EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

Exploratory Workshop Scheme

Standing Committee for Life, Earth and Environmental Sciences (LESC)

SCIENTIFIC REPORT

ESF Exploratory Workshop on

Ways To Reduce Carbon Foot Print Of Portland Cement Production And Cementitious Products

Coventry (UK), 22-23 June 2009

Convened by:

Eshmaiel Ganjian ① and Mark Tyrer②

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1. Executive Summary:

There were 23 delegates from 12 countries, the majority of whom made a presentation on their interest relevant to the topic of the workshop.

The workshop explored the potential for CO_2 savings in the European cement industry through the increased use of supplementary materials replacing Portland cement clinker in cement, especially those which are currently underused. The workshop focused on five inter-related themes:

1) The current state of CO_2 emissions in the European cement industry
2) Options for CO_2 reduction
3) Current trends for CO_2 reduction in cement manufacturing
4) Current research and emerging trends
5) Case studies and a discussion on future collaborative research

All presentations will be available on the weblog for participants of the workshop only in the pdf format, but not for general circulation. There were no objections to this.

The last session of the workshop was dedicated to the summing-up and further actions to be taken. These included the following:

- There is a need for more research, among others, on the following potential CO_2 reducers, with a view to create networks from this group to those in related industries:

    1. Metals sector : Steel and non-ferrous slags
    2. Natural pozzolans : Abundant, but reserves are not always recoverable
    3. Calcined clays : Alternatives to Metakaolin
    4. Mineral fines and combustion products – both pozzolanic and filler materials

- There is an immediate need for desk studies leading to state of the art reports on several of these areas, together with commercial viability statements, leading to a number of key research objectives, possibly funded by ESF. This will then lead to a major co-ordinated FP7 bid next year.

2. Scientific Content:

The workshop highlighted the following points:

- Concrete is the most widely used construction material on earth. In terms of its embedded carbon, it is a benign product, being associated with relatively little CO_2 per unit mass when compared with metals, glasses and polymers. Despite this, concrete produces roughly 150kg/t of CO_2, compared to, say, 2000 for glass and 3000 for steel, Conversely, it is made in such vast quantities, that it is responsible for over five percent of anthropogenic CO_2.
- It is expected that the cement production will grow by 3- 4 percent per annum in the next 10 years, such that CO_2 generation will become more dominant if nothing else changes.
- On European average the market share of Portland composite cements (EN197-1 CEM II) is more than 50% with increasing tendency. In contrast the market share of Portland cement (CEM I) continiusly decreased during the last 15 year to a current level below 30%.
- Raw material in clinker production accounts for about 0.53t CO_2/t at present, compared to 0.38t CO_2 /t for fuel demand.
- Changing from the wet to the dry process has reduced energy consumsion from 5.5 to 3.0GJ/tonne. Some estimates suggest a reduction to 2.8GJ/tonne may be possible in future.
- Less than 10% of all current cement could be served by presently available granulated blast furnace slag, so slag alone is not the sole solution – fly ash has much larger reserves and potential for re-use and other low-energy cements will also need to play a part. Limestone reserves are huge if it could be made more reactive, for example, by increasing the aluminium content of clinkers.
- Switching from coal (95kg CO_2) to oil (78) to gas (56) improves fuel CO_2 efficiency at kiln, confirming that fuel type has a role to play in CO_2 reduction.
- In summary, a common belief is that the CO_2 agenda is not critical yet – CO_2 generation will need to become much more expensive to make a worldwide economic impact. It may need to be as high as £50-100 / tonne to force the carbon agenda such that its impact on cement production forces a step-change.
- The three key issues are currently:
  - carbon reduction,
  - primary energy reduction and
  - whole life cycle costing (to include transport costs of all materials and fuels).

