Ultra High Performance Concrete Information and Literature Search - 2011
(UHPC I&LS-2011)

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Advanced Materials Effort and Counter IED Mitigation (Active Blast Protection)
Abstract: Ultra high performance concrete (UHPC) materials are advanced cementitious materials that display much higher levels of technical performance compared to conventional strength and high strength concretes. This category can include materials such as defect-free, dense particle, reactive powder, engineered composite, multi-scale particle, and fiber-reinforced concretes. UHPC materials can have unique advantages with respect to response capabilities, mechanical properties, environmental stability, construction methods and forms, and aesthetic qualities, and have the potential to help revitalize a deteriorating infrastructure. This report is the 2011 version of search results for open-source information and technical literature references on UHPC materials. References are provided on product information from engineering and scientific journals, conference proceedings, magazine articles, books, and patents. The scope extends from basic and applied research to construction projects.

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Preface

The research for the Ultra High Performance Concrete Information and Literature Search-2011 reported herein was conducted by personnel of the U.S. Army Engineer Research and Development Center (ERDC). Funding for the work was provided by the Department of Homeland Security, Science and Technology Directorate, Infrastructure Protection and Disaster Management Division: Mila Kennett, Program Manager.

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COL Kevin J. Wilson was Commander and Executive Director of ERDC. Dr. Jeffery P. Holland was Director.
Currently, there is a critical need for advanced building materials for the U.S. domestic infrastructure, not only for new high-performance construction, but also to enhance the performance of existing structures. These materials are required to be increasingly more energy-efficient, environmentally friendly, sustainable, and resilient. They need to meet multi-hazard and multi-performance design criteria and be easily produced and incorporated into construction. Furthermore, these materials must be cost effective through a structure’s life cycle.

Concrete is the most widely used material in building construction. However, there are durability, security, and sustainability issues concerning current commercially available products. Within the last few decades, research has been conducted on advanced cementitious materials displaying ultra high performance characteristics. This includes a broad range of materials such as defect-free, dense particle, reactive powder, engineered composite, multi-scale particle, and fiber-reinforced concretes. Research and commercial brands are available and examples are BCV® - beton composite vicat, BSI - Beton Special Industriel, CARDIFRC®, Cemtecmultiscale®, Ceracem®, CRC® - compact reinforced composites, Cor-Tuf®, DSP - densified small particles, Densit®, DFG UHPC, DORSICEM, Ducon®, Ductal®, MDF - macro-defect free, Microdur®, NIM - new inorganic materials, RPC - reactive powder concrete, SIFCON, and SIMCON.

For purposes of the current research effort, a definition of ultra high performance concrete (UHPC) is a class of “concrete” materials that display “ultra high” performance in at least one technical performance area and with an unconfined compressive strength approximately 20,000 psi (140 MPa) and higher. The materials can have high binder content and special fine aggregates. They may contain fibers to achieve non-brittle behavior and, if possible, to dispense with passive (non-prestressed) reinforcement. One type of UHPC material of interest has very small pores, low porosity, and disconnected pore spaces, and steam curing and pressure can be used to attain strengths approaching 30,000 psi (210 MPa) and higher. Example microstructures of a conventional strength concrete material and a reactive powder UHPC material are shown in Figure 1.
If viewed on the basis of just a cubic yard of material, the cost of UHPC materials can be over ten times greater than the cost of conventional strength concrete. However, UHPC materials may offer unique advantages and higher performance levels that justify the increased cost. Such factors to be considered include strength, ductility, flexibility and toughness, impact resistance, dimensional stability, durability / increased useful life, impermeability /freeze/thaw resistance, corrosion resistance, abrasion resistance, aggressive environment resistance, and chemical resistance. Other advantages may include ability to construct thin sections and use complex structural forms, elimination of passive reinforcement (reinforcement bars), precise replication, use of conventional concrete equipment, ability to cast by pouring, injection or extrusion techniques, self-consolidation, off-site manufacturing, fast construction, and reduced maintenance. From an aesthetic viewpoint, but also for security purposes such as disguising the appearance of the material, some UHPC mixtures may have color and texture options, sanded or polished surfaces, and even are made to look similar to materials such as stone or marble. Laboratory and field testing have shown that some UHPC materials may be significantly better than conventional concrete for protective structure applications. Research efforts on UHPC are being conducted around the world to reduce costs and use local and “green” materials.

