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Close-Range Photogrammetry as an Aid to Measurement of Marine Structures

Photogrammetry was found to offer an accurate and rapid means for making measurements of ships and offshore platforms during construction.

Introduction

In industry a growing demand has been created for the accurate measurement of components and assemblies as new manufacturing methods, often based on numerically controlled machines, replace those which rely on human skill and judgement. In the past, where components had to be joined, holes and machined surfaces were carefully transferred from one part to the next and complex surfaces were checked out by using some form of prepared template. Nowadays the more efficient manufacturing methods result in higher productivity of components, in a variety of shapes and sizes, but quality control checks become vital to the effective functioning of an assembly system.

As a technique for quality control, photogrammetry has much to offer industry. It provides a non-contact measuring process which is capable both of recording and of measuring a condition quickly, if necessary. This paper describes work undertaken to assess the value of photogrammetry in checking components and assembly of two marine structures: fixed-base offshore platforms and ships.

The Nature of Marine Structures

Marine structures have the following characteristics:

(1) They are assembled from a vast number of components.
(2) They are large when complete—up to 400m in length.
(3) They are relatively inaccessible and it is impossible or impractical to reach all points on them following their assembly.
(4) They are heavy and may contain up to 30,000 tons of steel. This, combined with their size, makes movement and manoeuvrability a demanding operation.
(5) They are elastic and deform in accordance with their orientation, method of support, and wind forces.
(6) They are affected dimensionally by changes in temperature.

Generally the accuracy of any quality control measurements taken on component units must be better than ± 3 mm. Those taken on the structure as a whole should be accurate to ± 10mm.

Fixed-Base Offshore Platforms

In June 1975, some five years after the discovery of oil in British offshore waters, the first trickle of oil has come ashore to Britain from the Argyll Field. This trickle will gradually build up to a flood as other fields come on-stream and Britain could become self-sufficient in oil by 1982.

The development of the North Sea oilfields has created an unprecedented demand in Europe for fixed-base offshore platforms.

ABSTRACT: *This paper discusses the application of close-range photogrammetry to the measurement of two types of marine structure: fixed-base offshore platforms and ships. Examples are given, with results, of typical applications and the value of photogrammetry in the measurement of such structures is assessed.*

RÉSUMÉ: *Cet article est consacré à l'utilisation de la photogrammétrie des objets rapprochés pour mesurer des structures navales de deux sortes, c.-à-d., des navires et des plates-formes à coque submergée. Après avoir exposé des cas typiques, avec les résultats obtenus par photogrammétrie, l'auteur propose une évaluation de cette méthode de mesurer ces structures.*

ZUSAMMENFASSUNG: *Der Aufsetz befaßt sich mit der Nahbereichsphotogrammetrie und ihrer Anwendung auf die Messungen von Schiffen und unbeweglichen Objekten im Meer (z.B. Ölbohrinseln). Typische Beispiele sowie Ergebnisse dieser Anwendung werden angeführt und erörtert im Lichte der Bedeutung der Photogrammetrie für derartige Messungen.*

This has led to the birth of a new construction industry and the establishment of fabrication yards around the coasts of Britain, France, Holland, and Norway. Considering oil production platforms alone, there are, at present, 11 being installed and a further 37 in the course of construction. It is anticipated that up to 80 platforms will be in position by 1980.

Basically the steel platforms consist of two parts: a jacket, so called because it wraps around the piles which secure it to the sea bed, and a deck structure which supports the various modules containing equipment and necessary services. The two parts are fabricated separately, the deck structure and modules being installed after the jacket is transported out to its location and installed on the sea bed. In the case of a drilling platform, the jacket has horizontal panels which serve to locate and support the well conductor tubes.

Concrete platforms serve the same function as a support tower for the deck modules and the conductor wells in the case of the drilling platform, the major difference being that they are fixed to the sea bed by their self-weight, not by piling.

These massive structures are now approaching heights of 300 m as development moves into deeper waters. Each represents a multi-million pound project of up to two years' duration.

Typical of the steel jackets are the two recently completed by Brown and Root-Wimpey Highlands Fabricators Limited in Scotland for the B. P. Forties Field (Figure 1). Both jackets are of similar design consisting essentially of four main tubular legs linked by a network of tubes joined together by nodes. Internally there are a series of conductor panels which, also, serve as stiffening panels. In all, the jacket contains some 17,000 tons of steel but the reusable flotation tanks and stabilizing spheres bring the total floating weight up to 33,000 tons. The jacket is erected on the flotation tanks in a horizontal position and is up-ended through 90°, by controlled flooding of the tanks, when on site in the North Sea. It is then parted from the flotation tanks and the deck structure added. In size these jackets are about 150m in height and measure 90m × 75m at the base reducing to 40m × 35m at the deck level.

