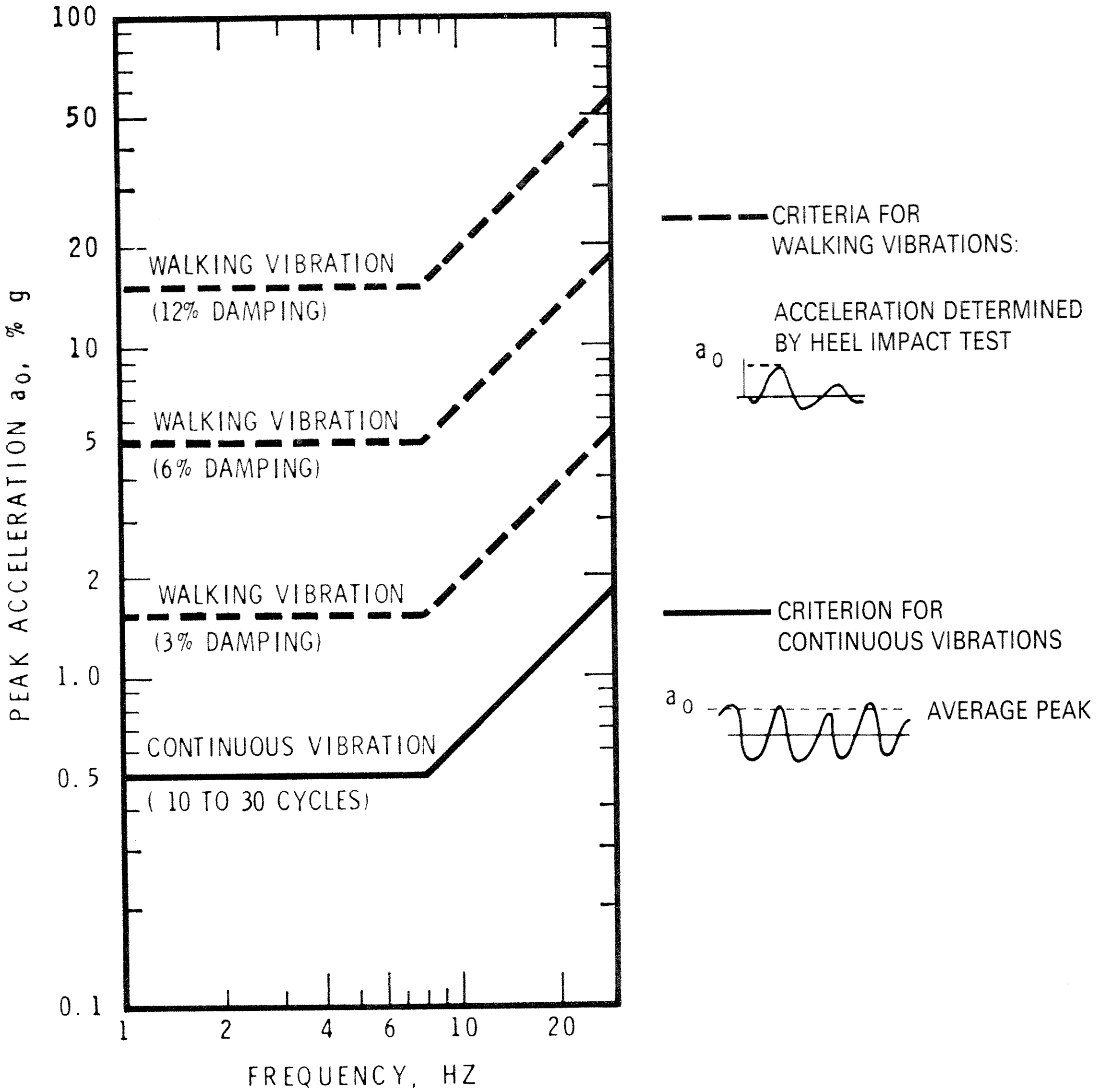


Figure 7.1
Annoyance Thresholds for Floor Vibrations due to Footstep (Residential, School, Office Occupancies) (as per S16.1-M84, Appendix G)

Commentary on Serviceability Criteria for Deflection and Vibrations, as published in Ref.(7.1), provides more specific guidance on vibrations due to rhythmic human activities. ***Transient vibrations*** arise due to impulses caused by footsteps or other impacts. Floor vibrations caused by such impulses decay at a rate dependent on the amount of available damping in (and on) the floor system.

