# Recent Developments and Perspectives Regarding the Standardisation and Quality Surveillance of Cement in the East, Central and South African Region

[1]Marinescu MVA[1]*
[1] *Eindhoven University of Technology, The Netherlands*
[2]Schmidt W
[2] *BAM Federal Institute for Materials Research and Testing, Berlin, Germany*
[2]Msinjili NS; [3]Uzoegbo HC; [4]Stipanovic Oslakovic I; [5]Kumaran GS;
[1]Brouwers HJH; [2]Kuehne H-C and [2]Rogge A
[3] *University of the Witwatersrand, Johannesburg, South Africa*
[4] *Institut IGH d.d (IGH)*
[5] *Kigali Institute of Science and Technology, Kigali, Rwanda*

***Abstract***
*The cement and concrete market in East, Central and Southern Africa is highly fragmented. The concrete industry in this area consists of multiple parties, including producers and suppliers of construction materials, formal and informal contractors, engineers and architects, unions of trades persons and workmen, governmental bodies and formal institutions of research and education. All these institutions mostly do not interact adequately, which makes building with cementitious materials susceptible to damage and failures. Completely opposed to the situation in Europe or North America, cement in Africa is often unaffordable, while manpower is cheap, which results in a questionable economisation of cement. Typically, there is not sufficient awareness of methods to sensibly reducing the cement content in concrete or replace Ordinary Portland Cement by adequate alternative materials. Research activities in this field of technology are often missing completely. Only few countries in the area, such as South Africa, are exempted from these issues.*
*This paper presents the SPIN project, which is a joint project of a consortium of 8 African and 3 European partners within the ACP Science and Technology Programme. The project is funded by the EC and ACP Secretariat is the project body. The main objective of the current project is to strengthen the cement and concrete industry in the East and Central African regions. The project shall generate reasonable solution strategies to implement clean, safe and sustainable cement and concrete technology on the African continent, including general and specific guidelines for sensible application. Furthermore it shall be the kick-off for future projects, research activities and the world-wide expansion of a European-African network.*
*The paper addresses special problems the cement and concrete market in Eastern, Central and Southern African countries has to face. Several options are presented in detail, which shall help overcoming the current situation. Customized solutions for the African market include rational methods for reducing the amount of cement used and the replacement of Ordinary Portland Cement with cheaper alternatives. The use of recycled concrete through a new and economically effective method, as well as the opportunity of using locally available resources is also discussed.*

***Originality***
The paper addresses the main topic "Chemistry and Engineering of the Construction process". The paper provides information on the developing Eastern and Central African construction world and gives solutions to better implementation of the standards to cement and concrete technology. It also gives emphasis on the use of alternative materials to cement production that not only decreases hazardous effects to the environment but also provides a beneficial solution to the East and Central African economy.

***Chief contributions***
The paper focuses less on direct recent research activities but rather on how state-of-the-art knowledge can contribute towards the implementation of future oriented and sustainable cement and concrete production under very special circumstances. Hence the paper contributes to the development of guidelines, international research exchange and new approaches to cement and concrete technology. Knowledge transfer and international cooperation are essential to the advancement in the building industry of East, Central and Southern Africa. These concepts are combined with innovative technical solutions related to the local market.

***Keywords:*** *Africa, clean and safe cement production, scientific network*

**[1] Corresponding author: Email m.v.a.marinescu@tue.nl Tel +31 40 247 46 87, Fax +31 40 243 85 95**

## Introduction

Africa has a raised level of technology and an elaborate infrastructure for cement and concrete use, but this is rather the exception than the rule in the Central- and South- African region. In East-African countries, and particularly the ones that suffered heavily from civil wars of the nineties such as Burundi, Rwanda and Uganda, the availability of cement and concrete is poor and these materials are not common in every day building practice. While in permanent buildings, concrete is one of the standard materials, in the semi-permanent building type concrete is typically used only for the ground floor and it is not at all used for temporary buildings. This means single projects that demand significant concrete volumes are rare, whereas there is a multitude of projects that only demand for small volumes. Most of the population relies on indigenous forms of construction requiring wood, ultimately contributing to deforestation.

