Construction using modern heavy lifting techniques

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Utilisation des techniques modernes de levage

Bauen mit modernen Schwerhebetechniken

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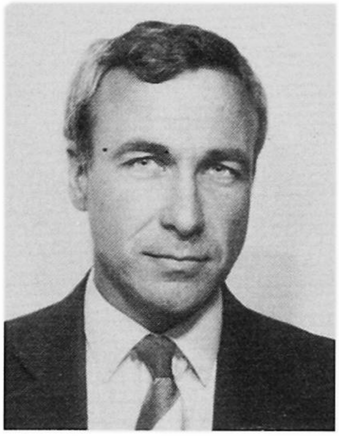

Peter Lowther, born 1944, received his civil engineering degree at the University College of Swansea and became a chartered engineer in 1972. His early experience was with contractors in mainly steel bridge construction and design. He is currently Manager of the Heavy Lifting Division of PSC Freyssinet.

SUMMARY
Engineers have always understood and appreciated the advantages and cost savings in being able to fabricate sections at ground level rather than high in the air and particularly under factory rather than site conditions. Recent years have seen the development and operation of very heavy duty support structures allied with the use of hydraulic jacking systems providing cost effective solutions which previously could not have been considered. This paper deals with three examples, in different industries, all involving ground level assembly followed by heavy lifting operations.

RESUME
Les ingénieurs ont toujours compris et apprécié les avantages et les économies de coûts de la fabrication d'éléments à terre plutôt qu'en l'air et surtout dans des conditions d'usine plutôt que de chantier. Les années récentes ont vu le développement des structures de levage à grand rendement et l'emploi de systèmes hydrauliques pour fournir de nouvelles solutions économiques. Ce document en présente trois exemples.

ZUSAMMENFASSUNG
Die Ingenieure haben immer die Vorteile und Kostenersparnisse der Vorfabrikation auf Bodenhöhe statt hoch in der Luft und insbesondere in der Fabrik statt auf dem Bauplatz erkannt. In den letzten Jahren wurden leistungsfähige Hebetechniken entwickelt, die sich hydraulischer Systeme bedienen und kostengünstige Lösungen ermöglichen, welche früher nicht in Betracht kamen. Der Beitrag behandelt drei Beispiele aus verschiedenen Industriezweigen. In allen Fällen erfolgt eine Bodenmontage mit anschliessender Anwendung der Schwerhebetechnik.

INTRODUCTION.

In recent years two industries in particular have generated the impetus for the development of equipment capable of lifting and moving very heavy loads. First the offshore industry. Here the availability of high capacity (now up to 8000 Tonnes) floating cranes, plus the need to reduce the number of offshore installation operations to a minimum has necessitated the pre-fabrication of sections, which must then be assembled in the construction yards by lifting, with the completed structure slid onto a barge. The second is the petro-chemical industry. In this industry economies of production can be achieved primarily by making the vessels taller. In addition special materials and steels are used, frequently under internal pressure requiring very high quality manufacture. The use of heavy lifting techniques makes it possible to fabricate these vessels in a controlled factory environment, limiting site work to a minimum of rearing the pre-fabricated vessel from a horizontal position to the vertical.

The fact that heavy lifting techniques have been developed for a particular purpose does not limit them to that purpose. Whilst conventional structural/ civil engineering probably would not have generated the impetus needed for this development, the fact that the equipment now exists has encouraged engineers to apply it far more readily than before in general construction.

EQUIPMENT.

In the first instance in conventional terms, we have had winch equipment which is used from existing structures. In all cases this required tie backs for the winch and snatch blocks with a reeving system to get the required carrying capacity.

To take the winch arrangement a stage further this was then developed into what are known as gin pole systems, where temporary structures are provided from which to hang the winch sheeve blocks for lifting particularly heavy structures. In this context several companies have systems which are capable of lifting loads of up to 1000 tonnes.

A further development of the winch arrangement is the mobile crane, which in its simplest form, is no more than a self propelled winch carrying its own counter weight to balance the load that is being lifted.

Cranes in particular have undergone enormous changes and developments over the last twenty years, leading up to the monsters that are now available in the world. Vehicles such as the 1000 ton Gottwald mobile cranes, the Demag crawler cranes capable of lifting up to 1600 tonnes when on rings, and at the very top end of the scale the Lampson Transi-lift Cranes with capacities of up to 2000 tonnes lifting to heights of up to 100 metres. What should be borne in mind with these very big cranes is that the very simplicity which has made cranes attractive for lifting operations has by this stage long since disappeared from the vehicle in question. To move the 1000 ton Gottwald with all its equipment takes a fleet of 80 lorries. The big crawler cranes require large clear working areas, and often special foundations to spread the load satisfactorily.

