**Zeitschrift:** IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

**Band:** 14 (1992)

**Artikel:** Future horizons for concrete construction

**Autor:** Cusens, A.R.

**DOI:** https://doi.org/10.5169/seals-853258

# Future Horizons for Concrete Construction

Perspectives dans la construction en béton

Neue Horizonte im Betonbau

**A.R. CUSENS**
Prof. of Civil Eng.
Univ. of Leeds
Leeds, UK

Tony Cusens graduated in 1951 from University College London. He has held research and academic posts in the UK, Sudan and Thailand and is active as a consultant on concrete structures. He is President of the Institution of Structural Engineers 1991-92.

**SUMMARY**

The paper reviews significant trends in concrete and discusses these in relation to materials and construction techniques. The importance of education and training at all levels, to spread a better understanding of concrete, is stressed. Future directions are signposted in terms of high performance concrete, better liaison between design and construction and new materials.

**RÉSUMÉ**

Cette étude analyse les tendances significatives du béton et les examine en fonction des matériaux et des techniques de construction. Elle souligne l'importance de l'éducation et de la formation à tous les niveaux, en vue de propager une meilleure compréhension du béton. Elle indique les voies futures à suivre sous forme de bétons à hautes performances, d'une meilleure liaison entre les projets et les réalisations, ainsi que de nouveaux matériaux.

**ZUSAMMENFASSUNG**

Der Beitrag diskutiert herausragende Trends im Betonbau, wie sie besonders im Bereich der Werkstoffe und der Verfahrenstechnik zu sehen sind. Ausbildung und Schulung zur Verbreitung besserer Betonkenntnisse sind auf allen Ebenen dringend geboten. Zukunftige Entwicklungen wie Hochleistungsbeton, neuartige Werkstoffe und eine bessere Verbindung der Projektierung mit der Ausführung werden skizziert.

## 1. INTRODUCTION

Primitive forms of concrete have been used in construction for at least two thousand years. However, the material, which engineers today identify as concrete, dates back only to the middle of the 19th century and began to achieve wide structural application about a hundred years ago. Around the turn of the century a few engineers began to appreciate the exciting potentialities of reinforced concrete and the freedom of design thereby created. Since that time, advances in the design and service performance of concrete structures have depended upon developments not only in the basic material properties of concrete but also in steel (e.g. leading to the practical realisation of prestressed concrete) and in plant and techniques of construction.

My own formative years as an engineer coincided with the emergence in post-war Europe and elsewhere of concrete as the dominant structural and architectural material for the latter half of the 20th century. During the 50's and 60's there was a dazzling succession of notable achievements and applications of concrete in structures. At this time prestressed concrete was making its first great strides en route to becoming the preferred material for medium span bridges; the architectural trend was to employ concrete as the dominant facing material, both inside and outside buildings. Most engineers thought that provided a reasonable job was made of mixing and placing, concrete could do no wrong - it was an adaptable material with a long maintenance-free design life.

Moving into the 70's and 80's, there has been a succession of problems with concrete construction. Most of these problems were avoidable but there is no doubt that they have undermined confidence. This has caused engineers to be much more careful to avoid mistakes and misuse of the material likely to lead to future difficulties in service and has persuaded architects to prefer brick to concrete as a facing material. This paper looks ahead to gauge the likely impact of recent developments in concrete in terms of both the material and the ways in which it is being employed in the construction of buildings and bridges.

Amongst the traditional constituents of concrete - Portland cement, water and aggregates, cement has changed with time to some extent because of trends in the manufacturing process - together perhaps with a perception by cement producers of user demands for higher strength concrete. Such changes have been well documented in the U.K. [1] and are probably representative of the situation in most other countries. However, other more significant trends have also been taking place over the last three decades

- development of cement-replacement materials and superplasticisers
- enhanced interest in the long-term performance of concretes
- greater collaboration between designer and constructor
- application of high strength concrete in practice.