7.3 TYPES OF OCCUPANCY

Human sensitivity to floor vibration differs in areas of different occupancies. Graphical representation of human annoyance criteria for floor vibrations, as proposed for use in residential, school, and office occupancies, is shown in Fig. 7.1. These annoyance thresholds, approximated by thresholds of definite perception, are expressed in terms of peak acceleration due to the standard heel impact test for various critical damping ratios and natural frequencies of floor assemblies.

Annoyance threshold design levels may be lowered for occupancies such as operating rooms and certain laboratories and may be raised for industrial occupancies where floor vibrations are less objectionable. Recent test results(7.2) also suggest a higher threshold level for walking areas of shopping centres.

Continuous vibrations caused by machines in operation can best be minimized by isolating this equipment from 'quiet' occupancies such as office areas. This is because most people find continuous vibration to be much more annoying than transient vibration which dies out quickly, that is, generally speaking, within 5 cycles(7.1). For continuous sinusoidal vibration, a threshold level of 0.5 percent of gravity acceleration is suggested by Appendix G. See Fig. 7.1. It should be noted that design and analysis of floor systems dealing with continuous floor vibration is generally applied to a very specific and isolated area of the total structure. Hence, in the following sections of this chapter, the question of continuous floor vibration is totally ignored while the design procedure dealing with the serviceability of composite steel floors under the subject of transient floor vibration due to footsteps for residential, school, and office occupancies is illustrated in accordance with Appendix G.

7.4 WALKING VIBRATION

Vibration due to footstep impact is considered the most common source of annoyance in lightly damped floors (e.g. open floor plan without partitions, bookshelves, file storage, etc.) of office, school and residential occupancies. One-way floor systems with spans less than 8 metres, and that satisfy live load deflection limitations, usually possess acceptable vibration characteristics.

The characteristics of transient vibrations due to footsteps on floor systems with spans greater than 8 metres and with natural frequencies of 4 to 15 hertz may be evaluated during a structural design using the procedures provided by Appendix G. These procedures are illustrated in the following text. Using this method, it can be shown that, for a floor system with natural frequencies less than 8 hertz, an increase in stiffness in the floor system causes an increase in the peak acceleration computed using the same heel-drop impact. When these results are plotted on the graph shown in Figure 7.1, it can be seen that, in such a case, the floor will be more susceptible to vibrations in the perceptible range, provided that damping of the floor assembly remains unchanged.

7.5 MATHEMATICAL SIMULATION OF VIBRATION CHARACTERISTICS

One-way Floor System

The performance of a floor can be determined by means of a performance test as proposed in Appendix G. In the absence of such a test, the vibration characteristics of a one-way system may be assessed by using the simple computational approach outlined in Appendix G. The frequency in hertz is given by,

$$f_1 = 156\sqrt{\frac{E\,I_T}{w\,L^4}} \qquad 7.1$$

where $E =$ 200 000 MPa,

$I_T =$ moment of inertia of the transformed T-section, in mm^4, (concrete transformed to steel with slab width equal to spacing of steel members, and slab thickness equal to t_e as defined in equation 7.3),

$w =$ total dead load (less movable partitions load allowance) per unit length, in N/mm,

$L =$ span, in mm.

Where the span is greater than 8 m and the fundamental frequency is less than 10 Hz, Allen and

Rainer(7.3) have shown that the peak acceleration due to heel-drop for a one-way system can be approximated by,

$$a_o = 0.9\,(2\pi f)\,J/M \qquad 7.2$$

in which,

f = fundamental frequency,
J = impulse due to a "standard heel-drop",
M = mass of an equivalent simple oscillator.

Assuming a "standard heel-drop" impulse of 70 N·s and a mass of an equivalent simply supported beam vibrating in the fundamental mode representing the floor system, a_o, in percent of gravitational acceleration, is then rewritten in Appendix G as,

$$a_o = \frac{60f}{q\,B\,L} \qquad 7.3$$

in which,

q = load due to floor plus contents (kPa), as appropriate,
B = 40 t_e, in metres,
L = span of beam, in metres,
t_e = average thickness of concrete deck-slab (m).