- Carbon capture and storage is a significant research challenge. Capture and re-use of CO_2 in the flue gases in cement manufacture is addressed in a recent patent by Mori (1995) in which CO_2 is reacted with limestone :

  $$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$$

  The calcium bicarbonate is benign and suitable for discharge to the sea.
- An option was reported to intensify CO_2 in flue and combine with O_2, as used in the glass industry. Where can captured CO_2 be safely stored and does it need to be on site where generated?
- Ternary cements, with mixed constituents introduce more possibilities. For example, clinker- fly ash-limestone combinations will produce and aluminium rich *CASH* gel and CAH that can react with limestone to form calcium carboaluminate hydrates leading to more chemical bound water resulting in higher strength and lower permability of concrete produced thereof. (In cement chemistry C = CaO, A = Al_2O_3, S = SiO_2, H = H_2O).
- Fluidised bed technology with calcinated clays can reduce CO_2 by about 26 percent, but it is recognised this depending greatly on the mineral composition of clay.
- Improving the grinding technology is as important to this industry as it is to many other industries.
- Use zero clinker cement for low strength applications, of which there are many.

3. Assessment of the results, contribution to the future direction of the field:

3.1 Assessment of the results.

There were two primary results of the meeting; the first was a detailed exchange of ideas and the second was a discussion of the needs of the industries represented and partners present and recommendation of how best to collaborate. The exchange of ideas is listed in section 2 above and an assessment follows:

1) **The needs of the cement producers** are two-fold. First there is an obvious need to lower CO_2 emissions whilst maintaining the profitable production of cement and the quality of the concrete structures. Much research has and continues to be funded directly from the industry and this divides into four broad categories:

i. **Blended or Composite Cements.** By comparison, all participants have experience in this area and the field of blended cements generated enthusiastic debate (See fig. 1). The cement industry has invested heavily in blended cements research over several decades. Commercially mature, this technology focuses on various material streams:

- Coal combustion ash / Pulverised fuel ash / Fly ash / Burnt oil shale
- Ground, Granulated Blast furnace Slag
- Limestone
- Silica Fume
- Rice Husk Ash
- Calcined clays (metakaolin and others)
- Natural Pozzolans

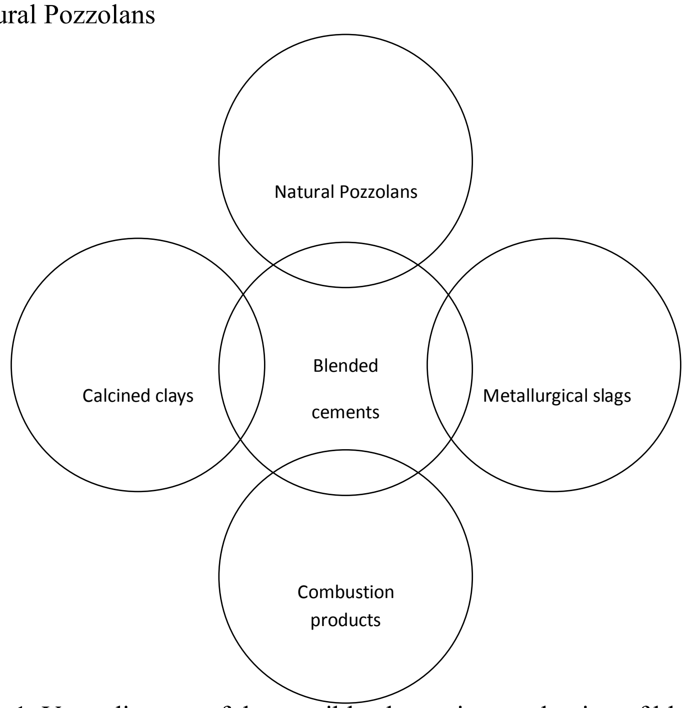

Figure 1. Venn diagram of the possible alternative production of blended cements.

