Repair of Concrete Bridges Using Parafil Ropes

by G. B. Guimaraes
C. J. Burgoyne

Synopsis: Parafil ropes are synthetic cables whose core consists of Kevlar yarns. Among other properties, these ropes present high strength, high modulus of elasticity, low weight and good resistance to enviromental effects. In particular, they do not corrode which makes them suitable for use outside the concrete, without reducing their longevity. The conjunction of these properties gives them great potential for use as prestressing cables for repair of structures in general. This potential is explored in this work, which presents some of the already known properties of the material, relevant for its application as prestressing cables, and the partial results of the work currently in progress to determine other properties. The paper presents general guidelines for the use of the cables in repair of structures, indications for the prestressing operation and comments on the anchorage and deflector areas.

Keywords: Bridges, Concrete, Prestressed, Repair, Parafil, Kevlar.

Giuseppe Guimaraes is a lecturer at Pontificia Universidade Catolica do Rio de Janeiro - PUC/RJ. He obtained his MSc degree from PUC/RJ and was a project engineer for 2 years. Currently he is completing his research on Parafil ropes at Imperial College, London, as part of his PhD.

Chris Burgoyne is a lecturer at Imperial College, London, specialising in prestressed concrete. His research interests include new materials for structural use and the application of expert systems to design.

INTRODUCTION

One of the main causes of deterioration of concrete bridges has been identified as corrosion of the reinforcing steel (1,2,3). Considerable effort has been expended on development of techniques to avoid corrosion by waterproofing the bridge deck, by using resin coated steel tendons (3), or by incorporating galvanized and stainless steel bars (4). These techniques have proved satisfactory in many cases, but the search for new ideas and materials continues, mainly on materials resistant to corrosion.

Parafil ropes present properties that make them suitable for use in prestressed concrete, both in new construction and repair. A recent structural application of this material was in the rehabilitation of three large cooling towers at Thorpe Marsh Power Station in England (5).

The relevant properties for structural applications of Type G Parafil ropes are outlined in this work along with practical guidelines for their use as prestressing tendons.

PARAFIL ROPES

Description

Parafil ropes are manufactured by the Fibres Division of Imperial Chemical Industries. They are formed of continuous synthetic yarns arranged in a parallel configuration and encased in a polymeric sheath. They are produced in three different versions which differ in the core material; the most suitable for application as prestressing tendons is Type G which has Kevlar 49 yarns as the core material.

Material Properties

Type G Parafil ropes have a linear stress-strain relationship with tensile strength of 1930 MPa and corresponding strain of 1.5%. The modulus of elasticity is about 126000 MPa which represents 2/3 of that of steel. The specific gravity is only 0.98 when dry or 1.08 when saturated.

Creep strain is very low when compared with that of others polymers. As a prestressing tendon in a concrete member, creep of the tendons manifests itself as stress relaxation and, for Parafil ropes, it is higher than that observed in low relaxation steel strands. The total losses, however, are similar to those in steel tendons, since the losses due to elastic deformation, shrinkage and creep of concrete are lower as a consequence of the lower modulus of elasticity of Parafil; there is also no loss due to anchorage slip.

Most polymers cannot sustain long term loads because of static fatigue, or stress-rupture. This is the phenomenon of fracture which occurs some time after the application of a constant stress lower than the nominal strength of the polymer. Theoretical and experimental work indicates that Type G Parafil ropes exhibit a lifetime of 100 years when subjected to a stress equivalent to 50% of their strength, or 50 years when this figure increases to 60% (6).

The fatigue properties of Parafil are excellent, exceeding those of steel. Because of the rope construction, there is little inter-fibre fretting, and so the full fatigue life of the yarns can be realised.

Parafil exhibits a negative coefficient of thermal expansion. Tests conducted by the authors have demonstrated that this coefficient depends on the applied stress. When subjected to stresses equivalent to 40% of its strength, the coefficient was found to be equal to $-6x10^{-6}/^{0}C$. At zero stress this figure is quoted by the manufacturer as $-2x10^{-6}/^{0}C$. Since the coefficient differs from that of concrete, fluctuations in stress will occur due to temperature changes.

Parafil ropes are resistant to corrosion. Although Kevlar 49 is affected by ultra-violet radiation and strongly alkaline solutions, the thermoplastic sheath of the ropes is a secure protection from these sources of attack.

Parafil ropes can only be used as unbonded tendons since there is no adhesion between the sheath and concrete (9). The lack of ductility in the yarn makes it undesirable for the ropes to be subjected to high local strains in the vicinity of a failure zone.

USE FOR REPAIR OF CONCRETE STRUCTURES

Termination

The termination consists of a cylinder with a conical hole in which a spike is introduced to press the yarns against the cylinder. A detailed description of the terminal can be found in reference (5).