The use of cement is by far less developed in East, Central and Southern African countries than in Europe, South Asia or North America. Many contractors offer services they do not provide permanently or for which the required equipment has to be borrowed (A study that was published in 2000 about the situation in Tanzania pointed out that only ca. 15% of the enterprises that offer concrete works own a concrete mixer (Mlinga *et al*., 2000)). Because of policy changes cut backs in public investments and a decrease of employment in the private sector have been observed in many countries (Wells *et al*., 2003). Furthermore, a shift from registered companies to informal contractors could be noticed (Wells *et al*., 2003, Mlinga *et al*., 2000, 2002). This situation makes it difficult for cement producing companies to expand and invest in a reliable cement and concrete infrastructure as established in most European countries.

In Europe, the material costs are typically very low and labour costs are the ones which increase the price for concrete structures. In many Eastern African countries, the situation is exactly the opposite. In Uganda for example, the retail price for a 50 kg bag of cement is about 12 $, which increases the pressure to reduce the cement content in concrete, regardless of technical aspects, or sometimes makes building with concrete simply unaffordable considering the income level in this country.

## General context

The East-, Central- and South African countries share a number of environmental conditions that need to be taken into account in the field of construction with cementitious materials.

- Exposure conditions – The climatic conditions in East and South Africa can be equatorial, semi-arid and marine, each bearing particular problems. The temperature and humidity changes can vary widely during one day, affording special considerations about the use of special cements such as sulphate resistant cement.
- Maritime climate conditions – East and Southern Africa have an enormous coast line, making building in these regions prone to corrosion problems, which would suggest the use of e.g. slag or pozzolan blended cements.
- ASR – Many regions provide disadvantageous climatic conditions (warm and humid) that accelerate problems related to alkali silica reaction. Low alkaline cements would help avoiding numerous problems.

Earthquakes and other hazards - Seismic activities in the eastern and central African region often occur between 4,0 and 7,5 on Richter scale (Twesigomwe *et al*., 1997) and are thus serious geographical dangers for concrete constructions. Figure 1 below shows earthquake events in Stilfontein. Furthermore, floods and storms are repeatedly reported during the last decades. Besides these natural factors, human-related shortcomings further increase the number of challenges the construction industry in the East-, Central- and South- African region has to face.

Figure 1: Building failures due to earthquakes in Stilfontein, South Africa (March 2005)

Engineers are typically well educated, even though cement is a rather new material in Africa. The experiences of Europe and North America, where building with concrete has been established for a long time, are well known and adopted. However the African education system typically does not allow training skilled concrete workers that are aware of the risks related to this material either during installation or due to handling (e.g. cement dermatitis). The responsibility for the safe application is much more on the side of engineers and material providers-, since standards and guidelines are missing.

This lack of regulations, combined with the need to reduce the high material costs as much as possible, lead to numerous sources for construction failure, which in turn often brought about harmful and even life threatening health issues for a high number of people:

- A ten storey building under construction collapsed in Dar es Salaam in June 2008. Although no permit for the project was issued, the work started already the year before.
- A three storey office building under construction collapsed in Johannesburg, South Africa, in October 2008 after occurrence of deep cracks was ignored. Two people died, 14 were injured.
- A three-storey business building in Kampala, Uganda, fell down in March 2009, after the foundation was loosened due to neighbouring construction works, 8 people died, 18 were injured.

The main causes for these disasters are man-made, such as poor cement quality, imprudent concrete production and formwork removal, poor workmanship, incompetent supervision, lack of testing, missing quality management and external control systems. These problems are compounded by very limited research and the lack of industrial coordination for proper functioning and advancement. Besides the necessity of improving building practices, awareness in the environmentally friendly and healthy treatment of cementitious materials is often missing. In most of the mentioned countries neither regulations nor awareness of how to protect health and environment exist. This applies for the exhaust during the cement processing as well as for the handling on the construction side, e.g. chromate reducing agents are largely unknown.

