Recent developments in structural precast concrete in Great Britain

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Recent Developments in Structural Precast Concrete in Great Britain [1])

Développement récent dans le domaine des ouvrages en béton préfabriqués en Grande Bretagne

Neuere Entwicklungen auf dem Gebiete der vorfabrizierten Betonbauten in Grossbritannien

1 - Introduction

There has been a very large increase in the use of structural precast concrete in building and civil engineering construction in Great Britain during the past fifteen years. In appropriate circumstances the use of precast units shows special advantages in both speed of erection and total cost, and is now being used for an increasing variety of residential and industrial buildings. The bulk of structural work in Britain is still by means of in-situ reinforced coincrete, however, and there is still a very wide field for expansion in the use of structural precast concrete.

The practice of precasting structural members, either on the site or in a factory, and erecting them to form the structural framework has been established for many years, but in the pre-war period was adopted only on a limited scale for comparatively small single storey buildings and floor units. The war-time demand for military huts and factory building which could be erected quickly and were economical in construction undoubtedly encouraged the development of reinforced concrete precast structural framing which has continued in the post-war period. The developments in prestressed concrete have also contributed in an important way. One of the chief factors which has encouraged the development of structural precast concrete has been the great improvement in the design, capacity and efficiency of lifting equipment now available to contractors, and it is the scope of its use and the great increase in size of the structural members, which are now prefabricated, that are the outstanding features of recent developments.

Improvements in factory methods and especially in the production of high quality concrete have produced further advantages for precasting, but

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[1]) This report was prepared by Mr. A. W. Hill at the request of the British Group of the International Association for Bridge and Structural Engineering.

cost has been, and still is, the most important influence on the decision as to whether a job should be of in-situ concrete or precast, and only in exceptional circumstances when some special advantage occurs, would it be used unless it was cheaper. Many factors affect cost, including the special difficulties arising in built up areas where working space is at a premium, but where traffic conditions provide increased difficulties in the delivery of all materials.

Both the architect and the engineer have, in its use, ample scope for original design, as their skill is not limited to the use of standard manufactured sections, although for the greatest economy a substantial amount of repetition is normally necessary. For some years the high cost of shuttering and centering has favoured the development of precast construction, but the ease with which the concreting operation is carried out at ground level is another important factor affecting cost. There may be certain disadvantages in the use of precast sections as compared with in-situ construction. Two of the advantages of in-situ reinforced concrete, its adaptability and continuity in framed structures, may not so easily be reproduced, but the final test of any method of construction lies in the economic advantages provided. Saving of time and invested capital are important considerations.

Of recent years there has been a tendency, particularly on large projects, to manufacture the precast units on the site in a temporary factory, to reduce the difficulties of transportation of the large units. In appropriate circumstances the highest standard of quality control can be achieved, and all the advantages arising from precasting fully utilised.

From the manufacturing aspect, production of units at an established factory should be advantageous because of the equipment and organisation available, and the use of the skilled labour attuned to the work of high quality concrete products, but the heavy cost of transport, additional loading and unloading, especially with large units, and to some extent the limitations of size so entailed are frequently the deciding factors in relation to the cost of the site factory. Often the best solution is a mixture of both methods, casting on site the very large columns and beams which it would be difficult and expensive to transport from the factory, but to use factory made products for the smaller units such as floor joists, roof slabs, purlins, wall slabs, etc., which can be transported easily on a normal lorry. The use of standardized products is an important factor in the overall economy.

2 - Advantages and disadvantages

The chief advantages of using precast units for concrete construction are:

a) The economy in the cost of the moulds since the units are usually cast on the flat and frequently on a prepared concrete floor and only side moulds are then required. These can be very quickly removed and reused. Great economy is provided through repetition.

b) The large reduction and in some cases the complete elimination of the scaffolding and mould supports. This becomes increasingly apparent with buildings of large height and span.

c) Economy in labour in working at ground level during casting as distinct from similar operations carried out a height.

e) With work at ground level either at the site or in a factory, much better control is provided of the formwork layout, the position of the reinforcement and the quality of the concrete resulting. Thorough compaction by vibration is more easily provided to assist quality control.

f) Further economy in labour is provided by the use of mass production methods where standardization of units is provided, and in the employment of machinery for their manufacture and erection.

g) Where work is carried out in a factory, weather conditions are not so critical, and continuous working is possible independent of weather conditions. This means also that skilled workers can more easily be retained in a factory and the site works are reduced to a minimum.

h) The speed of erection is greatly increased with a corresponding reduction in the cost of overheads and site supervision.

i) There is a substantial economy in the transport charges on temporary construction materials such as timber, scaffolding, etc., and storage of these on the site.

j) Precast structures with bolted joints can be removed and re-erected elsewhere.

k) Provision for thermal and moisture movements is easily provided in the joints. Shrinkage takes place within the unit before erection, and the subsequent stresses under load are more easily assessed.

There are, however, some disadvantages in the use of precast products as compared with in-situ construction, such as:

a) The extra handling of the units when made at a factory off site.

b) Difficulties in ensuring monolithic continuity in the structure and in some cases the necessity of using slightly larger sections because of the free-end conditions.

e) The care needed in order to design and construct satisfactory joints and supports betwen the prefabricated members.

That these disadvantages can be overcome by sound design and construction techniques has been well proved by the numbers of prefabricated structures which have been erected in competition with in-situ work, but the financial succes or otherwise of these jobs depends to a great extent on the engineer's organising ability in order that the full advantages of mass production and speedy erection can be utilised.

