Flexural Behaviour of Concrete Beams Prestressed with External Parallel-lay Aramid Ropes

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1 - Introduction

External prestressing techniques have been used both in new structures and for rehabilitation. Some advantages are the possibility of controlling and adjusting the tendon forces; ease of inspecting, replacing or adding tendons and lower weight of the structures. Many bridges have been designed and built using external tendons in Europe, USA and other countries over the last twenty years.

The steel tendons used for the reinforcement need careful protection against the various type of corrosion attack. Corrosion is one of the most problem that affects the durability of the structures. Innovations include progress in design procedures, in corrosion protection systems and in materials.

With the development and commercialisation of organic fibres with good corrosion resistance, high strength and high elastic modulus in the early 1970s, interest in using new materials has increased. One example which has already been used for prestressing tendons is Parafil, made of Kevlar fibre and produced by Linear Composites Ltd. Tests of full scale concrete beams prestressed with these tendons were carried out (Burgoyne et. al., 1991), showing that Parafil is a very suitable material for use as a non-corrodable prestressing tendon. However, more studies are necessary for understanding the overall behaviour of these structures because the behaviour of externally prestressed structures is itself complex, and the failure criteria for Parafil differ from those of steel tendons.

Branco (1993) carried out an experimental investigation on the behaviour of full scale concrete beams prestressed with Parafil ropes. Five beams were tested to study the influence of the span to effective depth ratio (L/d) on the flexural resistance of the beams. The results from the ultimate load tests showed that the overall behaviour of such structures is similar to that of beams with unbonded steel tendons and that failure occurred by crushing of concrete in the top flange.

The work described here will provide a theoretical understanding of the flexural behaviour of concrete beams prestressed with external Parafil tendons. This paper will describe an outline of this proposed research that is being undertaken in three phases.

2 - Outline of the Research Programme

2.1 - Underlying principles

The principles behind the methods proposed by researchers and Codes of Practice for predicting the stress increment in internal unbonded prestressing steel tendons at failure are being studied, with the aim of applying these ideas to Parafil tendons with suitable modifications. The most important variables will be identified that influence the stress variation in the prestressing tendon at both the working and ultimate loads.

The main difference in behaviour between internal and external unbonded tendons is the variation in cable eccentricity. The deflected shape of external tendons is not the same as that of the beam, since the displacement of external tendons is constrained only at the deviator points. This is a second-order effect at the working load but is very significant at the ultimate load.

2.2 - Numerical study

A numerical parametrical study of the flexural resistance of concrete beams prestressed with Parafil tendons is being carried out using the main parameters identified in the first phase. This study utilises a computer program developed by Campos (1993) based on the finite element method for the analysis of concrete structures prestressed with both bonded and unbonded tendons, including external prestressing. It takes account of both material and geometrical nonlinearities. The constitutive relationship for the concrete is that recommended by CEB/FIP Model Code 1990; reinforcing steel, prestressing steel and Parafil can all be included. Several examples have been analysed and compared with the experimental results of Branco (1993) (**Figure 1**) and Lees (1995); these have shown that the model can predict with accuracy the overall behaviour and failure mode of such beams.

Time-dependent effects of both concrete and Parafil, such as creep and relaxation, are being added to the model so that long-term response can be studied. It is intended that these results will lead to practical design methods for beams using Parafil.

2.3 - Experimental validation

The third phase will consist of an experimental investigation of prestressed concrete beams. The experimental data will be used to validate and calibrate the design methods proposed in the previous study.

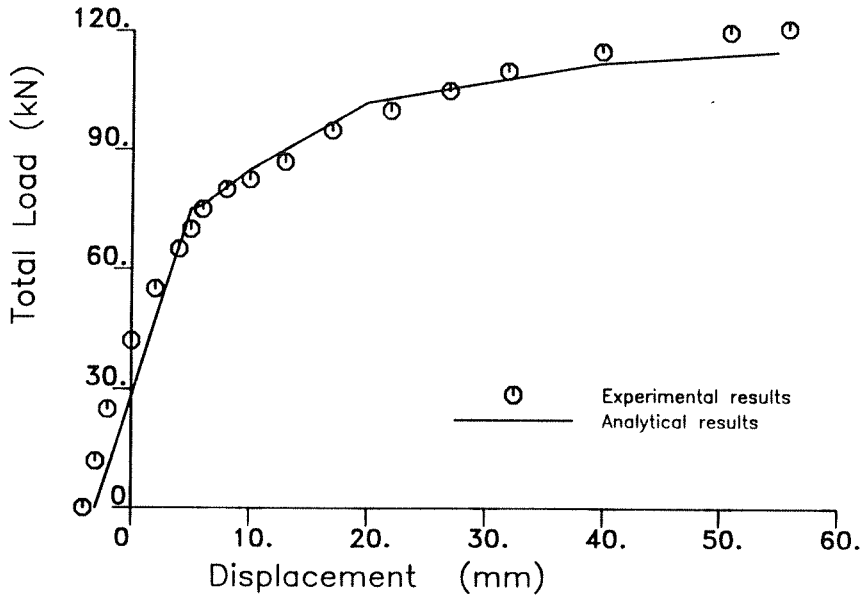

Figure 1 - Comparative curves between experimental and analytical results for a prestressed concrete beam with external Parafil tendons

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