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**V****Installing Prestressing Tendons in Arduous Conditions**

Travaux de précontrainte dans des conditions extrêmes

Vorspannarbeiten unter schwierigen Bedingungen

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**SUMMARY**

Prestressing operations require care and expertise even in the best working conditions. This article describes such activities afloat, 24 hours a day, in the winter months and in conjunction with slipforming operations during the construction of the 67 m high towers of the Cormorant 'A' oil production platform.

**RESUME**

Même dans des conditions optimales, les travaux de précontrainte nécessitent une grande expérience et une prudence extrême. Cet article montre les problèmes spéciaux – travaux en mer, 24 heures par jour, en hiver, coffrages glissants – rencontrés lors de l'exécution des travaux de précontrainte pour la construction de la plate-forme de pétrole Cormorant 'A', de 67 m de hauteur.

**ZUSAMMENFASSUNG**

Vorspannarbeiten verlangen selbst unter optimalen Bedingungen grosse Erfahrung und äusserste Vorsicht. Dieser Beitrag beschreibt solche Arbeiten auf offener See, im 24 h – Takt, während des Winters und im Zusammenhang mit dem Gleitschalverfahren beim Bau der 67 m hohen Erdölplattform Cormoran 'A'.



## INTRODUCTION

"Arduous" is defined in the Collins English Dictionary as :-

"requiring great physical or mental effort"

Thus arduous conditions can result from circumstances which require great physical or mental effort. Where circumstances require that both efforts occur simultaneously it must be recognised that the threshold of effort at which "arduous conditions" become "impossible conditions" is significantly reduced.

In conditions of combined physical and mental effort much can be done in a construction environment to alleviate the physical conditions. Preparation and thought also need to be directed to reducing the mental strain to ensure that the Works are completed on time and to the required standard of quality.

In particular the need to work to a very strict programme which must be met regardless of weather conditions adds to the required mental effort.

Failure to appreciate at an early stage the effects of the combination of physical and mental effort, and failure to ensure that all possible pressures, whether mental or physical, are alleviated will result in unsatisfactory workmanship, delays to the planned programme and, in the ultimate, technical failure.

### 1. THE WORKS

The Main Contract was for the construction by Sir Robert McAlpine & Sons Ltd., and Sea Tank Company of Paris of the North Sea oil production platform Cormorant 'A' for Shell Esso, fig. 1. The Main Contract programme required that the platform was completed and delivered to suit the North Sea weather window, i. e. a limited period in the summer months. Failure to meet this "window" would mean that oil production from the Cormorant 'A' platform would be delayed by 12 months, which possibility was unthinkable.

The Sub-contract was to install the prestressing tendons in each of the four 67m high towers whilst the towers were being constructed by the slipforming process, fig. 2. These Sub-contract works were completed by BBRV Marine which is a joint venture of the BBRV Licensees in Scandinavia (A/S Strangbetong), Switzerland (Stahlton AG) and the United Kingdom (Simonbuild Ltd).

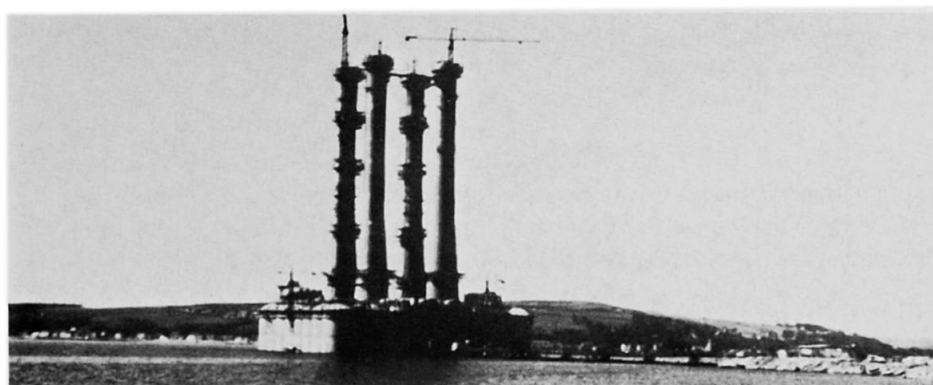


Fig. 1 The Cormorant 'A' Oil Production Platform.

