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Partially Prestressed Concrete

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SUMMARY

Partial prestressing has several advantages, and generally leads to a better behaviour of concrete structures. The rules of dimensioning differ greatly among the nations; they need a better precision and uniformity. Laboratory tests are necessary in order to achieve the best compromise between economy and durability.

For more than forty years, quite a number of controversial articles have been written about partial prestressing :
In the early 40's, P.W. ABELES and VON EMPERGER recommended the replacement of a part of the prestressing tendons by ordinary reinforcement. During the following decades, partial prestressed concrete has been developed in several countries, and the state of art of the use of this material was given by the FIP Symposium held in BUCAREST in September 1980.

The advantages of Partial Prestressed Concrete may be summarized as follows :

1. Under permanent and semi-permanent loads, the stress block of a fully prestressed section is almost triangular, rather than rectangular : in case of a positive bending moment, for instance, the bottom flange is subject to very high compressive stresses. The differential creep which results of this stress gradient induces long term deformations and deflections, difficult to foresee and to control.
On the contrary, partial prestressing allows to obtain, in each section of flexural members, a more uniform compressive stress, and, therefore, no parasitic deflection.

2. For the same reason, in some redundant fully prestressed structures, the hindered long term rotation of each section induces non negligible forces, which must be taken into account when designing the structure. This phenomenon, well known in cantilever built bridges, can be avoided by the use of partially prestressed concrete.

3. Reinforcing bars are more ductile than prestressing tendons, strands or wires, and partially prestressed concrete has a better behaviour than fully prestressed concrete, when submitted to seismic loading.

4. Some fully prestressed concrete structures have given rise to problems in the anchorage zones, or in the bottom flanges of girders, due to the congestion of these areas, and to the difficulties of concreting. Partial prestressing permits a better detailing, and in most cases it is possible to avoid intermediate tendon anchorages, which are always vulnerable and delicate.

Indeed, partially prestressed concrete has been used for decades in some European countries : DENMARK, SWITZERLAND, EASTERN COUNTRIES, etc... Partially prestressed concrete has also been codified and used for the design of all offshore platforms built and immersed in the North Sea. Furthermore, the criterion of concrete compressive stress, which characterizes full prestressing is not as absolute as it seems : for many years for instance, in "fully prestressed concrete" bridges, the effect of temperature gradients was neglected, and taking them into account is equivalent to designing these structures as partially prestressed, the only difference being that the detailing of reinforcing bars was not foreseen for the actual tensile stresses.

Some authors have defined the "degree of prestressing" :

– ratio $$\frac{\text{prestressing steel ultimate strength}}{\text{(prestressing steel + reinforcing steel) ultimate strength}}$$, or

– ratio $$\frac{\text{Bending moment of decompression}}{\text{Total bending moment under dead load and live load}}$$

These coefficients do not help the designer : the amounts of prestressing and reinforcing steel can be determined by applying the conditions of ultimate limit state, and serviceability requirements.

As the ultimate strength checking is not questionable, the serviceability criteria are more controversial : the three conditions to be fulfilled relate to deflections, fatigue, and crack width.

The deflections can be easily controlled, assuming that the sections are uncracked, or, if necessary, by taking into account the deformation of the cracked concrete.

The fatigue failure can also be prevented, by limiting the stress of the reinforcing bars, which are more exposed, to a value in the range of 200 N/mm^2. On the contrary, the checking of crack width is not very obvious. The CEB-FIP Model Code, and several national codes give formulas which aim to predict the crack width, as a function of various factors, such as diameter and spacing of bars, concrete strength and cover, etc ..., but the experience has shown that the durability was not influenced by the opening of cracks perpendicular to the main reinforcing bars. Furthermore, the existing codes do not make any distinction between reinforcing bars, post-tension prestressing tendons, and pretension tendons, although their behaviour, when exposed to aggressive environment, is quite dissimilar.

In order to satisfy economy as well as durability of prestressed structures, it seems necessary to undertake a programme of theoretical and experimental research covering the following subjects :

- For each destination of work, ratio of semi-permanent and frequent live load, versus total live load, in order to permit the checking of the durability conditions.
- Relation between crack width and corrosion (or fatigue and corrosion) in various environments.
- Effect of concrete crack width on behaviour of post-tension tendons, with various types of ducts.
- Effective bond of post-tension tendons with various types of ducts.