This has led to the development of alternative systems, usually based around hydraulics, both for the circumstances where it is uneconomic to transport these huge machines to site for the particular operation, or where despite their size and complexity, they are still unable to handle either the weights required or work in the space available.

The background of our own company is in post-tensioned concrete. The technology of gripping and anchoring high tensile steel cables is ideally suited to heavy-lifting. Based on this technology, a range of jacking units varying in size from single up to 37 strands, having lifting capacities of 15 Tonnes through to 560 Tonnes, and capable of automatically synchronised operation at speeds of up to 60 metres per hour, have now been developed.

The heavy lifting market is worldwide. Much of the cost of these operations has traditionally been in transport of the structural support equipment to and from site. The size of the sections frequently means that you are effectively paying for the transport of a box of air contained within a steel framework. In the Tower-Lift system we have developed an arrangement where the bracing members are all pinned to the main vertical legs so that the tower breaks down into no more than a series of tubes, which in themselves fit within standard container sizes, suitable for shipping on normal commercial vessels. All the tower legs have been fabricated with connections such that the bracings can be fitted to make either triangular or square towers depending on the capacity required. Specifically an individual square tower can carry an axial load of 1,200 tonnes with twin towers 84 metres high designed to lift loads up to 2,500 tonnes in weight.

The following descriptions are of three projects in which the Tower-Lift system was used in conjunction with centre hole lifting jacks to handle very different loads in dissimilar industries. It is very relevant to comment that the degree of difficulty of any particular lifting operation is only partially related to the weight of the load to be lifted.

PROJECTS

1. <u>Two 2500 Tonne lifting operations to facilitate fabrication of the Module Support Frames for the Brae 'A' Platform.</u>

The module support frame for the Marathon Brae Platform was designed as a tubular structural steel framework incorporating plant and equipment for the platform, with the complete assembly supported on 12 metre high tubular steel legs. To suit offshore craneage capacity the frame was constructed in two similar halves, each having a final lift weight of approximately 2500 Tonnes. Space restrictions in the Almeria yard of Dragados Y Construcciones, and the advantages of carrying out primary fabrication and outfitting at ground level led to a jack up procedure being adopted for construction of the modules. (Fig 1)

Several restrictions were placed on the design philosophy of the support structure.

Design considerations on the modules themselves necessitated lifting them from the offshore padears in the exact orientation which would be adopted by the offshore installation crane.

Any guys used to stabilise the support structure must be contained within the plan area of the structure.

The compacted ground of the site would accept a maximum bearing pressure of kkg/cm^2.

Erection and dismantling of the support structure and jacking system must not obstruct other operations concerned with the module fabrication.

The system must be applicable to the two different modules and be capable of movement from one to the other in a period not greater than 25 days.

The structure must be capable of erection and dismantling by the existing site Manitowoc cranes.

