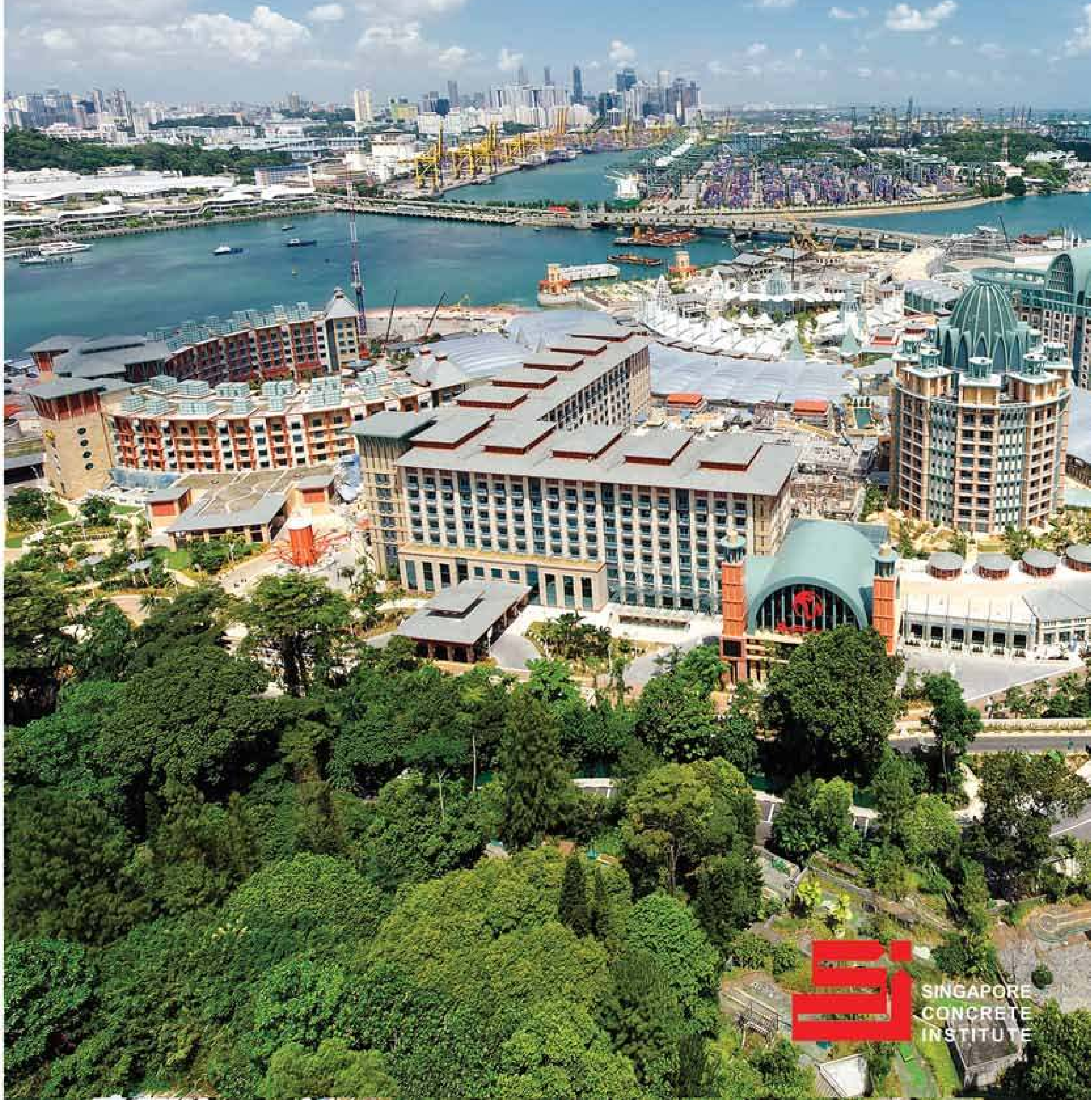
# SCI CONCRETUS

31 MAY 10 • MICA (P) No. 186/09/2009

Vol 1 No 2



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# President's Message

I am pleased to present to all our Singapore Concrete Institute members and readers our second issue of the SCI Concretus, a technical magazine-cum-directory which was launched on 17 November 2009.

