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nanotechnology in construction

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Preface

Nano-scale science emerged almost a century ago when molecular and then atomic- size objects were first observed and identified. Since then, *nanoscience* has developed greatly, particularly in the fields of physics, chemistry, medicine and fundamental materials science.

Nanotechnology emerged much later, with a rapid advance since the early 1990s, when demand for characterisation, manipulation, production or even assembly of objects at the nano-scale increased *and* the leading edge of technology advanced sufficiently to provide the first generation of effective tools for such applications.

Unlike nanoscience, *nanotechnology is an enabling technology*, which was particularly driven by the advancing micro-electronics industry, where continued miniaturisation was commercially highly desirable. The exploitation of nanotechnology progressed most rapidly in areas where there were immediate applications, leading to products of very high value or products which were mass-produced, where there was a strong market pull. In such areas the high cost of nanotechnology-based Research and Development facilities were recoverable over a commercially acceptable short to medium term. Over the last few years, promoters of nanotechnology succeeded in raising steeply the public profile of nanotechnology. Significant exploitation of new opportunities for investment commenced, assisted by a decline in growth of IT based business.

The construction industry differs substantially from other industries, especially in the unique nature of its product and in historically very low Research and Development investment, which often relies on adaptation and exploitation of advances from other scientific and technical fields. Construction is a very significant global economic area. However, largely because of its special characteristics, very little is known about the existing and likely future impact of nanotechnology. Where many conferences and similar events were already held in other, non-construction related, scientific and technical sectors, networking on an international scale advanced rapidly. It was time to organise an international forum on the specific topic of *construction and nanotechnology*, with a very wide scope, covering the whole spectrum of Research and Development and commercial construction and construction-related activities. The Advanced Concrete and Masonry Centre of the University of Paisley took on the organisation of the first such event in 2000, leading to the 1st International Symposium for Nanotechnology in Construction being held in Paisley in June 2003.

It was not a coincidence that the organisation of the 1st Symposium on Nanotechnology in Construction (NICOM 1) was carried out by the Advanced Concrete and Masonry Centre (ACMC) and the attached Scottish Centre for Nanotechnology in Construction Materials in Paisley, Scotland. The ACMC already had a track record of active research, which depended on the very early introduction and exploitation of nanotechnology in the construction materials field and commenced well before the recent rapid rise in promotion of nanotechnology overall. Research into advanced (simultaneously stronger and tougher) composites for construction applications, based on reinforcement of

brittle matrices (e.g. ceramic, carbon, but particularly cementitious) by multifilament reinforcing elements, had been carried out at the University of Paisley since the late 1970s. Further development and exploitation of this promising novel approach relied critically on characterisation and subsequent design/engineering of bond within and outside the fibre bundles. Progress slowed down in the absence of a technology to enable measurements and characterisation of key properties at the sub-micron scale. A sharp technology-watch was therefore maintained and when the first generation, then leading edge, nanotechnology-based instrumentation was developed for other applications (thin films/coatings, micro-electronics etc.), it was adapted for the new purpose and installed at the ACM Centre in Paisley in the early 1990s. The ACMC facilities, which enabled a gradual move from micro to nano-scale load application and indentation, were continually improved as technology advanced. In conjunction with the application of other advanced techniques, such as Focused Ion Beam micro-fabrication, which facilitated hitherto un-achievable shaping of diamond indenters, research progressed and Proof of the Concept for design and performance of the new generation of advanced composites was obtained in the late 1990s. This provided the required evidence for funding of a second, currently state-of-the-art, nano-indentation facility housed in a new specialist laboratory built away from the busy main Campus of the University of Paisley. A Scottish Centre for Nanotechnology in Construction Materials (SCNCM) was established as an integral part of the Advanced Concrete and Masonry Centre as part of project NANOCOM (2000-2003). The work of the SCNCM has now widened, as immediate applications for nano-scale based characterisation in the two other groups (Concrete Technology; Heritage Masonry) became apparent and are being presently pursued.

The experience, track record and current research of the team at Paisley enabled it to establish important collaborations in the broad field of Nanotechnology and Construction in the UK, and worldwide. A 'horizontal' RILEM Technical Committee TC-NCM on Nanotechnology of Construction Materials with a wide remit, chaired by Professor PJM Bartos, immediately attracted full membership of experts world-wide. It held its inaugural meeting in Madrid in September 2002.

The significance of nanotechnology related Research and Development has become recognised worldwide and government funding authorities and private/corporate investors have made substantial investments. This has included the European Commission, which provided financial support for the 1st International Symposium on Nanotechnology in Construction through project NANOCONEX (Growth, 2002-2003). The European Commission later adopted nanotechnology as one of the key topics within its 6th Framework (2002-2006) of support for research. At the Symposium, Mr Hervé Péro outlined the future activities of the EU in which nanotechnology and construction will be involved.