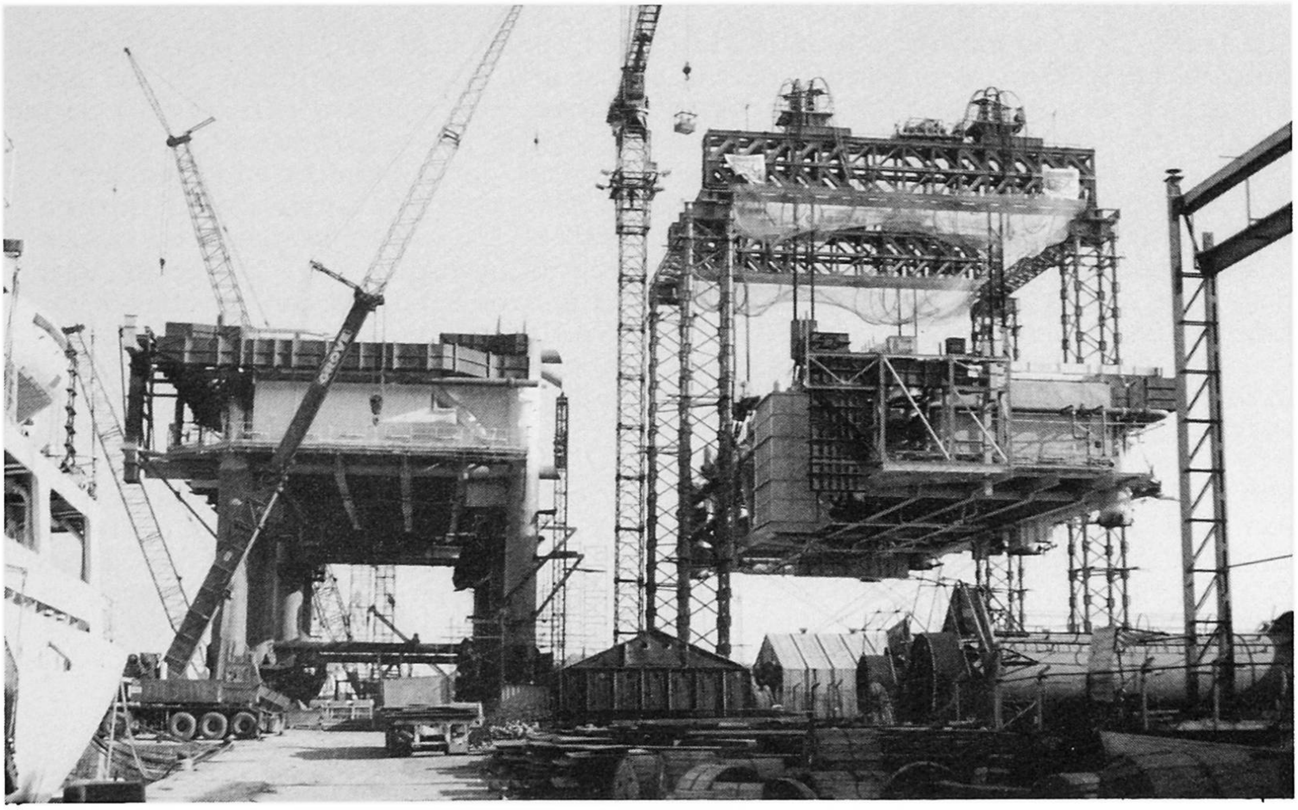

Fig. 1. Second module lifted alongside previously completed 1st module.

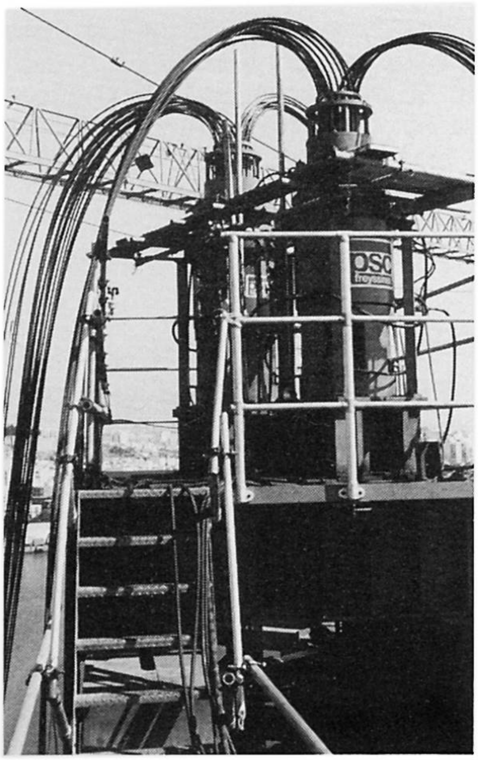

Fig. 2. Twin L600 lifting jacks.

The design arrangement chosen consisted basically of two free standing portal frames spanning across the top of the module to be lifted, and on top of which the actual lifting jacks were located. A simple prop and cross guy was provided to give stability between the portals with additional cross guys between the tower bases and the module bottom chords providing storm wind load stability in the other direction.

The Tower-Lift sections in their square format proved to have adequate capacity to accept the maximum vertical loading of 1080 Tonnes plus 30 Tonnes horizontal wind force at a free standing height of 36 metres.

Special K braced girders were designed and fabricated to span the required 30 metres across the girder to carry twin point loads of 1000 Tonnes each. The girders also had to be suitable for transport by road and capable of erection by the two Manitowoc 4100 cranes.

