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RATIONALIZATION OF PRESTRESSED CONCRETE SPINE BEAM DESIGN PHILOSOPHY FOR EXPERT SYSTEMS

by
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Abstract

The most important aim of expert systems is to emulate the expert. The majority of existing expert systems for design try to achieve this by integrating the phases of the design process within one software environment thus achieving an overall automation. These integrated systems tend to support design by numerous repeated analysis due to their inability to suggest good preliminary solutions. The feedback from numerical analyses is needed to modify the preliminary solutions.

It is argued here that human experts have a different approach to design problems. They try to minimise the iterative nature of design by suggesting preliminary solutions which have a higher chance of succeeding at the subsequent detailed design stage. Expert systems should be able to do the same. Ideally, good preliminary solutions should be tailored to the requirements; this means that they should take account of the majority of constraints and structural behaviours quantitatively while selecting the values for key design parameters. It is suggested here that the numerical processing power of the computer should be used to obtain good preliminary solutions by developing design algorithms, which can take account of governing factors at an early stage of the design process. These in turn can be used to encapsulate knowledge in the expert systems instead of the 'heuristics' which are used to incorporate past experience in existing expert systems.

In order to develop these design algorithms, it is necessary to unravel the rationale behind each decision made during the preliminary design stage. In this thesis, the work carried out to rationalize the philosophy of the design process of prestressed concrete spine beams is explained in detail. The main advantage of this approach is that the expert system is compact and fast in execution. It is also capable of guiding the designer in a consultation session either by suggesting appropriate values or allowable ranges for key design parameters, as is done by a human expert.

Keywords: Prestressed Concrete, Spine Beams, Bridges (structures), Expert Systems, Prolog, Deep Knowledge

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Declaration

This thesis is a report of research work carried out in the Department of Engineering , University of Cambridge, between October 1988 and January 1991. Except where references are made to other work, the content of this thesis is original and includes nothing which is the outcome of work done in collaboration. The work has not been submitted in part or in whole to any other university. This dissertation is 250 pages.

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Notation

A_b	Area of the bottom flange
A_{b-min}	Minimum area of the bottom flange allowed to prevent cracking
A_{b-span}	Required area of bottom flange at span critical section
$A_{b-support}$	Required area of bottom flange at support critical section
A_c	Area of the concrete section
A_t	Area of the top flange
A_w	Area of the web
b_z	Breadth of the section at a height z from the bottom
c	Ratio between concrete cover required and depth of the section
c_1	Position of top fibre (measured from centroid, always -ve)
c_2	Position of bottom fibre (measured from centroid, always +ve)
COR	Cantilever Overhang Ratio as defined on page 105
d	Depth of the section
e	Eccentricity of prestressing cable (measured +ve downwards from centroid)
e_{k1}, e_{k2}	Eccentricity at kern points (Z_2/A_c) and (Z_1/A_c)
e_{min}	Minimum eccentricity allowed considering cover limits
e_{max}	Maximum eccentricity allowed considering cover limits
e_p	Eccentricity of line of thrust
e_{p-min}	Minimum eccentricity of the line of thrust (upper bound)
e_{p-max}	Maximum eccentricity of the line of thrust (lower bound)
e_s	Eccentricity of actual cable profile
e_1	Distance to centroid of idealised top flange from the centroid of section
e_2	Distance to centroid of idealised bottom flange from the centroid of section
E	Young's modulus of the section
E_z	Young's modulus at a height z from the bottom fibre
f_c	Permissible stress of concrete in compression
f_{ct}	Permissible stress of concrete in compression at transfer
f_{cu}	Characteristic cube strength of concrete
f_{cw}	Permissible stress of concrete in compression at working load
f_t	Permissible stress of concrete in tension
f_{temp}	Temperature stresses due to direct strain and curvature
f_{tt}	Permissible stress of concrete in tension at transfer
f_{tw}	Permissible stress of concrete in tension at working load
I	Second moment of area about centroid

$l_{l(i)}$	Distance measured to left change point from i^{th} support
$l_{r(i)}$	Distance measured to right change point from i^{th} support
M	External moments acting on the section
M_a	Minimum working load moment
M_b	Maximum working load moment
M_f	Moment range in one span (mid-span sagging less pier hogging)
M_n	Moment due to notional loads
M_u	Ultimate state moment acting on the cross section
M_{2-min}	Minimum reactant moment due to prestressing effects
M_{2-max}	Maximum reactant moment due to prestressing effects
$(M_2)_j$	Reactant moment at internal support j
$(M_t)_j$	Continuity moment at internal support j due to temperature
n	Number of supports
N	Number of webs of a box girder
P	Horizontal component of the prestressing force in cable
P_B	Cable force corresponding to point B of Magnel diagram
$P_{n(i)}$	Cable force in the new cable at the i^{th} cable force change point
$P_{r(i)}$	Cable force in the running cable at i^{th} cable force change point
$P_{su(i)}$	Cable force over i^{th} support
P_t	Force in prestressing cable at transfer
P_1	Minimum prestress to satisfy moment range
P_2	Minimum prestress to satisfy lever arm
P_3	Minimum prestress for existence of line of thrust
P_4	Minimum prestress for existence of a line of thrust and maximum cable range
R	(Cable force at service)/(Cable force at transfer),
RMR	Reactant moment ratio as defined on page 64
t_b	Thickness of bottom flange
t_l	Linear transformation at left pier
t_m	Linear transformation at mid-span
t_r	Linear transformation at right pier
t_t	Thickness of top flange
t_w	Thickness of web
t_z	Temperature at a height z above the bottom of the section
w_b	Width of the bottom flange
w_s	Clear spacing between webs
w_t	Width of the top flange

x	Distance measured to cross section from the left support
z	Distance measured from the bottom fibre
$\bar{z}$	Distance to centroid from the bottom fibre
Z_1	Section modulus for upper fibre, I/c_1 (always -ve)
Z_2	Section modulus for lower fibre I/c_2 (always +ve)
α	Load factor for the ultimate limit state
α_c	Coefficient of expansion of concrete
α_i	($i = 1, 2$ and 3) Factors used to represent the idealised section as defined on page 84
$\alpha_{n(i)}$	Inclination of the anchor for new cable
$\alpha_{r(i)}$	Inclination of the running cable at force change point i
α_z	Coefficient of thermal expansion at height z
β	(Lever arm at ultimate)/(depth of the section)
β_j	Distribution coefficient for M_2
$\beta_{ll(i)}$	Inclination of lower bound of cable profile at left hand side of the i^{th} cable force change point
$\beta_{ur(i)}$	Inclination of upper bound of cable profile at right hand side of the i^{th} cable force change point
δ	(Maximum allowable concrete stress)/(Characteristic strength)
δ_i	($i = 1, 2$ and 3) Factors used to represent the idealised section as defined on page 84
ϕ	Diameter of the prestressing duct
ϕ_e, ϕ_l	Diameter of stirrups and longitudinal reinforcement in webs
ψ	Curvature due to temperature
ϵ_0	Direct strain due to temperature
κ	Total curvature caused by prestressing effects

In addition to these symbols, a number of others symbols are defined and used locally.