CONSTRUCTION DURING WORLD WAR II: MANAGEMENT AND FINANCIAL ADMINISTRATION

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A recent report on the teaching of construction history in Britain identified that there were few formal lectures at either undergraduate or postgraduate level. The vast re-armament and war production programmes of 1936 and onwards to 1945 required building and civil engineering construction on a scale, and at a speed, not previously undertaken. The aim of this research is to identify the government controls and the types of projects undertaken during this period and to investigate the role of the quantity surveyor and the relevant payment procedures. The research is reinforced with a detailed case study of the 'Mulberry Harbour' – one of the greatest construction and organisational achievements of the 20th century. The research is confined to published literature, initially difficult to locate, and much of which at the time was subject to the Official Secrets Act. The investigation has identified that all construction projects during WWII were subject to stringent controls by the British Government. A vast range of major construction works including ports, factories, airfields, barracks and military defences were executed during a period of severe shortages of skilled labour, materials and construction equipment. Payment methods to the contractors were initially based on target cost contracts and subsequently replaced by lump sum prices based on known norms incorporated into the Standard Schedules of Prices. Despite comprehensive control systems, national shortages of labour materials and plant the U.K. construction industry rose to the challenge during WWII and completed some remarkable projects – not least the Mulberry Harbour.

Keywords: construction history, Mulberry harbour, payment system, World War II.

INTRODUCTION

A report on the teaching of construction history in Britain identified that there were few formal lectures at either undergraduate or postgraduate level (Addis 2004:11-21). The report identified that the core curricula published by the Joint Board of Moderators, which accredits many engineering courses, now require them to include some input on the history of the subject.

The vast re-armament and war production programmes of 1936 and onwards required civil engineering construction on a scale, and at a speed, not previously undertaken. These huge projects were undertaken for the Admiralty, the War Office, the Air Ministry and the Ministry of Supply, often under the utmost security. The work was usually executed by civilian civil engineering contractors in collaboration with and under the direction of military personnel including the Royal Engineers. Critically the projects were executed during times of acute shortages in skilled labour, supervisory and administrative staff, key materials and lack of equipment.

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The objectives of this research are to identify the government controls and the types of projects undertaken during this period and investigate the role of the quantity surveyor together with the relevant payment procedures. The objectives will be reinforced in the case study examination of the 'Mulberry Harbour' – one of the greatest construction and organisational achievements of the 20th century.

GOVERNMENT CONTROLS

During this period the UK Government implemented severe measures of control on the building and civil engineering sectors including:

- A restriction of civil building – under the Defence Regulations of 1940 any private building work over £500 (£15,000 at 2008 prices*) could only be carried out with approval from a Government Department or with a licence from the Ministry of Works. The £500 limit was later reduced to £100 (£3,000) and in the London area to £10 (£300).
- Registration of contractors by the Ministry of Works as from 1941.
- Use of Ministry of Works Standard Schedule of Prices with contractors quoting on or off percentages for fixed price contracts.
- Payment by results to labour - became obligatory following the Essential Work (Building and Civil Engineering) Order 1941.
- Control of employment – under the Control of Employment Act 1939 carpenters, joiners and bricklayers were directed to undertakings where they were most needed; the following year the Emergency Powers (Defence) Act 1940 enabled the Minister of Labour to issue a number of Essential Works Orders under which employees on scheduled construction sites could no longer leave or be dismissed but in turn received guaranteed wages including overtime and bonus payments based on results.
- Control of building materials, including timber, steel, cement, tarmac, bricks and roofing materials through a Central Government Works and Building Priority Committee.
- Control of contractor's plant and allocation of new plant – in 1941 the Minister of Works made an Order under Defence Regulation 55 for the control of rates of hire of plant (this created a standard plant hire rate schedule which was particularly relevant in case of cost plus contracts). The provision of new plant, including spares, was controlled by the Ministry of Supply in conjunction with the Ministry of Works to whom contractors had to apply for permits to purchase.