Members of the RILEM TC-NCM and key partners in project NANOCONEX formed the Scientific Committee for the Symposium, chaired by Professor PJM Bartos. Their assistance in selection and reviewing of contributions and in chairing of Sessions at the Symposium is gratefully acknowledged. In addition, the US National Science Foundation, represented by Dr Ken Chong, supported the event by providing a review of developments in the USA and sponsoring participation at the Symposium of a group of leading US researchers in nanotechnology and construction.

There were many organisations and companies which supported the Symposium and whose contributions were much appreciated. However, the event, which attracted 130 delegates from 30 countries worldwide, would not have taken place without a number of colleagues at the University of Paisley who went well beyond their call of duty to ensure that the event was a success. It is impracticable to name all, however special thanks go to

Mrs Margaret Nocher, Administrator of the ACM Centre, for her efficient management of the very complex organisation during the preparation and running of the Symposium. This was significantly assisted by Mrs Lorraine Dymond and Mr Graham Brooks, whose untiring efforts helped to guarantee the financial stability of the event.

Dr Pavel Trtik, in early stages, and subsequently Dr John J Hughes, chaired the Organising Committee which co-ordinated all activities.

These proceedings, published by the Royal Society for Chemistry, contain only contributions which were selected and presented at the Symposium. The topics and emphasis of the contributions reflected the fragmented and unbalanced nature of current nano-related research in this very wide area. They also reflected the diversity of prospects for its further development, commercial exploitation and even societal impacts within different sectors of construction. It has been a considerable challenge for the Editors to provide a rational sequence in structure of the proceedings, if not a complete 'balance'. A number of contributions were genuinely multi-disciplinary in their content: an expected and desirable feature, which nevertheless complicated the editing of this publication. A few contributions, particularly from the United States, were presented but could not be provided as full papers. In such cases, the Editors decided to include extended abstracts in the Proceedings, with references, to maintain coverage of research in progress.

The "NICOM 1" Symposium was a path-finding event, the first of its kind, promoting awareness and then integration of Research and Development across traditional scientific and technical boundaries. Delegates at the Symposium unanimously endorsed this aspect as the best way forward, which maximises realistic potential for exploitation of nanotechnology in the whole of the construction domain. Learning about related/relevant research in other disciplines and being able to meet investigators from areas of research not normally encountered in specialised networks and through discussion of their work was much appreciated by all. It is expected that 'sectorial' events focusing on specific aspects, sections or products related to construction and nanotechnology will be held in the near future. Another wide-coverage, integrating and multidisciplinary 2nd International Symposium on Nanotechnology and Construction is then expected to follow in 2-3 years' time.

Professor Peter J.M. Bartos

Dr. John J. Hughes

Dr. Pavel Trtik

Dr. Wenzhong Zhu

Paisley, September 2003

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British Cement Association
The Institution of Structural Engineers

Contents

Modelling

Materials and Products

Applications

Part 1: Nanotechnology in Construction in the 21st Century

FROM NANOTECHNOLOGY TO NEW PRODUCTION SYSTEMS: THE EU PERSPECTIVE

Hervé Péro

DG Research - EUROPEAN COMMISSION – 200 rue de la Loi, Brussels

1 INTRODUCTION

It is my pleasure to be able to give a key note address on such an exciting subject, not only because I am an engineer by training and have worked several years in industry - therefore it reminds me of very good times - but also because research on nanotechnology and its applications represent a key factor for the development of high added value products and will surely provide the basis for a competitive and sustainable development of European industry.

2 NANOTECHNOLOGY

Nanotechnology is a relatively young field of science and technology, with an enormous market potential and societal and economic impacts, and for all industrial sectors. Nanotechnology is truly multidisciplinary. Research at the nano-scale frontier is unified by the need to develop knowledge, tools, techniques and expertise on atomic and molecular interactions for applications in real products. Nanotechnology covers a wide range of research and innovation aspects, for example: magnetic random access memories; simplification and use of biological molecular functionalities; nano-wires, nano-crystals, carbon nano-tubes, and quantum effects; industrial production of nano-coatings; epitaxial self-assembly, etc. Nanocomposites for example, which are hybrids of greatly differing components – often comprising an inorganic and an organic component – are probably among the most promising new materials. Their applications range from mechanically reinforced lightweight components to components for batteries, sensors, adhesives, packaging materials, pigments, building and construction materials and artificial body parts.

The development of a strong European position in this field, and the establishment of a European nanotechnology industry, requires a concerted approach at the European level in order to:

- Merge and facilitate complementary and unique competencies.
- Define strategic plans and positioning (roadmaps).
- Share large investments and/or common use of research facilities .
- Set up common R&D open platforms.
- Initiate cores for EU collaborations.