Owing to their size, weight, and complexity, the fabrication of these structures has created a number of problems in these early days. One of these has been to devise an efficient and accurate dimensional control system. Such a system is essential on a project of this kind in order to ensure a fit between components when they are lifted into position during erection. At present, dimensional control measurements are made by using conventional surveying instruments and techniques but photogrammetry is being considered as an alternative for certain units. One consortium (Brown & Root—Wimpey Highlands Fabricators Ltd) has, in fact, commissioned a feasibility study to look at photogrammetry and this has been carried out by

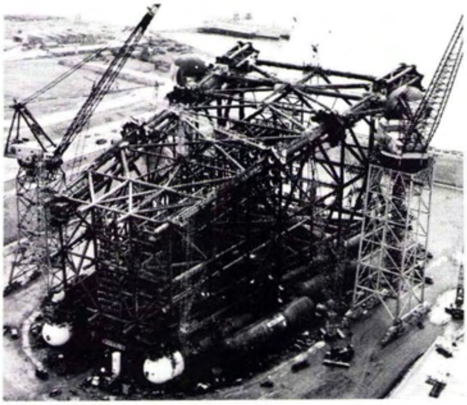


FIG. 1. A completed steel jacket awaiting the flooding of the graving dock prior to tow-out into the sea.

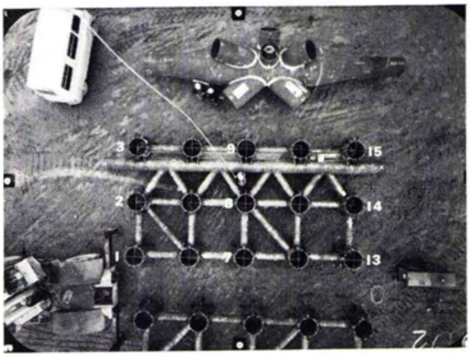


FIG. 2. Two types of steel jacket unit which have been measured by photogrammetry. In the centre is conductor panel–136E complete with strings to define the centre of each conductor guide. Above is a typical node.

Longdin and Browning (Surveys) Ltd in conjunction with the Department of Surveying, University of Newcastle upon Tyne.

In this study photogrammetry has been applied on three different types of unit:

(1) *Nodes*. These consist of a main tube, which may be up to 15m in length, from which a series of circular stubs project at varying angles (Figure 2). After fabrication, nodes must be checked to ensure that they lie within the specified dimensional tolerances. The information required to check this is the radii and roundness of the main tube and all circular stubs, the direction cosines and length of each stub. This information is derived from the calculation of the centre of each stub in the plane of its end. Such units are difficult to measure by conventional surveying techniques but are ideally suited to photogrammetric measurement. In order to cover the complete node it is sometimes necessary to take a series of stereopairs from various viewpoints.

(2) *Sub-assemblies*. These are larger in size than the nodes and are formed from several small units (Figure 2). Each sub-assembly must be checked after fit-up for completeness, and to ensure that it lies within given tolerances for overall size and to allow line-up of pile and conductor guides. As well as overall dimensions, therefore, the coordinates of the centres of all pile and conductor guides are needed. Once these coordinates are obtained, the sub-assembly may be translated and rotated in a computer into its eventual position on the main structure so as to check that it will match up prior to lifting. In this way it should be possible to eliminate the need for adjustment once erection commences.

(3) *Deck stabbing guides*. Once the jacket is complete, it is necessary to determine the relationship between the centres of the tubes which form the deck stabbing guides. These may be seen protruding from the top end of the jacket (i.e., to the left-hand side) in Figure 1. These measurements are needed so that the deck module will fit onto the stabbing guides when jacket and deck structure are united at sea. If specified tolerances are exceeded it is necessary to modify the deck structure before floating it out to sea. Photogrammetry is again ideally suited here because the stabbing guides are relatively inaccessible.

The application of photogrammetric measurement to these three types of unit marks only the beginning of its usage in this industry. Undoubtedly with time the range will be extended.