3 - Conditions for precast construction

Since the total materials in precast and in-situ construction are similar, precast concrete will be cheaper than in-situ when the savings in formwork exceed the cost of factory moulds, transport of the unit and its erection. The saving is generally greater for beams than for columns, and for floor units will be affected by the storey height, but in all cases the amount of repetition which allows re-use of moulds will be one of the principal factors.

Cost of transport has to be considered in each case, being related to weight of units and distance to be handled, but is also affected by the position of the site, the traffic on the route to be followed and the facilities available at factory and site for loading and unloading. The working space available at the site can also be an important factor.

The great improvements in crane design in recent years have considerably reduced the lifting and erection problems. Once a crane is employed on the site every effort should be made to utilise it to the maximum extent. For multi-storey work the developments with tower cranes have greatly assisted in the extension of use of precast concrete.

The developments in prestressed concrete have also made a marked contribution. The reduction in materials possible as compared with reinforced concrete has offered notable advantages in the production of standard pretensioned factory-made floor units, bridge beams and piles.

4 - Design considerations

In order to obtain the greatest advantage from precasting, the whole process of construction should be considered at the design stage. The first essential is that there should be considerable repetition so that moulds are re-used to the maximum possible extent. In such cases more attention can be given to the construction of the mould concerned, so that the tolerances on dimensions and shape of the finished product are kept small and the subsequent erection and fixing is made as easy as possible. When the positions and types of joints have been decided, the design of the units follows normal reinforced or prestressed concrete practice, with the additional check on handling and lifting stresses. The design of the joints, however, requires very careful consideration.

In the majority of the single storey structures erected in this country, plain bearings with bolted connections have been used, but these, though extremely simple to manufacture and erect, provide little continuity and may necessitate slightly heavier sections and reinforcement. If the joints are provided at or near the points of contraflexure, such increases are reduced to a minimum. With the hipped frame, hinged joints are usually provided at the ridge and at the feet of the columns, in fact providing a three hinged arch, but other arrangements are also used. If full continuity is to be provided, some form of in-situ joint is arranged after joining the reinforcement across the joint by lapping or welding. This increases the site work and may necessitate working platforms, but if the position of the joint is chosen with care, the gap may only be of small dimension. Continuity can also be provided by a combination of precast and in-situ work. Monolithic T-beam construction can be provided with an in-situ slab laid on a precast beam, allowing the use of the full depth of the beam for the live loading. Beams can be made continuous by mortar jointing the butt-ends over the support and accommodating the continuity reinforcement in the in-situ slab above. Beams and columns have also been framed together by resting the beam on a portion of the column and bending over into the in-situ slab some of the continuity bars which are projecting from the column. In all these cases the saving of shuttering and scaffolding, and the speed of erection, have played important parts in making the design economically advantageous.

The use of post-tensioning methods has provided another easy and effective solution to the problem of restoration of continuity after precasting in sections. Jointing of the units is in fact so simple that the member can be easily broken down into small units which can with advantage be cast in a factory if required. After assembly as beams or columns on the site and erected in position, further continuity can be provided by cables place through prepared holes in the units and stressed together. For large span schemes, the use of prestressed concrete can also be advantageous in reducing the dead weight.

Thus, while many ingenious solutions for connections have been evolved, many of which are illustrated in the examples which follow, no generally accepted type has developed. The most efficient moment-resisting joint is the in-situ joint, but it is probably true to say that the ideal joint has still to be produced. In various forms the joints based on timber and steel connections, such as mortices, brackets, cleats, etc. have been successfully employed but, for moment-resistance, the lapping or welding of reinforcement left projecting from adjacent units, either into in-situ concrete, or into grouted channels in the adjoining membres provides greater efficiency.

Very speedy erection programmes have been maintained, particularly with multistorey constructions for offices, flats, schools and colleges, with these techniques. The problems arising with tall columns have been reduced in some cases by casting columns in pairs connected by edge beams at the floor levels.

One of the advantages of the in-situ joint is the freedom provided to correct inaccuracies, and the ability to incorporate concrete over the whole section. The filling and packing with mortar of narrow joints between units and the closer tolerances necessary for successful work are expensive operations.

5 - Composite construction

The advantages of both precast and in-situ concrete can often be judiciously combined in composite construction to produce maximum economy. Those parts of the structure which require substantial formwork, high quality of concrete and good appearance can then be precast, while in-situ concrete is used for the jointing and for the bulk of the concrete on the site. Thus, the lower parts of beams or slabs are precast and in-situ concrete is used for the upper parts. In this way the monolithic character of the structure can be maintained.

The popularity of concrete facing slabs as an attractive and economical cladding for buildings has been a feature of recent years and is still increasing in Great Britain. In addition to the wide variety of texture, colour and partern now available, there has been a steady improvement in the production techniques employed by products manufacturers. Excellent examples of their use can be seen in modern multi-storey flat and office blocks, in churches and in factories, extending from simple infilling panels through permanent formwork for in-situ construction to full storeyheight panels in load-bearing construction.

In recent years, with the use of larger slabs, texture, colour and pattern have been developed with an accent on boldness, away from the early imitations of natural stone, so emphasising the inherent properties of the material.

6 - Survey of existing uses

In a short paper it is only possible to select a few examples of the successful use of structural precast concrete in buildings, structures and bridges in Great Britain from the wealth of successful constructions in recent years, but an attempt has also been made in this selection to indicate future trends. Much will depend on the increased use of mechanisation in the factory and on the site, and the maintenance and improvement of the quality and finish of the precast unit.