Of these the cement producers felt that the last two (calcined clays and natural pozzolans) offer the greatest and most immediate impact on CO_2 reduction in the foreseeable future. Research on thermally processed clays and natural pozzolans has, for the most part been concerned with their chemical and physical properties as supplementary cementing materials. Work on their reactions in ternary and higher-order mixtures remains incomplete and there is a need to collect and review extant work and to close the knowledge gaps. Of more immediate concern however, is the lack of knowledge at either a national or European level as to the extent of these resources, their locations, quantities and qualities.

ii. **Efficiencies in processing**. Several presentations referred to advances in kiln design, grinding technology and especially in heat integration through the use of pre-heaters and efficient use of low grade heat. Although this information was of interest to the audience, it described technologies away from the expertise of most participants. Consequently, this is not an area in which this workshop intends to attempt a future influence.

iii. **Low energy clinker development**. This has been a very active area of research in recent years and the principal groups of clinker types are:

- Belite – aluminate clinkers. Also known as *porsol* cements, this phase assemblage is dominated by CA ($CaO.Al_2O_3$) , $C_{12}A_7$ ($12CaO.7Al_2O_3$) and β-C_2S ($2CaO.SiO_2$). Formed from an appropriate mixture of bauxite, limestone and clay, the clinker is formed at relatively low temperature (1250-1300°C) presumably by solid state diffusion, thus avoiding formation of the more thermodynamically stable phase gehlenite (C_2AS). Known since the 1970s, there is renewed interest in this system owing to its low energy demands (both in terms of thermal processing and grinding) and its relatively simple chemistry.
- Sulpho-aluminate clinkers ($3CaO.3Al_2O_3.CaSO_4$) were originally developed in China (1975) at the China Building Materials Academy and are attractive clinkers as they form at some 100-200°C lower than conventional Portland cements. Formed from calcining limestone, bauxite and gypsum at around 1350°C, the clinker mineral assemblage is principally C_2S, C_4AF and yeelemite ($4CaO.3Al_2O_3.SO_3$). Unlike Portland cements, the hydrate assemblage is dominated by ettringite, rather than CSH and the degree of expansion associated with this phase may be controlled by the quantity of free portlandite interground with the product. In the absence of lime (shown by the presence of gibbsite, $Al(OH)_3$, in the hydrates) the binder is non-expansive, whilst when lime is present in sufficient amounts, all the aluminium is consumed by ettringite formation. This allows a high degree of control over the dimensional properties of the binder during hydration.
- Sulpho-belite clinkers (variously, sulpho-belite / sulphoaluminate-belite etc.) describe a family of low energy clinkers whose essential constituents are belite (C_2S) and tetracalcium trialuminate sulphate ($C_4A_3\underline{S}$). Depending on their composition, these clinkers may be designed to produce expansive binders or non-expansive binders offering high early strengths. Also produced at around 1350°C, these clinkers may use limestone, bauxite clay and gypsum along with a range of industrial by-products such as combustion ashes (predominantly PFA, but other ashes are suitable) blast furnace and other metallurgical slags. Many variants show promise, amongst which, raw meals containing borax and phosphogypsum noticeably reduce the reaction temperature necessary for clinker formation.
- Ferrite clinkers (usually ferrite *rich* clinkers) are formed during the calcination of limestone, magnetite and bauxite at 1300°C or greater and are dominated by phases in the C_4AF to C_6AF_2 range. In some ways analogous to aluminate-rich clinkers, their hydration is somewhat sluggish, but may be accelerated by fine grinding or chemical activation, for example with citrate and potassium carbonate. Although the subject of considerable research, they pose a processing difficulty in that they are comparatively hard and therefore expensive to grind.

iv. **Use of alternative fuels and raw materials.** Alternatives to fossil fuels have been used in cement manufacturing for some decades. Incorporation of tyre crumb into the fuel has proved a valuable means of disposal of otherwise waste rubber, with considerable energy benefits. For example, the US Portland Cement Association (PCA) estimates the average calorific value (per tonne) of scrap tyres to be 25% greater than coal, with considerable emissions savings and reduced ash yield. The use of alternative fuels is highly dependent on the location of a particular kiln and paper, packaging, plastics, saw-dust, waste solvents and oil are all suitable for use as alternative fuels. In tropical countries (especially South East Asia) rice husks, coconut wastes, bagasse (sugar cane waste) and wood chips all have a role as kiln fuels and development of these resources continues to grow. In industrialised countries, tyre scrap and waste oil dominate the alternative fuel load, yet biofuels (especially wood processing waste) are gaining popularity. Naturally, the elemental content of the fuel is of great importance, as it influences the phase chemistry of clinker. For this reason, careful control of halogens (from plastics and solvents) and sulphur (common in proteins present in some biofuels and in some mineral oils) must be made to ensure the product is within acceptable limits.