EXAMPLE—A CONDUCTOR PANEL

A typical sub-assembly is the conductor panel shown in Figure 2. This panel was measured both by photogrammetry and by conventional surveying techniques and will serve as an example to show the accuracies which may be achieved by using photogrammetry.

The panel, which measures about 13m × 6m, is composed of 15 conductor guides connected to a main tube whose axis is at right angles to the axes of the conductor guides. Preparation of the panel for measurement by conventional means had taken place by fixing strings across two diameters of each guide in order to define its centre.

Prior to photography, the ends of the main tube and conductor guides were accentuated with white chalk to allow measurement of a series of points around the outside perimeter of each guide during the analysis phase. For photo control, the distances between centres of guides 1-3, 1-15, 3-13, and 13-15 were taped.

Photography was taken with a Zeiss UMK 10/1318 camera mounted on a platform cantilevered out from the base of a personnel basket. The basket with camera operator was then hoisted by crane to a height of 12m and positioned over the panel. A stereopair was obtained by rotating the jib of the crane in order to give a base distance of approximately 4m between the exposures. This method of photography proved very satisfactory and relative tilt of the photographs was easily accommodated during analysis.

Initially the photographs were measured on a Wild A7 plotting instrument equipped with an EK5a coordinate recorder. Later, a Zeiss Steko 1818 stereocomparator fitted with digitisers was used to measure the same photographs. After taking control measurements, the following points were observed in the stereomodel: (1) the centre of each conductor guide as defined by the intersection of the string lines, and (2) at least eight points around the outside perimeter of each conductor guide.

From these measurements, the distances between centres of the conductor guides were computed. Comparisons were then made between each photogrammetric measurement and that produced by conventional means: also, the two photogrammetric measurements were compared. These results are given in Table 1. Whilst the two photogrammetric measurements show a good consistency (RMS error of ± 1.6mm), two large discrepancies of about 10mm and 15mm occurred between the conventional tape survey and the photogrammetric survey. Both of these distances were subsequently measured by tape and the discrepancies were reduced to 3mm and 5mm respectively.

By using the photogrammetric measurements, the coordinates of the centres of each conductor guide as defined by the string lines and as determined from a best-fit circle program were compared. The distances between these centres are listed in Table 2 and give a RMS error of ± 2.2mm. This indicates that it is unnecessary when using the photogrammetric method to define the centres by string lines. Table 2 also lists the radius of the best-fit circle to the eight measured points, together with the RMS error for each tube, which is a useful indicator of roundness.

SHIPS

Over the past eight years, the Department of Surveying, University of Newcastle upon

TABLE 1. COMPARISON OF THE DISTANCES BETWEEN TUBE CENTRES (DEFINED BY INTERSECTING STRINGS) AS DERIVED BY PHOTOGRAMMETRY AND TAPE SURVEY FOR CONDUCTOR PANEL –136E.

Tubes	Distance by Tape Survey (m)	Distance by Photogrammetry (m)		Differences (mm)		
		Wild A7	Steko 1818			
	1	2	3	1–2	1–3	2–3
1–4	2.4448	2.4394	2.4364	+5.4	+8.4	+3.0
4–7	2.4352	2.4342	2.4346	+1.0	+0.6	−0.4
7–10	2.4368	2.4358	2.4379	+1.0	−1.1	−2.1
10–13	2.4400	2.4444	2.4436	−4.4	−3.6	+0.8
2–5	2.4479	2.4325	2.4333	+15.4	+14.6	−0.8
5–8	2.4352	2.4342	2.4333	+1.0	+1.9	+0.9
8–11	2.4305	2.4348	2.4351	−4.3	−4.6	−0.3
11–14	2.4321	2.4329	2.4326	−0.8	−0.5	+0.3
3–6	2.4368	2.4361	2.4350	+0.7	+1.8	+1.1
6–9	2.4321	2.4298	2.4328	+2.3	−0.7	−3.0
9–12	2.4448	2.4477	2.4482	−2.9	−3.4	−0.5
12–15	2.4368	2.4417	2.4396	−4.9	−2.8	+2.1
1−2	2.4352	2.4316	2.4328	+3.6	+2.4	−1.2
2–3	2.4305	2.4294	2.4305	+1.1	0.0	−1.1
4–5	2.4384	2.4391	2.4371	−0.7	+1.3	+2.0
5–6	2.4162	2.4140	2.4164	+2.2	−0.2	−2.4
7–8	2.4384	2.4379	2.4396	+0.5	−1.2	−1.7
8–9	2.4321	2.4230	2.4217	+9.1	+10.4	+1.3
10–11	2.4416	2.4371	2.4377	+4.5	+3.9	−0.6
11–12	2.4273	2.4221	2.4212	+5.2	+6.1	+0.9
13–14	2.4305	2.4333	2.4327	−2.8	−2.2	+0.6
14–15	2.4273	2.4325	2.4301	−5.2	−2.8	+2.4
		RMS error		±4.9	±4.8	±1.6

