CASE STUDY TO DETERMINE THE CAMBER OF POST-TENSIONED ‘ I ’ BEAM

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CASE STUDY TO DETERMINE THE CAMBER OF POST- TENSIONED ‘I’ BEAM

LEE POH HUAT

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil-Structure)

Faculty of Civil Engineering
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MARCH 2005

I declare that this thesis entitled "Case Study To Determine The Camber Of Post-Tensioned 'I' Beam" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To Elissa and Bryan

for your companionship, understanding and

continuous encouragement over the years.

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ABSTRACT

A common problem that most contractors faced in beam bridge construction was to predict the actual camber of pre-tensioned or post-tensioned beams due to prestressing in order to achieve bridge design finished levels without any unforeseen additional construction cost. Four numbers of full scale 36m long post-tensioned "I" beam with overall height of 1.98m was used to measure the actual beam camber on site by means of checking the differences of beam's top levels while design estimation carried out is based on design code of practice for structural use of concrete BS 8110 by taken into consideration initial prestress losses due to friction and anchorage draw-in of tendons. Comparison between these two methods of evaluation reveals a significant difference. The results shows actual beam cambers measured on site are much larger compare to design prediction. The immediate camber occurred after prestressing is greater by 10.8% and continue to increase to 54.5% over 15 days with a sharp increase focused on the first 3 days after prestressing. From the findings, it's therefore concluded that deflection of post-tensioned beam cannot be predicted accurately due to many field factors which may possibly influence loss of prestress force in post-tensioned cables and behaviour of beam cambering process. However, design calculation can be used as an approximate estimation or as a guide for construction purposes

ABSTRAK

Suatu masalah umum yang sering dihadapi oleh kontraktor dalam kerja-kerja pembinaan jambatan jenis rasuk pra-tegang atau pasca-tegang ialah usaha untuk membuat anggaran nilai *camber* rasuk akibat daya mampatan dari tendon supaya aras rekabentuk jambatan dapat dicapai tanpa perbelanjaan lebihan yang tidak dijangka. Empat batang rasuk 'I' dengan panjang 36m serta tinggi 1.98m telah digunakan dalam kajian ini bagi menentukan nilai *camber* sebenar di tapak secara mengukur perbezaan aras atas rasuk. Pengiraan *camber* rasuk dibuat dengan merujuk kepada BS 8110 dan mengambil kira nilai kehilangan daya tegangan akibat geseran dan gelinciran tambat yang berlaku pada tendon. Perbandingan yang dijalankan ke atas kedua-dua jenis cara penilaian ini menunjukkan suatu perbezaan yang ketara dimana nilai *camber* sebenar yang diperolehi dari tapak mempunyai nilai yang lebih besar berbanding dengan hasil dari pengiraan. *Camber* awal yang diperolehi dari tapak mempunyai nilai lebihan sebanyak 10.8% pada permulaan dan meningkat kepada 54.5% dalam masa 15 hari selepas rasuk ditegang. Peningkatan nilai *camber* ini tertumpu kepada 3 hari yang pertama dengan nilai penambahan yang besar. Dari keputusan kajian ini, dapat disimpulkan bahawa nilai *camber* tidak dapat dianggarkan dengan mudah dan tepat disebabkan oleh beberapa faktor yang wujud di tapak yang berkemungkinan dapat mempengaruhi hilangan daya tegangan pada tendon serta proses pembentukan *camber* rasuk. Walau bagaimanapun, pengiraan *camber* rasuk masih boleh digunakan sebagai anggaran kasar serta panduan bagi tujuan pembinaan.

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σ_{co}	-	stress in concrete at the level of tendon
σ_{pi}	-	initial stress in tendon
A_c	-	the cross sectional area of concrete
A_{ps}	-	cross sectional area of tendon
m	-	modular ratio for steel and concrete
r	-	radius of gyration
$\frac{M_i e}{I_c}$	-	additional tensile stress at the level of tendon
e	-	eccentricity of tendon
$e_{(x)}$	-	eccentricity at section **x**
P_x	-	prestress force at distance **x** from jack
P_o	-	jacking force
P_i	-	prestress force at distance **i** from jack
ΔP_d	-	prestress loss due to anchorage draw-in
ΔP_{sh}	-	prestress loss due to shrinkage
ΔP_{cr}	-	prestress loss due to creep
ΔP_r	-	prestress loss due to relaxation of steel
L	-	length of tendon
L_d	-	extend of draw-in losses
L_i	-	distance from jack to section **i**
E_c	-	modulus elasticity of concrete
E_s	-	Young's modulus of strand
$E_{c.eff}$	-	effective modulus of elasticity
E_{ct}	-	instantaneous modulus of elasticity