We had received many positive feedback and suggestions for the inaugural issue and we hope that all our readers will find this issue even more exciting to read after a revamp of the design and layout.

This issue focuses a lot on the latest trend in concrete technologies especially in the area of sustainable development. We have also featured a special report from the Building and Construction Authority on the latest government initiatives to improve productivity in the construction sector.

We hope more companies, professionals, experts, researchers and government agencies will come forward to support the SCI Concretus by submitting many more interesting articles and reports for the benefits of all our readers out there.

The SCI Concretus will definitely gain wider readership as we uphold the quality and accuracy of this publication. We will also ensure a wider distribution to all institutions of higher learning, professional bodies and organizations in the related fields.

Happy reading!

**Oh Lock Soon**
**President**
**Singapore Concrete Institute**
**31 May 2010**

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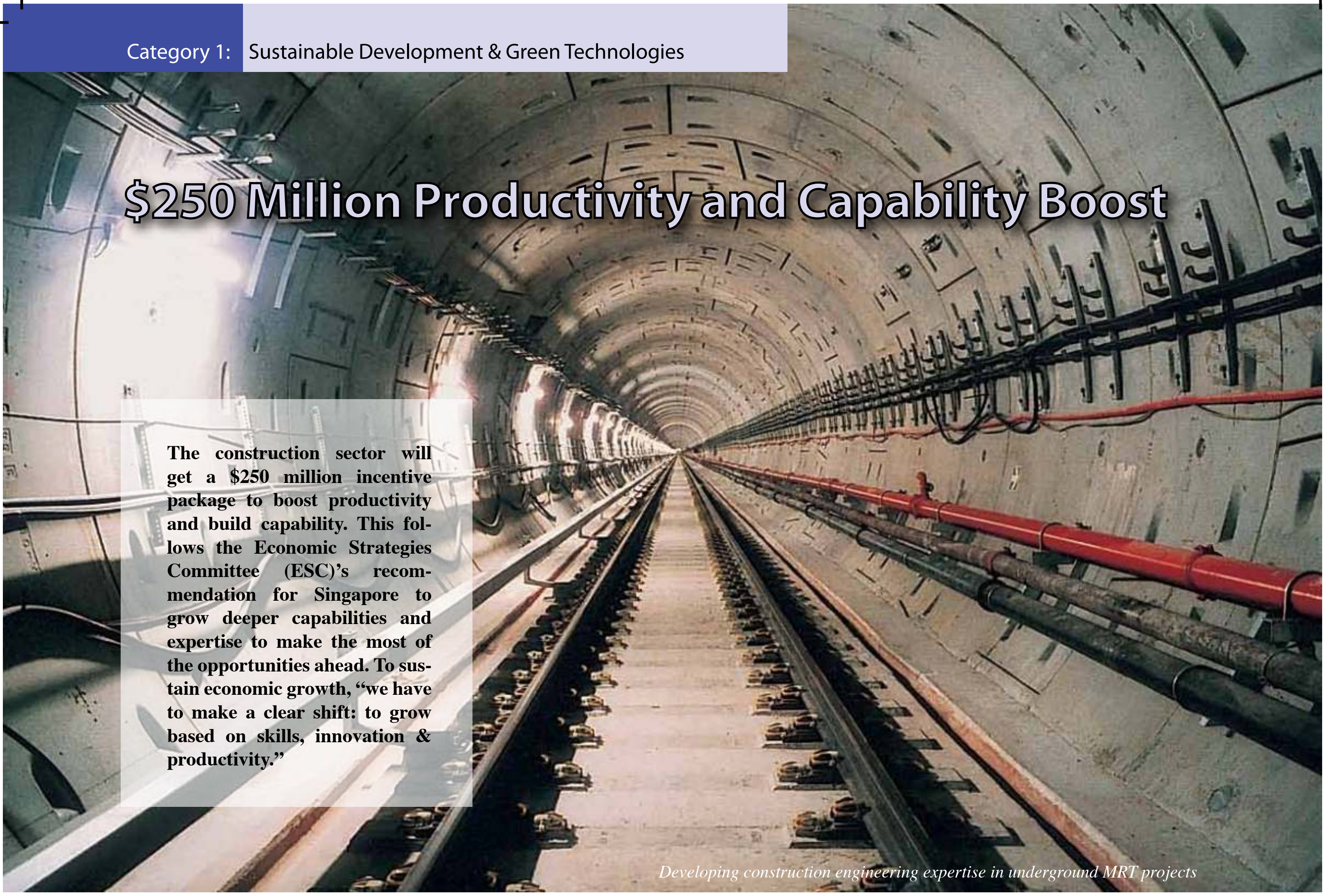
# $250 Million Productivity and Capability Boost