With precasting already applied to almost all forms of construction and established as an economical and sound method of construction, its future seems assured. In multistorey construction the problem of the

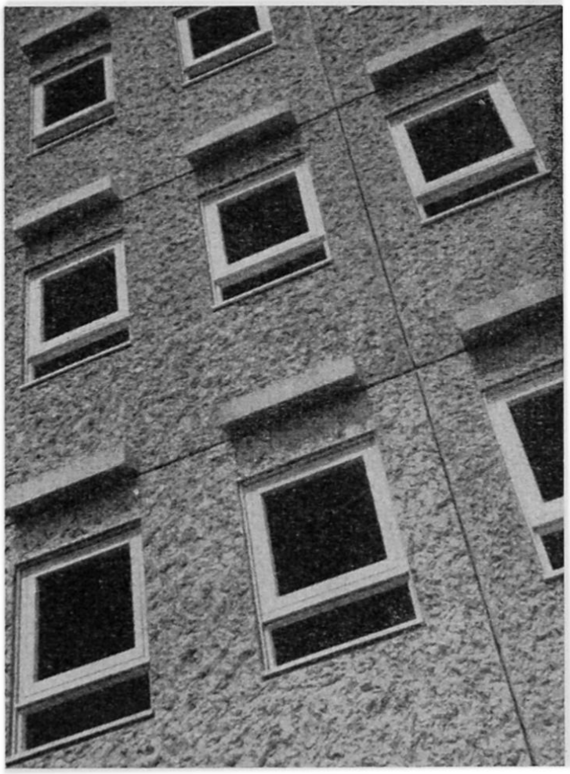


Fig. 1 - 20-storey block of flats at Smethwick of precast load-bearing walls with simulated rock finish.

weight of building units can be reduced by the use of lightweight structural concrete on an increasing scale, in civil engineering structures the use of larger units precast on site will only be limited by the capacity of the cranes available, while in bridges the advantages of precast prestressed beams for deck construction of increasing span with some standardization of section would seem to be a logical development. The introduction of housing from the factory methods to increase the rate of house and flat construction in Britain is imminent and in this structural concrete will play an increasing part (Figs. 1 and 2).

Structural precast concrete is already being used extensively in Great Britain for single and multi-storey buildings for flats, offices, stores, hospitals, schools and colleges, churches and factories; for road and railway bridges, footbridges and culverts; and in civil engineering structures for tanks and reservoirs, power stations, tunnels, docks and harbours, car parks and railway and omnibus stations.

7 - Use of structural precast concrete in buildings

In all types of buildings in Great Britain there is extensive use of precast floor units, both reinforced and prestressed. Over fifty concrete flooring systems are available varying from small box, Tee, trough and

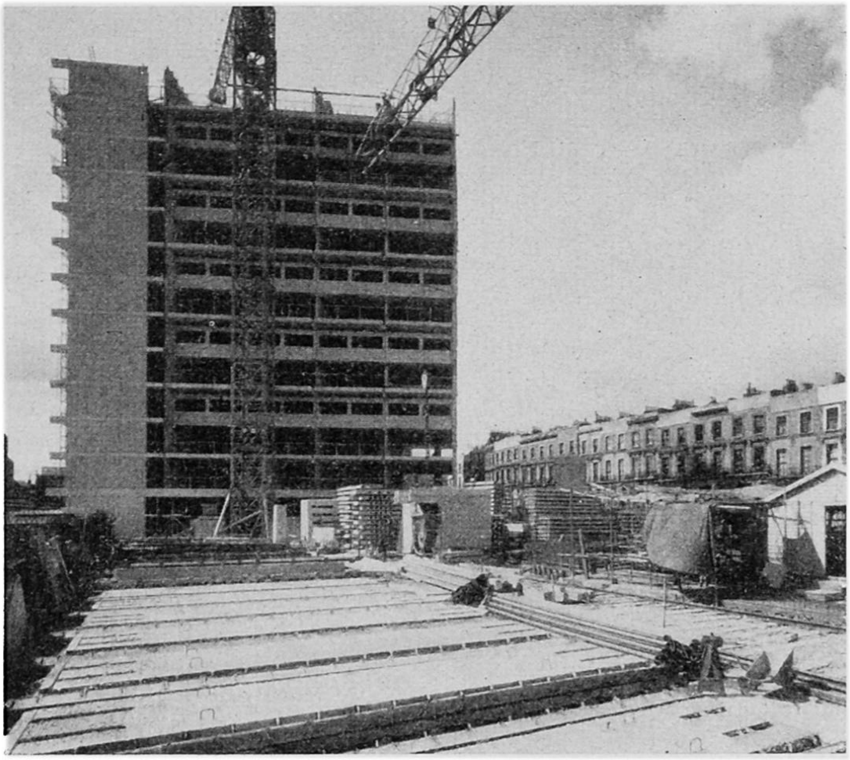


Fig. 2 - 21-storey maisonettes and flats at Warwick Crescent, Paddington, where precasting is done on site.

I-section units, with or without lightweight in-filling units, to large cored slabs. Many systems provide a composite construction when used in conjunction with in-situ concrete and continuity over the supports can be provided by embedded reinforcement in the additional in-situ concrete. Although most of these systems are more suitable for the small spans, say up to 20-25 ft, there are a few manufactures who provide standard hollow beam sections suitable for larger spans when uninterrupted space is required in buildings.

