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

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To Elissa and Bryan
for your companionship, understanding and
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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.

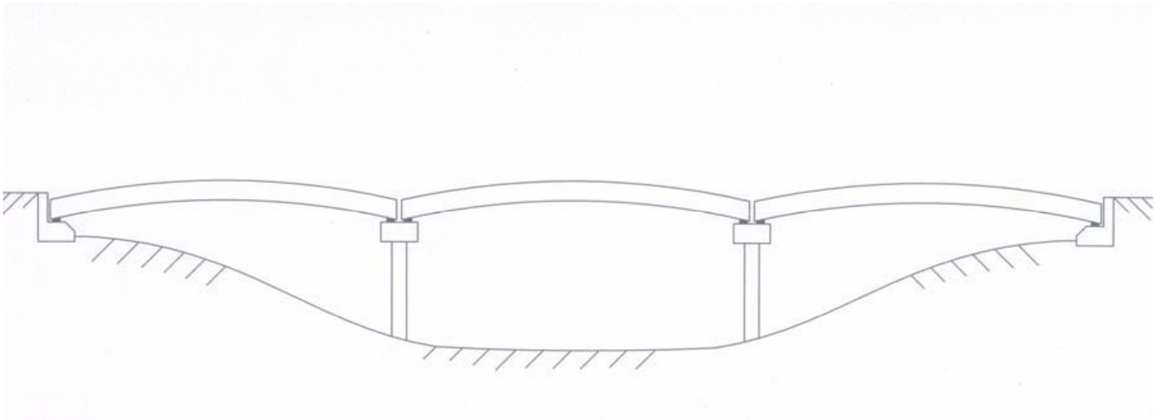
In the construction of pre-tensioned or post-tensioned beam bridges, a very common problem that most contractors faced was to determine and estimate the actual upward deflection or ***camber*** of pre-tensioned or post-tensioned beams due to prestressing. In order to achieve the design bridge finished 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.

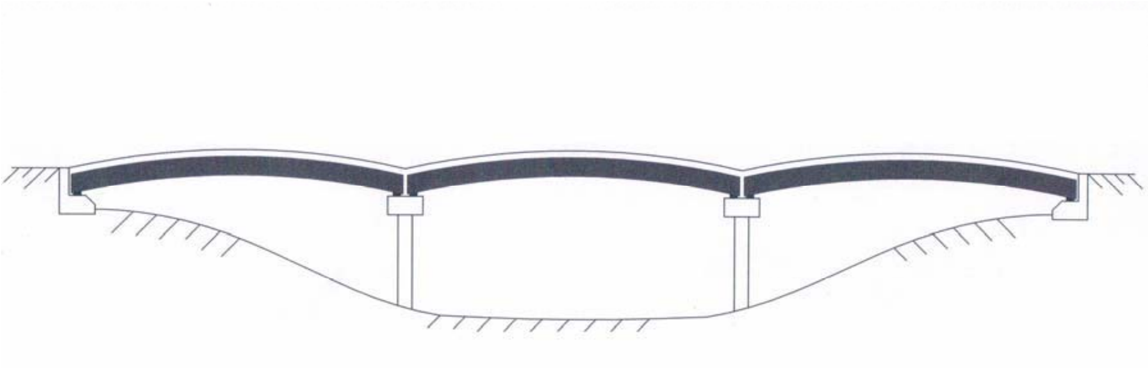
1.2 Problem Statement

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.

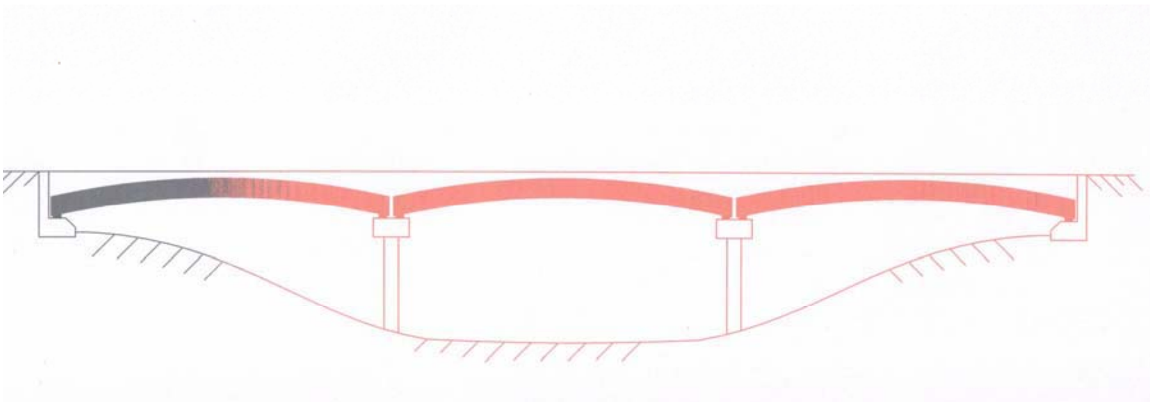
To overcome this problem, camber of pre-tensioned or post-tensioned beams shall be identified, and adjustment has to be made on the finished levels of beam seats, abutment walls and piers based on the estimated beam cambers accordingly and subsequently increase the thickness of deck slab at both ends 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.