## 2. THE TECHNICAL REQUIREMENTS

Slipforming has been extensively used in offshore concrete gravity platforms. New methods of placing and anchoring tendons for post-tensioning have been developed especially for the vertical tendons in the towers. Since wind and wave forces produce significant bending moments in these towers, and since these moments reduce with height, economy requires that the number of prestressing cables should be successively reduced to match the bending moment diagram.

The problems encountered in the conventional installation of prestressing tendons in slipformed towers are :-

- The additional operation of installing prestressing tendons after completion of the associated slipforming which can lead to an extra item on the critical path.
- The above operation requires the erection of another working platform additional to the one already present for slipforming.
- The constructional difficulties and the programme consequences of forming the internal buttresses at each tendon termination level after the completion of the slide.

Thus the major requirement which was achieved by the special procedures adopted in the Cormorant Platform Towers was to install and anchor 256 No. 375 tonne capacity tendons in the towers whilst they were being slipformed so that on completion of the slipforming operation, and as soon as the tower concrete had reached the required strength the prestressing of the towers could commence. By this method there was also no need for any access to the inside of the towers at any of the 64 tendon fixed end anchorage levels.

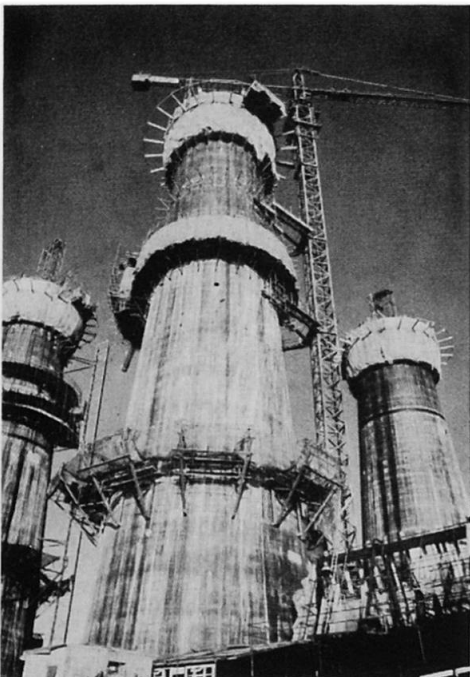


Fig. 2 Slipforming the 67m high towers.

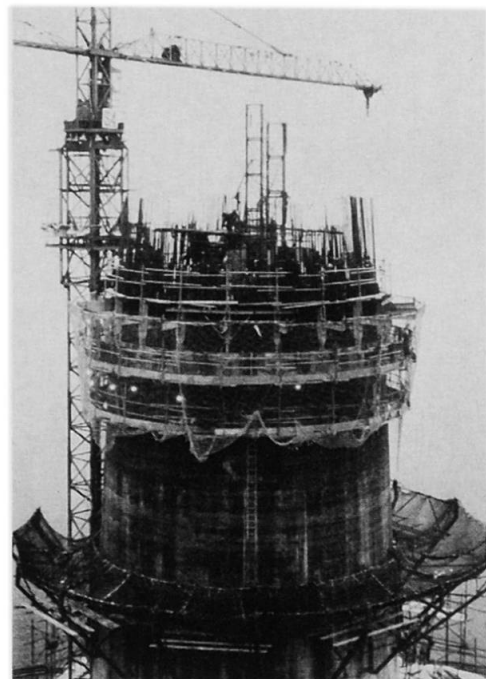


Fig. 3 The slipform platform



The load applied to the slipforming platform during tendon installation was to be kept to a minimum as increased loads would require extra lifting equipment which would cause congestion in an already limited area, fig. 3. It is also important in slipforming to avoid eccentric loads. Thus to lift tendons weighing up to 1.5 tonnes from different points around the slipforming platform would cause unacceptable slipforming conditions.