ε_{sh}	-	shrinkage strain
ε_{cr}	-	creep strain
μ	-	coefficient of friction
Θ	-	angle deviation of tendon
K	-	wobble factor
s	-	anchorage draw-in length
φ	-	creep coefficient
α	-	initial prestress losses
β	-	total prestress losses
y_{max}	-	maximum deflection at mid span
K	-	bending moment diagram's shape constant
$1/ r_b$	-	curvature at mid span or support for a cantilever
δ	-	deflection of beam
I_c	-	moment of inertia of section
γ_c	-	density of concrete

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CHAPTER 1

INTRODUCTION

1.1 General

A bridge is a structure that spans a divide such as stream, river, ravine, valley, railway track, roadway and waterway. The traffic that uses a bridge may include pedestrian or cycle traffic, vehicular or rail traffic, water or gas pipes or a combination of all the above. Bridges can generally be classified according to their function, materials of construction, form of superstructure, span and type of service. A bridge should be designed such that it is safe, aesthetically pleasing, and economical.

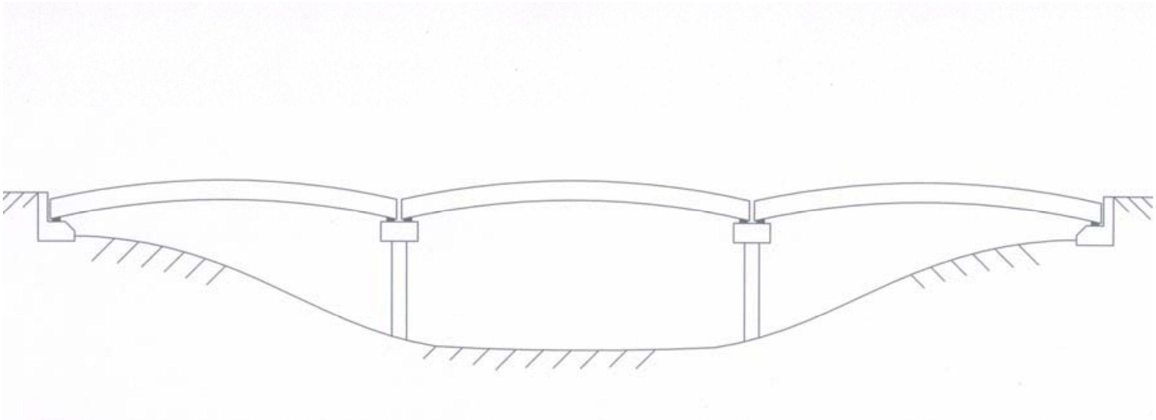
In the construction of pre-tensioned or post-tensioned beam bridges, a very common problem that most contractors faced was to determine and estimate the actual upward deflection or ***camber*** of pre-tensioned or post-tensioned beams due to prestressing. In order to achieve the design bridge finished levels without any unforeseen additional construction cost, camber of beams shall be accurately estimated. If it's under estimated, then the finished design levels will not be able to achieve without reducing the thickness of deck slab or bituminous wearing course.

While in the case of over estimated, the finished design levels can only be attained by increasing the deck slab or wearing course thickness and this is certainly will incurred additional construction cost.