**The construction sector will get a $250 million incentive package to boost productivity and build capability. This follows the Economic Strategies Committee (ESC)'s recommendation for Singapore to grow deeper capabilities and expertise to make the most of the opportunities ahead. To sustain economic growth, "we have to make a clear shift: to grow based on skills, innovation & productivity."**



*Developing construction engineering expertise in underground MRT projects*

As the construction sector remains one of the key pillars of Singapore's economy, the Government has set aside a $250 million incentive package in the form of the Construction Productivity and Capability Fund (CPCF) to help industry firms raise the quality of their workforce; lower the cost of adopting advanced construction technologies, and build up their engineering capability to undertake complex projects.

## Workforce Development

To raise the quality of the workforce, the Fund will co-fund the cost of skills upgrading and assessment of workers for CoreTrade registration and the course fees of other higher value-adding qualifications at supervisory levels*. At the PMET levels, the BCA-Industry Built Environment Scholarship has also raised the minimum sponsorship level from $10,000 to $14,000 per year for each Singaporean and Singapore Permanent Resident scholar.

**applicable only to stipulated courses listed in http://www.bca.gov.sg*

## Technology Adoption

With the new Fund, firms can also look forward to financial support when they adopt advanced construction technologies and re-engineer their workflow to improve productivity. BCA will co-fund the purchase and leasing of equipment and support firms that embark on technical reviews, adaptation studies and developmental projects to raise productivity. The industry, particularly the small- and medium-sized firms, should take this good opportunity to harness technology for long-term productivity benefits.

To transform the next generation of building design and construction, BCA will also defray part of the cost incurred by firms to

*The productivity centre will be the platform to showcase new construction technologies* leverage on the use of Building Information Modeling (BIM) technology to improve the work processes. This will help to improve co-ordination across the construction value chain and reduce rework downstream.

BCA will also work with the industry to strengthen the existing Buildability Score Framework to require greater adoption of buildable designs and the use of more prefabricated products to ease construction work on site. Going beyond the design stage, BCA will extend this framework to include downstream construction works. Builders will be required to adopt more labour-efficient technologies or construction methods, measured using a set of constructability indices.

## Capability Building

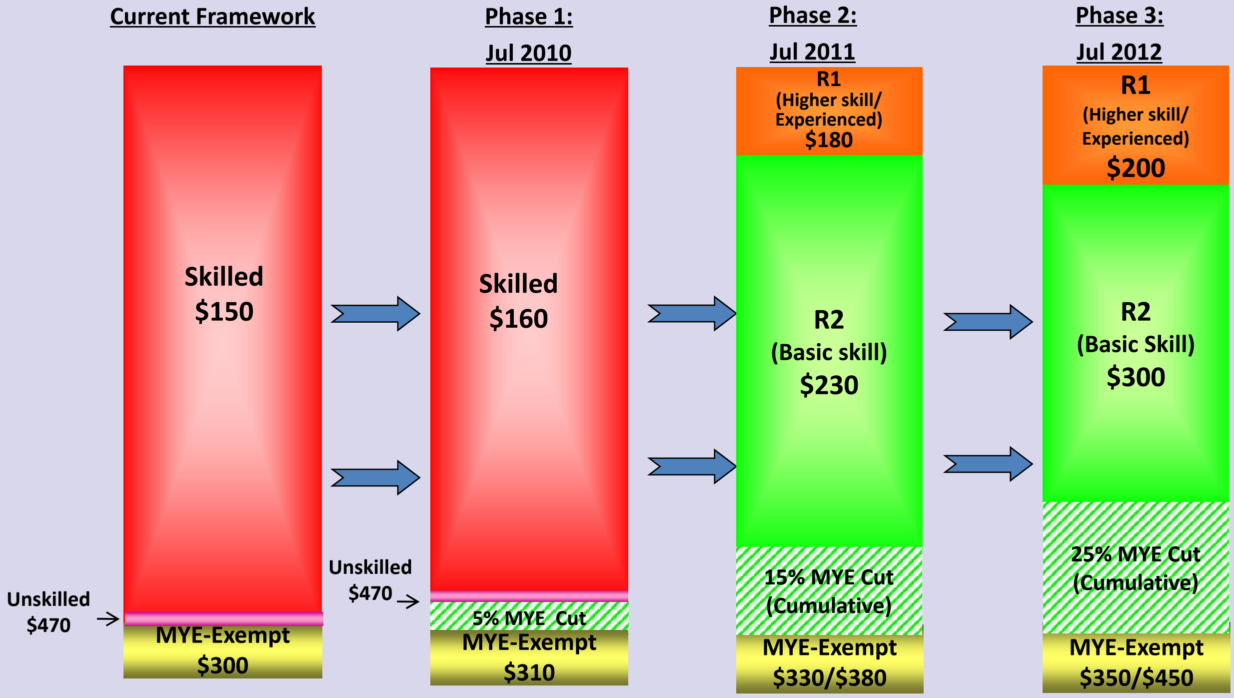
Besides technology adoption, the upcoming strong pipeline of complex civil engineering projects and the increasing number of relatively more complex building projects present the industry with great opportunities to build up their engineering capabilities. BCA will introduce a holistic programme to nurture progressive builders with specialised capabilities to undertake complex construction projects. This programme will help to defray the cost of internal capability building, such as immersion programmes for staff to gain experience in complex construction works and the engagement of specialist consultants to catalyse knowledge transfer to build up in-house engineering expertise.