Location of the L600 lifting jacks on top of structure was necessary in such a way that wide positional variations were possible to allow for changes in the centroid position between the two modules. This was accomplished using a series of support beams which could be positioned to suit the particular requirements at each position. Twin jacks were provided at each of the four lifting positions with those at the heavy end of the structure fitted with 37/18 cables and those at the light end 30/18 cables. The total lifting capacity available from the eight jacks based on their normal safe working load was 4500 Tonnes (Fig. 2).

Two pairs of jacks on each of the main cross girders were powered by a single power pack capable of giving a maximum rate of lift of 6 metres per hour.

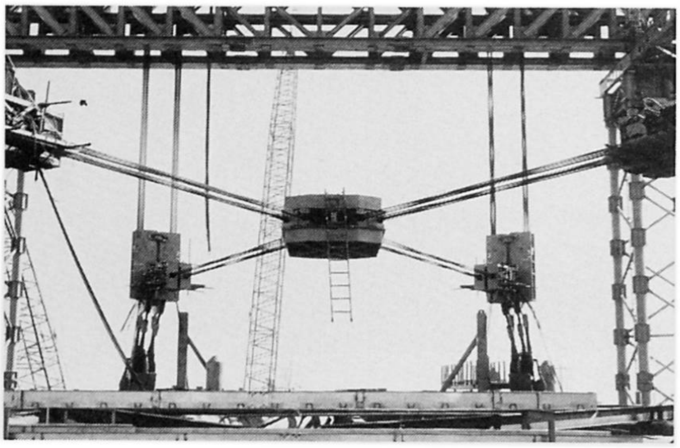

Fig. 3 Tension Frame Assembly.

Fig. 4 Three-Way Connector.

A tension frame assembly was provided to convert the vertical force from the lifting jacks into the individual reaction necessary on the main offshore pad-ears. This was assembled from four three-way connectors which formed the link between the vertical jack cables, inclined twin $5\frac{1}{4}$" diameter wire rope slings, and horizontal cables from the four positions which met at a single fabrication positioned over the module centroid. To provide full adjustment of the horizontal cables under load if necessary L180 jacks were incorporated in the three way connector assemblies (Figs 3 and 4).

Assembly of the support structure on site started at the end of November 1981 with the first actual lifting operation taking place on Sunday 31st January 1982. After installation of the four inner legs a further lift of 1.5 metres was carried out, with final lowering down onto the support pads taking place on 16th February. The centre hole jacks provided the facility to adjust the level of the structure to within 5mm for leg installation and complete support of the 2500 Tonne structure throughout the leg welding operations.

Dismantling and re-assembly of the 900 tonne structure onto the second module started immediately and was completed in 19 days to give a lift date for the second module of Sunday 7th March. The actual lifting operation for this module being completed from start to finish in a period of 4½ hours.

2. Erection of 788 Tonne 102 Metre high Ethylene Fractionator.

The ethylene fractionator for the Fife Ethylene Project has a dressed weight of 788 Tonnes, and stands 102 metres above the Scottish Countryside. For client Esso Chemical and Managing Contractor C.E. Lummus, the initial decision was whether to lift this monster vessel in one piece or erect in sections as delivered from the fabricators, with subsequent dressing in the air. To eliminate the high cost of scaffolding and because dressing the column at ground level was both safer and quicker, the decision was made to weld the five sections together and fully dress the vessel at ground level with subsequent lifting as a single unit.

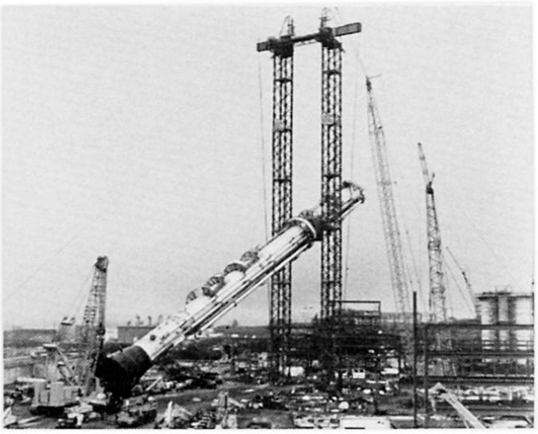

Fig. 5 Vessel Lifted 30 metres

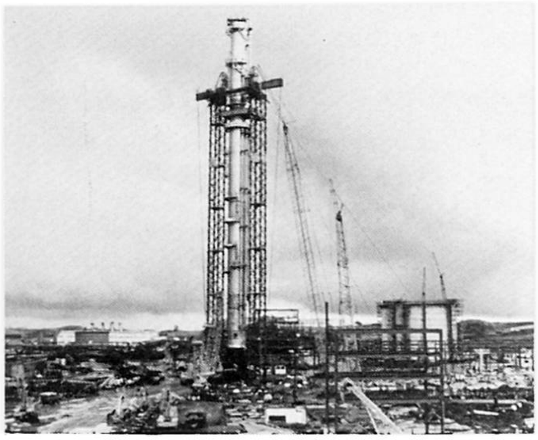

Fig. 6 Lift completed.

