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Editorial
Vade mecum*

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In September 2002, the 5th Triennial Congress was held at Dundee University, covering a wide range of issues relating to concrete's capabilities and future. The congress was of an international nature and consequently the trends, benefits, threats and concerns expressed are of global relevance. My closing address at the congress endeavoured to bring together such matters in a way so as to give a broad direction for concrete's further development. These thoughts are summarised in this editorial and may strike a chord with the readership.

Concrete is the most widely used construction material globally. It has become established in technically advanced countries and it has been estimated that some 1200 to 2400 kg per head of population are made each year (Glasser, F. P., pers. comm.).

Notwithstanding its wide use it faces challenges from alternative materials such as steel, wood, glass, plastics and natural masonry. Despite such challenges concrete remains the most widely used construction material globally and that situation is likely to continue, albeit with some changes. Some drivers for change are as follows:

- functionality
- aesthetics
- competitiveness
- opportunity
- serviceability
- environmental issues
- safety
- fashion.

In responding to change, particular sectors are gaining in prominence. One such example is the use of organic and inorganic composites internally and externally with concrete. These new materials offer better durability, lower weight and higher strength, ease of transportation, low thermal conductivity and less energy to make. For these reasons, the adoption of composite materials technology should be welcomed but, as with so many innovations in our industry, exploitation is guarded. It is clear that questions are being raised over the slowness to adopt new ideas and innovations within concrete construction.

Conceptually, fibre-reinforced composites are not new and the ground rules for design and selecting them are established.[1] However, reinforced concrete still consists conceptually of large steel fibres (rebar) as reinforcement in an inorganic matrix rather than organic.

Proven performance based on unequivocal data is key to acceptance by specifiers and users alike to give confidence in the adoption of such new technologies. Are such radical developments welcomed and do we express the functional benefits well enough to persuade clients, specifiers and designers to adopt these new options?

Composite materials should respond in a ductile manner—for example, they should be tough rather than simply strong. It is suggested that value should replace cost in selecting options. This is compatible with the concept of whole life costing, another strand repeated throughout the congress.

Do regulations and standardisation stimulate or impede innovation? Regulations can stimulate by demanding new and more exacting performance levels. The means of showing compliance with the regulations—for example, conforming to a standard or established technical specification—may not assist change. Performance not based on prescriptive specifications is one answer, but to implement such an approach requires a will to adopt and change. One stimulant to development is a clear performance demand. In the case of fibre-reinforced plastics, the stimulant has been seismic performance. Typical fibres are carbon, glass and aramids, which maintain cohesion beyond the point of failure.

The pursuit of lightweight and toughness is highly desirable and while carbon fibres have a role to play in achieving these objectives, it needs to be remembered that carbon can act as a noble metal in the galvanic

* Follow me

series; while it will not corrode, may cause less noble metals relative to it to do so. The carbon itself is conductive and given the right combination of conditions may exacerbate the process.

We now swing away from what might be perceived as high tech to something more mundane but no less important, namely floors and slabs. Flooring seems to represent a typical case of 'we seem to know what to do but do not always do it'. Self imposed inadequacy! Flooring is undoubtedly a substantial activity with some 1·5 million m^3 of concrete a year being used in the UK alone. However, what in principle could be simpler than a slab? What could be simpler than a slab made of concrete? The physical principles are known, or are they? When you take into account the conditions under which concrete for flooring is laid, that assumption might be questioned.

The problems with floors are global and commonplace. Notwithstanding all of this there would appear to be no substitute for concrete. Incipient cheapness, while a determining factor in flooring contracts at some €27 per m^2 (approximately £17·50)—the equivalent of a medium-quality fitted carpet—I cannot imagine the average fitted carpet functioning like an industrial floor.

An industrial floor is a good example of a multifaceted performance requirement from something that is basically very simple. Why has this topic received so little attention? Value, longevity and robust performance rather than cost might be a better approach. In this sector cost seems to dominate. Floor quality appears to have reached a plateau in terms of economically obtained quality. Again, this is a plea for whole life costing.

Concrete repair and rehabilitation still dominate the concrete scene, yet concrete's failures are a relatively small proportion of concrete's use. Failure is also small relative to new applications of concrete (e.g. self-compacting and ultra-high strength concrete) and in relation to major projects such as the second Severn crossing. However, in money and nuisance value terms, the profile of rehabilitation and repair is high and in that sense it attracts attention. It is the longer-term inadequacies such as poor appearance, sulphate and chloride attack, sulphation and carbonation that need to be addressed. Have these problems resulted from pursuing cost containment, lower cement contents and reduced cover rather than long-term value?

The entire topic of concrete's pathology and degradation processes is worthy of our attention. How do we extend with confidence the lifespan of concrete structures? Do we simply use concrete and design buildings, towns and cities as we have always done? Is such an approach sustainable?

Exploitation of new materials' options that will have a longer service life will compete with concrete. It is difficult to predict where the initiative for change will come from. Will it be radical design, reflecting efficient function or will it be ad hoc picking up on personal preferences and available options? Will the drive be regulation or market opportunism? Did the development of self-compacting concrete start with an engineering need or the availability of such a material's option, driven in turn by dispersant technology applied to cementitious suspensions rather than by sound market research justifying such a material. In a capitalist economy the ultimate drive is financial well-being, and planning and opportunism will live close together resulting in a somewhat volatile cocktail. So will concrete's future development be ad hoc and random or will sustainability, efficiency and environmental concerns dominate? Will such concerns only be responded to by wealthy economies with the less endowed creating their own appropriate technologies?