In Europe, the Cembureau report "Environmental Benefits of Using Alternative Fuels in Cement Production" (CEMBUREAU, 1999) quantifies the case for combustion of alternative fuels in a cement kiln, rather than in a waste incinerator and demonstrates considerable energy and emissions savings favouring kiln combustion. For biofuel (calorific value 16 GJ/t) and solvent waste (26 GJ/t) the net reduction in emissions are 1,619 kg CO2/t waste and 2,609 kg CO2/t waste respectively, providing considerable justification for the practice beyond the obvious advantage in reducing the quantities of waste to be disposed of by other routes.

Alternative raw materials are important in cement manufacture, for two reasons. First it may be uneconomic to transport a material over large distances when a suitable alternative is available and secondly, many low energy clinkers require alternative materials for their feedstocks. Considering conventional clinker production, blastfurnace slag can (at least in part) be used as a source of calcium, where transport of limestone is only marginally economic. Similarly, coal fired power station fly ash may replace clay, as a source of both silica and alumina and spent foundry sands are regularly used as a silica source in clinker production. The possibility of replacement of mined iron (oxide) ore by roasted pyrite is attractive, where a suitable route to capturing the SO2 emissions is economic. The Cembureau estimate (C. Lorea, 2006) is that approximately 6.5 % (14 Mtonnes) of the raw meal used in Europe is derived from alternative feed stocks. The PCA report "Beneficial Reuse of Materials in the Cement Manufacturing Process" (PCA 2007) list the major alternative materials in use in North America in terms of the elements of benefit to clinker manufacture:

- Filter cake (element varies)
- Cracking catalysts (Si, Al)
- Blast furnace slag (Si, Fe, Al)
- Foundry sand (Si)
- Petroleum contaminated soil (Si, Al)
- Bottom ash (Fe, Si, Al)
- Water treatment sludges (Al, Si)
- Fly ash (Fe, Si, Al)
- Refractory brick (Al, Si)

Section i (above) lists the major alternative clinker types and describes the alterative materials from which they are commonly manufactured. Substitution of materials is certainly possible and the evolution of low energy clinker types will continue to develop for the foreseeable future.

2) **The needs of the mineral industries** are a fine balance between the profitable and sustainable recovery of raw materials with an equally sustainable strategy for waste minimisation. Throughout the wide and varied operations in the European mineral sector, the issue of waste management is recurrent. The possible re-use of mineral fines would have economic, societal and environmental benefits reaching far outside this industrial sector. Considering the surplus minerals with most potential for use by the cements industry, six were discussed at length:

- Clay-soil overburden moved during quarrying and mining operations
- Clay-rich washing from aggregate cleaning and rock processing
- Shale and slate waste with an otherwise limited market
- Rock cutting and crushing fines
- Limestone flour

- Processed mineral wastes such as burnt oil shale, combustion ashes and dredgings

The view of the Minerals Industry representatives is (as with the cements producers) that a comprehensive review is needed on a regional, national and European level of the locations, quantities and compositions of the mineral by-products available for re-use. This should address the sustainability of supply (i.e. current operations) and assess legacy wastes from previous operations, which my usefully be recovered.

3) **The needs of the metals producers** are analogous to that of the mineral sector: A requirement exists for the economic and environmentally sustainable re-use of the by-products of metals smelting and refining. Three principal by-products are of concern:

- Blast furnace slag from the production of iron. This is mostly destined for use in construction, dominantly as an industrial latent hydraulic material or air-cooled slag aggregate. It poses few problems in its effective re-use as it is well established as a supplementary cementitious material.
- Steel converter slags. By-products from the basic oxygen process (*BOS slags*) and the electric arc process (*EAF dust*) are the greatest issue for the metals industries in terms of their scale. The limitation is the variability of supply and variability of composition, compounded somewhat by the high density of the material and the hardness of BOS slag. Considerable (but still fragmented) research has been undertaken (largely instigated by the metals producers) into the use of steel slags as pozzolans and a body of knowledge exists on their incorporation as clinkers.
- Non-Ferrous slags. These materials are highly variable in composition and owing to the geochemical associations of elements present in many non-ferrous ores, commonly pose a toxicity hazard. Additionally, the slagging process varies between different metals, so the bulk chemistry of the slag varies between metal types (*e.g.,* borate-, halide-, carbonate-based slags). Consequently, it seems unlikely that they will make significant impact in the cements market and as the available quantities are low (in comparison with the needs of the cement producers) only very localised use is envisaged.