The position of the lifting trunnions at 72 metres above the base rather than at the top of the vessel encouraged consideration of alternative arrangements for the Tower-Lift system for this lift. The conventional arrangement of single towers either side of the vessel with the lifting jacks mounted on top of a cross-head beam spanning between the towers did not take particular advantage of the trunnion position, although was technically acceptable, with triangular format towers or square format towers satisfactory for design wind speeds of 70 m.p.h. or 105 m.p.h. respectively. To gain advantage from the trunnion position a proposal based on the use of square format towers, with the lifting jacks cantilevered beyond the inside face of the towers to directly above the trunnion position on the vessel was used, limiting the total tower height to 76 metres. The balancing reaction from the lifting jacks was resisted by tie-back cables anchoring the rear end of the cantilever beams down to the base steelwork of the tower itself. Square format towers proved to have ample capacity to accept the resulting 565 Tonnes axial force in each tower plus a design wind speed of 70 m.p.h. for the vessel at any stage of lift.

Twin 46 Tonne guy units were attached to the top of each tower and anchored back to dead men located in position to suit other site construction, no intermediate guys were required. To balance the guy forces at the tower top, a stability frame joined the towers as a horizontal portal giving adequate clearance for the vessel to lift inside the towers. A fabricated trunnion connection link and wind guide assembly was used for the direct connection onto the vessel trunnions and to transmit wind forces and reactions from the tailing-in crane into the vertical legs of the towers throughout the lift.

A further requirement on this very safety conscious project, was that the entire operation must be carried out by remote control to limit any need for personnel to be on the support structures during the lift to an absolute minimum. All lifting operations were controlled by two levers and eight selector buttons from a remote panel. Information available to the operator included actual lifting loads on the L600 jacks, jack stroke position, plus data on all secondary control systems. (Fig. 7).

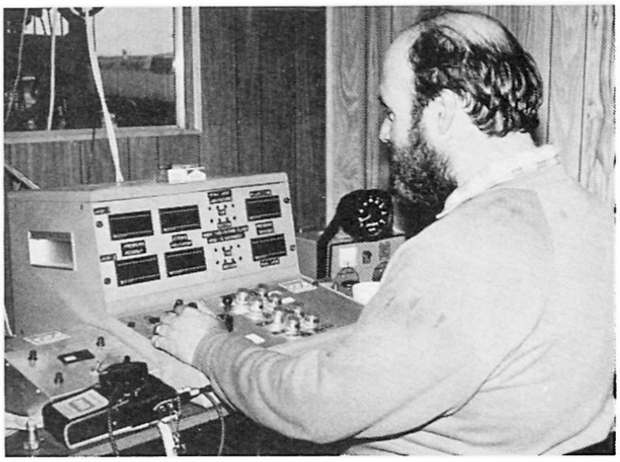

Fig. 7 Remote Control Panel.

3. Erection of Steel Superstructure of Foyle Bridge.

Foyle Bridge was the subject of a design and build competition won by the consortium of R.D.L - Graham. The winning proposal showed the main river crossing as a three span steel base girder bridge. The design was based on prefabrication of the steelwork into two sections for each of the sidespans, spanning between the abutments and cantilevering out beyond the piers into the main span, with a final two sections joining together the opposing sidespans. All fabrication would be carried out in a Belfast Shipyard, followed by barge transport to site where the sidespans would be required to be lifted into position on the pier tops, followed by simultaneous lifting of the centre span section from a barge moored on the river. Each of the sidespans had an overall length of 177m a width of 11.3m and weight of 900 Tonnes with each of the centre span sections having a length of 170m, a width of 11.3m and a weight of 690 Tonnes.