For single storey construction considerable use is made of precast concrete portal frames and some standardization exists for spans of up to

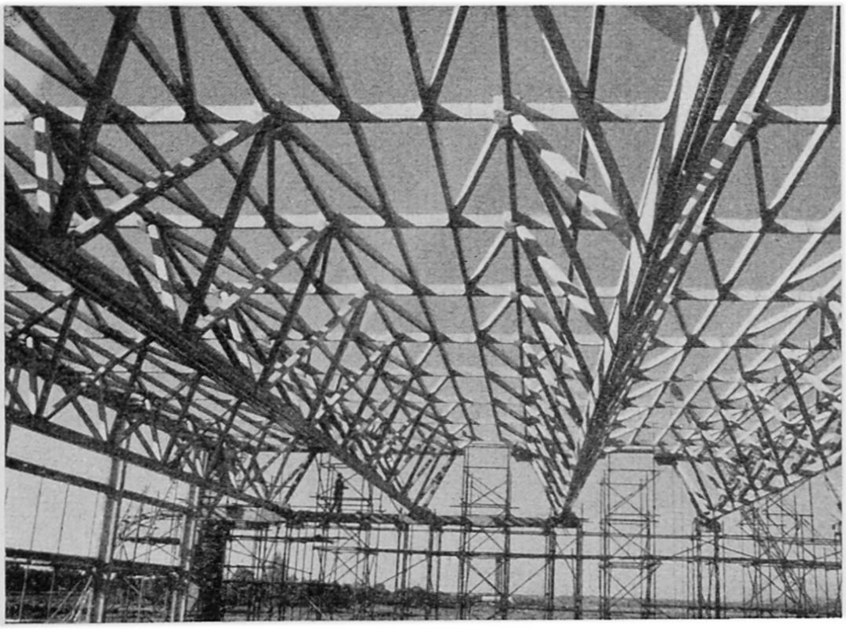


Fig. 3 - Transair Hangar at Gatwick Airport of prestressed precast concrete.

60 ft. Considerably larger spans have been provided also, with a tendency in these cases to carry out the precasting on the site often on the factory floor. Frames are also available of the north-light and monitor type, and precasting of shell-roof sections subsequently prestressed together has been carried out. Standard roof truss units are also avaible for buildings of medium span (Figs. 3, 4 and 5).

There have been considerable developments in the use of precast concrete for multistorey construction, particularly in relation to offices and

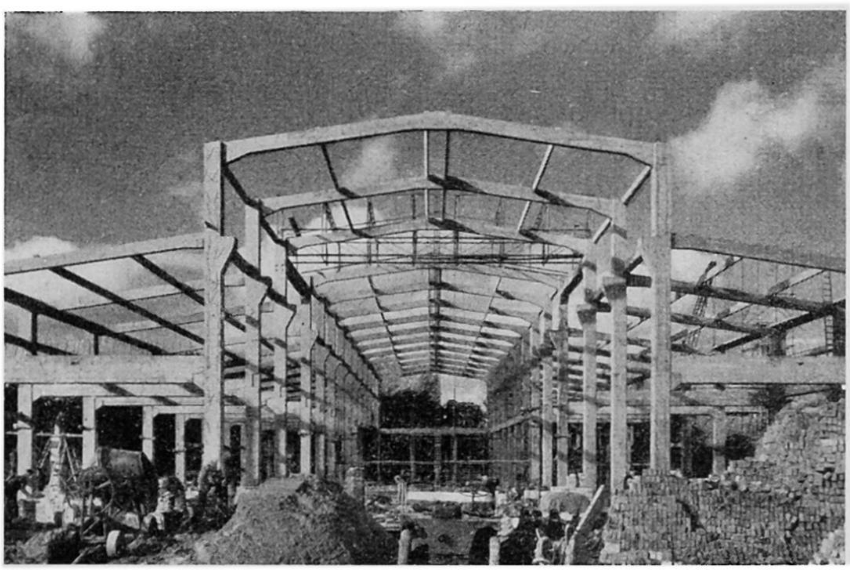


Fig. 4 - Reinforced concrete framework in factory for Access Equipment Co. Ltd at Hemel Hempstead.

flats in London and the principal cities, and to a lesser extent in schools and colleges. Beam and column framing have been developed in a variety of forms to receive precast flooring systems, the whole structure being rigidly connected compositely by means of in-situ concrete joints. Column erection has been simplified by the development of cruciform and H-units, and very high rates of erection have been achieved of a storey in a week or under. Buildings of this type are usually clad with precast concrete cladding units incorporating a special finish with exposed aggregate or profiled patterns. For multi-storey flats where the spans are usually small,

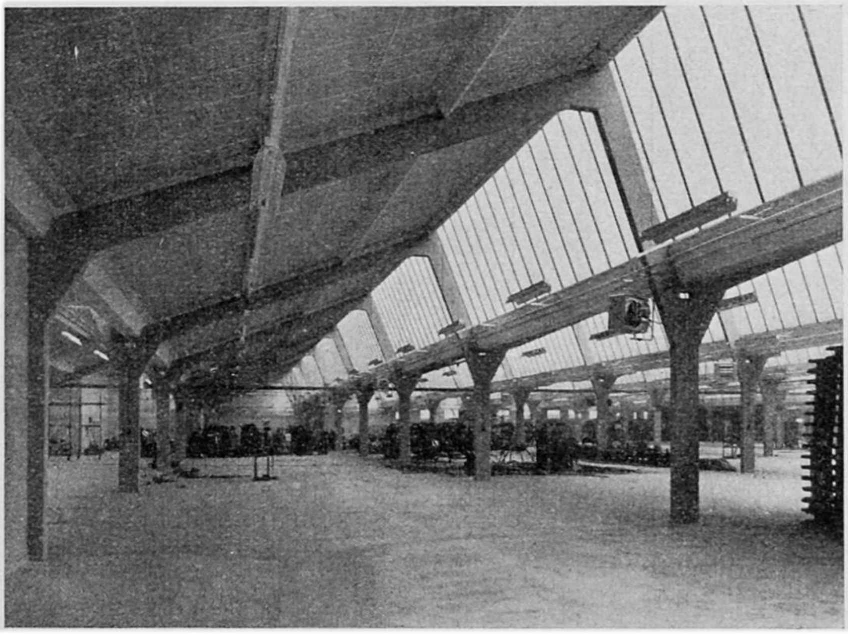


Fig. 5 - Precast northlight framework for factory at Bracknell New Town.

developments in load bearing walls and precast large slab floors have provided very rapid erection techniques, and increasing use is being made of factory processes to incorporate finishes and services before the units are taken to the site (Fig. 6).