| pType of Fund | What is Funded? | How Much is the Funding? | Who is Eligible? |
|---|---|---|---|
| **(i) Workforce Development** | | | |
| Workforce Training and Upgrading | Cost of selected skill assessment and training courses for workers | • *Up to 80% of the course/training/skills assessment fees* | Industry firms |
| BCA-Industry Built Environment Scholarship | Co- sponsorship of Scholarship | • *50% of the annual minimum scholarship sum of $14,000 for each Singaporean and Singapore Permanent Resident scholar* | Industry firms |
| **(ii) Technology Adoption** | | | |
| Mechanisation Credit (MechC) | Cost of purchasing or leasing of equipment that improves productivity of the specific work process by at least 20% | • *Up to 50% co-funding for equipment purchase, capped at $20,000, whichever is lower*<br>• *Up to 50% co-funding for equipment leasing, capped at $5,000, whichever is lower* | Singapore-registered contractors, specialist contractors and subcontractors |
| Productivity Enhancement Voucher (PEV) | Cost of engaging Knowledge Institutions (KIs) or external consultants to develop simple and practical ideas that improve the productivity of the specific work process by at least 20% | • *Up to 50% co-funding, capped at $20,000, whichever is lower* | Singapore-registered contractors, specialist contractors and subcontractors |
| Productivity Improvement Project (PIP) | Cost of undertaking projects which involves the application of technology and re-engineering of work processes to improve productivity of the specific work process by at least 20% | • *Up to 50% co-funding at firm and group level*<br>• *Up to 70% co-funding at industry level* | Singapore-registered contractors or *and* prefabricators |
| BIM Fund | Cost of adopting BIM technology into work processes | • *Up to 50% co-funding for training and consultancy, capped at $7,000 per firm*<br>• *Up to 50% co-funding for consultancy and software/hardware for a group of firms working on a project, capped at $70,000 per project* | Singapore-registered design, consultancy and construction firms |

To front the call for higher productivity, BCA has set up a Construction Productivity Centre. The Centre will work closely with the industry to meet the specific needs of construction firms and to introduce suitable advanced construction technology to help firms achieve higher productivity.

Through the Construction Productivity Centre and with support from the $250 million Construction Productivity and Capability Fund, BCA will work with the stakeholders to transform the construction industry into one that is productive, resilient and technologically advanced.

## Man-Year Entitlement (MYE) System & Construction Tiered Levy Framework




The changes to the Man-Year Entitlements (MYE) and levy framework have been introduced to achieve two objectives. Firstly, through MYE cuts and levy increases, the industry can be steered towards greater technology adoption and optimisation of labour usage. Secondly, it is to encourage the industry to upgrade and retain their better and more experienced workers.