**Solution strategies**

Cement production in East and Central Africa is mostly handled by large companies or institutions. The future potential on the African market suggest strong synergies between local producers and established global players. Lafarge, Heidelberger and Holcim are traditionally strong in South and East Africa. Just recently HeidelbergCement agreed a cooperation with George Forrest, in order to triple cement production capacity in the Democratic Republic of Congo. Schwenk just finished the construction of a new cement plant in Namibia, also with focus on the neighbouring countries, Botswana and Angola. In Tanzania there are only three large known cement manufacturers, the leading being Twiga Cement (Heidelberg Group), followed by Tanga Cement (Holcim Group) and after Mbeya Cement (Lafarge Group). For production in Tanzania, the quality of cement has to be passed by the national standards produced by Tanzania Bureau of Standards (TBS). Every cement manufacturer is visited by a TBS official in the department of quality control to run a number of tests in order to approve the cement product before it is put on the market. This is the same for imported cement; a sample has to be tested first before put on the market. Once approved the label TBS has to be imprinted on the product. However there are many construction sites that are using cement that do not have the imprint of TBS, hence buildings are subjected to failures causing deaths and injuries. A better implementation of the regulations would decrease the frequency of such events.

African cements are traditionally often blended cements. This, however, is a result of the necessity to save energy and not of technical considerations. In 2008, green cements were firstly established in South Africa. The general availability and the variety of raw materials in Africa are huge and open up enormous future potentials for the further development of improved environmentally friendly cements and cementitious binders. The infrastructure, however, makes it difficult to bring quality materials where they are needed. Hima Cement in Uganda, another subsidiary of Lafarge Group, has completed a major expansion project worth Ush265 billion ($118 million) with installed capacity of 10 million bags per year, as it seeks to satisfy growing demand and environmental compliance requirements (The East African Nairobi, 2010). The new production capacity is said to be capable of eliminating the need for cement imports in the next two to three years. Also, the advanced technology at the new plant will ensure little or no dust emissions because of its ability to treat waste with both normal and generator-driven power supply.

In Tanzania the majority of construction takes place in the urban areas where 75% of the total population lives. The major building materials are concrete and sandcrete blocks (Egmond - de Wilde De Ligny *et al*., 2004). It is estimated that the demand for these building blocks in Tanzania might almost triple from the currently estimated 87.4 million tonnes in 2009 to 219.0 million tonnes in 2050 respectively (Woodbridge *et al*., 1997, WBCSD, 2009). The share of locally available raw materials used to produce building materials in Tanzania is about 47% of the required amount (in 1992); the rest is imported which puts strain on the country's economic situation. An increased use of local resources and a disproportionate future demand for the availability of local materials will result in a decline of the natural resources due to expansion of the construction industry (Mufuruki Tobias *et al*., 2007, Sabai *et al*., 2009). A comparable situation can be expected for the neighbouring countries.

The disposal of construction waste in most African countries is largely not regulated. Therefore, the waste is often dumped in landfills or near wet lands, not only contaminating water reserves but also becoming health hazards by turning into breeding grounds for various diseases. In Tanzania, for instance, an increasing generation of construction and demolition waste (C&DW), including concrete rubble, can be observed, which is currently deposited in dumping sites (not landfills) or just anywhere (Sabai *et al*., 2009). Waste generation could be turned into an opportunity to provide the construction industry with useful building materials, a practice generally accepted all over the world. In its report on "Recycled concrete", WBCSD (2009) gives a breakdown of C&DW recycling on European countries, between others. Among the total C&DW recovery, recycled aggregate accounts for 6% to 8% of aggregate use. The greatest users are the United Kingdom, the Netherlands, Belgium, Switzerland and Germany. In the US, recycled aggregates are produced by natural aggregate producers (50%), contractors (36%) and debris recycling centres (14%). In Japan, the concrete recycling ratio reached 96% in 2006, from only 48% in 1990, and it is mostly used as sub-base material in road construction (Oikonomou, 2005). In China, the amount of C&DW has reached 30–40% of the whole city solid wastes, with waste concrete occupying a large percent (around one third), according to Li (2008). In the case of using recycled concrete aggregates (RCAs) for concrete, different countries have their own limit of use (Bossink and Brouwers 1996). In the WBCSD report (2009), the US is mentioned to have a limit of 10% RCA as substitute for new aggregates. UK recommends a maximum of 20% RCA, Australian guidelines state that up to 30% replacement has no undesired effect, while in Germany the guidelines allow up to 45% replacement with RCA in certain cases. Other local waste products among others are Rice husks ash, Saw dust ash, Waste burnt clay and Corn cob ash. These can be used as additions for concrete, however, if treated sensibly, they can also increase the benefit for the cement industry, as they posses pozzolanic properties and hence the potential to create a new generation of blended cements in Africa.