4) **The needs of the waste management industry** similarly reflect those above, in that safe and sustainable re-use of waste materials is of critical importance to quality of life. Minimising the volumes of materials sent to landfill throughout Europe has raised new issues in waste management, as increased quantities of material are processed through *Energy-From-Waste* plants. The combustion products from various waste streams all have potential as components in blended cements. Some are surprisingly variable from a single source or within an industry, whilst others show a high degree of uniformity. Those of greatest interest to this Workshop were:

- Municipal waste incinerator ash
- Sewage sludge ash
- Paper mill sludge ash
- Road gully wastes
- Harbour and canal dredgings

Research is ongoing on these and many other waste streams including means of upgrading and all have a potential role to play in the sustainable supply of CO_2 efficient cements.

5) **Societal needs** reflect those cited above and emphasise the urgency with which we must satisfy the twin challenges of an affordable built environment with lessened environmental impact. Energy and resource efficiency would seem to offer the most readily achievable means with which these two issues may be addressed.

3.2 Contribution to the future direction of the field.

General agreement was reached that new directions in blended cements research is needed. Although there are many gaps in the scientific knowledge, relatively few attempts have been made to draw together the wealth of high quality science underpinning CO_2 efficiency in cement manufacture. It was the view of the participants that a networking activity would form the most efficient basis on which to identify the knowledge gaps and that mobility grants (for example the *Marie Curie Programme*) offer a route to work more closely together

Scientifically, six areas were identified in which additional knowledge is required:

i. Optimisation of existing material blends to maximise material performance
ii. An increased understanding of the systems under investigation; essentially bridging the gap between the chemical sciences and physical and engineering sciences in cement and concrete
iii. Focused research into the hydration and performance of ternary and higher-order cement blends
iv. Development of predictive methods by which the combined performance of new materials may be assessed with defined confidence
v. An increased understanding of the speciation of transition metals in cements and their hydrates, allowing a knowledge-based decision to be made about their effective safety in construction materials
vi. Research into means by which the reactivity of latently hydraulic materials may be increased

From an engineering standpoint there were three strongly recommended actions which are important in shaping the direction in which the field should develop:

i. There is a need for universally agreed methods of acceptance-testing by which new materials may be screened rapidly and their suitability for use in blended cements assessed.
ii. As the majority of all cement produced world-wide will be used in structural concrete, there is a need to maintain the current level of durability of cementitious binders with the possible new cement types.
iii. There is a need to influence both the development and use of standards and codes of practice. The relationship between acceptance testing and standards could be better defined. The dichotomy between performance-based standards (potentially taking a very long time before new materials may enter a market) and compositional-based standards (potentially increasing risks to safety and commerce) should be addressed.

Lastly, there were three recommendations in the political, educational and legal arenas:

i. The types of cement manufactured are likely to diversify as market demands become more specific. There is a need for educational activities to ensure this increases resource efficiency and reduced CO_2 impact from the engineering practitioners.
ii. There is a need to work with experts in economics or economic geography in making best use of scientific and engineering research resources. For example, costs (energy, environmental and economic) associated with transport, storage and processing are often inadequately defined in practice, resulting in poor predictions of the actual gains made in an operational change.
iii. The scientific community needs to make greater effort to communicate effectively with political and economic decision makers. This is reflected in the very low (and largely declining) degree of research funding in cement science over the last two decades. If we are to enjoy continued global development, the provision of sustainable buildings must be optimised in terms of their environmental impact and this must be addressed in policy terms as well as by science, engineering and commerce.