To meet the second objective, the new tiered levy framework will use levy differentials to distinguish the experienced and skilled foreign workers – armed with CoreTrade or other specialised qualifications – from the newer entrants with basic skills.

The Government is mindful of the impact of these policy changes to the industry. The changes will thus be progressively introduced over three phases to give the industry adequate time to adopt technology and adjust their labour deployment. In particular, the levy increase in the first phase, in July 2010, will be kept to a minimum level of $10 to minimise the cost impact on existing projects.

- Source: BCA newsletter pillar 2010 issue 2.

# New product conformity scheme for concrete to SS EN 206-1 standard – the way forward

Singapore will be migrating from the current British Standards based codes to the Eurocodes progressively over the next few years. The process of reviewing the Eurocodes for adoption to be published as our SS EN standards is well underway at the moment. The first few SS EN standards to be published are the standards for construction products, namely concrete; and Singapore's new standard for concrete specification is SS EN 206-1. This new standard is to be used in conjunction with the complementary standards SS 544-1 & 2. Together, these 3 standards form a complete package for the specification, production and conformity of fresh concrete.

The SS EN 206-1 standard has provisions for 3rd party product conformity certification of ready-mixed concrete and it is a means of providing assurance that the concrete conforms to the specified standard. It is encouraging to note that the industry recognizes the importance of using good quality concrete that conforms to standard. Hence, the industry stakeholders together with Singapore Accreditation Council (SAC) and the Building and Construction Authority (BCA) have introduced an accreditation scheme for this purpose.

With effect from 1 October 2010, BCA will require concrete mixes for structural works to be certified and supplied by batching plants which hold valid product conformity certificates issued by certification bodies accredited under SAC's Accreditation Scheme for Ready-Mixed Concrete (RMC) Certification. With this requirement all on-site batching plants and plants supplying concrete for structural precast elements will also need to be certified.

As Singapore diversifies her sources of strategic raw material used in the construction sector, this Scheme aims to ensure that the consistency and quality of concrete produced here meet current international standards. The industry is encouraged to start specifying this requirement for their new development projects.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# Samwoh Eco-Green Building - A Key Milestone Towards Sustainable Development

*By Dr Ho Nyok Yong, Dr Kelvin Lee Yang Pin and Mr Lim Wee Fong*
*(contact : drho33@samwoh.com.sg)*

Samwoh Corporation Pte Ltd (Samwoh) was founded in the early 1970s as a transport and logistics company. Over the years, Samwoh has morphed into a leading integrated construction company and green construction materials supplier. In an effort to meet the stringent demands of the construction market of today, the company has invested in relevant leading-edge technologies and focused on research and development of green products in the past years. To be in line with the government's directive towards sustainable development, Samwoh has also invested heavily on recycling facilities to process construction and demolition waste, asphalt pavement waste and other industrial by-products for re-utilization in the construction industry. One of the recent developments is the Samwoh Eco-Green Park.

## Samwoh Eco-Green Building

Samwoh Eco-Green Building has marked a significant milestone in sustainable development in Singapore. It is part of the Samwoh Eco-Green Park that was officially opened on 22 March 2010 by Ms. Grace Fu, Senior Minister of State for National Development and Education. The park is opened to the public for education purposes. It comprises three green premises which were constructed after extensive research and development works, namely:

- Samwoh Eco-Green Building - the first building in this region to be constructed using concrete with up to 100% of recycled concrete aggregate (RCA) derived from construction and demolition waste;
- Asphalt recycling plant - which employs state-of-the-art technology to recycle asphalt pavement waste; and
- Ready mixed concrete plant - which is equipped with recycling capabilities to produce eco-concrete that contains recycled materials and to recycle fresh waste concrete into aggregate and sand.

*Samwoh Eco-Green Park*

***The Building has attained the "BCA Green Mark Platinum Award 2010"***

*Samwoh C&D Waste Recycling Plant*

*Close-up view of RCA*

## Research Project

Samwoh Eco-Green Building was constructed as part of a research project which is partially funded by the MND (Ministry of National Development of Singapore) research grant. The project was undertaken by Samwoh, Building and Construction Authority (BCA) and Nanyang Technological University (NTU). The objective of this project is to evaluate the feasibility of using recycled concrete aggregate (RCA), produced from construction and demolition waste, in structural concrete. The study involves two stages:

**Stage 1** – Extensive laboratory evaluation of the performance of concrete with RCA

**Stage 2** – Construction and structural monitoring of a three-storey building constructed using concrete containing RCA

About two million tonnes of construction and demolition (C&D) waste is produced annually in Singapore. The disposal of the waste posed a major environmental problem due to limited land space. The C&D waste can be properly processed to produce RCA. The RCA used in this building was produced from the company's own recycling plant located at Sarimbun Recycling Park. The process includes crushing, removal of ferrous metals and foreign materials such as bricks, wood and plastics as well as screening into different particle sizes. The detailed description of the production process of RCA is given in Ho et al. (2008).