Special precast concrete systems, both reinforced and prestressed, have been developed and used for schools, where the standardization of dimensions by the Ministry of Education has been of the greatest importance and assistance. Precast concrete, because of the rapid rate of completion, has been used for large shops and stores, and is being developed for the new hospital programme and extensions of barrack facilities for the Forces. Most of the new churches built in Britain since the war have been based on a concrete frame because of the adaptability to form, ability to provide large open spans, speed of construction and economy (Figs. 7 and 8).

8 - Use of structural precast concrete in Bridges

One of the outstanding features of highway bridge construction in Britain since the war has been the extensive use of prestressed concrete, and particularly for bridges of 50 ft or less this has involved the use of

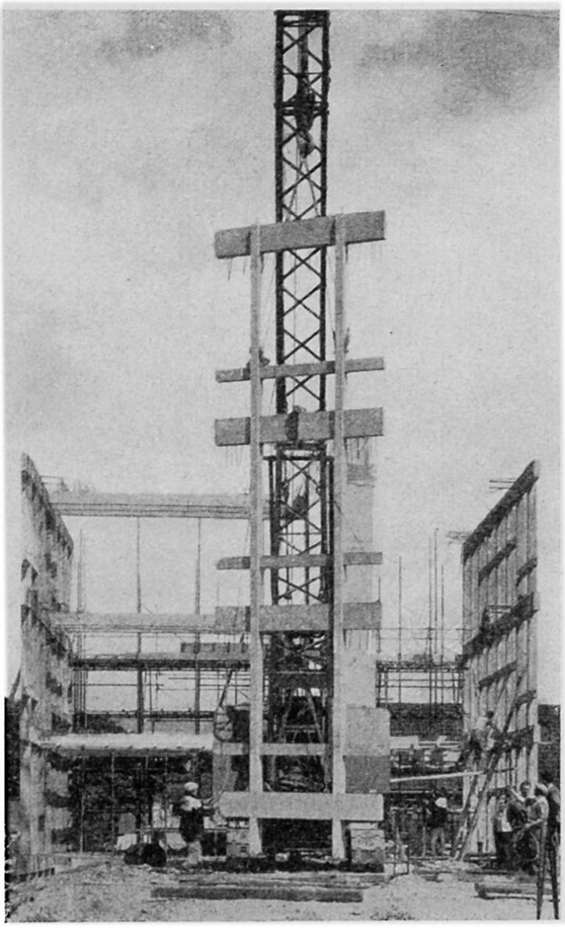


Fig. 6 - H-frame column units being erected for the Marley Tile Co. Ltd.

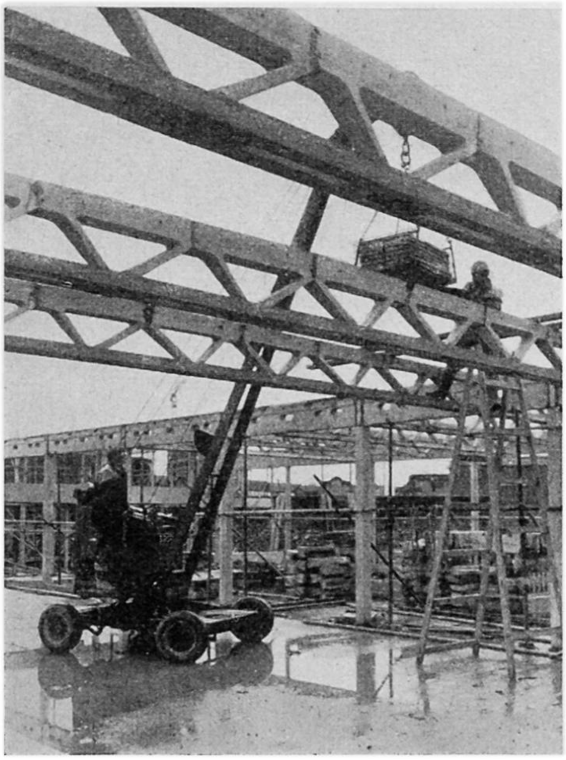


Fig. 7 - Laingspan units being erected for the Alperton School.

precast pretensioned beams. Because of the large number of bridges involved in this range of span, the Prestressed Concrete Development Group produced a standard section for inverted T-beams which could be used with in-situ concrete to form a slab deck. Transverse distribution of loading was arranged by means of mild steel bars threaded through holes in the precast beams. For spans between 50 ft and 90 ft a standard box section beam is now being developed, and beyond this a standard I-section beam to be used at 5 ft centres with a cast-in-situ deck slab. In addition to standardizing the section of these beams, which allows the manufacturer to stock standard steel moulds, the Group has developed a design procedure which has been agreed with the Ministry of Transport (Figs. 9 and 10).

