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Ninian Central Concrete Gravity Platform

Plate-forme centrale Ninian en béton

Betonschwergewichtsplattform der Ninian Zentrale

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SUMMARY
This paper reviews the experiences gained in executing the largest post-tensioning sub-contract ever let in the United Kingdom. Standard systems have been used, but new equipement had to be built to fabricate, handle and thread the very long tendons involved. In particular, the threading and grouting of tall vertical tendons, which is not encountered in routine prestressing contracts, has led to considerable development work. The final successful solution, to overcome the problem of bleeding, is described.

RESUME
Cette contribution examine les expériences acquises lors de l'exécution du contrat le plus important de sous-traitance en post-tension jamais décerné au Royaume-Uni. On a adopté des systèmes standards mais il a fallu construire un matériel nouveau pour fabriquer, manutentionner et enfiler de longs câbles. En particulier, les opérations d'enfilage et d'injection de très grands câbles verticaux qui sortent du cadre habituel des travaux en matière de précontrainte ont amenés à des développements importants. La solution adoptée afin de surmonter avec succès le problème de l'exsudation, fait l'objet d'une description.

ZUSAMMENFASSUNG
Dieser Beitrag berichtet über die Erfahrungen, welche bei der Ausführung des grössten Nachspannungs-Untervertrages, der jemals in Grossbritanien vergeben wurde, gewonnen werden konnten. Herkömmliche Systeme sind benutzt worden, jedoch mussten neue Anlagen konstruiert werden, um die äusserst langen Drähte fabrizieren, handhaben und einfädeln zu können. Insbesondere das Einfädeln und Untergiessen von langen vertikalen Kabeln, was bei gewöhnlichen Vorspannungsarbeiten nicht anzutreffen ist, hat zu erheblichen Entwicklungsarbeiten geführt. Die gewählte, erfolgreiche Lösung zur Überwindung des Abzapfproblems wird beschrieben.

1. INTRODUCTION

Currently, some degree of prestressing is considered essential in offshore gravity structures, partly to save weight and partly in an attempt to minimise cracking, but there are very few special requirements for the prestressing system, unlike nuclear structures for example. Ordinary commercial systems can be used, perhaps slightly modified to permit electrical interconnection for corrosion protection. In terms of modern practice in bridges, the systems employed are universally rather small.

Up to date, companies within the Freyssinet Group have been responsible for providing the prestressing system and equipment for eight deep water gravity platforms, of three basic designs, and have actually carried out sub-contract work on six of these. The biggest by far was the Central Platform for the Ninian Field, built at Loch Kishorn in Scotland, where the prestressing sub-contract executed by PSC Freyssinet Limited was the largest ever let in the U.K. This was the fifth platform built to the Doris design, but the first in the U.K.

A standard 12/15mm strand prestressing system was used throughout, and the sub-contract included the supply of prestressing materials and equipment, tendon fabrication, installation, stressing and grouting, together with bar stressing.

2. PRESTRESSING LAYOUT

The layout of prestressing tendons in the platform structure is essentially as follows :

- Straight horizontal tendons up to 150 metres long in the base
- Curved horizontal tendons up to 140 metres long in the walls, normally anchored at the diaphragms.
- Straight, and some looped, horizontal tendons in the diaphragms.
- Vertical 'U' tendons, up to 75 metres in height, in the walls and diaphragms.

In addition, 8,320 No. 40mm diameter Macalloy bars connect the steel skirt to the main concrete platform structure.

3. DUCTS

Although made from a heavier gauge of steel than in normal bridge work, standard spirally wound prestressing ducting was used horizontally, and this was transported to site by rail, in 6 metre lengths, and connected on site using metal sleeves.

There was extensive use of smooth bore steel tubing, primarily as a construction aid, to facilitate tendon threading around relatively sharp bends, and to ensure a largely self-supporting duct system during slipforming operations, although by virtue of its increased wall thickness, this tube does offer added corrosion protection, and improved resistance to interconnection where ducts cross at 90 degrees and touch.

This tube was pre-bent to the appropriate radius off site and connected with a spigot and socket joint, formed on site. Pre-bending to large smooth curves was carried out on a pipe-bending machine, but occasionaly in-situ adjustments were made by heating the tube locally, when in position.

On tight bends, down to about 1.2 metres radius, the tube was larger in diameter, to facilitate tendon threading, so that special adaptor pieces were produced to join the bends to the normal diameter of tube.

4. TENDON MAKING

Machines do exist capable of pushing strands into ducts directly from the coils. Because of the length of many of the ducts, the speed of construction, the orientation of some of the anchorages, and the need to protect the strand from exposure, such machines were not widely used on this structure, and most tendons were pre-made and then pulled into place. Strand pushing was restricted to a very few ducts, usually in emergencies.

Roughly 3,500 tonnes of strand were factory fabricated into tendons, on a long bed, recoiled and transported to site by rail. There were advantages in this, because an extensive and expensive site installation was avoided, and the tendon making plant is permanent, serving more than one site.

12/15mm strand tendons, up to 150 m long and weighing 2.25 tonnes, were satisfactorily recoiled, with a diameter less than 2.5 metres.

All strand had to receive a coating of soluble oil at the manufacturing plant, for corrosion protection, and this needed renewing during tendon fabrication; consequently, the strands were run through an oil bath, and also the tendons coiled up in store at Loch Kishorn were sprayed at regular intervals with the same oil.

The tendons were all provided with a welded eye on both ends for towing and threading.

5. TENDON THREADING

All ducts were checked for obstructions, usually by blowing through a plunger carrying a light line, which was then used to draw back the main pulling cable. Most horizontal tendons were simply winched in, and quite low forces were involved, perhaps due to the oil on the strand and duct, coupled with the majority of relatively simple tendon profiles. A winch of 1.5 tonne capacity, reacting off the structure itself, was normally adequate; however, looped horizontal tendons did sometimes present problems and required greater forces.