TABLE 2. COMPUTED RADII AND RMS ERRORS OF THE BEST FIT CIRCLES TO THE MEASURED POINTS TOGETHER WITH THE DISTANCES BETWEEN DERIVED AND MARKED CENTRES FOR EACH TUBE.

Tube	Computed Radius (mm)	RMS error (mm)	Distance Between Derived and Marked Centre (mm)
1	430.9	±1.0	2.5
2	430.6	±1.0	2.9
3	430.2	±1.3	5.1
4	430.8	±0.7	0.4
5	430.7	±0.7	1.4
6	430.1	±1.5	2.0
7	430.8	±1.1	1.3
8	430.5	±1.0	1.4
9	431.1	±1.9	2.4
10	430.9	±0.7	0.9
11	431.6	±1.0	1.7
12	431.7	±2.0	0.9
13	431.6	±1.1	2.3
14	431.2	±1.4	1.8
15	432.1	±1.0	0
			RMS error ±2.2

Tyne and the British Ship Research Association (BSRA) have collaborated to examine the feasibility of adopting photogrammetric techniques as an integral part of the shipbuilding production process.

At the present time, two important developments are taking place in the ship production process. First, with the consolidation of shipyards into large groups, it has been possible to concentrate production of units in fabrication shops which may be some distance away from the yard where the ship is being erected. A further stage in this development is the construction of part-ships in one or more yards for final joining afloat or in dry-dock. This building technique has already been used by the AKER group in Norway where part-ships were built by the Bergen Mekeniske Verksteder shipyard, launched, and then towed to the Stord Verft shipyard, some 50 km. away, for joining to the remaining part-ship under construction at Stord.

The second development is due to the increase in the size of ships, in particular tankers, beyond the capacity of many existing berths and building docks. The ship must then be built as two sections in series on the berth and then welded together when afloat. This method has been successfully employed by the Nederlandsche Dok en Scheepsbouw Mij. in Holland and, more recently, by the Scott-Lithgow Group in Britain, who have adopted it as practice.

Both of these developments have created a demand for rigorous checks on quality control at all stages of production in order to maintain an efficient hull assembly process. To meet this demand, new techniques are being considered for acquiring quality control measurements. One of these techniques is photogrammetry.

Discrepancies, though usually small, frequently occur between the design and as-built dimensions of units and sub-assemblies. Where adjoining units are being fabricated in the same shop and close to the berth, the checking of the as-built dimensions of each structure and its relationship to the adjoining structure is fairly simple and has created few problems. Procedures for the feedback of information from berth to fabrication shop can be established so that the dimensions of subsequent units may be adjusted at the time of manufacture.

When fabrication is in shops remote from the berth, any checking and, if necessary, modification must be done before the structure is moved to the berth. In this way minimum time and effort are expended on the rectification of errors during the erection process.

The use of numerically-controlled machines for cutting steel plate has improved the dimensional accuracy of units and sub-assemblies. Nevertheless it is still necessary to check them to see that they meet given accuracy requirements. Further, any checking must be done as swiftly as possible so that no delays occur in the erection process due to the non-availability of particular units. Photogrammetry, with its ability to measure accurately in three dimensions and to record rapidly a condition with little disruption to production work, would seem ideally suited to this task.

The units and sub-assemblies in shipbuilding are of similar size to those mentioned in the previous section on fixed-base offshore platforms and the accuracy of measurement required is comparable. Consequently the units may be photographed, controlled, and measured in exactly the same way as those of the fixed-base offshore platforms. To date, many units and sub-assemblies have been measured photogrammetrically. Typical of them is the bulbous bow unit (Figure 3) where discrepancies of up to 30 mm were found between the design and as-built dimensions.