### 3. THE TECHNICAL SOLUTIONS

The method to avoid these problems whilst allowing the installation of the prestressing tendons during the slipforming process involved fastening an "upper tube unit", fig. 4, onto the top of the ducting at each tendon installation level. This unit was 3m long and incorporated :-

- a conventional end anchor plate at the top end
- a smaller bearing plate at the bottom end to distribute the stresses applied, during the installation of the tendon, to the relatively young concrete of the tower.

The tendon was installed along a tortuous route extending from the platform deck to the slipform platform as shown in fig. 5, by fixing a lifting device (a linear winch) to the top plate when the concrete had been placed to within 0.5m of the upper plate. At this stage the lower plate was 2.5m into the concrete and was bearing on concrete which had achieved sufficient strength to withstand the loads transmitted through the tube unit from the lifting device. When the tendon had been lifted to the correct distance above the top plate of the tube unit, chocks were positioned between the tube unit upper plate and the underside of the tendon fixed anchorage. The lifting device was then removed and the slipforming proceeded, without delay, past and covering the completed fixed end anchorage, fig. 6.

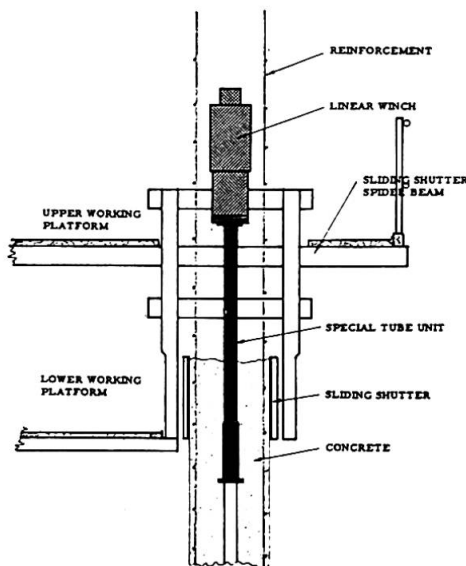


Fig. 4 Tendon lifting arrangements

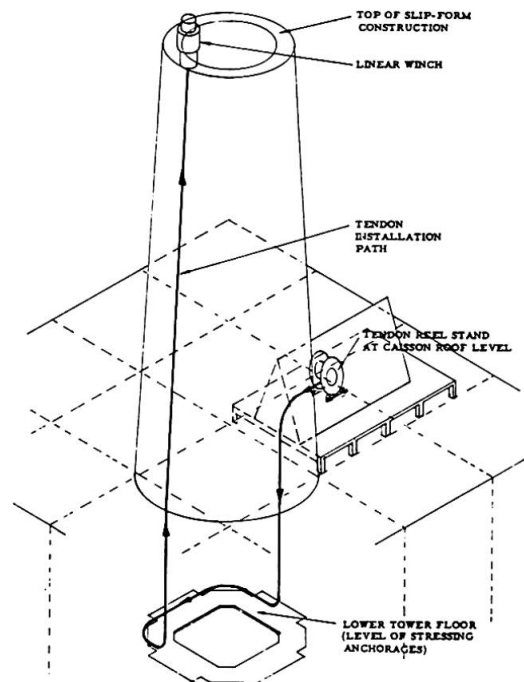


Fig. 5 Tendon installation route

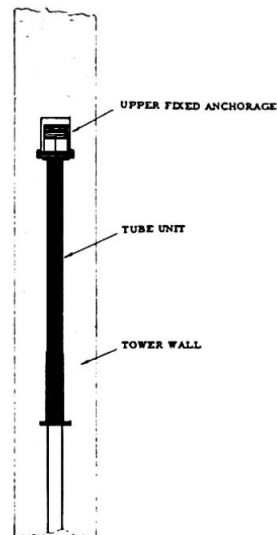


Fig. 6 Tendon fixed anchorage after passage of slipform

#### 4. THE WORKING CONDITIONS

The Main Contract programme required that the tower construction was completed by a specific date and in order to achieve that date the Main Contractor decided to slipform the towers. Thus the above technical solution had to be continuously operable day or night, in any weather condition, and without any doubt whatsoever.

