UNIVERSITI PUTRA MALAYSIA

EVALUATION OF EFFECTIVE SECTION FOR STANDARD PRESTRESS CONCRETE SECTIONS UNDER FLEXURE

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EVALUATION OF EFFECTIVE SECTION FOR STANDARD PRESTRESS CONCRETE SECTIONS UNDER FLEXURE

by

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A project report submitted
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PROJECT APPROVAL SHEET

This project report attached hereto, entitled "**Evaluation of Effective Section for Standard Prestress Concrete Sections under Flexure**" and submitted by **Ahmad Rosli bin Abdul Rahman** in partial fulfilment of the requirement for the degree of Master of Science (Structural Engineering & Construction) is hereby accepted.

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ABSTRACT

A study on the analysis and design of prestressed concrete standard bridge beams sections and calculation done using Microsoft Excel 2000 is presented. Standard sections shapes and sectional properties are selected and determined from available standard bridge beams section series and are grouped into the I-, T-, inverted T, U-, box and Y-beams type. All types of the standard bridge beam shape were analyse to the smallest dimension or size that can sustained the standard loads (service and ultimate loads) and comply to the limiting criteria i.e. deflection, shear, compressive and tensile stress. This was applied in the spreadsheet programs to determine the limits of prestress force and eccentricity, prestress force losses, cable zone, moment ultimate and moment of resistance, shear and deflection.

A study and analysis were carried out on the smallest standard sectional dimension in the standard beam type series under various spans, its sectional properties, strength and physical, to determine the most efficient and economical section in term of the amount or cost of concrete and steel tendons.

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CHAPTER 1 : INTRODUCTION

1.1 The Need for Effective Sections

Modern structural engineering in the 21st centuary tends to progress towards more economic structures through gradually improved methods of design and the use of higher strength materials. This result in a reduction of cross-sectional dimensions of the members and consequently weight saving of the structures. Such developments are particularly important in the field of reinforced concrete, where the dead loads represents a substantial part of the total design load. Similarly in multistory buildings, any saving in depth of members, multiplied by the number of stories, can represent a substantial saving in total height, loads on foundations, length of heating and electrical ducts, plumbing risers, and wall and partition surface.

Significant saving can be achieved by the use of high-strength concrete and steel in conjunction with present day design methods, which permits an accurate appraisal of member strength. However, there are limitations to this development, due mainly to the interelated problems of cracking and deflection at service loads. The efficient use of high strength steel is limited by the fact that the amount of cracking (width and number of cracks) is proportional to the strain and therefore the stress, in the steel. Although moderate amount of cracking is normally not objectionable in structural concrete, excessive cracking is undesirable in that it expose the steel to corrosion.

The use of high strength materials is further limited by deflection considerations, particularly when refined analysis is used. The slender member that result may permit deflections that are functionally or visually unacceptable. This is further aggravated by cracking, which reduces the flexural stiffness of members.

Prestressed concrete design the cross-section proportion and dimensions are selected to suit the job at hand requirements. To produce an ideal proportions beam for a given case the designer change the member depth, modifying the web thickness, and varying the flanges widths and thickness independently to satisfy the requirements.

1.2 Shapes of Standard Prestressed Concrete Sections

In bridge deck slab, to illustrate the basic design principles, the simplest shape of cross-section, namely rectangular was chosen. Where there is freedom to choose a more economical section, the designer must decide which shape of section to use for a particular situation.

Flexural stresses as the result of external or imposed bending moments were in most cases controlling the selection of the geometrical dimensions of the prestressed concrete section.

The design process starts with the choice of a preliminary geometry, and by trial and adjustment it converges to a final section with geometrical details of the concrete cross section and the sizes and alignment of the prestressing strands. The section check to satisfy the flexural (bending) requirements of concrete and steel stress limitations

Once assumes the geometrical properties of the section to be prestressed and then proceed to determine whether the section can safely carry the prestressing forces and the required external or applied loads

The selection of the best shapes for prestressed concrete sections under flexure rely on many factors. The simplest shapes is the rectangular shape possessed by all solid slabs and used for some short span beams. As far as formwork is concerned, the rectangular section is the most economical, but the kern distance are small, and the available lever arm for the steel or tendons is limited. Concrete near the centroidal axis and on the tension side is not efective in resisting moment, especially at the ultimate stage. As observed from a few calculation of working examples, the rectangular section is not as efficient in the use of the concrete section as is the I-shaped section.