These trends are closely inter-connected and will be discussed under two headings:

A - Materials for Concrete
B - Construction Techniques

## 2. MATERIALS FOR CONCRETE

### 2.1 Cement-replacement Materials

Initial moves to replace a proportion of Portland cement in concrete arose principally from a search by industry to find uses for waste materials. Can we use it in concrete? - seems to be an early question which arises for waste products. However, research has shown that three such materials have beneficial effects in concrete.

- Pulverised fuel ash (pfa, often known as fly ash) a waste product from coal-fired power stations has been widely used typically replacing 20-30% of Portland cement, the presence of pfa slows down the early growth of strength of concrete; if properly cured, it will enhance the final strength and decrease the permeability of the concrete.

- Ground granulated blast-furnace slag (ggbs) from iron production has also found extensive application. It can enhance strength but has particular merits in lowering the heat of hydration in large pours and in improving the resistance of concrete to sulphate attack.
- Condensed silica fume (csf) which stems from silicon production is a very fine material (also known as micro-silica) which can, with care, produce very high strength concrete.

These products can be of significant value in concrete structures but all require particular attention in placing and curing. The workability of concrete mixes containing csf poses special difficulties if placing is not carried out expeditiously. Without adequate curing for at least three days [2] the potential long-term strength and durability of concrete which includes pfa, ggbs or csf will not be achievable.

### 2.2 Superplasticisers

The development of chemical admixtures in order to modify the early behaviour of fresh concrete has long been a feature of the manufacture of concrete elements. Retarders and accelerators have been used when appropriate to modify the setting process. Plasticisers are employed to improve the flow properties and help the placing of concrete in complex shapes, around formwork or in difficult environmental conditions. The advent of superplasticisers [3] which have dramatically enhanced flow properties and workability without sacrifice of strength, has been a great boon in concrete construction. It has led to inherent improvements for in situ concrete and has made more possible the practical use of all the cement-replacement materials described above. Concrete containing a superplasticiser can be pumped for long distances (vertically or horizontally), revolutionising work on confined construction sites.

### 2.3 Permeable Formwork

Concrete engineers constantly emphasise the importance of the exposed surface region of a structural element. The durability of the element relies upon the ability of this region, 15-20mm thick, to resist the ingress of air, water, chlorides, sulphates and other deleterious substances. Attention has been drawn to methods of improving the surface region and various coatings and surface treatment have been tried, with varying success. The introduction of a proprietary system of permeable formwork, which effectively drains off surplus cement paste and air from the surface, has provided a means of permanently improving the surface region by eliminating blow holes and lowering the porosity and permeability of the formed surface of the concrete. Recent research [4] has shown the effectiveness of this technique and it is to be hoped that widespread use will not be hindered by high cost.

## 3. CONSTRUCTION TECHNIQUES

Closer collaboration between designer and contractor has led to major improvements in concrete structures and significant advances in the economics and speed of construction.

### 3.1 Fast Track Construction

There have been major projects in large cities such as Chicago, Hong Kong and London which have concentrated upon 'fast track' concrete construction. For example in London, the Broadgate and Docklands projects have provided opportunities [5]for the application of well-designed combinations of precast and in-situ construction and the first major use in Britain of post-tensioned (bonded and unbonded) concrete floors. Information technology has also played its part; the availability at comparatively low cost of sophisticated software and hardware now permits rapid and accurate analysis and design of complex structural frames. Thereby, over-conservative designs can be eliminated.

## 3.2 High Performance Concrete

The United States has led the world in the employment of high strength concrete for tall buildings, adopted primarily to reduce the excessively large column dimensions needed for conventional concrete. Thus in the concrete building which is currently the tallest in the world (Fig. 1) - 311 South Wacker Drive in Chicago - it is reported [6] that concrete of 110MPa cylinder strength was used for the base columns and 72MPa higher up the building. Other U.S. buildings have used an even higher specification for a cylinder strength of 130MPa.