The problems and arduous conditions anticipated and the steps taken to overcome them were :-

##### 4.1 Staff and operative availability

During slipforming operations sufficient experienced staff and operatives from the U.K., Switzerland and Sweden were resident in the site camps to provide three complete teams.

##### 4.2 Double shift working

Two 12 hour shifts were worked each day and as three teams were available this meant each team working four shifts, and on standby for two shifts when changing from day to night or from night to day shifts. Thus arrangements were made for frequent breaks and for a complete spare team to be on standby should the need arise, either for an extra team or an extra individual.



### 4.3 Weather conditions

In the winter months off the West coast of Scotland high winds and low temperatures can be expected. In the event, the average maximum wind speed per shift in the six months duration of the slipforming was 29.9 mph, with recorded wind speeds in excess of 50 mph on 27 different shifts. Similarly temperatures below freezing were encountered on 63% of the shifts worked, with the lowest temperature recorded at the top of the towers being  $-11^{\circ}\text{C}$ .

In anticipation of these conditions the Main Contractor had taken care to ensure that :-

- The site camp was comfortable.
- High quality site meals were provided.
- Protection was provided on the floating platform.
- Protective wind and waterproof clothing was provided.
- Hot drinks were provided at frequent intervals.

### 4.4 Standby equipment

Duplicate installation equipment was in position at each location. Also, spares for all items of plant were stored on the Cormorant 'A' platform, with certain light spares available on each slide platform.

### 4.5 Precautions

Stringent precautions were taken to avoid situations which might cause delay or which might increase difficulties in the execution of the work.

These precautions fall into two main classes :-

Avoidance of difficulty by :

- attention to inspection and control procedures
- equipment maintenance by planning, by adequate numbers of fitters and by adequate availability of spares
- taking precautions to prevent ducts becoming blocked by foreign bodies, by damage and by 'lips' at joints e.g. temporary caps were positioned on the top of the vertical duct sections at all times during the tower construction.

Anticipating problems :

All possible eventualities were considered and catered for before work actually commenced on site, e.g. in order to prevent interruption to slipforming in the event of cable installation being delayed, 1m long duct



extenders were designed and pre-manufactured. This then allowed the level of the top of the duct to be raised and the slipforming to proceed whilst the installation problem was overcome.

## 5. INCENTIVES

As the prime requirement was not to delay the slipforming, the incentive scheme for both operatives and staff was related to slipforming progress, although payments took account of :-

- the remoteness of the site
- the extended periods between week-end leaves
- camp life
- double shift working
- standby requirements

## 6. PROBLEMS

Despite all care in planning, in execution, in inspections, and in the provision of standby arrangements, problems will and do occur when the techniques are innovative and the conditions are so arduous.

For this reason the senior management on the site was and should be of a very high calibre - higher than might be believed if one looked solely at the size of the contracts.

The correctness of this decision is demonstrated by the only major problem which occurred during the execution of the works when a crucial item of specially developed but well tested equipment proved to be unable to continue to work safely and reliably in the extreme environmental conditions. It proved less capable of dealing with and responding to the pressures of the situation than did the operatives.

The problem was appreciated at an early stage and the winches were replaced during the slide by an alternative and, in the event, satisfactory powered pull lifts. The transition was made without causing any delay to the slipforming process.

All other problems which were encountered were overcome by taking advantage of the various standby arrangements.

## 7. CONCLUSION

All 256 BBRV prestressing cables were satisfactorily installed during the slipforming operation without causing any delay to the construction of the towers and immediately on completion of that construction prestressing of the tower tendons was able to commence.



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