"Most of these controls…. were still in force when the war ended." "Their character was not negative; on the contrary, their underlying purpose was to free the Government building programme from all extraneous impediment and competition. To harness all resources of the building industry to a grand strategic plan was the common objective of so many varied measures" (Kohan 1952:195). Smyth (1985:103) identifies how the U.K. construction industry rose to the challenge and was transformed during WWII, with a select band of large and expanded contractors increasing their workload by diversifying into large civil engineering projects, other engineering projects, open cast mining as well as more conventional construction work.

TYPES OF PROJECT

During WWII many major building and civil engineering projects were executed for the U.K. Government Ministries including: Admiralty – dockyards, naval bases, deep water military ports, docks and harbours, underground storage depots, oil storage facilities, floating docks, a hundred miles of sea defences including sea forts in the Thames and Mersey estuaries, and a huge causeway at Scapa Flow in the Orkneys; War Office – military barracks including the 49.9m. (£1.5bn.) accommodation, hospitals and stores for the American forces (codenamed 'Bolero') and hundred miles of inland stop defences; The Air Ministry – new airfields, factories, repair yards; Ministry of Supply – Royal Ordnance factories; Ministry of War Transport - transport systems - roads, railways and bridges.

Underground factory

In 1943 contractors Alfred McAlpine were approached by The Ministry of Aircraft Production to undertake their biggest job to date – a huge £7 million (£210m.) underground factory for the Bristol Aeroplane Company at Corsham in Wiltshire.

"The vast undertaking required the recruitment of an army of 10,000 workers, most of whom were accommodated in prefab huts in eight camps with canteens and all other amenities including a cinema, and of course a number of bars: McAlpines could not let such an army of workers – many of them Irish and heavy drinkers – loose on surrounding towns and villages" (Gray 1987:35).

"And it was a long day. After Dunkirk, construction workers were instructed to work twelve by seven, that is to say a twelve-hour shift seven days a week. They were paid overtime for the long hours, but that was the official standard shift and, of course, as a matter of pride all the site agents and management personnel worked exactly the same hours or even a bit longer, and some of them cracked under the strain" (Gray 1987:37).

Munitions factories

In October 1939 Bovis were awarded a contract to build the Swynnerton munitions factory in the Staffordshire countryside. This huge project on a 1,000-acre site was at the time Bovis's largest. At its peak 11,500 people were employed on site with 50 general foreman and over 100 architects and draftsmen to translate the original pencil drawings into proper drawings. Due to the acute labour shortage Bovis established a training school for women where they were taught bricklaying, carpentry and painting skills. The initial estimated cost of the Swynnerton munitions factory was £5million (£150m) however the final cost which included new hostels for the munitions workers was £13.6million (£408m) (Cooper 2000:68).

Airfields

During the years 1939 to 1945, four hundred and forty-four Royal Air Force airfields were constructed in the United Kingdom with paved runways, perimeter tracks, and hard-standings. During the peak construction year of 1942, with a labour force of sixty thousand men, new airfields were being turned out an average rate of one every 3 days in addition to sixty-three major extensions to existing stations (Hudson 1948:5).

The whole of the airfield projects were planned administered and supervised by engineering and technical staff operating directly under the Directorate General of Works of the Air Ministry, with the construction work carried out by British contractors. In the early stages of the war programme, the Air Ministry were far-

sighted enough to select and encourage several major contractors – W&C French, John Laing, Robert McAlpine and George Wimpey. It was on the foundation of these contractors that the airfield construction was based and from which grew a contracting army. Overall in the five years of war, one hundred and thirty six contractors were engaged on a total of eight hundred separate contracts ranging in value from £25,000 (£750,000) to over £3.5m (£105m.) "Six contractors between them, carried out one hundred and ninety-six contracts of major value" (Hudson 1948:44).

These projects required large earthmoving operations, on average involving 500,000 cubic yards of earthworks but on special sites up to 3,000,000 cubic yards. By 1942 this vast operation was utilising heavy American plant of the crawler, tractor and scraper type together with British equipment. The paved runways were mainly constructed using concrete paving with or without asphalt or tarmacadam surfacing.