Vertical tendons were threaded from the top downwards, and adequate braking force was needed, which was solved by feeding each tendon from an air powered dispenser, fitted with an automatic brake, to which the tendon was attached by means of the second eye. On 'U' shaped ducts, a winch was used to pull the tendon up the second leg, after it had been carried down the first leg by gravity, or pushed by a dispenser.

6. STRESSING

Stressing presented no new technical problems, but was a formidible exercise in planning and, to avoid constantly moving the equipment, it was necessary to provide 20 jacks and pumps on site. 8 stressing operations were sometimes in progress at the same time, so it was necessary to make a permanent mark on the strand behind the jack, usually by a saw-cut, so that the extension achieved could be checked at any time subsequently, by the Inspectors.

The correlation between calculated load and extension was usually within 5%, presumably due to the workmanship in duct fixing and to the fact that the oil on the strand and duct effectively inhibited any rusting.

With so much activity in a relatively confined area, safety during prestressing operations is obviously a major concern. However, there was no accident attributable to the stressing on this job.

7. GROUTING

Ordinary cement based grout was used throughout, and fairly conventional techniques were used for horizontal tendons, although it was normally impossible to get the grout pump near to the anchorages. Consequently, a central mixing and pumping plant with large diameter delivery lines, up to 300m in length, had to be used, coupled with a retarded grout. In addition, to guard against possible interconnection, several ducts were sometimes grouted simultaneously.

Experience finally showed that it was not necessary to flush out the soluble oil before grouting, it was carried out with the waste grout.

An expanding and water reducing admixture was employed, with a water/cement ratio between 0.34 and 0.40, and it was possible to produce complete filling of the 'U' tubes by pumping from the top, and topping up afterwards, under gravity.

It was known from previous work that bleed water tends to be driven up strands, ahead of the main column of grout, a phenomenon known as the 'wick' effect. It was decided to turn this to advantage, and the strands were therefore left protruding from the top anchorage to encourage bleeding to waste; finally the duct was re-grouted, by gravity at the top anchorage, using a small quantity of retarded grout, which forced the remaining bleed water up the strands.

An anti-bleed additive was investigated, but appeared to offer little advantage with the existing plant, in view of the increased pumping pressures and the greatly increased mixing time involved.

Based upon this experience, the following observations can be made, relating to the grouting of tall vertical ducts.

- Before undertaking the grouting of any job, it is necessary to carry out a trial on site to prove the proposed plant and method, in conjunction with the actual cement. Any reinjection in this trial should be carried out with a coloured grout, to determine the degree of penetration, and then the duct should be cut for inspection. An expanding agent should be employed.

- The maximum grouting pressure will sometimes need to be a good deal higher than in horizontal work, and this may require special treatment at the anchorage where grouting is carried out. Much lower pressures are involved in grouting 'U' tubes, thus minimising bleeding.

- Strands should be allowed to protrude through the grout seal on the top anchorage to facilitate the wick effect. The bleeding from these strands will probably be in excess of that measured in a conventional test in a cylinder, due to the pressure filtration effect up the strands during grouting.

- Previous researchers have cast doubt on the value of the practice of holding pressure on the grout column for a period after injection. Here this has not been done, with no discernible detrimental effects, so it appears to be a time-consuming practice that can be abandoned.

- Reinjection may be carried out from the top, within an hour after the completion of the initial grouting, most simply by installing a small header tank containing 15 - 20 litres of fresh retarded grout about 1 metre above the top anchorage to provide a continuous reservoir. Bleeding from strands will then occur anew.

8. RECORDS AND QUALITY CONTROL

Very detailed records had to be kept, of all aspects of the prestressing work, so that the complete case history of any tendon in any duct was known. It had to be possible to trace a strand from manufacture, through tendon making, to tendon threading, stressing and grouting. All prestressing materials were subjected to inspection by the Certifying Authority.

Routine quality control tests were carried out on the grout, for fluidity and bleeding. Fluidity was measured with a flow cone, which is a simple and acceptable site test, although unfortunately not yet standardised completely so that cones of different dimensions are encountered. The time taken to fill a one litre container, from a full cone, is taken as the flow time, and, times in the approximate range of 12 seconds - 30 seconds were normally satisfactory, grouts with higher flow times tended to block in the pumping mains and those with lower flow times exhibited excessive bleeding. This test is probably best used as a basis of comparison of fluidity, once a satisfactory mix has been established.

Both the limits of bleeding and the method of test were generally those recommended by the F.I.P. viz : the bleeding at 20 degrees C, of a sample of grout 100mm diameter and 100m high, must not exceed 2% at 3 hours after mixing, with an absolute maximum value of 4%, and complete re-absorbtion of all bleed water after 24 hours. With heavily retarded grout, this reabsorbtion requirement was difficult to achieve, and was relaxed to 48 hours, to allow for complete setting of the grout.

9. DOCK GATES

The two concrete gates to the dry dock, form part of the development of the site facilities by Howard-Doris Limited, and, in any other location, would be regarded as a considerable job in themselves, although they were dwarfed by the adjacent platform. Each gate is roughly 83 metres long x 14 metres wide x 15 metres high, and is composed of 24 cells formed by two internal longitudinal walls and seven internal cross walls.

1647 No. 25mm diameter Macalloy bars were used for the vertical prestressing, with 530 No. 32mm diameter Macalloy bars transversely. For the longitudinal prestressing, the same 12/15mm strand system was used as on the main platform, with the tendons on the sea side overlapping at the central wall, and stressed internally, to avoid the use of stressing anchorages on the ends of the gates.

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