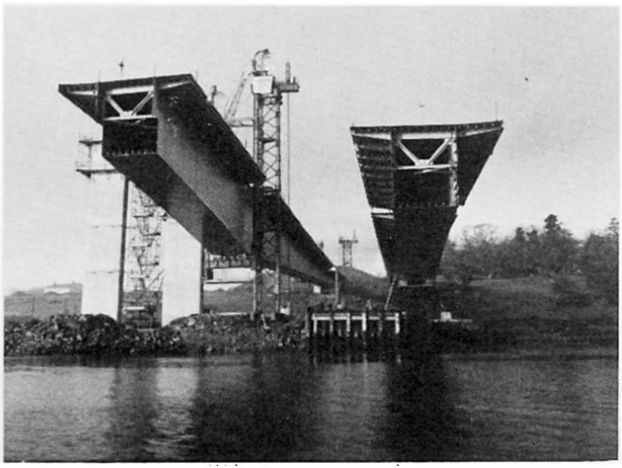

Fig. 8. Start of sidespan lifting operation

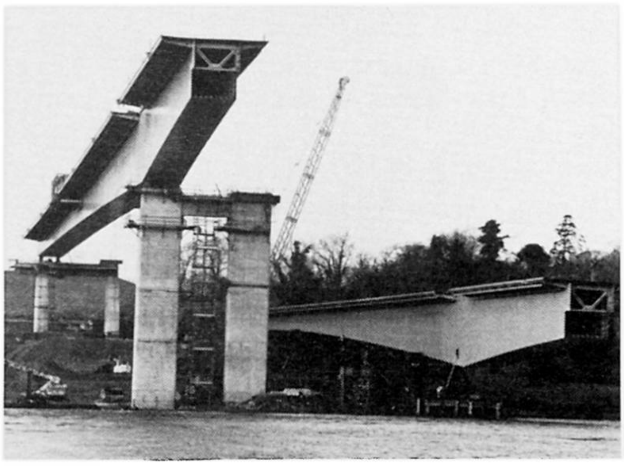

Fig. 9. Sidespan in final position

For sidespan erection the chosen solution involved the use of a triangular format tower to give support to the lifting jacks on the side furthest from the pier, with the pier side jacks mounted directly on beams clamped to the pier itself. The unguyed towers were stabilised by the use of two removable light-weight frames connected to the pier. During the lifting of the bridge the lower frame was installed to permit removal of the upper frame. Support to the bridge was achieved by the use of lifting beams slung beneath the bridge and supporting the permanent bearings directly. After lifting a stressed bolt connection between the lifting beam and pier support beams enabled the pier side jack to be removed and the section to be traversed sideways onto the pier top.

On completion of all four sidespan operations, lifting jacks were installed on the ends of the sidespan cantilevers and the centre span sections lifted simultaneously from a barge moored across the river.

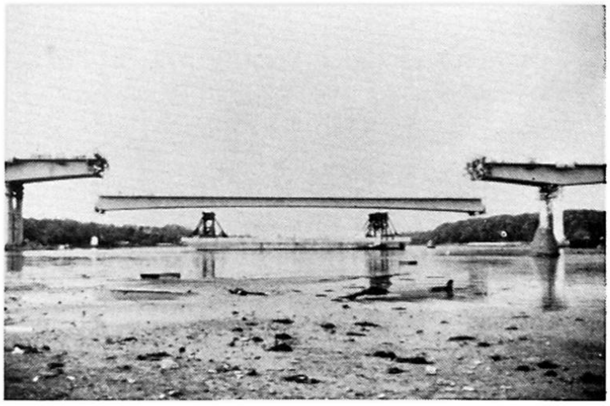

Fig. 10 Centre span lifting operation.

CONCLUSIONS

There is nothing new about pre-fabrication at ground level with subsequent lifting into position. Brunel and Telford both exploited this method of construction in the last century. The development of modern hydraulic systems coupled with the availability of heavy duty support systems has meant that these techniques can be considered, and be cost-effective, in far more general circumstances. As always the best results are achieved by discussion between designer and specialist contractor as early as possible in the design process.

ACKNOWLEDGEMENTS

1. Module Support Frames

Client : Marathon Oil U.K.
Main Contractor : Dragados Y. Construcciones.

2. Ethylene Fractionator

Client : Essochem Olefins
Main Contractor : C.E. Lummus.

3. Foyle Bridge

Client : Department of the Environment - Northern Ireland.
Main Contractor : R.D.L. - Graham.

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