Following the assessment of f_1 and a_o, Fig. 7.1, representing annoyance criteria for floor vibrations, can then be used to determine the amount of required damping in (and on) the floor system. Note again that Fig. 7.1 is intended for use in residential, school, office and similar occupancies. Recent research data(7.4) have shown that damping is the most influential parameter. Transient vibration can be more effectively controlled by increasing damping than by reducing acceleration or by altering the frequencies of the floor.

Floor finishing, carpet, furniture, ceiling, ducts and fire protection materials contribute considerably to total damping of a floor system. Partitions, either above or below the floor (in certain situations), if favourably located and oriented, also provide a substantial amount of damping. The following values are suggested in Appendix G for design calculations:

	Damping in Percent Critical
– Bare floor (fully composite construction)	2
– Finished composite floor (with ceiling, ducts, flooring, furniture)	5
– Finished floor with partitions.	12

Two-way Interaction

Often, trusses or beams are supported by girders (such as those in an interior floor bay) instead of rigid supports. The floor frequency, f, of a two-way system is smaller than f_1 or f_2, where f_2 is the frequency of floor in the girder direction. An approximation for f, using Dunkerley's formula, is suggested in Appendix G:

$$f = (f_1^{-2} + f_2^{-2})^{-0.5} \qquad 7.4$$

If f_1 is much smaller than f_2 (say $f_1 < 0.5\,f_2$), the floor behaves like a one-way ***beam*** system. Hence the equivalent vibrating floor area, BL, shall be computed as noted in equation 7.3. When f_2 is much less than f_1, one-way ***girder*** behaviour prevails. In this case, the product BL may be estimated as the tributary floor area supported by the girder. For cases where f_1 and f_2 are close, the formula provided by Appendix G for calculating equivalent vibrating floor area of the two-way system may be used:

$$BL = \left(\frac{f}{f_1}\right)^2 B_1\,L_1 + \left(\frac{f}{f_2}\right)^2 B_2\,L_2 \qquad 7.5$$

where the subscripts 1 and 2 denote the beam and girder systems respectively.

Often, in practice, a true two-way beam and girder interaction is prevented by certain non-structural features in the building. A spandrel girder or a girder at the location of a full height partition is in effect so stiff that one-way beam vibration may prevail. When it becomes doubtful as to whether a true two-way behaviour exists, one may investigate one-way behaviour in addition to that of the two-way system, keeping in mind that, in any event, damping is the dominant factor and field test data for two-way systems are still lacking. The simple-approach calculation that is outlined in this Chapter is illustrated in the examples in Section 7.6.

The stub-girder floor system is clearly a two-way beam/girder system. The design method recommended in the previous paragraphs of this section to determine fundamental frequency and peak acceleration of floor systems is also applicable to a stub-girder floor (7.5). Also see Section 7.6 for worked example.

7.6 DESIGN EXAMPLES

Since floor vibration due to one or more occupants walking is the most common source of annoyance, this section demonstrates how the simple procedure described in this chapter is used to assess the vibration characteristics of a floor due to a "standard heel-drop". This approximate method may be useful in deciding whether there is likely to be a problem sufficient to warrant further investigation. In view of its limitations however, this simple approach does not always provide a definitive conclusion to this highly complex and somewhat subjective matter.

Example 1: Assess the "standard heel-drop" vibration characteristics of the typical floor designed in Chapter 4. Figure 7.E1 shows the plan of this hollow composite beam and girder floor.

Since the vibration characteristics of typical bay 'A' and typical bay 'B' (both identified in Fig. 7.E1) can be quite different, the acceptability of each is investigated.