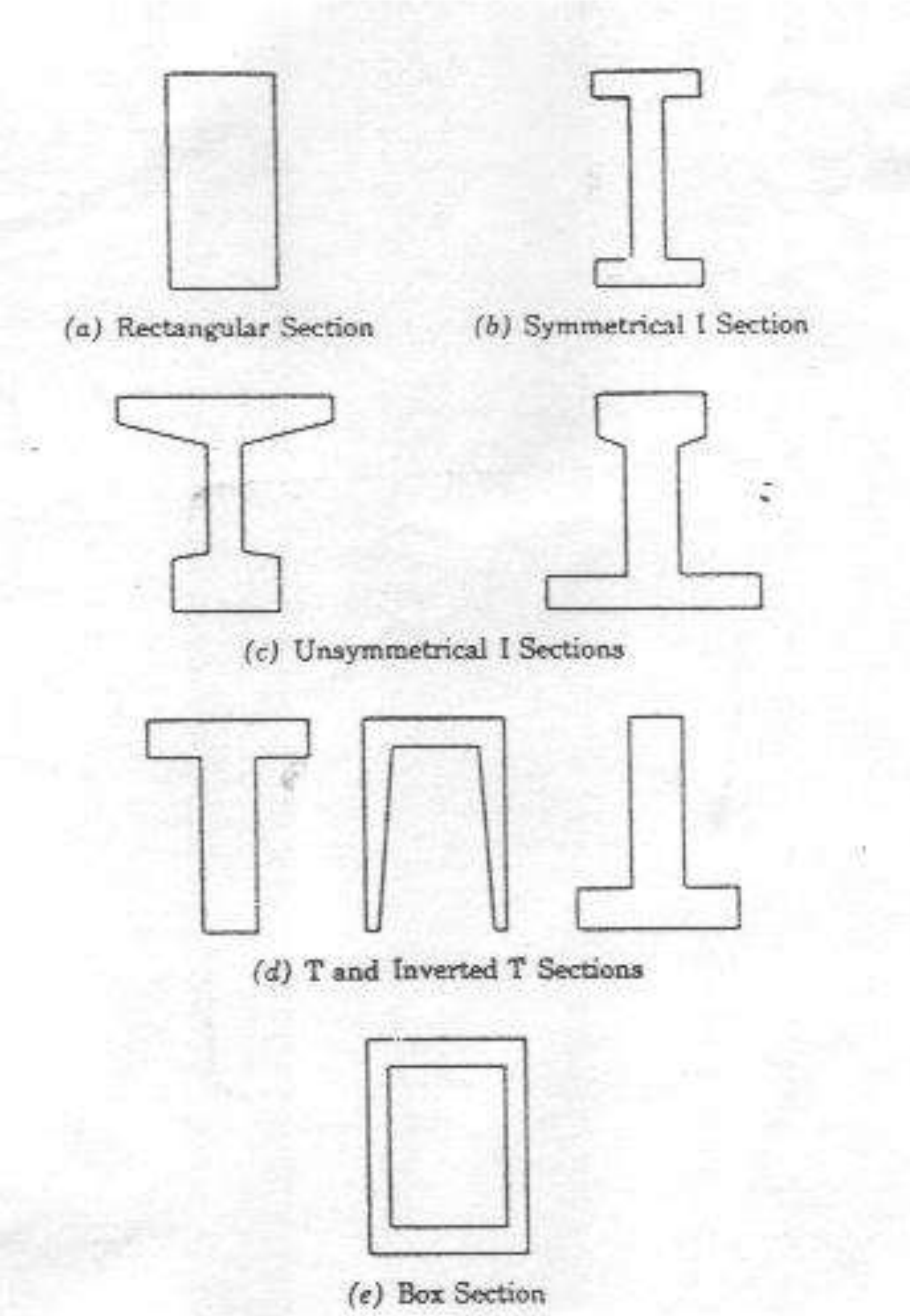

Fig. 1.1 Examples of the standard bridge beam sections

Hence other shapes shown in Figure 1.1 are frequently used for prestressed concrete.

1. The symmetrical and the unsymmetrical I-section
2. The T-section
3. The inverted T-section
4. The box section

The suitability of these shapes will depend on the particular requiremets. The I-section has its concrete concentrated near the extreme fibres where it can most effectively furnish the compressive force, both at transfer of prestress force and under working and ultimate loads. The more the concrete is concentrated near the extreme fibres, the greater will be the kern distances, and the greater will be the lever arm furnished for the internal resisting couple. However this principle of concentrating the concrete in the extreme fibres cannot be carried too far, because the width and thickness of the flanges are governed by practical considerations, and the web must have a minimum thickness to carry the shear, to avoid buckling, and to permit proper placement of concrete.