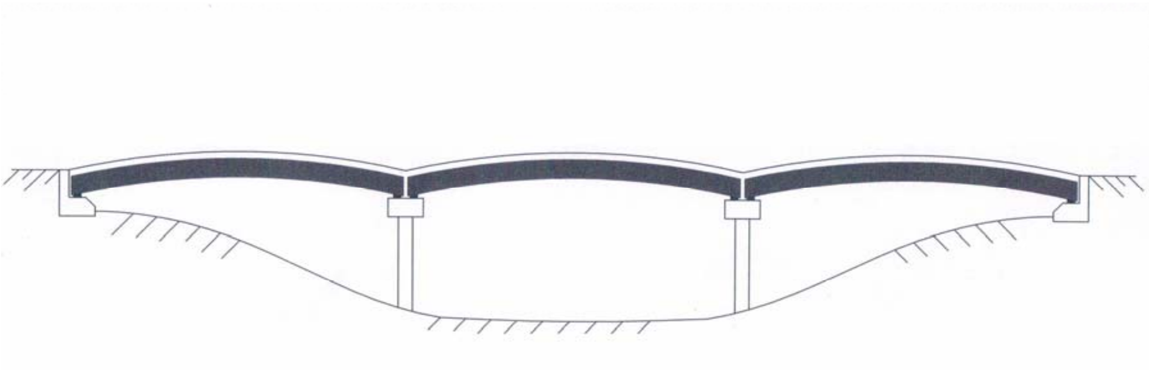
1.2 Problem Statement

One of the important criteria in bridge design and construction is to produce a smooth driving surface for a comfortable driving experience by the road user. In order to achieve the design bridge surface finished levels without compromising on the deck slab or bituminous wearing course thickness, camber on bridge surface needs to be estimated and accounted for when the riding surface is established. If camber of beam is not accounted for by designer and ignored by the contractor in a multi span bridge construction, it may leads to an undulating or “roller coaster” riding surface and potential hazard to travelling public especially on a superelevated bridge deck.

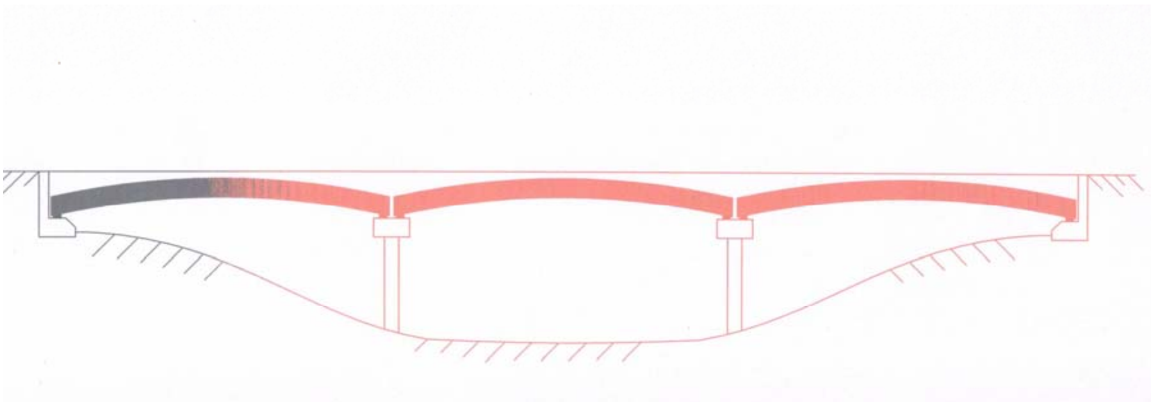
To overcome this problem, camber of pre-tensioned or post-tensioned beams shall be identified, and adjustment has to be made on the finished levels of beam seats, abutment walls and piers based on the estimated beam cambers accordingly and subsequently increase the thickness of deck slab at both ends of each span of bridge to compensate the adjusted levels in order to produce a smooth bridge deck surface. (Figure 1.1)



Beam camber for a 3 spans bridge



An undulating bridge surface due to fixed deck thickness



Thickening deck slab to overcome beam camber's problem

Figure 1.1 : Schematic illustration of beam camber for a 3 spans bridge

1.3 Objective of Study

The purpose of this study is to determine the actual camber of post-tensioned "I" beam. Among the objectives are :-

- To determine the actual beam camber on site for post-tensioned " I " beam.
- Compare beam camber between design estimation based on BS 8110 and actual site data.
- And, to identify various factors that can possibly influence the deflection of post-tensioned beam.

1.4 Scope of Study

The scope of this study will be focused on full scale 36m long post-tensioned "I" beam with overall height of 1.98m.(Figure 1.2) Field data for actual beam camber will be measured base on differences of survey levels before and after prestressing of post-tensioned cables, while design estimation is based on BS 8110.

The possible criteria that may affect deflection of post-tensioned beam such as strength of concrete, modulus of elasticity, creep and shrinkage of concrete will be monitored. Insitu concrete specimens such as concrete cubes and concrete cylinders will be collected and laboratory testing will also be carried out.