In all cases the necessary war-time controls of materials, plant and labour made the site planning and programme of work very much the concern of the Air Ministry. Furthermore, as contractors, particularly smaller firms, were unable to obtain the total plant required for the airfield work by 1944 the Air Ministry had become holders of considerable quantities of construction plant obtained under Lend-Lease or by allocation controlled by a Central inter-Departmental Committee. The Air Ministry holding included, but was not limited to 360 tractors and bulldozers, 250 excavators, 34 scrapers, 406 rollers, 5,300 tipping lorries, 220 dumpers, 150 concrete mixers, 500 power pumps (Hudson 1948:45).

THE ROLE OF THE QUANTITY SURVEYOR

During the Second World War quantity surveying was a reserved occupation from the outset and in 1939 firms of quantity surveyors were appointed by the army to supervise both the execution of works and establishing the costs of the cost plus contracts under which hutted camps were required to house the military (Nisbet 1989:132). From the beginning of and throughout the war there was a quantity surveying division in the War Office, Directorate of Fortification and Works. In 1926 the Royal Engineers had established the post of Surveyor of Works who was a commissioned officer. These were assisted and supported by civilian staff of quantity surveyors and technical assistants. By 1939 there were about 54 Surveyors of Works and at their peak the number rose to about 280 with about 300 assistants, many served in the Middle East, India, Iraq and Italy (Nisbet 1997:143).

PAYMENT SYSTEMS

The price to paid by the owner in construction contracts during World War II was usually determined by a variation in one of two ways: by a 'fixed price' or a 'cost plus' contract.

Fixed Price Contracts

Fixed price contracts might include the following variations:

- Lump sum contracts – no quantities prepared, builder responsible for carrying out works shown on the drawings and specification; might be single sum or aggregate of various prices for different items of work.
- Bill of quantities – based on fully detailed quantities prepared by client's quantity surveyor to which builder inserts prices; most widely used in normal times.

- Schedule contracts – based on a schedule either prepared ad hoc for the job or contained in a printed price schedule published by one or other of the Government departments.

Cost Reimbursement Contracts

Cost reimbursement contracts were used where the character or scope of the work was undetermined at the time of the contract, where time was not available for the preparation of the particulars, and also where the builder might be unwilling to give fixed prices for work having regard to fluctuations in the cost of materials, wages or output of labour (Kohan, 1952:469).

Cost reimbursement contracts could take the following forms:

- Cost plus percentage contracts – the fee paid to the contractor was an agreed percentage of the actual cost of the building, as ascertained after the building was completed. This was the quickest way of arriving at an agreement and avoiding delay. It was the standard method of dealing with repair of bomb damaged property. However higher costs meant higher fees so there was no incentive for efficiency.
- Cost and fixed fee – fixed lump sum fee agreed between the architect/engineer and the contractor calculated based on the estimate of the cost. Whatever the ultimate cost the contractor received this exact sum (subject only to allowances for any agreed variations).
- Value cost contracts – normal fee was calculated as a percentage of a careful valuation of the work actually done, made on the basis of agreed schedule of prices. If the final cost was below the valuation then the fee was increased and vice versa. The contractor then had a definite financial incentive to economy. Kohan 1952:470 noted that "The value cost method was considered appropriate only for use by large organisations with highly competent staffs (sic) who have continuous programmes of work to carry out."

The Simon Committee Report 'The Placing and Management of Building Contracts' considered that the cost plus percentage approach was "unsatisfactory and undesirable and should only be used where the work is undetermined, or is of utmost urgency, and care should be taken to employ only reputable contractors with the provision of effective supervision on behalf of the building owner" (M.O.W. 1944:14)

"During the rearmament period and for the first year of the war the use of cost plus contracts had been more widespread than could be justified in principle cannot be denied. War Office experience of militia camps had been unfortunate, and could be justified only by the extreme urgency in the circumstances which called the camps into being." As a typical example, five camps, to accommodate 50,000 militia, had been estimated to cost £7.5 million (£225 m) but had actually cost £16 million (£480m) (Kohan 1952:475).