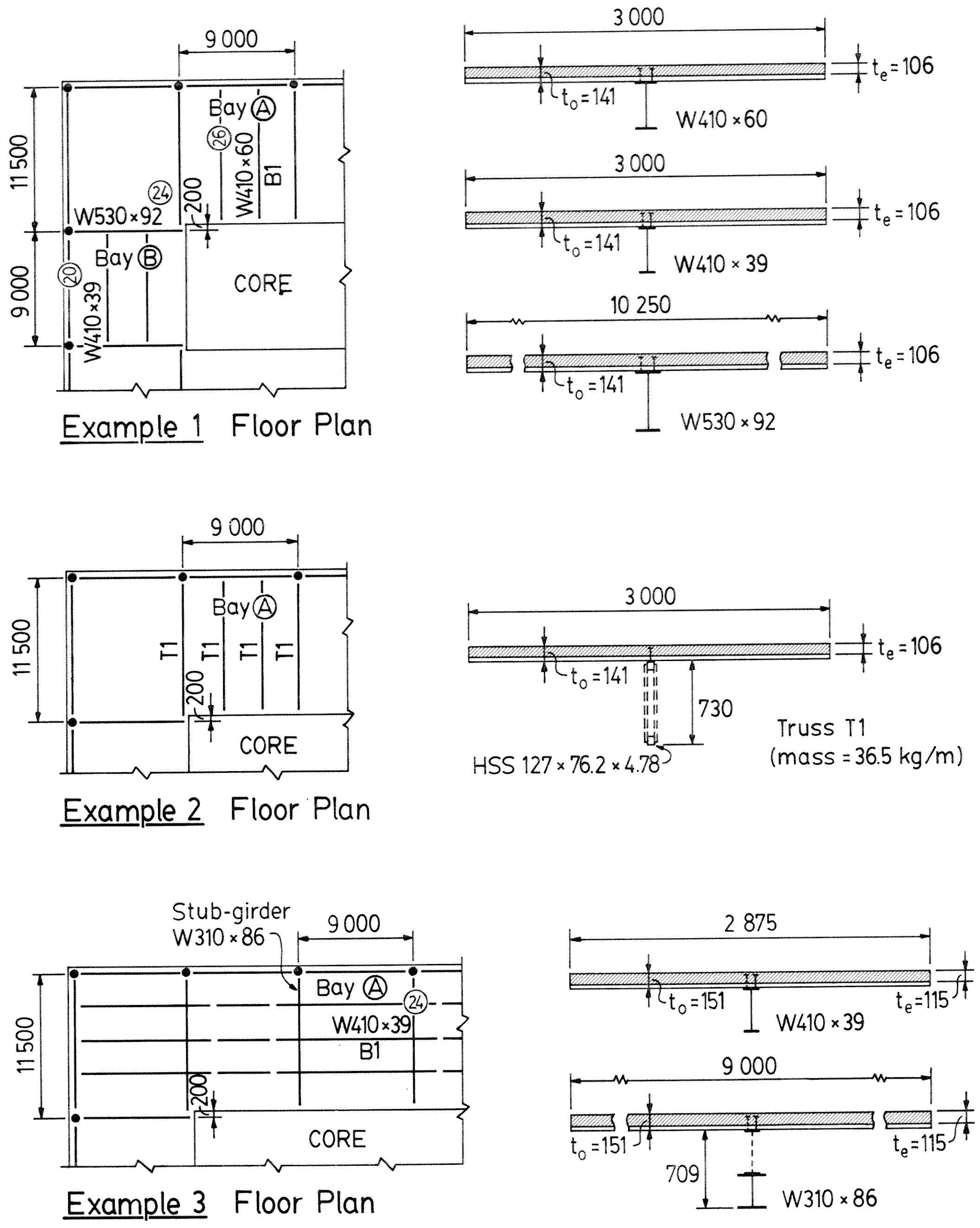
– *Bay 'A'*

Floor beams, B1, span between the rigid core wall and the spandrel girders which also provide fairly stiff supports. Therefore, one-way beam behaviour likely prevails.

Find I_T

$$t_e = \frac{\text{slab dead load}}{w_c\,g} = \frac{2.40 \times 10^6}{2\,300(9.81)} = 106 \text{ mm} \; ; \; n = 9.43$$

Element	Transformed Area (mm²)	Distance from top of slab y (mm)	Ay 10^3 mm³	Ay² 10^6 mm⁴	I_{local} 10^6 mm⁴
Concrete	33 722	53.0	1 787	94.7	31.6
W410×60	7 580	344.5	2 611	899.6	216
Total	41 302		4 398	994.3	247.6



Example 1 Floor Plan

Example 2 Floor Plan

Example 3 Floor Plan

Figure 7.E1
Floor Design Example Key Plans and Member Sizes (for Assessment of Standard Heel-Drop Vibration Characteristics)

$$\overline{y} = \frac{4\,398 \times 10^3}{41\,302} = 106.5 \text{ mm}$$

$$I_T = (994.3 + 247.6) \times 10^6 - 41\,302\,(106.5)^2 = 773 \times 10^6 \text{ mm}^4$$