The problem of ensuring equivalence of adjacent units becomes even more acute when attempting to join complete half-ship units when afloat and in tidal waters subject to inclement weather. The need for any fairing during the joining operation must now be eliminated as far as possible so that the welding together of the two halves may be expeditiously carried out. To achieve this, a comprehensive record of every part of the mating face prior to launching must be made. Since the first half-ship will have been launched prior to erection of the second, no adjustments are possible on it. Following measurement of the second half, however, modifications may be made to ensure a perfect match with the first half before it is launched. This is again a situation ideally suited for photogrammetric measurement and a trial has been conducted to assess the dimensional equivalence of the mating faces of a supertanker.

The application of photogrammetry in the hull assembly process is just one of many existing, or potential, applications in the shipbuilding industry (Weinert, 1969). The additional applications fall into three main categories:

(1) Applications involving the measurement of models in order to obtain constructional (full size) dimensions. An example is the work reported by Smith (1971) on models of engine room arrangements.

(2) Applications concerned with the measurement of transitory conditions, usually in association with model experiments. For example, the wave patterns around a ship during towing trials may be conveniently measured photogrammetrically.

(3) Applications to determine the accuracy of blanks, moulds, and end products in the manufacture of ships' propellers (Knodler and Kupke, 1974).

EXAMPLE—A SUPERTANKER BUILT IN TWO HALVES

The first vessel in the history of British shipbuilding to have been built by the half-ship construction technique was launched in 1973. This ship, a 258,000 ton deadweight tanker, is 345 m long. The stern section (length 214m) was built first and launched. It was joined to the bow section (length 131m), built on the same berth immediately afterwards, some 10 months later.

In order to ensure the success of the joining operation, it was essential to assess the dimensional equivalence of the mating midship faces which measured 50m in width by 30m in height (Figure 4). To mark off the leading edge of each section to form a datum plane, which was perpendicular to the ship's centreline and lay in the plane of declivity of the ship, a proven laser beam technique was used by the shipbuilders. Following this, an accurate record of the hardspots lying in this datum plane was needed. The hardspots were taken as the intersections of each longitudinal or longitudinal bulkhead with the shell plate and totalled 234 points for each midship face. The coordinate system adopted is shown in Figure 5.

With little experience in the half-ship construction technique, the shipbuilders were anxious to obtain as many measurements as possible on each half by a variety of methods.

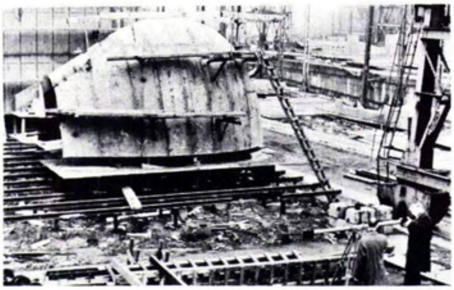


FIG. 3. The bulbous bow unit of a ship being photographed with Galileo-Santoni Type A stereocamera on a 2m base bar.

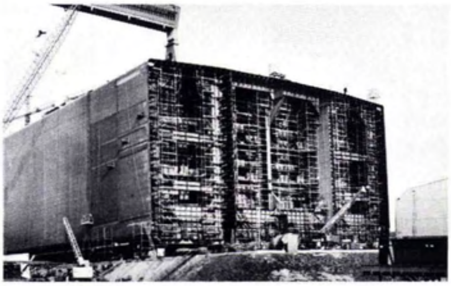


FIG. 4. The midship section of the stern portion of the supertanker.

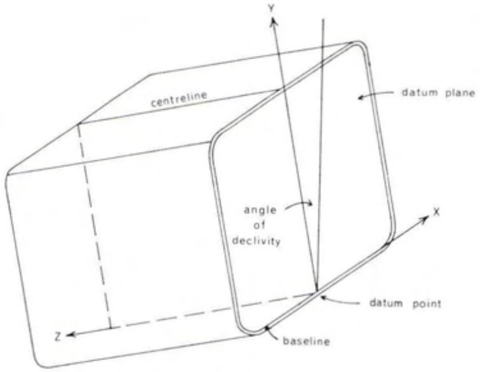


FIG. 5 The coordinate system adopted for measurement on the midship section.

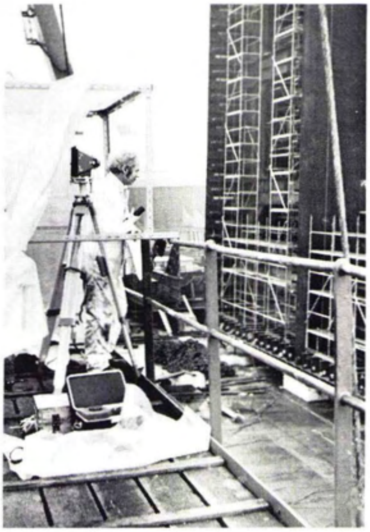


FIG. 6. The Galileo-Santoni metric camera in position on the camera platform whilst photographing the bow portion of the supertanker. This platform is suspended from the Goliath crane.