Target cost was used regularly in the Second World War in order to achieve speed of construction by letting contracts as soon as possible and proved financially more robust than its predecessor, cost plus. In 1944 the Simon Committee Report confirmed this approach stating "We have no hesitation in saying that a contract in which the normal fee is based on an estimate of cost but fluctuated in inverse ratio according to whether the cost exceeds or is less than that estimate, is the best type of cost reimbursement contract known to us" (M.O.W. 1944:36).

John W. Laing himself took a leading part with the Ministry in developing a system of target costing for wartime airfield contracts, in which his thinking on production bonuses for his own employees is clearly in evidence. "The system was crude at first, and plainly depended for its effectiveness on the accuracy of the original targets, but as experience was gained it became possible to replace the target by a price based on a known norm and a schedule of quantities. Other queries obviously arose, relating to such items as whether maintenance of non-mechanical plant was included in the set cost or was extra, or how standing time for mechanical plant should be treated, and the system led to the Ministry itself being closely involved, through its surveyor, in the actual running of contracts. Continuous costing was necessary, and the long years of John Laing's development of his own contract-costing techniques began to contribute effectively to the wider national interest" (Coad 1979:153).

Payment by Results

Following the introduction of the Essential Work (Building and Civil Engineering) Order of 1941 the Government made it obligatory for all undertakings or sites listed to introduce a system of payment by results for workers. Targets of outputs were fixed for specified operations, and bonuses, shared in a stated proportion between foremen, craftsmen and labourers, were paid if the targets were exceeded. Introduced at first for excavations, concreting and bricklaying, the scheme proved effective and was extended to other operations, though not to permanent housing. "The Mulberry Phoenix components and airfield construction were among the successful applications of the scheme, which thus made an important contribution to victory" (Coad 1979:162).

Standard Schedules of Prices

In 1939, with the urgency for re-armament, the usual lengthy procedures of competitive tendering that normally insisted on by Governments became impractical and discussions took place between the leaders of industry and the Air Ministry over alternative methods. During 1939-1945 the use of bills of quantities was largely abandoned by government departments as a result of the urgent needs of the services and wartime requirements. They were replaced by various types of contracts based on prime cost and schedule of rates (Nisbet 1989:37). This is confirmed by Cooper 2000:73 who states "Initially bills of quantities were replaced by prime-cost contracting but in 1941 Government policy shifted towards lump sum awards. However, in practice there was usually no time for the tendering process, and the authorities appointed the contractor on the basis of an agreed schedule of rates. The final lump sum did not generally emerge until completion of the project."

The letting of fixed price contracts was made easier by the use of the Ministry of Works Standard Schedule of Prices, a list containing prices of work in each of the customary trades. Kohan 1952:146 confirms that "A small committee worked out the actual cost of work based on an efficient contractor applying the system of payment by results and including all profit and overheads etc." Such prices were fixed with reference to stated rates of pay for tradesmen, labourers and navvies, and to basic prices of principal materials. Using these constants, with various allowances, rates were built up to ensure uniform overhead charges and profit in each trade. The schedule was then used for the pricing of bills of quantities to be issued to contractors as a basis for tenders quoting on or off percentages. It could also be used where no bill of quantities were prepared, but where a bill of preliminaries or some similar arrangement was made to cover charges. "Several departments used schedules of this

sort freely during the war in order to enable them to place work promptly before particulars had been worked out and, therefore, before a bill of quantities in its proper sense could be prepared" (Kohan 1952:469).

In these ways the Schedule obviated the use of cost plus form of contract for specified categories of work and simplified the preparation of bills of quantities. The Schedule became universally used and was an effective check on prices. "A contract could be let without plans simply by a contractor quoting plus or minus against the Schedule of Prices. Its use was a powerful force in extending payment by results, because the prices could not be achieved without payment by results" (Kohan 1952:146).

In modern times, Chanter and Swallow (2007:227) identify that the former Property Services Agency (PSA) of the DoE made great use of a standard pre-priced schedule with the work measured at completion, or interim stages, by using the relevant rates. It is noted that a version of this procurement arrangement is still in use today by Wolverhampton City Council for minor repairs to social housing. Chanter and Swallow (2007:228) concur that schedule contracts do fulfil a useful role for many types of maintenance contracts.