In determining the effect of challenges to concrete, the diagnosis stage is very important. The comparison with forensic science is justified and the diagnostician has many techniques at his disposal. Threats, such as thaumasite sulphate attack (TSA), alkali–silica reaction (ASR), alkali–carbonate reaction (ACR) and delayed ettringite formation (DEF) all challenge concrete, but we have to keep the potential problems in context. Notwithstanding this, the avoidance of ASR and ACR by selecting suitable aggregates remains a global issue.

Physico-chemical techniques have resulted in preventative and remedial measures such as cathodic protection, electrochemical re-alkalisation and chloride removal. All have a place and the latter two may well have moved on from being something of a curiosity to full-scale practical application.[2]

Shah *et al*. see the following targets for concrete in the twenty-first century:[3]

- more durable
- more constructable
- more predictable
- 'greener'.

I would add:

- more sustainable
- more competitive.

Since concrete is a global material, a case could be made for such developments to be globally supported with the results available to all. At the present time research cultures are very nationally and even regionally based, resulting in considerable duplication of effort on the one hand but also inventive variety on the other. The basic principle of such issues as rheology, hydration, corrosion and loading characteristics could be conducted in one or two locations whereas much effort is disposed at numerous locations around the world, each competing for funds and technical recognition.

It is only when we draw people together at such events as the Dundee congresses that we identify the common features. It depends upon whether a global material such as concrete requires global development in a global economy with appropriate planning and prioritising or whether a more parochial approach is more beneficial, if somewhat wasteful.

Concrete's form and appearance should be predictable—this means no unpleasant surprises. Natural ageing should be taken into account and neatness should be a prime aim for concrete development, but again a low-cost outlook does not aid aesthetic development. Production of high-quality surfaces, edges and joints is a priority with high-quality materials being required, resulting in ready-for-finishing details, for example, painting and wallpapering. There are opportunities for higher strengths and toughnesses—thin and slender structures, shells, lattices, profiled beams and columns; all are attainable.

'Concrete is a material for all reasons' and, if its permanency could be assured, we might invest more in some of these value-added options. But firstly, here are some disturbing facts.[4]

- In the UK about 25% of the energy used in industry is accounted for by the manufacture and transportation of building materials.
- It is estimated that 8% of global CO_2 emissions result from concrete production.
- One ton of CO_2 is produced per ton of Portland cement.
- Cement production is growing, particularly in developing countries, and what we gain by going in one direction to save the environment may be offset by trends in the opposite direction. In summary do we need an alternative to Portland cement? Such options are coming into play already.

Cements that require reduced energy for production (16% in some cases) and in turn produce less CO_2 (10% less) are seemingly attainable. Cements based upon belite with properties comparable to Portland cements and with some evidence to indicate that durability of resulting concretes might even be improved, have been produced on a commercial scale in China. There is also the recent TecEco development based on magnesium oxide (Glasser, F. P., pers. comm.). What is the future for these alternatives?

The use of fly ash, bottom ash and clean coal ash in cement production with new energy-generating technologies yielding different coal-derived ashes assists the quest for energy containment. There are many new end uses for waste materials—for example, sewage sludge for lightweight aggregates and for making clay bricks.

The task of carrying the environmental banner often falls to the lot of the manufacturer but contractors have a role to play as well. Greater integration and cooperation emphasise quality and safety and, to a lesser extent, cost—as has been the habit to date. These principles are set out in Egan's *Rethinking Construction*.[5] How do these attitudes impinge upon concreting activities?

First, starting with design concepts, concrete can play a role by way of its thermal mass in providing better air quality and natural ventilation. To effect radical change we need an integrated approach involving concrete design and function and increasing the overlap between environmental concerns and how we build.

It has been estimated[6] that a potential 400 million tons of reusable concrete, stone and brick from industrialised countries is available, and for such a resource to be available we have to consider the means of deconstruction and reclaiming the materials used—joined up construction underwritten by a joined up sense of public conscience. We need some form of fiscal encouragement to create a culture of change. We also need to plan for longer life and adaptability of buildings. Durability design should get as much attention as structural design.

Conclusions

(*a*) Concrete is capable of considerable further performance-based development and should not posture as a low-technology stereotype.

(*b*) Sustainability will remain a motivator for regulators, designers and concrete material providers. Is there a sustainable alternative to Portland cement?

(*c*) Adopted technology should be in proportion to prevailing local conditions.

(*d*) Creating a concrete culture at an operative level with recognition of skill status will help to exploit new developments and make the aim of best practice a reality.

(*e*) Laboratory-based data must reconcile with what happens in practice—transfer of micro mechanisms to macro fact. Methods of diagnosis should be accurate and unambiguous, performed by those qualified to do so and interpretation should be subject to severe scrutiny.

(*f*) The role of water needs more committed study. Water is necessary for the transformation of cement into masonry but it is also responsible for much of concrete's degradation.

(*g*) Development is needed of tough concrete rather than high-strength but brittle concretes.

(*h*) The visual appearance of concrete with time is of concern. Concrete should remain pristine and not take on a patina of industrial downgrading.

(*i*) Coating and sealing may not be sufficient. We have to understand how concrete behaves with fluctuations in its surroundings at a micro-mechanistic level.

(*j*) Can we consider structures that do not contain normal reinforcement but rely solely on metal fibres and a reconstituted matrix?

(*k*) The use of recycled and waste materials should be encouraged using legislation and tax incentives for those that comply—a stick and carrot approach.

I welcome your views.

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