Given the maritime climate conditions, durability regulations are also necessary in East and Southern African countries. A rapid chloride migration (RCM) test used in Europe and North America could be implemented, as it only requires a basic setup, is fast, cost-efficient and easy to use. In Europe, the NT Build 492 and the German BAW-Merkblatt "Chlorideindringwiderstand" regulate the use of this test and explain its relation to structure lifetime. In the US, the "AASHTO TP64-03 Standard method of test for prediction of chloride penetration in hydraulic cement concrete by the rapid migration procedure" provides the instructions for the RCM use.

**The SPIN project**

The construction sector has traditionally been an important source of employment in African towns. The present situation in most of the project partners' countries (apart from South Africa) offers high future potentials. Demography and poor infrastructure suggest enormous building needs. Concrete as the most common building material will play a major role in the future construction technology in Africa. Over the last ten years, growth in cement consumption in the E.A region increased by at least 46% and the industry features parallel growth in other related sectors such as aggregates or natural puzzolanas. The future potential is underlined by the increasable production of cement per capita in eastern Africa, which is ≈ 0,033 tons. In Germany, it is more than ten times higher, although urban areas and infrastructure are already largely on high level.
Worldwide, cement and concrete experts are at the cutting-edge to sustainable, green, healthy but nonetheless high-performance concrete. The current relatively low development of the cement and concrete industry in Africa offers the unique chance to start directly on the best achievable and sustainable level, if only expertise is sufficiently available. It should not be neglected that concrete is a product with comparably low transport ranges, which means that an improved concrete market will mainly support the local economy without exceeding financial drains to the international market, thus fostering the fight against poverty, which is an urgent need in most African countries.
In 2010, a consortium generated from institutions from seven African and three European countries commenced working on a project with the acronym SPIN with the duration of 3 years, related to the establishment of future oriented cement and concrete technology with focus on East, Central and Southern Africa. The acronym stands for "Spearhead Network for innovative, clean and safe Cement & Concrete Technologies". The project partners are listed in Table 1 below. The main objective of the project is to strengthen the cement and concrete industry in the East and Central African regions. The project shall be the kick-off for future projects, research activities and the expansion of the network.

Table 1: SPIN project partners

| Partner (Institution) | City, Country |
|---|---|
| University of Lubumbashi (UNILU) | Lubumbashi, Democratic Republic of Congo |
| Department of Geological Survey (DGS) | Entebbe, Uganda |
| Université de Burundi (UBB) | Bujumbura, Burundi |
| Kigali Institute of Science and Technology (KIST) | Kigali, Rwanda |
| University of Dar es Salaam (UDSM) | Dar es Salaam, Tanzania |
| Eduardo Mondlane University (EMM) | Maputo, Mozambique |
| University of Witwatersrand (WITS)<br>Advanced Cement training & Projects cc | Johannesburg, South Africa |
| BAM Federal Institute for Materials Research and Testing | Berlin, Germany |
| Eindhoven University of Technology (TUE) | Eindhoven, The Netherlands |
| Institut IGH d.d (IGH) | Zagreb, Croatia |

SPIN aims to improve African concrete technology by unveiling to key actors the crucial issues and opportunities related to environmental impact, health protection, alternative energy sources and affordability. The network will foster the establishment of modern, green and sustainable cement and concrete technology and promote alternative and appropriate technologies that uniquely contribute to development or poverty reduction in Africa. It is obvious that proper cement and concrete technology can only be established if experts are cross-linked, have the access to current knowledge world-wide and the measures to bring scientific results quickly into practice. Therefore, the SPIN project is generated as a knowledge exchange network of experts with links to research and education, public authorities and industrial research and consulting.
SPIN will increase the expertise in cement and concrete technology in Africa by offering chances for African institutions to get expert consulting about chances and possibilities in modern concrete technology. This is exercised by worldwide workshops and laboratory analyses. Furthermore work placements in high-level institutions will strengthen the handling and understanding of modern testing facilities. A concluding international conference about cement and concrete in Africa is currently in planning stage. The major output of the consortium's work is a handbook for excellent concrete technology in and for Africa with the character of a direction sign, addressing to the topics and objectives shown in Figure 2 under consideration of the specific boundary conditions Africa exhibits. It will give a clear prospectus of the state of the art of cement and concrete in Africa and offers proper solutions for affordable technology that can improve Africa's economy. All participating institutions should become established as "Spearhead Institutions", fostering proper cement sciences and technologies in a wide area. Figure 2 shows the interrelations between overall topics and objectives.