Extensive use of precasting has been made also for large span bridges and this has frequently been successfully accomplished at a site factory where the higest degree of control has been established. Often these precast units have been used compositely with in-situ concrete to form a continuous structure under full live load conditions with obvious economy in design. Urban motorways will provide an important field for development for

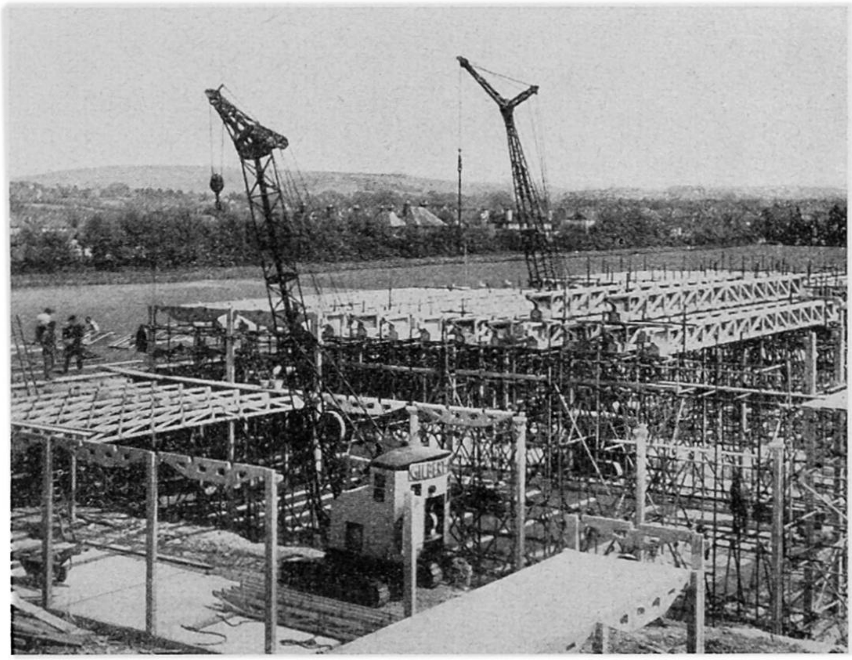


Fig. 8 - Precast concrete units of the Intergrid system for Worthing Secondary Technical School.

precast concrete and both the Hammersmith flyover, recently completed, and the elevated road, under construction west of the Chiswick flyover, incorporate extensive use of precast prestressed concrete. Most of the major motorway constructions include the provision of large span footbridges which have frequently been successfully built of precast units to give a slim and elegant profile (Fig. 11).

In the urban areas the necessity for pedestrian subways at busy road intersections has resulted in the extensive use of precast concrete subway-trough units, to which precast roof slabs are added and jointed with in-situ connections.

For factory construction of bridge units, the Ministry of Transport restrictions on haulage of units exceeding 90 ft have an important bearing

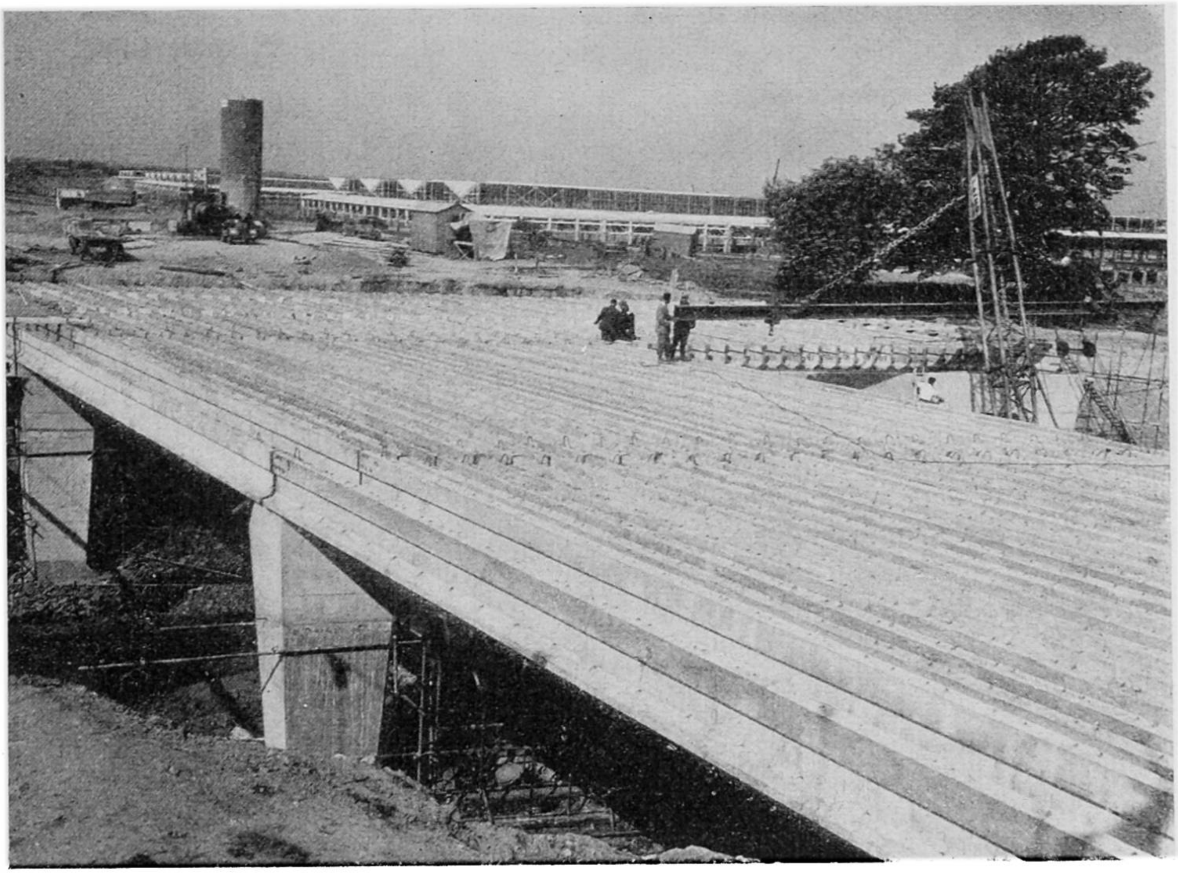


Fig. 9 - Standard inverted T-section beams for Easter Inch Bridge, Scotland.