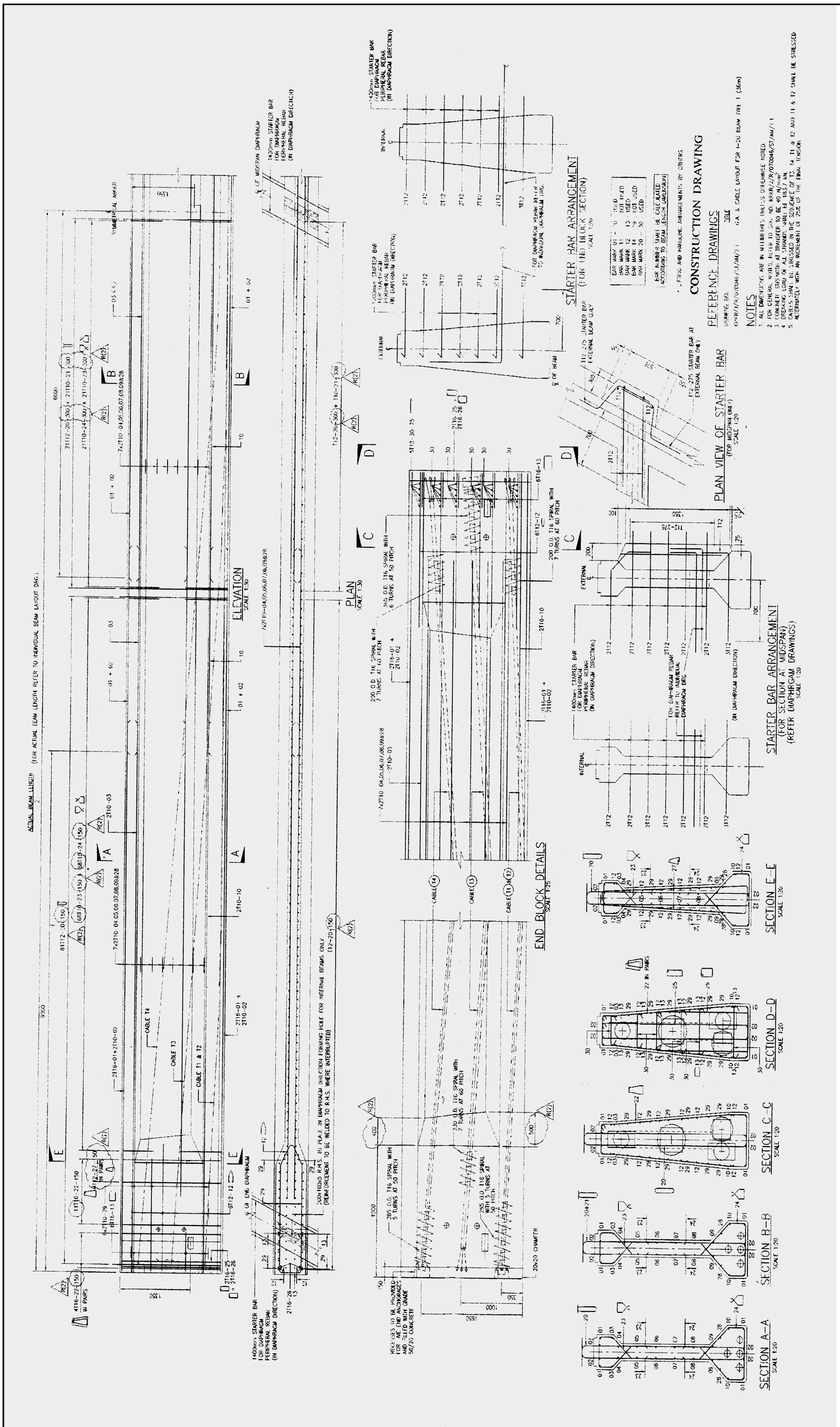


Figure 1.2 : Typical detail for 36m post-tensioned beam

CHAPTER II

Literature Review

2.1 Introduction

The precasting industry for prestressed concrete has in recent years become a well-established entity. Efficient management and outstanding quality control procedures have awarded the industry a highly competitive position in the construction market. Prestressed concrete superstructures generally eliminate the need for construction falsework which has always been economically advantageous.