If the M_i/M_T ratio (M_T is the total moment which controls the stresses under the action of the working or serviceability loads and M_i is the girder load moment which determines the location of the centre of gravity of steel (c.g.s.) and the stresses at transfer) is sufficiently large, there is little danger of overstressing the flanges at transfer, and concrete in the bottom flange can be accordingly diminished. This will result in an unsymmetrical I-section which when carried to the fullest extent becomes a T-section. A T-section similar to that for reinforced beams, is often most economical, since the concrete is concentrated at the top flange where it is most effective in supplying the compressive force. The internal arm of the resisting couple at maximum design load is greater than for rectangular sections. It may not be economically used, however where the M_i/M_T ratio is small, because the centre of pressure at transfer may lie below the bottom kern point. Then tensile stresses may result in the top flange and high compressive stressess in the bottom flange.

The unsymmetrical I-section with a bigger bottom flange, like a rail section, is not economical one in carrying ultimate moment, since there is relatively little concrete on the compression flange. However there is a great deal of materials to resist the initial prestress. It can be economically used for certain composite sections, where the tension flange is precast and the compression flange is poured in place. This section requires very little girder moment to bring the centre of pressure within the kern and hence is suitable when the M_i/M_T ratio is small. When carried to the extreme, this section becomes an inverted T-section. Unsymmetrical section is good choice if:

i) available stress range at top and bottom are not the same;
ii) the beam must provide flat useful surface as well as offering load-carrying capacity;
iii) the beam become part of composite construction; and
iv) the beam must provide supporting surface.

The box section has the same properties as the I-section in resisting moment. In fact, their section properties are identical. The adoption of one or the other will depend on the practical requirements of each structure.

Generally I, T and box section with relatively thin webs and flanges are more efficient than other sectional members with thicker parts.

Summarizing the above discussion, for economy in steel and concrete it is best to put the concrete most near the extreme fibers of the compression. When the M_i/M_T ratio is small, more concrete near the tension flange may be necessary. When the M_i/M_T ratio is large, there is little danger of overstressing at transfer, and concrete in tension flange is required only to house the tendons properly.

In choosing the shapes, prime importance must be given to the simplicity of formwork. When the formwork is to be used once, it may constitute the major cost of the beam, so that any irregular shapes for the purpose of saving concrete or steel may not be in the interest of overall economy. On the other hand, when the forms can be reused repeatedly, more complicated shapes may be justified.

For plants producing precast elements, it is often economical to construct forms that can be easily modified to suit different span and depths. For example, by filling up the stems/ribs for the section, several depth can be obtained. Or by ommitting the center portions of a tapered beam or decreasing the distance between the side forms, one set of forms can be made to fit many shorter span.

Sections must be further designed to enable proper placement of concrete around the tendons and the corners. This is especially true when proper vibration cannot be ensured. The use of fillets at corners is often desirable. It is also common practice to taper the sides of the flanges. Such tapering will permit easier stripping of the formwork an easier placement of concrete.

The usefulness of a particular section depends on the simplicity and reusability of the formwork, the appearance of the sections, the degree of difficulty of placing the concrete and the theoretical properties of the cross sections.

1.3 Types and Advantages of Composite Construction

For composite construction in prestressed concrete usually consists of precast, prestressed members acting in combination with a cast in-situ concrete component. The composite member is formed in at least two separate stages with some or all of the prestressing normally applied before the completion of the final stages. The precast and the cast insitu elements are mechanically bonded to each other to ensure that the separate components act together as a single composite member.

Composite prestressed concrete beams are widely used in the construction of highway bridges. For short- and medium-span bridges, standarddized I-shaped or trough-shaped girders (which may be either pretensioned or post-tensioned) are erected between the piers and a reinforced concrete slab is cast onto the top flange of the girders. The precast girders and the in situ slab are bonded together to form a stiff and strong composite bridge deck.

The two concrete elements, which together form the composite structure, have different concrete strengths, different elastic moduli, and different creep and shrinkage characteristics. The precast element is generally of better quality concrete than the concrete in the cast in situ element bacause usually it has a higher specified target strength and is subjected to better quality control and better curing conditions. With the concrete in the precast element being older and of better quality than the in situ concrete, restraining actions will develop in the composite structure with time owing to differential creep and shrinkage movements. These effects should be carefully considered in the prestressed concrete design.