As a result, photogrammetry was added to the methods used on this ship.

The photography was taken using a Galileo-Santoni Type A stereometric camera (f = 150mm, format 130mm × 180mm) detached from the supporting base bar and held in a special mounting head with the greater format dimension vertical (Figure 6). A camera to subject distance of 16m was selected in an attempt to achieve the desired accuracy of ± 3mm for the X and Y coordinates. From this distance two strips, each containing thirteen photographs, were needed to cover the midship face after allowing for the usual overlaps.

The only practical way to gain the necessary height for the camera stations of each strip (7m and 20.5m above the base of the ship) was to position the camera on a platform suspended from the Goliath crane which straddles the building berth. This created photographic problems owing to the continual movement of the camera platform. A viewfinder was fitted to the camera and guide lines positioned on the section, to indicate the coverage required for each photograph, in an effort to overcome these problems.

Because of the continual demand for this crane during the working week and for other operational reasons, each midship face was photographed during a rest weekend when virtually complete and awaiting launch. Photography of the stern section was taken two weeks before launching but the bow section was photographed 11 weeks prior to launch so as to allow time for any modifications. On both occasions the weather on the days made available for photography was far from ideal.

A number of points on the face were targeted prior to photography to serve as photo control. The points were later coordinated from angular measurements taken with a Wild T2 theodolite from survey stations at the ends of a baseline running at right angles to the ship's centreline. The baseline was measured with a Tellurometer MA100. The control point positions were selected so as to give a good distribution throughout each strip and to allow adequate joining of the strips.

Analysis of the photography was carried out on a Wild A7 plotting instrument equipped with EK5a coordinate recorder. For each strip, a strip triangulation was performed by the method of independent models (AIM). Natural detail points occurring on the structure were used as pass points. Since the final form of the measurements was a set of coordinates of the hardspots lying in the plane of the midship section, it was possible to measure these points on each model at the same time as the triangulation was progressing. Each model had, therefore, only to be set up once and the as-built coordinates of the hardspots were output along with the control and pass points following strip adjustment. A block adjustment was not applied and mean coordinate values were accepted for all hardspots in the lateral overlap of the strips.

The results indicate a RMS error of ± 6mm in the X and Y coordinates as derived by photogrammetry. Plate 1 is a plot showing the shape of the as-built midship sections superimposed onto the design section. This plot was drawn by using an automatic draughting machine which was programmed to exaggerate by a factor of 10X any difference between as-built and design coordinates of each hardspot in the critical direction (i.e., the *X* coordinate difference for the side shell and longitudinal bulkheads and in *Y* for the deck and bottom shell). In this way discrepancies between the mating faces are more readily seen.

The maximum discrepancies found were of the order of 30mm and the RMS error for the whole section was ± 11mm. Generally the larger errors occurred in those parts of the structure where some flexibility remained, such as along the longitudinal bulkheads. In those parts which were submerged during the joining operation and where fairing would be difficult, the errors were much smaller. The shell plate itself is 25 or 30mm thick and errors of this order were acceptable.

Because of the rapidity with which the joining operation was carried out, due largely to the high quality of the match, it was difficult to check actual discrepancies against those predicted by photogrammetric means. However, at those few locations where a check was possible the discrepancies were confirmed to within a few millimetres.

This trial has successfully demonstrated the feasibility of using photogrammetry to assess the equivalence of the mating faces of a ship built in two halves. The accuracy of measurement achieved, whilst not as good as that planned for, was acceptable in this instance and is probably within the required tolerances for measurements of this nature. Improvements in accuracy could be expected with modifications to the technique. More detailed accounts of this trial are reported elsewhere (Newton, 1974; Jack, 1974).

THE VALUE OF PHOTOGRAMMETRY

The advantages to be gained from the use of photogrammetry in the measurement of marine structures may be summarized.

(1) Photogrammetry allows separation of the data acquisition and data processing phases. As a result, the on-site time is reduced to a minimum and amounts only to the time needed to carry out the photography and control survey. In the case of each half-ship the on-site time amounted to two days, of which one-half day was spent on photography. For a unit of a fixed-base offshore platform the on-site time may be as little as three hours (two hours preparation and one hour photography) whereas direct measurement of the unit would take at least twice that time.