<table>
<tr><th></th><th>Health Improvement</th><th>Environment Protection</th><th>Energy Saving</th><th>Additional Benefit</th></tr>
<tr><td rowspan="7">Cement, alternative binders and cement plant processing</td><td>Agents for the reduction of chronium (VI)</td><td rowspan="2"></td><td rowspan="4"></td><td>Involvement of local industry in value chain</td></tr>
<tr><td>Reduction of harmful emissions from cement plants</td><td rowspan="3"></td></tr>
<tr><td colspan="2">Reduction of heavy metals in cement</td></tr>
<tr><td colspan="2">Upgrading of cement plant technolgy to reduce emissions</td></tr>
<tr><td rowspan="3"></td><td colspan="2">Alternative binder components for cement to reduce CO2</td><td>Use of finely ground limestone and gypsum as fertilizers</td></tr>
<tr><td colspan="2">Use of nanotechnogy- grinding aids and catalysis for low clinkering temps to reduce CO2</td><td>Promotion of SADC, CEPGL and EAC countries as high-tech regions</td></tr>
<tr><td colspan="2">Use of agricultural waste as fuel for the cement production</td><td>Involvement of local framers, producers, or industry in value chain</td></tr>
<tr><td rowspan="7">Concrete components</td><td colspan="2">Setting up of sustainable concrete technology for water or crop storage</td><td></td><td>Improvement of supply infrastructure</td></tr>
<tr><td colspan="3">Use of natural filler materials for concrete</td><td>Involvement of local framers, producers, or industry in value chain</td></tr>
<tr><td colspan="3">Reduction of CO2 by the use of (waste) filler materials for concrete</td><td>Involvement of local industry in value chain</td></tr>
<tr><td colspan="3">Reduction of CO2 - Use of waste and/or recycling material aggregates for concrete</td><td>Recycling concrete as water-mineral-reservoir / fertilisers</td></tr>
<tr><td colspan="3">Reduction of CO2 - Use of waste material fibres for concrete</td><td>Additional benefit for agricultural industry</td></tr>
<tr><td rowspan="2"></td><td>Active reduction of CO2 by catalysts / surfaces</td><td></td><td>Promotion of SADC, CEPGL and EAC countries as high-tech regions</td></tr>
<tr><td colspan="2">Reduction of cement requirement by optimising concrete (packing density)</td><td></td></tr>
<tr><td rowspan="6">Application and concrete plant processing</td><td colspan="2">Implementation of rules for accident prevention in the application of concrete</td><td></td><td rowspan="2"></td></tr>
<tr><td colspan="3">Clean application of concrete</td></tr>
<tr><td rowspan="4"></td><td colspan="2">Reduction of CO2 - Reduction of cement by use of admixtures (consistency/compactability)</td><td>Involvement of local industry in value chain</td></tr>
<tr><td colspan="2">Reduction of hazardous emissions from concrete plant processing</td><td rowspan="3"></td></tr>
<tr><td colspan="2">Concrete technology for energy saving concreting (dry-mixed compounds / SCC /…)</td></tr>
<tr><td></td><td>Energy saving pre-cast plant technology</td></tr>
<tr><td rowspan="4">Concrete components and durability</td><td colspan="2">Leaching from Buildings</td><td rowspan="3"></td><td rowspan="2"></td></tr>
<tr><td colspan="2">Setting up of sustainable concrete technology for hazardous/maritime regions</td></tr>
<tr><td colspan="2">Introducing concrete technology for the retrofitting of historical/infrastructural constructions</td><td>Conservation of historical buildings</td></tr>
<tr><td colspan="3">Waste materials for improvement of building insulation properties</td><td></td></tr>
</table>