The advantages of the prestressed concrete composite constructions over the non-composite constructions are:

1. Significant reduction in construction costs can be achieved with use of cheaper standardised and factory produced precast elements and speed up or faster construction time.
2. Better quality and high mechanical properties for precast concrete elements where it is being manufactured in a controlled prestressing plant or factory.
3. Reducing falsework and shoring costs as the precast elements can support the forms for the cast in-situ concrete. The elemination of scaffolding and falsework is often a major advantage over other forms or method of

construction and permits the construction to proceed without or with minor interuption to the work or traffic beneath.

4. The in situ concrete can provide significant increases to both the strength and stiffness of the precast girders and also provides lateral stability.

The cross-sections of some typical examples of composite prestressed concrete members commonly used in buildings and bridges construction are as shown in Figure 1.2.

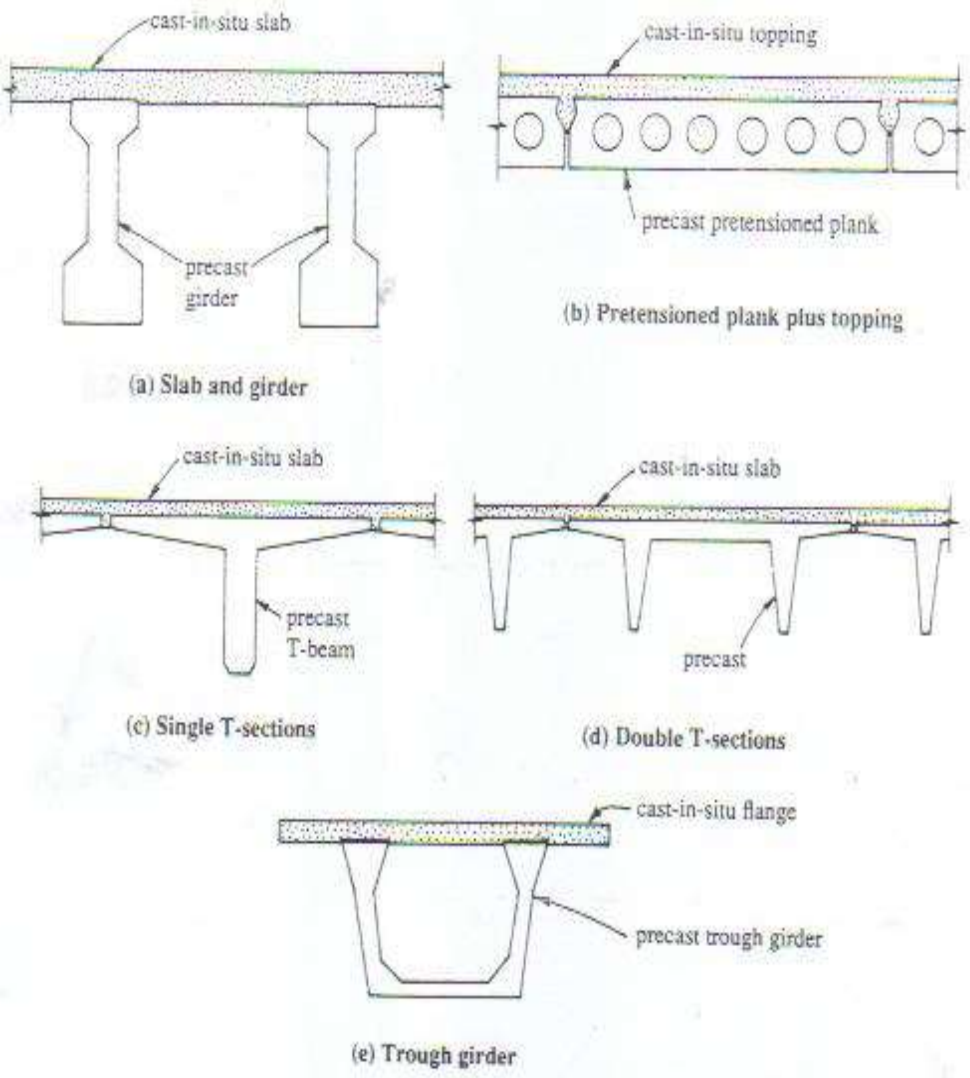

Figure 1.2 Typical examples of composite cross-sections

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