(2) Because of the reduction in on-site time and because photogrammetry is a non-contact measuring technique, there is little or no disruption of production. Photography is a relatively quick process and good use may be made of rest weekends and lunch breaks for the purpose.

(3) Objects difficult to survey by conventional techniques may be measured with ease by photogrammetry. In comparison, direct measurement appears as a time-consuming, less accurate and, on occasions, physically dangerous activity.

(4) Considerable savings in erection time should be possible if the fit-up of a unit or sub-assembly can be guaranteed, by photogrammetric measurement, prior to lifting it into position. This should result in shorter production times and, also, in financial savings.

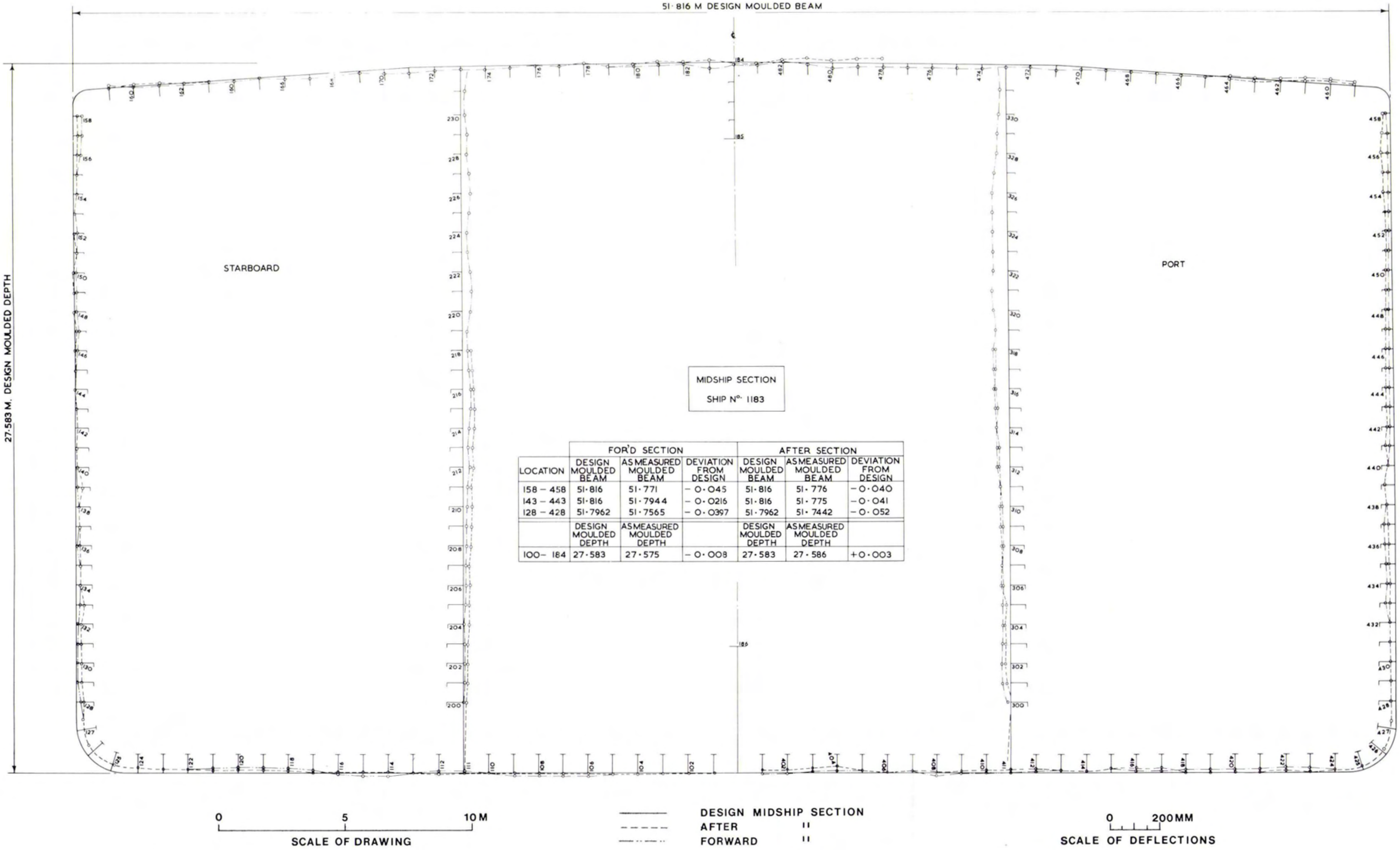
(5) Photogrammetry provides a permanent record in the form of photographic plates of the as-built dimensions of the structure. These plates may be remeasured at any time in the future if a need arises.

