1 Introduction

1.1 General

Segments are slices of a structural element between joints which are perpendicular to the longitudinal axis of the structure stressed together by means of prestressing tendons. The first segmental bridge was built by Eugene Freyssinet in the late 1940s. He used precast E-beam segments for construction of well-known six bridges over the Marne River in France [1]. The longitudinal structures were assembled from precast elements that were prestressed vertically and connected by dry joints and longitudinal post-tensioned tendons. Precast segments were also used by Jean Muller to build a girder bridge in upstate New York, where longitudinal girders were precast in three segments each, which were assembled by dry joints and longitudinal post-tensioning tendons [1a]. The above mentioned type of constructions refers to E-beam segmental bridges. Nowadays, mainly hollow box girder segmental bridges are built (Fig. 1.1, 1.2). The first one was the bridge over the Seine at Choisy-le-Roi in France, which was built in 1962 and has length l = 37+55+37 = 129 m [1b]. The various hollow box sections are shown in figure 1.1.

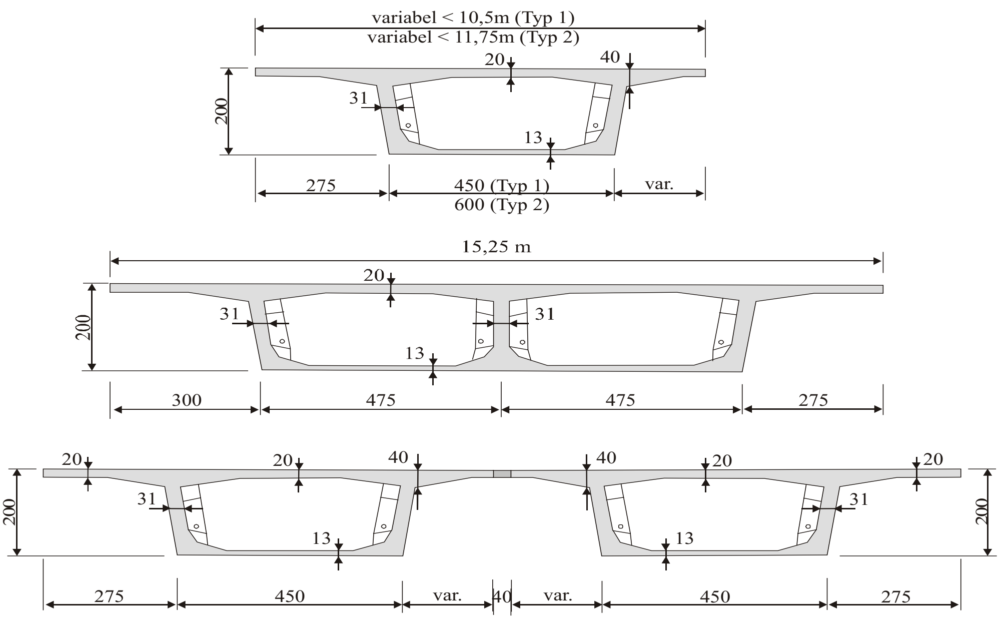

Figure 1.1 Cross-sections of the Seine bridge at Choisy-le-Roi in France

Segmental hollow box girder bridges have gained great acceptance throughout the world and the instance of use of this type of construction have increased rapidly in the recent years [100]. In Germany the first segmental bridge over the River Lech was built in 1968. In 1999 the 'Deutscher Beton-Verein' published the first recommendations for the design of hollow box girder segmental bridges [13].
In this thesis the term segmental bridge refers to a structure, which consists of prefabricated segments with hollow box girder cross-section that are stressed together by tendons.

Figure 1.2 Segmental hollow box girder bridge (SES Bangkok)

The main advantages of this type of construction are as follows:

- due to mass production in a precast yard it has the potential for achieving high quality and high strength concrete
- appearance: arbitrary shape of segment, coloured concrete surface
- short construction time because segments are prefabricated while the substructure is being built – no need of in-situ concrete
- no need of falsework (but erection truss required)
- the possibility of change of curvature in horizontal and vertical directions of the structure and also for roadway super elevation
- the effect of creep and shrinkage will be less since the precast segments will have appropriate age before erection and stressing longitudinally

- the construction is not affected by weather conditions (dry joints)
- the traffic is not disturbed by the construction
- the dead load of the structure is reduced due to hollow box section and external prestressing
- it is economical as it requires less mild reinforcement
- full prestressed structure – no tensile stresses under serviceability loads; higher fatigue strength
- easy transportation of prefabricated elements - small segments in relation to long I-beams

The disadvantages for this type of construction are:

- careful geometry control is required during production of segments
- development of new design method
- extra cost for prestressing and erection truss
- careful alignment control during erection
- safety (e.g. in case of fire)
- joints between segments

1.1.1 Prestressing

Segmental bridges can be prestressed internally, externally or a combination of the two. Cracks that have reached the internal tendons in the joint have caused serious serviceability problems in the past. These cracks cannot be limited since there is no mild reinforcement that crosses the joint. For this reason, nowadays mainly external prestressing, where the tendons are located inside the hollow box but outside the concrete, is used in segmental construction (Fig. 1.3). Therefore in this thesis only this type of tendon layout will be treated.