Quality tests were carried out on the RCA to ensure that it is compliant with SS EN 12620 in accordance with BCA requirements so as to safegaurd the quality of final products. Some of the tests include water absorption, flakiness index, Los Angeles abrasion test, impurities content, sulphate content, chloride content, petrographic test etc.

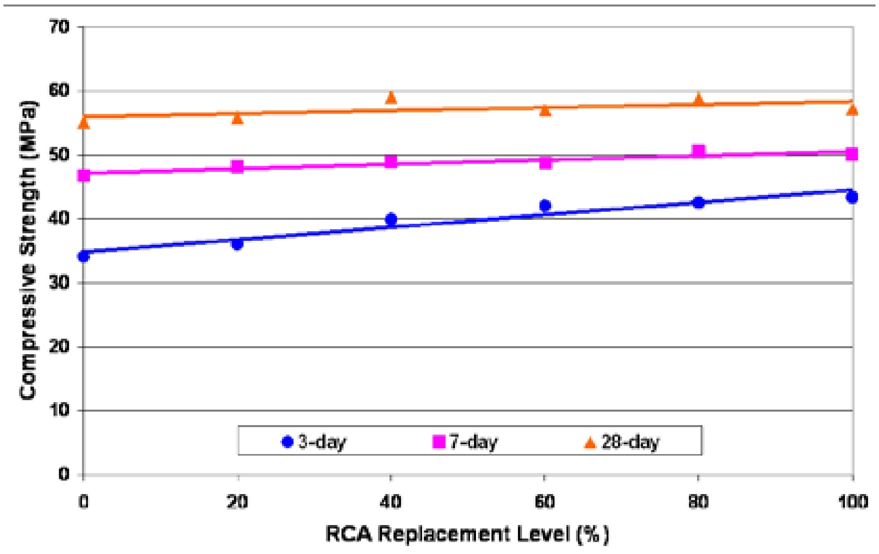
Stage 1 of the project also includes an in-depth study of the engineering properties of RCA and the concrete containing RCA. A rational mix design method is used for designing concrete in this study as proposed by Ho et al. (2009). The method is able to evaluate the effects of RCA on the properties of hardened concrete.

The test results have shown that the compressive strength of concrete with RCA were comparable to that of concrete with granite. Other engineering properties also showed good performance. Hence it is feasible to produce concrete with up to 100% RCA using the proposed rational method of mix design.

Various concrete grades from Grade 20 to 60 with RCA contents ranging from 0% to 100% (by mass of coarse aggregate) were studied. The analysis was carried out with respect to a series of mechanical and durability tests which include:

| | | |
|---|---|---|
| Compressive strength | Creep | Initial surface absorption |
| Elastic modulus | Drying shrinkage | Sulphate attack |
| Flexural strength | Chloride ingress | Water permeability |
| Indirect tensile strength | Drying & wetting test | Water absorption |