However, Chanter and Swallow (2007:228) identify a number of reasons why the process of allowing contractors to state their offer in terms of a percentage on or off schedule rates is in fact a flawed concept that is unlikely to allow recovery in line with those normally charged by the contractor. "In order to arrive at a realistic estimate, a contractor should estimate the likely proportions of schedule items in the job at hand, and then determine a percentage adjustment that will equate the cost based on the schedule of rates to the cost he would obtain through his normal rates" (Chanter and Swallow 2007:228).

Potts (2008: 178-194) includes a comprehensive review of payment systems since WWII and identifies how the allocation of risk through payment systems can influence the likelihood of project success. Potts (2008:184-186) also identifies how innovative payment systems based on tendered payment schedules and milestones have been successful on some projects e.g. the Hong Kong Mass Transit Railway, but not on others e.g. the Jubilee Line Extension, London.

CASE STUDY: MULBERRY HARBOUR (1943-1944)

"The story of the Mulberry harbours must rank among the most remarkable to emerge from the Second World War. In terms of engineering achievements it is surely one of the greatest of all time." (Hartcup 1977: inner jacket). Although the Allied commands recognised that they could successfully land a large force on the Normandy beaches concerns remained over reinforcing and re supplying the units ashore. The challenge was to pre-fabricate a port, in the safety of the U.K. dockyards and factories, of a kind, which could be towed to the place where it was wanted. The purpose of the Mulberry harbour was to provide shelter for shipping, and secondly, facilities for discharging cargo.

The construction of the Mulberry harbour components was executed in the utmost secrecy throughout Great Britain using a total labour force of 45,000 -50,000 with the bulk of the work executed in 6 months working night and day. This vast logistical enterprise was undertaken at a time of national emergency and national shortages of skilled labour and key materials. The Mulberry Harbour project is estimated to have cost between £30 - £40 million (D.H.Little (1948) within 'The Civil Engineer in War', ICE, vol. 2:442) - at today's prices between £900 million and £1.2 billion.

The artificial harbours when completed contained a complex infrastructure of 213 concrete caissons ('phoenix') forming the inner breakwater, 23 pierheads ('spuds') around 16 km (10 miles) of flexible steel roadways ('whales') floating on 500 steel/concrete pontoons ('beetles') enclosed within a lagoon of 93 specially constructed cruciform-shaped steel outer breakwaters ('bombardons') – the latter which were designed by the Admiralty - all of which required towing across the Channel to form the harbours on the Normandy coast.

Overall orders were placed with 550 companies spread throughout Britain. None of these contractors had drawings of the complete scheme and complete security was maintained. The Mulberry components when completed were towed to their assembly points on the South Coast. The 'bombardons' were secured at Portland, the blockships – 70 hulks to be sunk as outer breakwaters - were moored at Poole, the 'phoenix' and 'whales' were concentrated between Southampton, Portsmouth, Selsey and Dungeness (White 1980:9).

The inner breakwaters (code-named 'phoenix') were built in six different sizes with the largest 204 ft. long 56 ft wide and 60 ft high (equivalent to a six storey building) and weighed up to nearly 7,000 tons each. These huge monolithic cellular concrete structures were built in the form of a ship for floating to their destination. As few graving docks of the requisite capacity were available twelve special basins had to be constructed on the Thames behind the riverbanks. The work to the phoenixes was carried at fourteen different sites around the coast including the River Thames and the River Clyde, Plymouth, Goole, Middlesbrough and on slipways built on the foreshore in the Southampton and Portsmouth areas (Kennard 1947: 771-772.). Once completed, the floating sections were towed to assembly areas on the South coast, at Selsey in West Sussex and Dunganess in Kent, until their final journey being towed by a team of one hundred and fifty tugs across the Channel.