In summary, advanced cementitious materials known as UHPC have a strong potential to help in the revitalization of a deteriorating infrastructure and in the building of new infrastructure that is sustainable, resilient, and long-lasting. However, to date, application of this material has been limited in the U.S. construction industry.
This UHPC Information and Literature Search-2011 (UHPC I&LS-2011) is a “work in-progress” to provide a listing of information on and references for UHPC materials with respect to basic and applied research, technical data, and project information. It is an expansion and update of an unpublished, baseline UHPC I&LS that was generated by the author in 2008. In the UHPC I&LS-2011 report, information and reference items from the baseline UHPC I&LS are given in black and not preceded by a symbol. An item preceeded by a plus sign (symbol “+) is a reference obtained subsequent to the 2008 version. An item preceded by a negative sign (symbol “-”) and displayed in a light gray color was obtained from the reference section of a document referenced in the baseline UHPC I&LS, and the item content needs to be verified and its corresponding reference material needs to be obtained.

The UHPC I&LS-2011 is divided into three sections: Section 1 contains a listing of product information references; Section 2 is a bibliography of technical documents and articles from engineering and scientific journals, conference proceedings, magazines, and books; and Section 3 includes a list of U.S. and foreign patents on UHPC materials and their precursors. It is hoped that this report provides a helpful and efficient resource for anyone interested in UHPC materials and their potential to enhance infrastructure performance.

**Section 1: UHPC Products and Information**

The following is a listing of information on UHPC products, technical data, and projects:

**Bekaert**

Bekaert StrHiCsteel fibres 2003

+Ceracem. Sika Ceracem®: Brevet BSI®

+CRC® – Compact Reinforced Composite www.cr-tech.com
  +CRC® – Intro web
  +CRC® – A description
  +CRC® – Compact Reinforced Composite
  +CRC® – Durability
  +CRC® – Safety Data Sheet
  +CRC® JointCast
  +CRC® JointCast – Handling instructions
  +CRC® JointCast – Examples of applications
+CRC® Joints - High strength joints for precast bridge slabs – Summary report
+Tech-Wise – Off-shore wind turbine towers in high-strength concrete

Densit®

Densit® advantages[1]
+Densit® – CtO’s field of operations
Densit® pro-concrete-binder[1]
Densit® pro-flexbinder-uk[1]
Densit® pro-inducast-3000-uk[1]
Densit® pro-inducast-4000-uk[1]
Densit® pro-inducast-6000-uk[1]
Densit® pro-inducast-tt5-uk[1]
Densit® security barriers
Densit®

Ductal® – Lafarge, Bouygues & Rhodia

Lafarge, Bouygues & Rhodia websites
http://www.lafargenorthamerica.com/wps/portal/
http://www.imagineductal.com/imagineductal/history.asp?RND=3P4IS4OECDFDIYXR