Before installing the rope in the structure, it must be cut to length and the terminals fitted. The rope must be cut in such a way that, after prestressing, its extended length is such that the outer thread of the terminal is just protruding from the end block as shown in figure 1. Allowance should be made for rope bed-down and rope extension. The rope should be pre loaded to 60% of its nominal strength in order to ensure that the spike is fully bedded within the terminal.

Prestressing Operation

Figure 1 illustrates the prestressing operation using Parafil ropes. The rope, already cut-to-length and with the terminals fitted, is installed in the duct; the jack is mounted on a trestle and the prestressing force applied through a pullrod; having applied the load, the locknut is tightened resulting in the final arrangement shown in the figure. Depending on the contact area between the locknut and the concrete, a steel end-plate might be necessary in order to distribute the compressive stress imposed by the nut.

Repair of Bridges

The primary advantage of Parafil ropes is the resistance to corrosion. Thus, it is not necessary to place the cables within ducts in the concrete, nor is it necessary to provide extensive corrosion protection to external tendons.

The tendon will need to be anchored to the beam at the ends, but this can be achieved by means of a steel bracket bolted to the existing structure, or possibly with a concrete block fixed to the structure by reinforced or short prestressing bolts (8).

Similar arrangements can be made at deflection points where changes in tendon direction are required. Tests carried out on ropes with deflection angle of 15^0 and radius of curvature equal to 50 times the rope diameter (6), showed that the strength of the ropes were not affected. These are the maximum values permitted in the British codes of practice for post-tensioned steel tendons. In these tests PTFE tape, wrapped along the contact length between the rope and the deflector, was used successfully to minimise friction and also to avoid damage to the sheath of the ropes.

The logical position for such tendons would be inside the void of box girder bridges, or fixed to the webs of simple I-beam girders. In the case of bridges built by balanced cantilever method, where additional tendons are sometimes required to resist creep deflections (10), the tendons can be fixed immediately below the soffit of the top flange.

In the case of the cooling towers at Thorpe Marsh Power Station, where circumferential prestress was required to eliminate cracking, Parafil ropes were supported on stainless steel brackets bolted to the tower before being stressed. The light weight of Parafil ropes allowed the complete system to be installed from a suspended cage without the use of cranes which would have been required for a steel alternative.

CONCLUSIONS

Parafil ropes, with their good structural properties, light weight and resistance to corrosion, are finding applications in many structural areas. They are particularly suited to use for repair of concrete structures, where they can be placed outside the concrete without fear of environmental attack.

Once the properties become more widely appreciated by engineers, it is expected that Parafil ropes will be widely used for the repair of the very large number of structures where the prestress is inadequate, or where the existing steel tendons are showing sign of corrosion.

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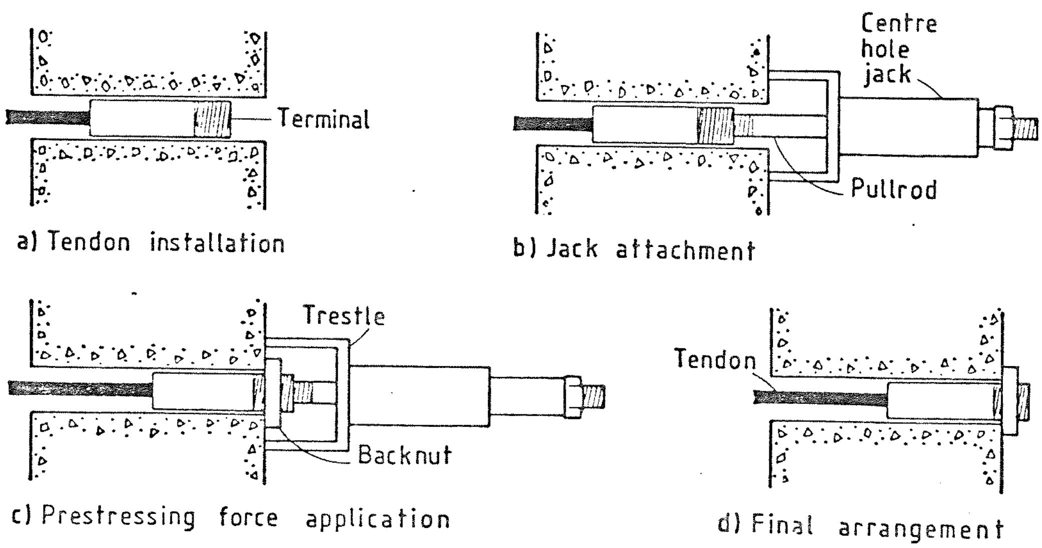

Figure 1 - PRESTRESSING OPERATION