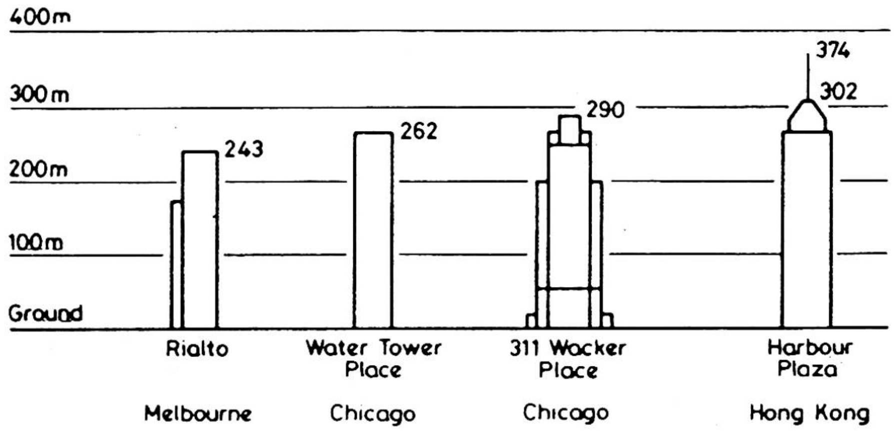


Fig. 1 - Tall buildings of concrete construction [7]

In Hong Kong, 60MPa cube strength concrete (equivalent to about 48MPa cylinder strength) is being used in the 78 storey Harbour Plaza building currently under construction. On completion it will be the tallest reinforced concrete building in the world (Fig. 1). The use of high strength concrete leads to the idea, identified by several authors, [8, 9], of high performance concrete which incorporates three parameters:

- high compressive strength
- high durability
- high deformational (or dimensional) stability.

All three parameters can be of importance for key structures. In tall buildings, high strength should go hand in hand with high deformational stability or stiffness. A high value of modulus of elasticity of concrete will reduce sway and should be included in the specification; however, brittleness can be an undesirable characteristic of some high strength concretes. High durability will also be required in harsh environmental conditions. In North Sea offshore concrete structures for the oil and gas industries, the demand for a concrete possessing a high compressive strength and adequate durability to combat the hostile environment led to the specification not only of a high strength grade but also of maximum values of permeability. This form of specification was repeated even more stringently for the Channel Tunnel. Nevertheless, no simple, rapid test of concrete permeability has been adopted as a standard in Britain or elsewhere; thus permeability monitoring tends to be very limited during the production stages of such projects. This issue needs to be resolved quickly if the specification of permeability is to have any real meaning beyond the stage of mix design.

For concrete bridges all three parameters become essential. For example, match-cast segmental construction, which has proved to be an outstandingly successful technique for multi-span prestressed concrete bridges lends itself to (and benefits from) the use of high performance concrete. Deformational characteristics assume importance - a high modulus of electricity, low creep and low shrinkage are all desirable properties. Strength and durability are also paramount in this form of structure, bearing in mind the very large costs which have been incurred in recent years in maintenance and repair of concrete bridge decks and sub-structures, in the United States and elsewhere.

Within the limited scope of this paper it has only been possible to indicate some general developments in construction techniques illustrated by one or two examples from recent practice. However, the inter-dependence of construction techniques and choice of concrete is clear; advances in construction techniques for concrete are normally only possible when accompanied by improvements in concrete and its properties.

## 4. WHAT NEXT?

Concrete construction is now at an extremely interesting stage in its evolution. It has suffered in the past from its own apparent advantages, in that it is very simple to make concrete: its constituents are readily available and even unskilled, untrained labourers can make a credible concrete slab or lintel. This low technology approach is still with us, but in many countries the high costs of maintenance, repair or replacement of defective concrete structures are even more persuasive to clients than the voices of the many engineers who have long understood that concrete needs a high-tech approach, with well trained personnel on site. Attitudes are certainly changing, but everywhere, more effective education and training in concrete construction for engineers and concretors are needed to maintain evolutionary progress.