Ductal® – Technical & Project Information

Ductal® – Technical Information
+CSTB Ductal® -FO Evaluation Technique, 28 pgs.
Ductal00 FAQ
Ductal00 Introduction Comm Kit
Ductal01 WhatIsDuctal
Ductal02 HowStrongIsDuctal
Ductal03 HowDurableIsDuctal
Ductal04 AestheticsOfDuctal
Ductal05 HowDuctileIsDuctal
Ductal® – Products and Services
+Ductal® A revolutionary new material for new solutions, 38 pgs.
Ductal® Aesthetic qualities
Ductal® At a glance
+Ductal® BS1000 – Product Data Sheet
Ductal® Characteristics
Ductal® Durability data
Ductal® Durability
Ductal® History and Evolution
Ductal® Mechanical performance
+Ductal® Product Data Sheet AN1000
+Ductal® Product Data Sheet AR1000
+Ductal® Product Data Sheet BS1000
+Ductal® Product Data Sheet CS1000
+Ductal® Product Data Sheet JS1000
Ductal® Spec-FM Gris 2GM2.0
Ductal® Spec-FM Gris 3GM2.0
Ductal® Spec-FM Gris Feu 2GM2.0F
Ductal® Spec-FM Gris Feu 3GM2.0F
Ductal® Spec-FO Blanc 2Bo4.3
Ductal® Spec-FO Blanc 3Bo4.3
Ductal® Spec-FO Gris 2Go4.3
Ductal® Spec-FO Gris 3G04.3
Ductal® Standard Operating Procedure
Ductal® TechChar Metallic Fibres – Imperial
Ductal® TechChar Metallic Fibres – Metric
Ductal® TechChar Organic Fibres – Imperial
Ductal® TechChar Organic Fibres – Metric
Ductal® Trademark
+Ductal® Ultra-High Performance Concrete - Building Envelope Solutions
Ductal® What can Ductal do for you
Ductal® What is ductal
Lafarge cement manuf 1
Lafarge cement manuf 2
Lafarge cement manuf 3
Lafarge cement manuf 4
Lafarge Ductal® – Architectural Brochure
Lafarge Ductal® MechPerf web 2006
Lafarge Ductal® Passanti home 2007
Lafarge Ductal® Premix MSDS
Lafarge Ductal® R&D
Lafarge Research – Nanomaterials
Lafarge Research – Nanotechnologies – Monteiro
Monteiro – Strength presentation
RPC concrete
+VSL Ductal® - Roof protection system against mortar threats. 2007, 2 pgs.
+VSL Ductal® protection solutions. 8 pgs.
z Lafarge Ductal® docs

Ductal® Projects
CN de Arts&Metiere Ductal
Ductal®-o-AESTHETICS
Ductal®-o-DUCTILITY
Ductal®-o-DURABILITY
Ductal®-o-STRENGTH
Ductal® – aalborgwhite wu_01_2007
Ductal® Applications Bridges & Footbridges – words
Ductal® Applications Bridges & Footbridges
Ductal® Applications Building Envelope
Ductal® Applications Urban Environment
Ductal® Architect Ductal Qualities
Ductal® Architect References
Ductal® Architect Testimony
Ductal® Discover Ductal Engineering Office
Ductal® Engr Office Methods & Calculations
Ductal® Engr Office References
Ductal® Engr Office Testimony
Ductal® Owner Durability and Maintenance
Ductal® Owner References
Ductal® Owner Standards and Certifications
Ductal® Owner Testimony
Ductal® Potential Applications
Ductal® Precaster Applications
Ductal® Precaster References
Ductal® Precaster Testimony
Ductal® Renovation
Ductal® Structure
Ductal® Bus shelter
Ductal® Escaliers Decors – Staircase
Ductal® Joppa long span silo roofs
Ductal® Shawnessy LRT Awards PrRel
Ductal® Thias Bus Center 03122007-MIPIM-uk
ETT Proposal FLA Ductal®
Lafarge Ductal® Making headlines - Photos
Lafarge – Ductal® Correctional Facilities
Lafarge – Ductal® Projects – 0 List – website
Lafarge – Ductal® Projects – Alberta Construction
Lafarge – Ductal® Projects – Anchor Plates for Seawall Tie
Lafarge – Ductal® Projects – Anchor Plates
Lafarge – Ductal® Projects – Cottenom Cooling Towers Beam
Lafarge – Ductal® Projects – Detroit-Columns
Lafarge – Ductal® Projects – Joppa Long Span Silo Roof
Lafarge – Ductal® Projects – Martel Tree
Lafarge – Ductal® Projects – Monaco Train Station
Lafarge – Ductal® Projects – ratp thiais
Lafarge – Ductal® Projects – Shawnessy LRT Station
Lafarge – Ductal® Projects – Sherbrooke Bridge
Lafarge – Ductal® Projects – The Footbridge of Peace
Lafarge – Seonyu – Ductal® 09162004-press_Skorea_042602-uk
Lafarge Discover Ductal® Owner
Lafarge Ductal® A new dimension of concrete
Lafarge Ductal® Aesthetic Qualities
Lafarge Ductal® Concrete
Lafarge Ductal® Making headlines – Photos
Lafarge Ductal® Making Headlines
Lafarge Ductal® New Applications
Lafarge Ductal® Newsletter 2005 ANGnum2
Lafarge Ductal® Precaster
Lafarge Ductal® Sustainable Development
Lafarge Ductal® Use
Lafarge NA Ductal® projects
Lafarge NA Project list
Lafarge Research Hypergreen
z Ductal® Projects – misc images 1
z Ductal® Projects – misc images 2
z Ductal® Projects – additional information