Figure 1.3 Externally prestressed segmental bridge (SES Bangkok)–pier segment

The advantages of external prestressing are as follows:

- inspection and replacement of tendons is possible
- easier installation of longitudinal tendons
- good corrosion protection of post-tension cables
- less dead load since no tendons are located in the webs (thinner webs)
- grouting is easier due to the straight alignment
- less friction (no wobble losses)
- prestressing force can be modified after construction due to extra ducts

The disadvantages of external prestressing are as follows:

- additional mild reinforcement required as the increase of tendon stress $\div\omega_p$ is small under ultimate loads
- additional cost for duct, anchorage, deviators
- polygonal tendon layout
- deviators and eccentric anchorage for post-tensioning forces required

1.1.2 Construction – Assembling of segments

From the beginning, post-tensioned segmental box girder bridges have been refined and modified in many different ways. Segments can be precast or cast-in-place; precasting can be done with short line or long line casting beds. Erection can be done by balanced cantilever construction method, progressive placement method or span-by-span construction method (Fig. 1.4).

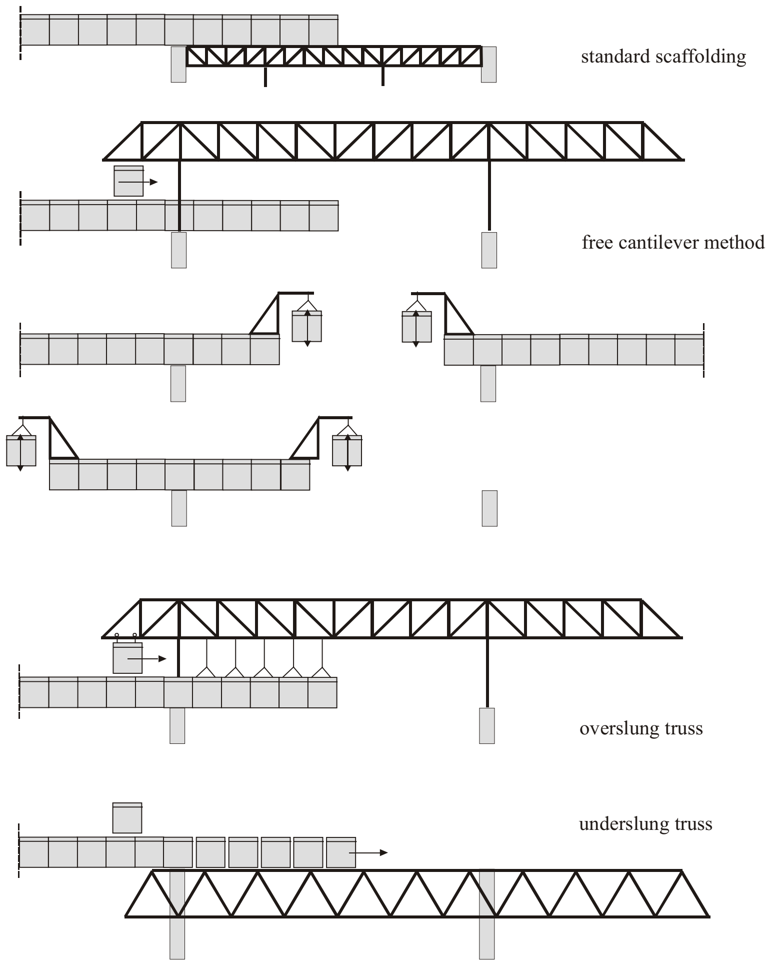

Figure 1.4 Construction methods

The term "balanced cantilever construction" describes phase construction of bridge superstructure. The construction starts from the piers cantilevering out to both sides in such a way that each phase is tied to the previous one by post tensioning tendons, incorporated to permanent structure, so that each base serves as a construction base for the following one [1a].

The progressive method, "the step-by-step erection" process is derived from cantilever construction, where segments are placed in a successive cantilever fashion. The construction starts at one end and proceeds continuously to the other end. The method is valid for both precast and cast-in-place segments. This construction method has been used for the “Ile de Ré Bridge” [8, 9] in France. Due to excessive high cantilever bending moments the section has to be fixed over the permanent pier during construction. To reduce this load either a temporary bent or a temporary movable tower-stay assembly can be used. The cantilever method is mostly used for very long spans.

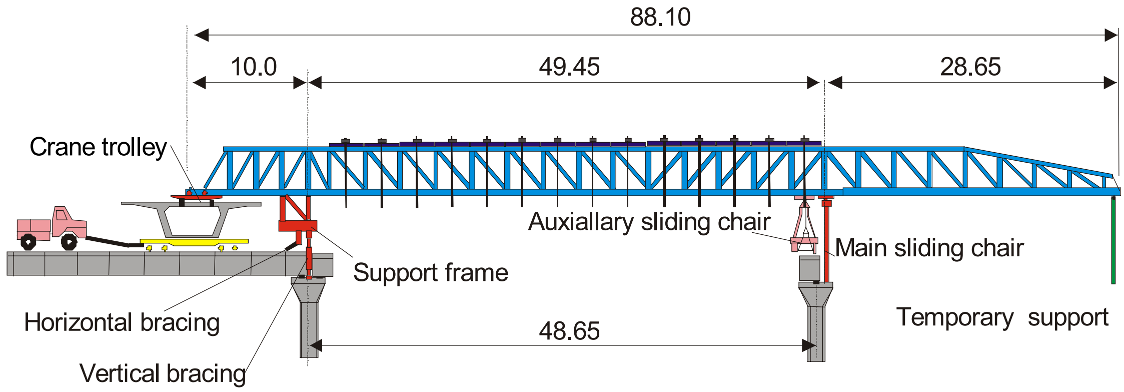

Figure 1.5 Span by span method of construction (overslung truss)