From Example in Section 4.14

$$w = 0.584 + (2.4 + 0.2 + 0.5)(3) = 9.88 \text{ N/mm} \qquad \text{(or kN/m)}$$

$$f = 156\sqrt{\frac{E\,I_T}{w\,L^4}} \qquad \text{(Eq. 7.1)}$$

$$= 156\sqrt{\frac{200\,000\,(773 \times 10^6)}{9.88\,(11\,300)^4}} = 4.83 \text{ Hz}$$

$$q = (9.88)/(3) = 3.29 \text{ kPa (floor plus contents)}$$

$$a_o = \frac{60\,f}{q\,BL} \qquad \text{(Eq. 7.3)}$$

$$= \frac{(60)(4.83)}{(3.29)(40)(0.106)(11.3)}$$

$$= 1.8\%\ g$$

A point representing f = 4.8 Hz and $a_o \simeq 1.8\%$ g is labelled as '1a' in Fig. 7.E2, for which a critical damping ratio somewhere between 3% and 4% is required. Damping amounting to approximately 5% of critical damping (see Section 7.5) is available in the finished floor *per se* (assuming worst condition of no partition, bookcase or other form of on-the-floor damping). Bay 'A' is therefore acceptable.

—Bay 'B'

Consider W410×39 composite beams supported by W530×92 composite girders.

Find I_{T1} (beam)

Element	Transformed Area (mm²)	Distance from top of slab y (mm)	Ay 10^3 mm³	Ay² 10^6 mm⁴	I_{local} 10^6 mm⁴
Concrete	33 722	53.0	1 787	94.7	31.6
W410×39	4 990	340.5	1 699	578.5	127
Total	38 712		3 486	673.2	158.6

$$\overline{y} = \frac{3\,486 \times 10^3}{38\,712} = 90.05 \text{ mm}$$

$$I_{T1} = (673.2 + 158.6) \times 10^6 - 38\,712\,(90.05)^2 = 518 \times 10^6 \text{ mm}^4$$

$$w_1 = 0.384 + (2.4 + 0.2 + 0.5)(3) = 9.68 \text{ N/mm}$$

$$f_1 = 156\sqrt{\frac{200\,000\,(518 \times 10^6)}{9.68\,(9\,000)^4}} = 6.30 \text{ Hz}$$

Find I_{T2} (girder)

Element	Transformed Area (mm²)	Distance from top of slab y (mm)	Ay 10^3 mm³	Ay² 10^6 mm⁴	I_{local} 10^6 mm⁴
Concrete	115 217	53.0	6 106	323.6	107.9
W530×92	11 800	407.5	4 808	1 959	552
Total	127 017		10 914	2 283	659.9

$$\overline{y} = \frac{10\,914 \times 10^3}{127\,017} = 85.93 \text{ mm}$$

$$I_{T2} = (2\,283 + 659.9) \times 10^6 - 127\,017\,(85.93)^2 = 2\,005 \times 10^6 \text{ mm}^4$$

$$w_2 = 0.907 + (2.4 + 0.2 + 0.5)(10.25) = 32.68 \text{ N/mm}$$

$$f_2 = 156\sqrt{\frac{200\,000\,(2\,005 \times 10^6)}{32.68(9\,200)^4}} = 6.46 \text{ Hz}$$

Therefore, floor frequency can be computed as:

$$f = (f_1^{-2} + f_2^{-2})^{-0.5} \qquad \text{(Eq. 7.4)}$$

$$= (6.3^{-2} + 6.46^{-2})^{-0.5}$$

$$= 4.51 \text{ Hz}$$

Since f_1 (= 6.3) $\simeq$ f_2 (=6.46), two-way interaction exists.
B_1L_1 (of the beam system) = (40)(0.106)(9) = 38.2 m²
B_2L_2 (of the girder system) $\simeq$ (10.25)(6.1) = 62.5 m²

Hence, the area of equivalent vibrating floor is:

$$BL = \left(\frac{f}{f_1}\right)^2 B_1L_1 + \left(\frac{f}{f_2}\right)^2 B_2L_2 \qquad \text{(Eq. 7.5)}$$

$$= \left(\frac{4.51}{6.3}\right)^2(38.2) + \left(\frac{4.51}{6.46}\right)^2(62.5)$$