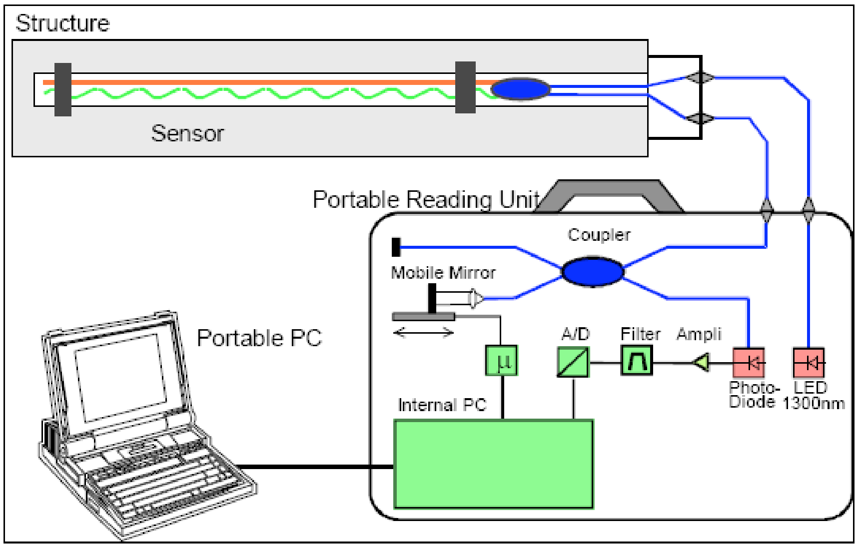
Based on the laboratory study, Grade 40 concrete with up to 100% RCA (hereinafter known as RCA concrete) was used to construct the building in Stage 2 of the project. The building comprises three storeys. The RCA concrete was used for the construction of all the structural members of the building which include the beams, columns, slabs and walls. To provide an analysis of the in-situ performance of the RCA concrete, fibre-optic sensors were embedded in the columns to provide real time monitoring of the building. The sensors measure the deformation of the columns which can be used to analyse the structural behaviour of the building. The data gathered from this maiden research will help BCA to update the building code requirements to allow the use of RCA in all buildings.




*Test results for concrete with various RCA contents (Ho et al., 2009)*

## Conclusion

The Samwoh Eco-Green Building has demonstrated the feasibility of using concrete with RCA in structural concrete. The results obtained from the study can be used to expand the existing building codes to include the use of RCA in buildings. With this showcase, it is hopeful that RCA can be used in future structural buildings which will reduce our dependence on natural aggregate and thereby, contribute towards our nation's goal to achieve sustainable development.




*Structural Health Monitoring System*

*Some research & development works being carried out*

## References

a) Ho N. Y., Lee Y. P. K., and Tan J. Y. "Beneficial Use of Recycled Concrete Aggregate for Road Construction in Singapore". 6th International Conference on Road and Airfield Pavement Technology, Sapporo, Japan. 20 to 23 July 2008.

b) Ho N. Y., Lee Y. P. K., Lim W. F., Ting S. K., Soh Y. and Low G. L. "Efficient Utilization of Recycled Concrete Aggregate for Structural Concrete Applications". 27th Conference of the ASEAN Federation of Engineering Organisations, Singapore. 30 Nov to 2 Dec 2009.

# Samwoh is proud to receive BCA Green Mark Platinum Award 2010

**Samwoh Eco-Green Park**
Located at 51 Kranji Crescent Singapore 728661

## SAMWOH

Founded in 1975, Samwoh Corporation is a leading integrated construction company. For years, the company has been investing heavily in Green business, which is inline with the government's directive towards sustainable construction.

The company's latest development is Samwoh Eco-Green Park, which consists of 3 green premises :

1. Samwoh Eco-Green building is the first in this region to be constructed using concrete with up to 100% of recycled concrete aggregate after extensive research. The building is used to house the new Samwoh R&D Centre.
2. Asphalt recycling plant which employs state-of-the-art technology to recycle asphalt pavement waste.
3. Ready mixed concrete plant which is equipped with recycling capability to produce Eco-concrete that contains recycled materials.

The park was officially opened by Guest-of-honor, Ms Grace Fu, Senior Minister of State for National Development and Education on 22 March 2010.

The successful completion of Samwoh Eco-Green Park showcases a breakthrough in construction technology that will pave the way towards greater sustainability and environmental consciousness in construction projects.

## Samwoh Group Specializes in :

- Supply of Ready-Mixed Concrete & Eco-Concrete
- Civil Engineering & Infrastructure Construction
- Quarrying & Supply of Building Materials
- Blasting Services
- Recycling of Construction Wastes
- Machineries Trading & Rental Services
- Supply of Sea Sand
- Supply & Laying of Asphalt Premix
- Precast Concrete Components
- Specialised Construction Products
- Concrete Imprint Systems
- Transportation & Logistics Services
- R&D and Consultancy Services

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# If Concrete Can Speak Am I Durable?