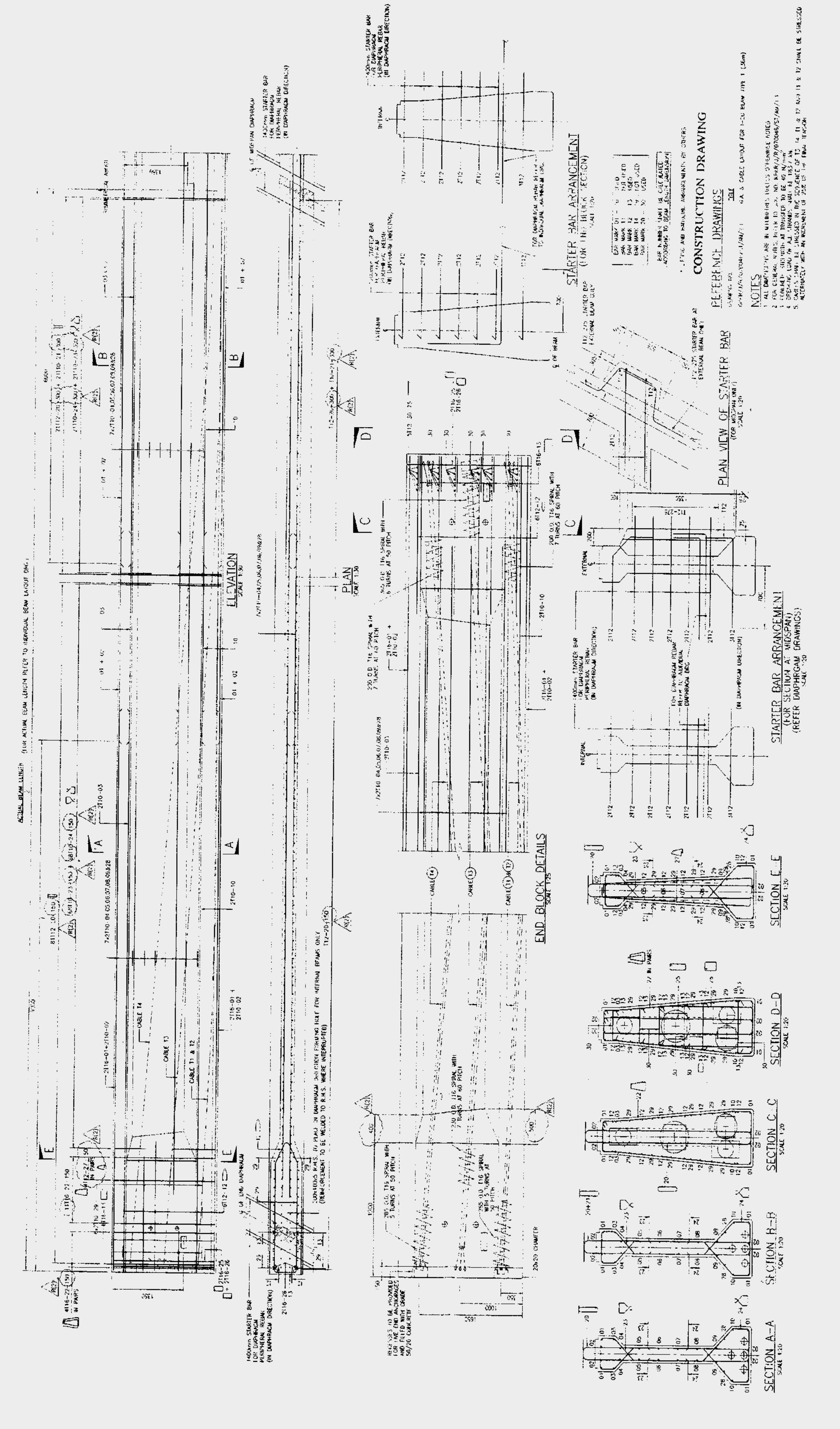


Figure 1.2 : Typical detail for 36m post-tensioned beam

CHAPTER V

Conclusion and Recommendation

5.1 Conclusions

Computations of short-term deflections in prestressed concrete flexural members are made with the assumption that the concrete section acts as an elastic and homogeneous material. This assumption is only approximately correct, as the elastic modulus for concrete is not a constant value for all stress levels. In addition, the elastic modulus varies with the age of the concrete and is influenced by other factors. Furthermore, differences between assumed and actual dimensions of the concrete cross section and prestressed reinforcements often exist. As a result, deflection computations for prestressed concrete are approximations and should not be considered to have high precision.

From the four post-tensioned beams studied, the results shows the actual beam cambers measured are much larger than design estimation based on design code BS 8110. It's therefore can be 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.

5.2 Recommendation for Future Study

As the prestressing industry is gaining popular in Malaysia, particularly in the field of bridge engineering, it would be desirable to recommend to carry out future studies on this topic by evaluate the effects of creep and shrinkage of concrete, modulus of elasticity of concrete, and environmental factors. Research is also recommended to investigate beam camber for :

- Other types of post-tensioned beam
- Pre-tensioned beam

The data from such studies would be very helpful to validate the findings of this study and it would be very useful as reference for future beam bridge construction.

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