$$= 50 \text{ m}^2$$

Peak acceleration, a_o, in terms of percent of gravitational acceleration,

$$a_o = \frac{60f}{q\ BL}$$

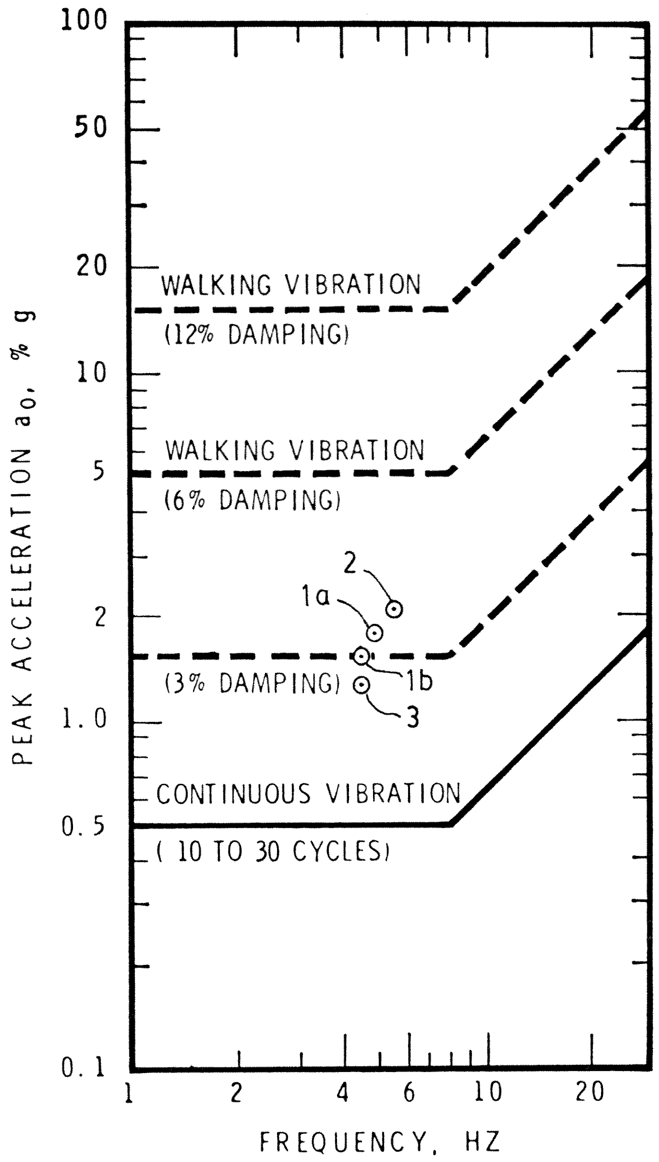


Figure 7.E2
Results of the Standard Heel-Drop Vibration Characteristic Assessments

$$= \frac{(60)(4.51)}{(3.29)(50)}$$

$$= 1.6\% \text{ g}$$

On Fig. 7.E2, a point is labelled as '1b' corresponding to a frequency of 4.51 Hz and a_o of 1.6 % g. Approximately 3% of critical damping is required, and hence bay B is considered to be satisfactory.

Example 2: Using the "standard heel-drop" simulation, assess the vibration characteristics of the typical floor bay 'A' as identified in Fig. 7.E1 using the HSS truss designed in Chapter 5 (see also Fig. 5.E3).

Find I_T $t_e = 106$ mm (see Example 1)

Element	Transformed Area (mm^2)	Distance from top of slab y (mm)	Ay 10^3 mm^3	Ay^2 10^6 mm^4	I_{local} 10^6 mm^4
Concrete	33 722	53.0	1 787	94.7	31.6
HSS127×76.2 ×4.78	1 790	807.5	1 445	1 167	3.8
Total	35 512		3 232	1 261.7	35.4

$$\bar{y} = \frac{3\,232 \times 10^3}{35\,512} = 91.0 \text{ mm}$$

$$I_{chords} = (1\,261.7 + 35.4) \times 10^6 - 35\,512\,(91)^2$$
$$= 1\,003 \times 10^6 \text{ mm}^4$$

$I_{wr} = 51 \times 10^6$ mm^4 see P. 206 (I-reduction due to open webs)

$$I_T = (\,1\,003 - 51) \times 10^6 = 952 \times 10^6 \text{ mm}^4$$

Compute frequency, $f = 156\sqrt{\dfrac{E\,I_T}{w\,L^4}}$ (Eq. 7.1)