- Increase attractiveness of research groups for e.g. junior researchers.

The European Union via the Framework Programmes funds only part of the research in Europe (its contribution corresponds to roughly 6% of overall European investment in research). The current Framework Programme (period 2003-2006) is open to international co-operation virtually with all Countries in the world. Despite its reduced quantity, by quality the Union's research plays a key role for European integration and acts as catalyst of much larger impact. In orientative terms, the total European investment in the nano-research is being estimated around 700M Euro per year.

3 RESEARCH AND THE CONSTRUCTION SECTOR

The **Construction sector**, with annual turnover of almost 1000 Billion €, total directly employed workforce of more than 11 million people, and another 15 million indirect employment is Europe's major industrial sector contributing with about 10% to the GDP. It is of enormous importance for European social and economic cohesion, considering also the facts that it is largely dominated by **small and medium size enterprises and it motivates the economic activity of all other sectors by consuming products and services and providing space and infrastructure**. Europe is world leader with 30% of the overall market but construction is mainly local business as less than 4% of the market is international.

Facing challenges of competitiveness and the needs for modernisation, the commitment of the sector in research is a key priority. The construction sector drastically needs research activities, for the competitiveness of its large projects of course, for ensuring safety of infrastructures such as bridges or tunnels, for maintaining the world cultural heritage, but also to support modernisation of the numerous SMEs (97% of enterprises).

However, the fact that this industry is very fragmented makes the changes happen very slowly. Tight regulation is also one of the characteristics of this sector, which needs to be taken into account in forecasting any technical progress. Long life span, high costs, and particular business model are also obstacles for drastic innovation. However, the signs of changes are there; we see more and more public-private partnerships, service contracts, performance based approaches, products/services, etc.

The Construction sector has continuously participated in European Research Programmes for more than 15 years and has clearly demonstrated its interests in different fields of research and innovation:

- Higher performance and intelligent materials, including for repair and rehabilitation of existing structures.
- Innovative systems that optimise the "design-production-service-end of life" value-chain through the development of new tools based on information technologies.
- New technologies for processing of multicultural applications/products.
- New production methods that drastically reduce the amount of water, energy and waste, as well as environment technologies linked with recycling or recovery of products.

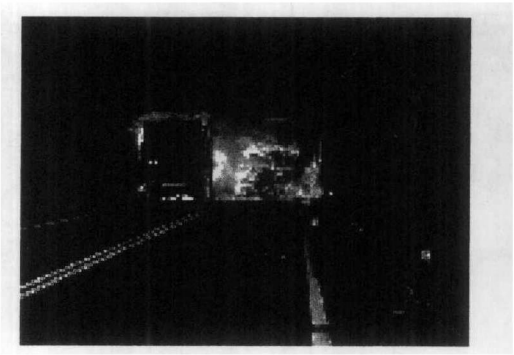

Figure 1 *Fire in tunnels (network FIT, project UPTUN)*

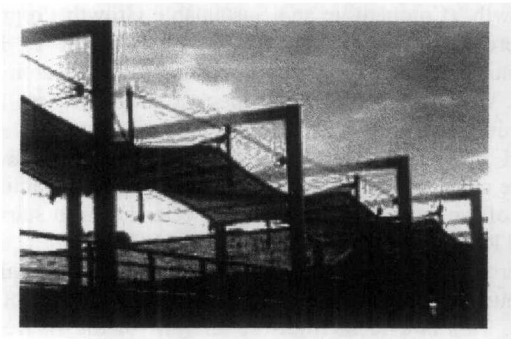

Figure 2 *Lightweight membrane construction (TENSINET)*

Innovation in construction is largely "invisible" for the general public. It involves very often the use of new technologies and/or materials for the design, construction or maintenance of well-known products. As generic and high added value products, many elements of the built environment are at the basis of the competitiveness of European industry as a whole, as well as the basis of many clean and safe technologies for a better world.

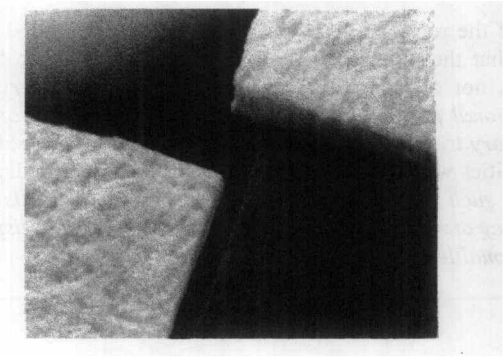

Figure 3 *Construction: Nonwovens for insulation of interiors.*