Against these advantages must be weighed the following disadvantages.

(1) The measurements of such structures are usually required quickly. This creates few problems from the photographic point of view but inevitably there is then a delay whilst the photography is returned to the photogrammetric organization for measurement. If photogrammetry is to be useful as a quality control aid on individual units of marine structures, a maximum turn-around time of 24 hours must be considered. This virtually means that the measurements must be carried out on-site. To do this, the individual organization must set up its own measuring laboratory or the photogrammetric organization must be equipped with a mobile laboratory.
In the case of half-ship sections, the urgency is not so great. If the measurements are available within a week of photography this should allow ample time for any modification.

(2) The high capital cost of equipment and the need for trained personnel to operate it make the establishment and running of a photogrammetric unit expensive. Savings in manpower and production times must be possible to justify this expenditure.

(3) In many applications there is a lack of flexibility in the time of photography. This may mean that photography has to be taken in conditions of poor light, high winds, or even rain, with detrimental effects. Once photography is taken, however, photogrammetric measurement is virtually independent of the weather.



	FOR'D SECTION			AFTER SECTION		
LOCATION	DESIGN MOULDED BEAM	AS MEASURED MOULDED BEAM	DEVIATION FROM DESIGN	DESIGN MOULDED BEAM	AS MEASURED MOULDED BEAM	DEVIATION FROM DESIGN
158 – 458	51·816	51·771	– 0·045	51·816	51·776	–0·040
143 – 443	51·816	51·7944	– 0·0216	51·816	51·775	–0·041
128 – 428	51·7962	51·7565	– 0·0397	51·7962	51·7442	–0·052
	DESIGN MOULDED DEPTH	AS MEASURED MOULDED DEPTH		DESIGN MOULDED DEPTH	AS MEASURED MOULDED DEPTH	
100 – 184	27·583	27·575	– 0·008	27·583	27·586	+0·003

PLATE 1. A plot showing the as-built stern and bow midship sections as measured by photogrammetry superimposed upon the design section.

CONCLUSIONS

Photogrammetry has been shown to provide a technique for dimensional quality control of marine structures which will give the necessary accuracy. The attraction of the technique undoubtedly lies in the fact that the recording can be undertaken in a short time with minimum disruption to production work. The lack of flexibility in the time of photography, the need for quick results and the cost may, however, hinder its adoption.

To date, any evidence of this has been to the contrary and it is pleasing that, as a result of the feasibility studies outlined in this paper, further developments have taken place. Brown and Root-Wimpey Highlands Fabricators Ltd. have now set up their own photogrammetric unit to measure the units and sub-assemblies of fixed-base offshore platforms. The unit is equipped with a Zeiss UMK camera and Steko 1818 stereocomparator. The stereocomparator is fitted with Whitwell digitisers and is interfaced to a Wang 600 minicomputer for the computational work (Figure 7).

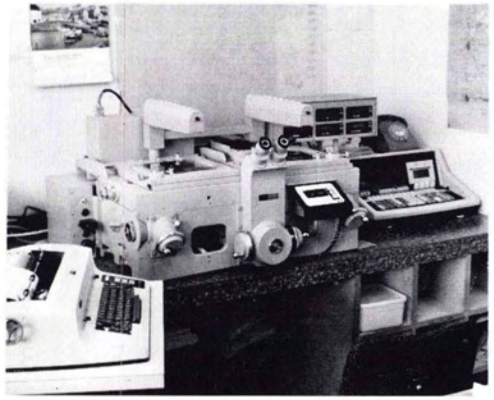


FIG. 7 The Zeiss Steko 1818 stereocomparator fitted with Whitwell digitisers and interfaced with a Wang 600 mini-computer at Highland Fabricators Ltd.

Photogrammetry also is being used on a second supertanker under construction by the half-ship technique.

In spite of these developments there is still further work to be done. So far no account has been taken of the behaviour of such structures when subject to temperature changes. Further, the post-launch changes in shape have not been analyzed. It is hoped that studies in these directions will be possible in the future.

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