The concrete phoenixes were constructed by a team of twenty four large contracting companies and two formations of the U.S.A. Forces (Wood 1948:355). The contractors included Balfour Beatty, Costain, Bovis, Sir Robert McAlpine, Laing, Taylor Woodrow and Nuttall who are all still operating today and Cubitts and Mowlem who have since both been absorbed into Carillion. Six firms of engineering companies were engaged for the work including Rendell Palmer and Tritton, Oscar Faber and Sir Alexander Gibb who are all operating today as part of larger consulting groups.

Kohan 1952:342 identifies that "For the supply and organisation, under conditions of the most stringent secrecy, of all the skilled men who could be mustered for the undertaking – carpenters, steel-fixers, scaffolders and other tradesmen – the responsibility was that of the Ministry of Works and of the building industry, as well as of the Ministry of Labour and the Ministry of Supply. A special branch of the Ministry of Supply, largely recruited from outside specialists experienced in kindred work, was formed on 27th September 1943 to carry out the Phoenix programme. This branch was responsible for the methods of construction, and for finding contractors to carry out the work and consulting engineers to supervise it in detail. The branch also arranged, in conjunction with the Ministry of Works and the other Ministries concerned, for the supply of materials and labour, the acquisition of sites, the transport both of material and of labour and the billeting, welfare and supervision of the large number of workers engaged."

In detail the 'phoenix' project was organised as follows: design – War Office; materials and labour – Ministry of Supply; site organisation, skilled supervision, key men and control of the works – Contractors; supervision – consulting engineers (Wood 1948:342).

The work of construction commenced in December 1943 and the original programme was completed in 150 days. Work proceeded by night and day; overall the 213 phoenixes comprised 545,00 cubic yards of reinforced concrete and 66,000 tons of reinforcing steel. The first caisson arrived at Arromanche in Normandy on D-day +1 – June 7 1944.

On June 9, just three days after D-Day, the two harbours were constructed at Omaha Beach (Mulberry A) and Arromanches (Mulberry B). However a large storm on June 19 destroyed the American harbour at Omaha, due to it not being securely anchored on the seabed. The British harbour, renamed Port Winston, was also damaged by the 'bombardons' which crashed into the concrete caissons. Sir Bruce White had foreseen the dangers of split responsibility with the Admiralty responsible for designing the 'bombardons'and the War Office the rest of the components (White 1980:10).

Mulberry B was in use for 5 months during which time over 2 million men, half a million vehicles and 4 million tons of supplies passed through the harbour. General Eisenhower stated that 'Mulberry exceeded our best hopes'. The invasion of Europe, impossible without the artificial harbours, had been accomplished by British engineering skill (White 1980:10).

Following the success of Mulberry, the group of contractors engaged in the 'phoenix' caissons joined for mutual planning of post-war pre-fabricated house construction (Coad 1979:160).

CONCLUSIONS

All construction projects executed under WWII were executed under strict government controls during times of acute shortages of labour, materials and equipment. Strong leadership from the top was critical with the direct involvement of Prime Minister Sir Winston Churchill, Sir Bruce White, Sir Malcolm McAlpine and John W. Laing. The civil engineering projects were immensely challenging – none more so than the Mulberry Harbour. The innovative solution of a floating harbour, with the elements constructed throughout Britain, then towed to the South coast and eventually assembled off the Normandy coast must surely rank as one the greatest civil engineering and construction management achievements of the twentieth century. Today with global warming and extensive flooding floating concrete caissons might be considered a suitable solution for buildings at severe risk of floods.

During WWII quantity surveyors played a critical role in the financial administration of these projects during this period of national emergency. Two main types of payment systems were used – fixed price and cost reimbursement. The target cost method of payment was eventually replaced by payments based on the known norm and a schedule of quantities. The two significant payment tools were the Ministry of Works' Standard Schedule of Prices and 'payment by results' for the site based labour. However, due to the national emergency the emphasis was often on the time factor to the detriment of cost and to some extent quality.

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* The multiplier of 30 applied to 1943 prices has been based on the comparison of the U.K. Retail Price Index (1943 RPI - 7.2, 2008 RPI - 217.7) (www.wolfbane.com/rpi.htm - accessed 10 December 2008).