Like ordinary reinforced concrete, prestressed concrete consists of concrete resisting compression and reinforcement resisting tension. Based on the concept that reinforced concrete’s tensile strength is limited while its compressive strength is extensive, consequently, prestressing become essential in many applications in order to fully utilise the compressive strength of reinforced concrete and through proper design, elimination or control of cracking and deflection can be achieved.

2.2 Materials for Prestressed Concrete

2.21 Concrete

Concrete, particularly high-strength concrete, is a major constituent of all prestressed concrete elements. Strength and endurance are two major qualities that are particularly important in prestressed concrete structures. Long-term detrimental effects can rapidly reduce the prestressing forces and could result in unexpected failure. Hence, measures have to be taken to ensure strict quality control and quality assurance at the various stages of production.

The mechanical properties of hardened concrete can be classified into two categories: short-term or instantaneous properties and long-term properties. The short-term properties are strength in compression, tension, and shear; and stiffness, as measured by the modulus of elasticity. The long-term properties can be classified in terms of creep and shrinkage. The range of concrete strength normally used for prestressed concrete is shown in Table 2.1

Table 2.1 : Comprehensive strength for prestressed concrete

	Compressive strength at initial prestress (N/mm^2)	**Specified standard strength** (N/mm^2)
Post-tensioning system	More than 20	More than 24
Pre-tensioning system	More than 30	More than 35

In the pre-tensioning system, the anchorage of the prestressed concrete steel is required to have enough bond strength as in the bond between steel and concrete. So, higher values of specified standard strength are adopted compared to those of the post-tensioning system where a lower value in strength is used as there is no necessity for high bond strength due to the anchorage method.

2.22 Prestressing Reinforcement

Due to the high creep and shrinkage losses in concrete, effective prestressing can be achieved by using very high-strength steel in prestressed concrete. Such high-stressed steels are able to counterbalance these losses in the surrounding concrete and have adequate leftover stress levels to sustain the required prestressing force. Prestressing reinforcement used in prestressed concrete can be in the form of single wire, strand or high strength bars covered by respective British Standards as follows:

i) wire, (BS5896 : 1980)
ii) strand, (BS5896: 1980)
iii) bars, (BS4486: 1980)

High strength steel wire came in a range of diameter from 3 to 7mm with carbon content of 0.7-0.85%. For pre-tensioned concrete members, the prestress force is transferred to the concrete by bond between the steel and concrete. This bond is substantially increased if indentations are made on the wire surface such as crimped and undulating instead of a straight.

Strand is produced by spinning several individual wires around a central core wire for most prestressing application since single wire generally does not have sufficient strength. Modern strands comprise of seven wires with overall diameters ranging from 8 to 18mm are widely used in prestressing industry. Hot-rolled alloy-steel bars are varying in diameter from 20 to 40mm, and are stretched once they have cooled in order to improve their mechanical properties. They may be ribbed, to provide a continuous thread, or smooth with threads at the ends of the bars. In both cases the threads are used to anchor the bars or to provide a coupling between adjacent bars.

The use of solid high-yield bars is generally limited as they do not have the flexibility to be profiled along the length of the member. High tensile steel wire is by far the more widely used material for both pre-tensioning and post-tensioning. In post-tensioned concrete, it is common to group many strands together to form a cable or tendon. A complete prestressing tendon can be made up of as many strands as are needed to carry the required tension, will all the strands enclosed in a single duct. In addition, large structures may have many individual tendons running parallel to each other along the length of the member.

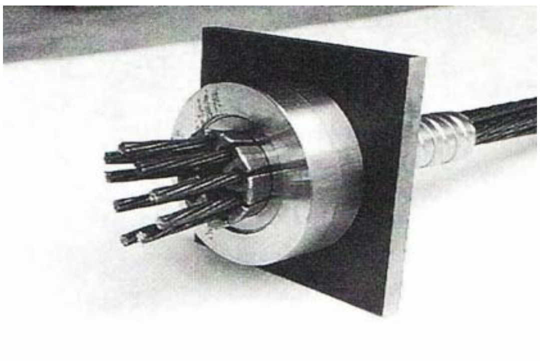
An important point to consider with all the types of steel described above is that their high strength is produce by essentially a cold-working process. Thus, during storage and construction care must be taken not to expose the steel to heat from causes such as welding.