Figure 2: Schematic representation of topics and objectives of the SPIN project

The open structure of the SPIN network allows the integration of friend institutions and industry as well as the future expansion. The project's internal analysis allows increasing capacities of each institution and the formulated guidelines and roadmaps foster the implementation of research policies. The generation of joint research projects based on the network and its cooperation are a major goal of SPIN, as well as the dissemination of knowledge to the industry and the scientific community by publications, workshops and conferences. Finally, the training of experts and the consulting on laboratory structures and equipment will improve the research quality of the particular institutions significantly.
The project will generate the necessary knowledge and technology that will considerably improve the technological status of the African cement and concrete sector. SPIN aims, as a flagship and ambitious project to transform the rather traditional cement and concrete sector in East, Central and South African countries into a modern, competitive and knowledge-based industry through the introduction of radical innovations and the incorporation of emerging technologies from South Africa and the EU partners. The technologies to be introduced address the complete production-value chain (raw materials processing, transport, supply and application, new products and materials) and also activities relating to dissemination and training, support and technology transfer issues.

## Acknowledgements

The project is funded by the ACP Science and Technology Programme, a programme of the ACP Group of States, with the financial assistance of the European Union. The authors would like to thank ACP and EC for their support.

## References

- Bossink, B.A.G. & Brouwers, H.J.H. 1996. Solid waste in the construction industry, quantification and source evaluation. ASCE Journal of Construction Engineering and Management 122, 55 – 60.
- Egmond - de Wilde De Ligny, E.L.C. van, Kumaraswamy, M.M., Ofori, G., Ogunlana, S. 2004. International technology and knowledge flows in the global economy: The impact on sustainable development of the construction industry, working paper and research agenda for collaborative research between The Eindhoven Univ. of Technology, Univ. of Hongkong, National Univ. of Singapore, Asian Inst. of Technologies.
- Li, X. 2008. Recycling and reuse of waste concrete in China: Part I. Material behaviour of recycled aggregate concrete. Resources, Conservation and Recycling 53, 36-44.
- Mlinga, R. S. & Lema, N. M. 2000. Informal contractors in Tanzania: Their characteristics and reasons for informality. Proceedings of the 2nd international conference of the CIB Task Group 29 (TG29) on construction in developing countries, Gaberone, Botswana.
- Mlinga, R. S. & Wells, J. 2002. Collaboration between formal and informal enterprises in the construction sector in Tanzania. Habitat International 26, 269-280.
- Mufuruki Tobias, S.; van Egmond Emilia L. C., Scheublin Frits J.M. 2007. Reusing and Recycling Construction Aggregates as Mitigation Measures to Environmental Destruction: The Case of Dar es Salaam. Tanzania (CIB2007-485), Proceedings of the CIB World Building Congress 2007 on Construction for Development, Cape Town.
- Oikonomou, N.D. 2005. Recycled concrete aggregates. Cement and Concrete Composites 27, 315-318.
- Sabai, M.M., Lichtenberg, J.J.N., Egmond - de Wilde De Ligny, E.L.C. van, Mato, R.R.A.M., Cox, M.G.D.M. 2009. Sustainable Innovation by Production of Building Materials from Construction Waste in Tanzania. Studiesdag 16 Oktober 2009. Nederlandse Vereniging voor Afrika Studies .
- The East African Newspaper (Nairobi), 2010. http://www.theeastafrican.co.ke/
- Twesigomwe, E. M. 1997. Seismic hazards in Uganda. Journal of African Earth Sciences 24, 183-195.
- Wells, J. & Wall, D. 2003. The expansion of employment opportunities in the building construction sector in the context of structural adjustment: some evidence from Kenya and Tanzania. Habitat Int. 27, 325-337.
- Woodbridge, M. E. 1997. The development and value of a construction material information system. Annual Roads Convention on Road Transport: The key to development. Dar es Salaam, Tanzania.
- World Business Council for Sustainable Development (WBCSD), 2009. Concrete Recycling: The cement sustainability initiative. http://www.wbcsdcement.org/pdf/CSI-RecyclingConcrete-FullReport.pdf .