In conclusion, the workshop united stakeholders from diverse scientific disciplines who shared a passionate concern for the CO_2 agenda in cement manufacture. Each contribution was extremely valuable and collectively, the participants will focus on developing the field through co-operation on materials development and assessment.

4. Workshop outcomes: Dissemination and future actions:

A summary of the workshop will be published in a leading journal (Advances in Cements Research) whose editor has indicated that this report would be welcomed.

A meeting report has been issued as a MIRO e-mail bulletin advising companies in the minerals industries of the issues addressed during this workshop

Independently, a technical report will be produced collectively and released (free of copyright) to all participants in both hard copy and electronic format. This will allow the widest dissemination of the workshop's findings.

Each partner will consider how best to disseminate the findings to a wide audience. Wherever possible, this will include policy makers to whom both our findings and future plans should be made known.

An agreement has been made to pursue funding by all of the participants to establish a scientific network in this field. It will have three objectives:

1) To provide opportunity for the exchange of ideas, expertise and people

2) To seek funding for co-operative research, through the ESF, industry and through the European Union

3) To undertake the desk studies described in section 3, assessing the available European resources in expanded clays, natural pozzolans, combustion products, mineral and metal processing fines.

5. References:

CEMBUREAU (1999), Environmental Benefits of Using Alternative Fuels in Cement Production, The European Cement Associaton, Brussels, CEMBUREAU, No. Editeur: D/1999/5457/February.

Claude Lorea (2006), IEA meeting-4 Sept 06-Use of alternative fuels-CL, Ir. Claude Lorea, Technical Director of CEMBUREAU, http://www.iea.org/textbase/work/2006/cement/Lorea_4.pdf

PCA (2007), PCA R&D Serial No. 2868, Beneficial Reuse of Materials in the CementManufacturing Process, By Schreiber, Yonley & Associates for the Portland Cement Association.

6. Final programme:

Sunday 21st June 2009

Afternoon *Arrival*

19:00 *Meet in Travelodge hotel foyer Broadgate CV1 1LZ (Tel: 0871 984 6385)*

***Supper** in Coventry: Pizza Exresss 10A Hay Lane, (Tel: 024 7663 3156)*
If you arrive late, we have booked the upstairs dining room for 7:30pm

Monday 22nd June 2009

08:40 – 09:00 **Welcome by Convenors**
Dr. Eshmaiel Ganjian, Coventry University and
Dr. Mark Tyrer, Mineral Industry Research Organisation

Presentation of the European Science Foundation (ESF)
Dr. Eshmaiel Ganjian, On behaf of standing committee for Life, Earth and Environmental Sciences (LESC)

09:00 – 10:00 **Introduction of the Participants**
Each participant should introduce themselves and describe their interests, current work and plans (2-3 minutes per person)

Session 1: The current state of CO_2 emissions in the European cement industry

10:00 – 10:20 **1 "Embedded Carbon and cement. an Industry Overview"**
Prof. Alan Maries (University College, London, UK)

10:20 – 10:40 **2 "Current Practices in CO_2 minimisation"**
Mr. Jonathan Churchman-Davies (Serco DST, Hook, UK)

10:40 – 11:00 *Coffee / Tea Break*

11:00 – 11:20 **Discussion of Session 1**

Session 2: Options for CO_2 reduction

11:20 – 11:40 **3 "Reducing carbon dioxide emissions from cement manufacture"**
Dr. Harald Justnes (SINTEF Building and Infrastructure, Trondheim, Norway)

11:40 – 12:00 **4 "Cement replacement materials – industrial pozzolans"**
Dr. Mark Tyrer (MIRO, Birmingham, UK)

12:00 – 12:20 **5 "Cement replacement materials from the waste industries"**
Dr. Chris Cheeseman (Imperial College, London, UK)

12:20 – 12:40 **6 "Cement replacement materials from the metals industries"**
Prof. Bo Björkman (Luleå University of Technology, Luleå, Sweden)