$w = 37.1\,(9.81)/1\,000 + (2.4 + 0.2 + 0.5)(3)$ see P. 210
$= 9.66$ N/mm (or kN/m)

$$f = 156\sqrt{\frac{200\,000\,(952 \times 10^6)}{9.66\,(11\,300)^4}} = 5.42 \text{ Hz}$$

$$q = (9.66)/(3) = 3.22 \text{ kPa}$$

$$a_o = \frac{60\,f}{q\,BL}$$

$$= \frac{(60)(5.42)}{(3.22)(40)(0.106)(11.3)}$$

$$= 2.1\%\ g$$

A point labelled '2' is plotted in Figure 7.E2 using the computed values, $f = 5.42$ Hz and $a_o = 2.1\%$ g. The resulting plot shows that a critical damping ratio of about 4% is needed to satisfy the annoyance-threshold for floor vibration due to footsteps. Using Appendix G, and assuming that the finished composite truss floor is mostly open and without partitions, the available floor damping in percent of critical may be estimated at around 5 percent, which is greater than the required 4 percent. Therefore, the design is acceptable.

Example 3: Floor plan and member sizes for a stub-girder floor bay 'A' are shown in Fig. 7.E1. Using the "standard heel-drop" simulation, assess the vibration characteristics of the floor bay.

$$t_e = \frac{2.6 \times 10^6}{2\,300\,(9.81)} = 115 \text{ mm} \qquad n = 8.44$$

I_{T1}, (for floor beams B1) may be computed using procedure as shown in Example 1.

$$I_{T1} = 550 \times 10^6 \text{ mm}^4.$$

For stub-girder moment of inertia, I_{T2}, the following procedure may be followed.

From section 6.19, the elastic maximum deflection of stub-girder (with no consideration of concrete creep) is given as 0.1168P (mm), where P is given as a point load from member B1, in kN.

Assume girder span = 11 500 mm

Assume equivalent composite (prismatic) girder moment of inertia = I_t

Girder deflection at mid-span (3 equally spaced point loads),

$$\Delta = \frac{19}{384}\frac{P\,L^3}{E\,I_t}$$

Equating deflections,

$$0.1168\,P = \frac{19}{384}\frac{P\,L^3}{E\,I_t}$$

solving for I_t,

$$I_t = \frac{19}{384}\frac{(11\,500)^3}{(200)(0.1168)} = 3\,221 \times 10^6 \text{ mm}^4$$

From Table 4.6, a prismatic member of W610×155, with a deck-slab of 76 mm deck and 75 mm slab (of effective width = 2 556, as shown in Section 6.19), would provide a moment of inertia of $3\,146 \times 10^6$ mm^4 ($\simeq 3\,221 \times 10^6$ mm^4).

Using this equivalent section, and a slab width of 9 000 mm, and t_e of 115 mm, the value of I_{T2} may be obtained as $4\,126 \times 10^6$ mm^4.

$$w_1 = 0.384 + (2.6 + 0.2 + 0.5)(3) = 10.3 \text{ N/mm}$$

$$w_2 \simeq (0.847) + (9)(0.384/3) + (2.6 + 0.2 + 0.5)(9) = 31.7 \text{ N/mm}$$

$$q = w_2/(9) = 3.52 \text{ kPa}$$

$$f_1 = 156\sqrt{\frac{200\,000\,(550 \times 10^6)}{10.3\,(9\,000)^4}} = 6.3 \text{ Hz}$$

$$f_2 = 156\sqrt{\frac{200\,000\,(4\,126 \times 10^6)}{31.7\,(11\,300)^4}} = 6.2 \text{ Hz}$$

$$f = \left(f_1^{-2} + f_2^{-2}\right)^{-0.5} = 4.4 \text{ Hz}$$

$B_1L_1 = (40)(0.115)(9) = 41.4 \text{ m}^2$

$B_2L_2 = (9)(11.3)(3)/(4) = 76.3 \text{ m}^2$ (tributary floor area supported by the girder)

$$BL = \left(\frac{4.4}{6.3}\right)^2 (41.4) + \left(\frac{4.4}{6.2}\right)^2 (76.3)$$

$$= 58.6 \text{ m}^2$$

$$a_o = \frac{60 \text{ f}}{\text{q BL}}$$

$$= \frac{(60)(4.4)}{(3.52)(58.6)}$$

$$= 1.3\% \text{ g}$$

A critical damping ratio of between 2 to 3 percent is required (see point '3' in Figure 7.E2). This is less than the estimated available floor damping of about 5 percent of critical. The stub-girder floor design is acceptable.

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