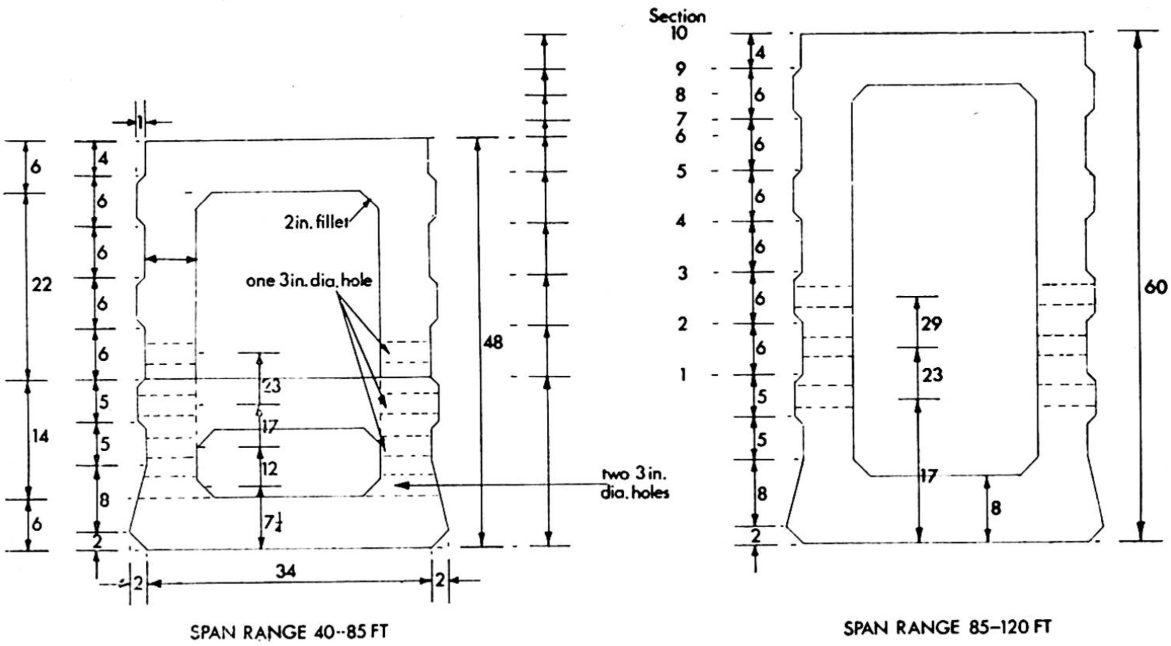


Fig. 10 - Standard box sections for bridges of span 40 - 120 ft.

on the decision to cast larger units in sections or even at a special site factory, unless railway transportation is a suitable alternative.

Much of the railway modernisation programme has been successfully completed by the use of precast units. In many cases occupation of the railway line or the closing of the road can only be allowed for very limited periods and the speed of construction provided by precast concrete units is often the deciding factor. Precast concrete has also been used extensively in station reconstruction.

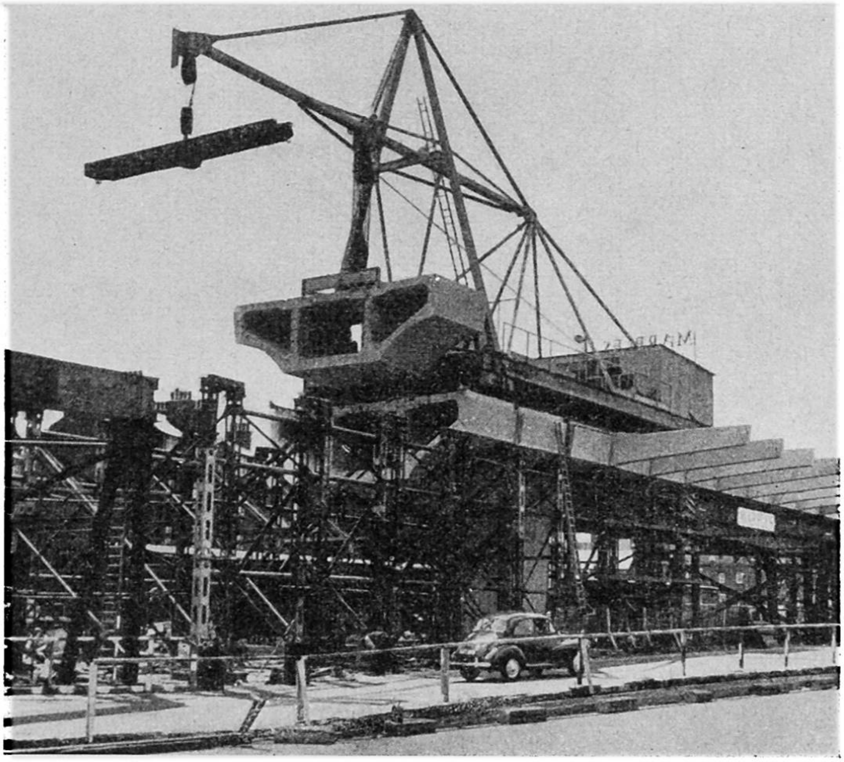


Fig. 11 - Precast concrete units for Hammersmith Flyover.