12:40 – 13:00 **Discussion of Session 2**

13:10 – 14:10 ***Lunch** in Draper's Suite,* St. Mary's Guildhall

14:10 – 14:30 *Tour of St. Mary's Guildhall*

Session 3: Current trends for CO_2 reduction in cement manufacturing

14:40 – 15:00 **7 "Options for CO_2 minimisation during cement clinker production"**
Mr. Claude Haehnel (Italcementi Group, Guerville, France)

15:00 – 15:20 **8 "Current Practice in the European Cement Industry "**
Dr. Reiner Haerdtl (Heidleberg Cement AG., Heidleberg, Germany)

15:20 – 15:40 **Discussion of Session 3**

Session 4: Current research and emerging trends

15:40 – 16:00 **9 "Fluidized Bed Technology for Production of Blended Cement"**
Dr. Edgar Gasafi (Outotec, Pori, Finland)

16:00 – 16:20 *Coffee / Tea Break*

16:20 – 16:40 **10 "The underlying science of process optimisation"**
Prof. Herbert Pöllmann (Martin-Luther-Universität Halle-Wittenberg, Halle/Saale, Germany)

17:00 – 17:20 **11 "Low energy cements research"**
Dra. Ana Guerrero (Inst. Eduardo Torroja, Madrid, Spain)

17:20 – 17:40 **12 "Scientific research in blended cement systems"**
Prof. Giacomo Moriconi (Università Politecnica delle Marche, Ancona, Italy)

17:40 – 18:00 **13 "Engineering applications of low-energy blended cements"**
Dr. Roger West (Trinity College Dublin, Ireland)

18:00– 18:20 **Discussion of Session 4**

18:00– 18:20 **Closing summary – Day 1**
Convenors

19:25 *Meet in Travelodge hotel foyer Broadgate CV1 1LZ. (Tel: 0871 984 6385)*

***Supper** in Coventry: Myo (www.myo-restaurant.co.uk) The Old Fire Station, Hales Street. CV1 1JA (Tel: 024 7655 3551) If you arrive late, we have booked a table at the back of the restaurant from 7:30pm*

~21:00 ***Drinks** in a traditional pub "The Whitefriars" (www.whitefriarscov.com) 114-115 Gosford Street, CV1 5DL (Tel: 0871 917 0007). We have booked the "red" room upstairs from 9pm, so we can all sit together.*

Tuesday, 23rd June 2009

Session 5: Case studies – collaborative research

09:00 – 09:20 **14 "The NANOCEM Network and Carbon dioxide"**
Dr. Mette Geiker (Technical University of Denmark, Lybgby, Denmark)

09:20 - 09:40 **15 "The TNO programme"**
Dr. Willy Peelen (TNO, Delft, Netherlands)

09:40 - 10:00 **16 "The ietcc – csic programme"**
Dra. Marta Castelotte (Inst. Eduardo Torroja, Madrid, Spain)

10:00 – 10:20 **Discussion of Session 5**

10:20 – 10:40 *Coffee / Tea Break*

Session 6: Summing up and further actions

10:40 – 11:00 **17 "The contribution and needs of the metal industries"**
Prof. Pekka Taskinen (Helsinki University of Technology, Helsinki, Finland)

11:00 – 11:20 **18 "Summary – research needs and research contributions"**
Prof. Jos Brouwers (University of Twente, Netherlands) **and Prof Harald Justnes** (SINTEF, Trondheim, Norway)

11:20 – 11:40	**19 "Response from the producers"** **Mr. Claude Haehnel** (Italcementi Guerville, France) **and Dr. Reiner Haerdtl** (Heidleberg Cement, Leimen, Germany)
11:40 – 13:10	**Discussion on follow-up activities / networking / collaboration** ▪ ESF "à la carte" programme ▪ ESF "EUROCORES"programme ▪ EU Framework Programme 7
13:10 – 13:20	**Closing Address** **Convenors**
13.30 - 14:30	***Lunch*** *in the Executive Suite, University Dining Rooms*
	Departure

7. Final list of participants:

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8. Statistical information on participants:

Countries of origin

UK	6	SE	2
NL	2	ES	2
FI	2	DK	1
BE	2	NO	1
IT	1	IE	1

Gender repartition

Male: 20 Female: 3