2.23 Anchorage System and Equipment

For both pre-tensioning and post-tensioning of concrete members, specialist equipment is required for stressing the steel and anchoring the stressed steel to the concrete. A wide variety of systems has been developed for these purposes, many of which are patented by their manufacturers. The tensioning of the steel is usually achieved by mechanical jacking using hydraulic jacks. In pre-tensioning, the jacks pull the steel against the supports of the casting beds. The strands in pre-tensioned members are often stressed individually using small jacks. In post-tensioning, the jacks pull the steel against the hardening concrete member itself. As the strands are usually grouped in tendons, large multi-strand jacks are often used to tension all the strands in the tendon simultaneously.

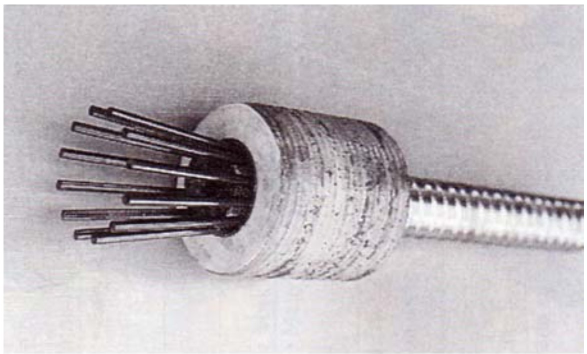
In pre-tensioning, before the prestress is transferred to the concrete a temporary anchor are required to hold the ends of the strands while they are being tensioned. One of the most popular methods of anchoring the ends of the strands in the casting bed is the wedge grip of a tendon and to hold the strands permanently in the tendon anchor. The bearing plate on the anchor transmits the force in the strands to the main body of the assembly which in turn transmits the force to the surrounding concrete. Some anchorage system and their devices are shown in Figure 2.1

a) BBRV stressing anchors

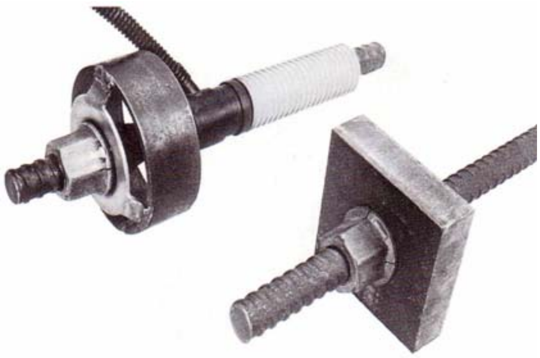


b) OBC stressing anchor

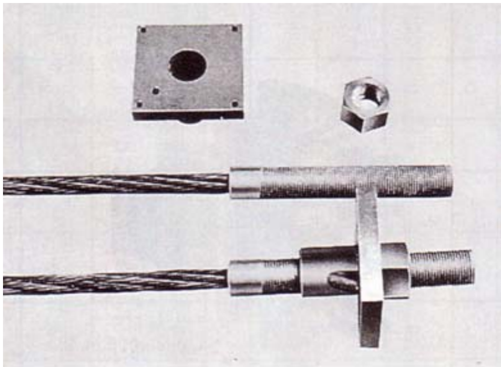
c) CCL strand force anchorage



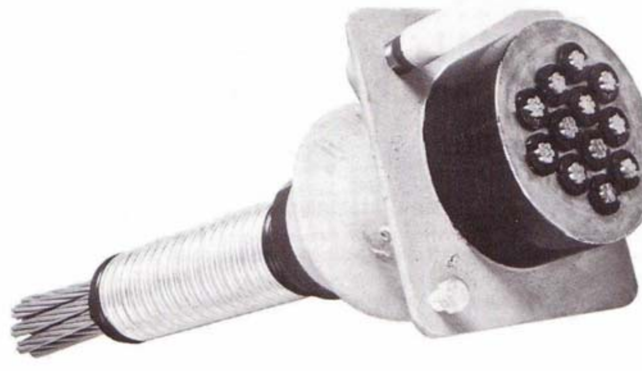
d) Fireyssinet anchorage



e) Dividag anchorage



f) SEEE anchorage



g) VSL stressing anchorage

Figure 2.1 : Types of anchorage system