9 - Use of structural precast concrete in civil engineering structures

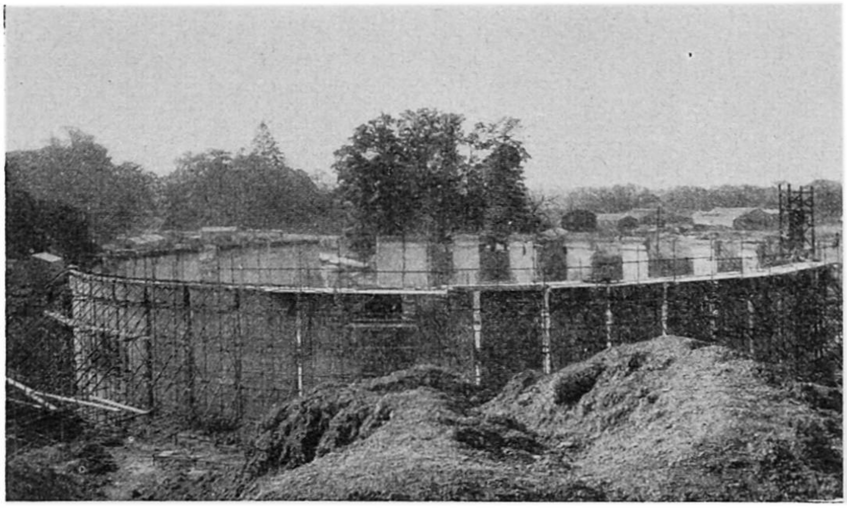
a) *Tanks*

Precast concrete units have been used for the construction of prestressed cylindrical tanks for water supply and storage. The ability to provide high quality concrete in units cast on the ground is of particular value in this form of construction, shrinkage cracking is avoided and the subsequent application of the circumferential stressing successfully closes the joints between the units. The largest tank to date utilising this procedure is the 3 million gallon tank at Windsor, which is 160 ft internal diameter with a depth of water of 24 ft (Fig. 12).

b) *Power Stations*

The advantages of precasting for the structural members in modern power stations have been used in connection with site factory work. Units of 50 to 60 tons have been cast on the ground and lifted into position. Typical examples are Aberthaw Power Station and Acton Lane Power Station (Fig. 13).

Fig. 12 - 160 ft dia. tank at Windsor using precast units cast on site.



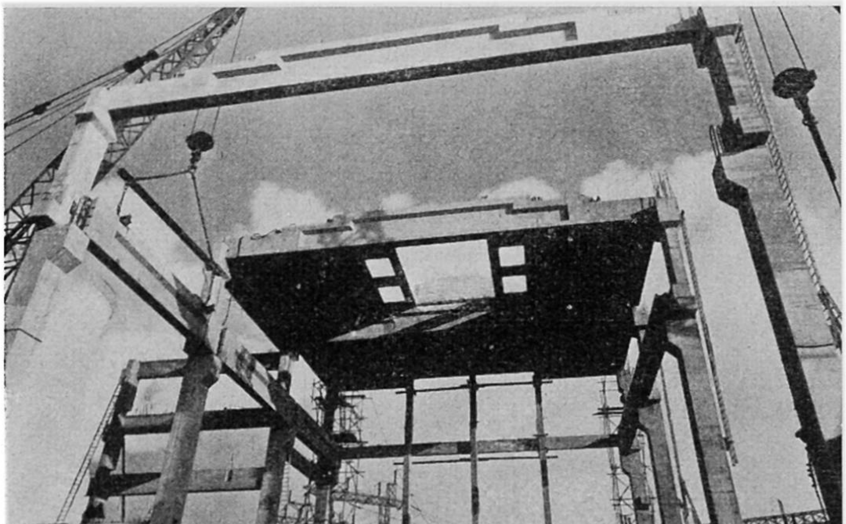


Fig. 13 - Precast concrete beam and column construction for Acton Lane Power Station.

c) *Tunnels*

Considerable use has been made of precast concrete tunnel segments for new railway and road tunnels, and for deep conduits for water supply. The latest developments provide facilities for stressing the units against

Fig. 14 - Tees Dock Quay of precast concrete elements manufactured on site.

the adjacent soil and very rapid rates of construction are possible. The tunnel segments are very much cheaper than the alternative solution in metal. The new Potters Bar Tunnel was constructed in this way and long lengths of this system are proposed for the new tube railway Victoria to Walthamstow.

d) *Docks and Harbours*

Recent dock and harbour work has included large quantities of precast concrete units for jetties and piers. Where considerable repetition occurs, considerable advantages arise in cost and speed of construction through the utilisation of factory made units. Where the units are large, a site factory can offer additional advantages. In addition to the extensive work on the Thames, the recently completed No. 1 Quay at Tees Dock, 3220 ft long and 90 ft wide supported on concrete cylinders, made extensive use of precast prestressed concrete (Fig. 14).

e) *Multi storey Car Parks*

With the increasing problems of vehicle parking in large cities, more multi-storey car parks are needed and precast concrete has already shown that it has an important application in this field The ability to provide economically large open spaces to facilitate the close parking of vehicles and the high fire resistance provided with modern design techniques without extra cost will add to its field of use in the future. Important examples in this field are the garage in the City of London in Shoe Lane and the Fairfield Car Park at Croydon (Fig. 15).

f) *Other Concrete Products*

Extensive use of precast concrete piles in Britain has favoured the development of pretensioned piles with their easier handling and driving. These are used as bearer piles and for sheeting piles. Most of these are factory made. Concrete pipes are also extensively used for water supply and sewage disposal, and diameters up to 8 ft are available in both reinforced and prestressed concrete. For street lighting, concrete columns are in frequent use, but developments with poles for transmission lines have not been successfully utilised on a large scale. Concrete railway sleepers are being used extensively in modernization programmes.

Fig. 15 - Multi-storey car park, Croydon.

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