Lafarge, Bouygues & Rhodia & VSL
Bouygues – SefiFrance
Bouygues & Rhodia
Lafarge 03222006-press_themabook-Brochure_Chair_sustainable-uk
Lafarge 03222006-press_themabook-PressKit_Chair_sustainable-uk
Lafarge 06202005-pub_sus_dev-Lafarge_and_wwf_partnership-uk
Lafarge 06212006-press_sus_dev-Lafarge_Award_Renew_Energy__uk
Lafarge 06222006-press_group_finance-Excellence_2008_analyst_pres-uk
Lafarge 22032006-press_sus-academic_chair-uk
Lafarge – 05312006-press-arts_et_metiers_exhibition-uk
Lafarge – Batimat 09162004-press2003_110303-uk
Lafarge – Batimat 09152004-press_2001_110201-uk
Lafarge – CNRS 09162004-press_CNRS_012202-uk
Lafarge – Hypergreen 03092006-press_sus_products-MIPIM-uk
Lafarge – Lafargeenviroev
Lafarge – Thias Bus Center Ductal® 03122007-press-MIPIM_mar07-uk
Lafarge – WETC 09162004-press_products-R&D_100903-uk
Lafarge Annual Report 2004
Lafarge ANON CementAn2004
Lafarge Group web 2006
Lafarge Joppa Roofs Nova Award NomBook2003
Lafarge Lafont Interview 2006
Lafarge Overview web 2006
Lafarge Sales web 2006
Lafarge Technology Center
Lafarge, Bouygues & Rhodia Co Symbols
Lafarge Perry ecosmart
Perry PressRelease2003 Shawnessy LRT Station
Perry PressRelease Detroit Columns
Rhodia_dans_le_monde
VSL Int website 2007

Ducon® [http://www.excendinc.com]
Ducon® rev
Excend-DUCON®SecurityProducts2007

ERDC – VHSC, Cor-Tuf
WES Treat Island

+Fondu Fyre – Anon, Wikipedia, 2010

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the “APC® concrete,” 2009
+The world’s first practical use of 200 newtons per square millimeter-strong
advanced performance concrete, 2008
+Technology established for high fire-resistant and high-strength concrete able
to withstand up to 200 newtons per square millimeter, 2006
+Construction of a 56-story reinforced concrete condominium, the tallest in
Japan, 2002
+Preparing for an era of 50-floor-class superhigh-rise RC structures, 2002
+New superhigh-strength concrete with advanced fire resistance that can expand
floor space and reduce the costs and construction time of 50-story-class RC
condominium high-rises, 2000

Section 2: UHPC References

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and presentations available as open source information on UHPC materials:

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March 2008, Kassel, Germany, Eds. E. Fehling, M. Schmidt, S. Stürwald (Kassel,

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Performance Fibre Reinforced Concrete - Designing and Building with UHPFRC:
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Section 3: U.S. and Foreign Patents on UHPC and Precursor Materials

The following is a listing of patent websites and patents on UHPC and precursor materials:

Patent websites

European Patent Office
http://www.epo.org/patents.html
http://gb.espacenet.com/search97cgi/s97_cgi.exe?Action=FormGen&Template=gb/EN/home.hts

US Patent and Trademark Office, Department of Commerce
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http://www.wipo.int/portal/index.html.en

Patent download
http://free.patentfetcher.com/Patent-Fetcher-Form.php
**Patents**


Ultra high performance concrete (UHPC) materials are advanced cementitious materials that display much higher levels of technical performance compared to conventional strength and high strength concretes. This category can include materials such as defect-free, dense particle, reactive powder, engineered composite, multi-scale particle, and fiber-reinforced concretes. UHPC materials can have unique advantages with respect to response capabilities, mechanical properties, environmental stability, construction methods and forms, and aesthetic qualities and have the potential to help revitalize a deteriorating infrastructure. This report is the 2011 version of search results for open-source information and technical literature references on UHPC materials. References are provided on product information from engineering and scientific journals, conference proceedings, magazine articles, books, and patents. The scope extends from basic and applied research to construction projects.