The adoption of high performance concrete for prestige projects is an excellent indicator for the future. It has been adequately demonstrated in the United States [6] that high performance mixes for buildings can be produced consistently by ready mix suppliers and placed successfully on site. The critical importance of extended curing procedures is again stressed here. Sampling and testing including routine taking of cores from the structure are essential; for structures in harsh environments, tests should include the measurement of permeability or diffusion of the concrete. Other major projects such as off-shore structures and bridges are increasingly employing high performance concrete to ensure satisfactory long-term performance.

The closer integration of design and construction with careful review of alternative schemes at the concept design stage, taking due account of speed, cost and ease of construction, is leading to benefits for client, designer, contractor and user. A recent case study [10] on a building in London's Docklands Enterprise Zone has set out the options considered, as well as the chosen solution, which was an interesting in situ concrete building with post-tensioned floors. Publication of case studies of this type is a valuable initiative which could usefully be repeated in other countries. In reports of completed structures, often too little is heard of the rejected solutions and the reasons for the final decisions made. However, the important conclusion to be drawn here is the desirability of close liaison between engineers experienced in both design and construction, architect, building services engineer and client for best use of available technology in concrete.

It is difficult to forecast with any precision the development of new materials. Steel continues to reign supreme as the reinforcing medium for concrete. In terms of corrosion it poses problems and there are various developments of non-corroding polymer materials as possible alternatives to steel. Kevlar has been employed for cables for certain structures; it needs protection from ultra-violet light but is non-corrosive and has a reasonable performance in creep [11]. Other high modulus polymers, produced by extrusion or die-drawing, thereby re-orienting the molecules in one direction, are strong in tension, but have a poor creep performance [12]. However, new possibilities are being examined in research in several countries and in the near future we should see polymer materials used as reinforcement for concrete elements in marine or other environments where concrete structures deteriorate rapidly

Future horizons for concrete encompass better use of established technology, arising from a wider understanding at all levels of concrete as a material. They also include further developments in technology and the use of new materials within concrete and as reinforcement.

## REFERENCES


1. CONCRETE SOCIETY, Changes in the Properties of Ordinary Portland Cement and their Effects on Concrete. Technical Report No. 29, 1987.
2. GOWRIPALAN N. et al., Effect of Curing on Durability. Concrete International, Feb. 1990, pp. 47-54.
3. HEWLETT P.C. and EDMEADES R.M., Superplasticised Concrete. Current Practice Sheet 94 & 95, Concrete, April-May 1984.
4. PRICE F. and WIDDOWS S.J., The Effects of Permeable Formwork on the Surface Properties of Concrete. Magazine of Concrete Research 43, 155, June 1991, pp. 93-104.
5. BENNETT D.F.J., Advances in Concrete Construction Technology. British Cement Association, 16 pp., 1989.
6. SHEEHAN T., High Strength Concrete - A Review of U.S. Expertise. Concrete, Nov.-Dec. 1991, pp. 35-37.
7. CUSENS A.R., Concrete Steps to Construction's Future. Structural Engineer 69, 21, 1991, pp. 365-368.
8. MEHTA P.K. and AITCIN P., Principles Underlying Production of High Performance Concrete. Cement, Concrete and Aggregates 12, No. 2, 1990, pp. 70-78.
9. MAHER Y., The French Approach to Using HPC. Concrete International 13, No. 7, July 1991, pp. 28-32.
10. BENNETT D.F.H. and BILLINGHAM A., Exchange Tower. British Cement Association, 13 pp. 1991.
11. CHAMBERS J.J., Long Term Properties of Parafil. Proc. Symposium on Engineering Applications of Parafil ropes (C.J. Burgoyne, Ed.), Imperial College, London, 1988, pp. 21-28.
12. GOWRIPALAN N and CUSENS A.R., Modified Polymer Bar Reinforcement in Concrete Elements. Construction and Building Materials 2, 2, June 1988, pp. 106-111.