*By Dr. Tam Chat Tim, Associate Professorial Fellow*
*National University of Singapore*

"The oldest concrete so far discovered dates from around 7000 BC, and was found in 1985 when a bulldozer uncovered a concrete floor during the construction of a road at Yiftah El southern Galilee, Israel." [1] My ancient ancestor was a lime concrete. By around 300 BC, my Roman ancestor became volcanic ash with lime. The Colosseum in Rome still stands to-day. Now-a-days I come from lime and clay. Bronze strips and rods acted as reinforcement to enable me to take "tension". To-day they are replaced with steel bars.

Who are those that tend to destroy me? In the 1930's the first British concrete design code recognized sulfate in the ground as my attacker. Of course other industrial chemicals can be equally aggressive to my well being. However, my defence against sulfate has been provided by having very low tricalcium aluminate in my cementitious composition. Even my other potential weakness in the form of reactive aggregate can be mitigated by controlling my cementitious composition in having sufficiently low total alkali content.

There are others who react with components within me but they do not destroy me. However, my important role as the protector of embedded steel can be compromised. I can suffer from carbonation when carbon dioxide from the service environment reacts with the calcium hydroxide in my body fluid, eventually reducing the pH in my pore fluid to a level (around 9 to 10) that is not adequate for protecting the embedded steel from corrosion. Carbonation per se does not destroy me, but it is corrosion products from the steel that break me up.

Chloride ions can also penetrate my body by diffusion through my body fluid. They also do not destroy me. However, at sufficiently high concentration, they too induce corrosion in the embedded steel within me. It is steel corrosion that leads to my breaking up eventually.

When alternate types of reinforcement not subject to corrosion become economically viable, this problem will disappear – I shall be truly durable.

In the mean time, and until performance-based design approach reaches the stage of being codified, in the deemed-to-satisfy approach, I need to be given the proper type of cementitious materials, including fly ash and/or ground granulated blastfurnace slag to enable me to perform my protector's role better. Reducing the volume of capillary pore within my system with low water/cement ratio enhances my capability to keep out or at least slow down the ingress of carbon dioxide and/or chloride ions. Currently, for the deemed-to-satisfy approach, guidance on how to make me resistant to the various exposure classes, including sulfate and corrosion induced by carbonation or chloride ingress has been provided in a recent Singapore standard [2].

As a protector of embedded steel only my place in the cover zone has to perform. This offers an alternate to requiring my whole volume to have high performance to resist the ingress of these chemicals. To act as a shield against these chemicals, I can do so just as a sacrificial formwork with the best high performance characteristics that can be economically justified, instead of the high cost to do so with my whole volume. Such an example is described in Appendix A in Reference [3]. Tam [4] presented a comparison of relative cost between providing only the cover zone instead of the whole volume to illustrate the potential cost saving.

Now that you know how durable I can be and the means to enable me to better protect the steel bars within me as intended by designers, I shall play my part in sustainable construction to the best of my ability.

## References

[1] Concrete through the ages, British Cement Association, Crowthorne, Berkshire, UK, 1999, 37pp

[2] Singapore Standard, SS 544: Part 1: 2009, Concrete – Complementary Singapore Standard to SS EN 206-1, Part 1: Method of specifying and guidance for the specifier, SPRING Singapore, 2009, 65pp

[3] Durability of Materials and Structures in Building and Civil Engineering, Chapter 2, The Durability of Concrete Structures in the Tropics, Tam, C.T., Loh, Y.H. and Tee, C.P., Appendix A, Innovative Application of Ferrocement for Durable Marine Structures (North Eastern Coast Reclamation Phase 4 Area at Punggol and Coney Island), pp 53-60, Ed. C.W. Yu and John W. Bull, Whittles Publishing, Caithness, Scotland, UK.

[4] Tam, C. T., Conceptual Design Against High Aggressive Ground Conditions – FRC Alternate Solution, 4th International Specialty Conference on Fibre Reinforced Materials, 30-31 October 2006, Hong Kong, SAR, Ed. C. Stanley, T.S. Lok and P. Prochazka, CI-Premier, Singapore, pp 181-186.

## Further reading:

Technical Report No. 61, Enhancing reinforced concrete durability, Concrete Society, London, 2004, 208pp

# 'Concrete on a Roll' changes the way concrete is laid.

Concrete is normally poured, towelled, cast or even sprayed. Now it is available in roll format, thanks to an innovative new company from South Wales who have developed a material called Concrete Cloth. Although the material has been around for almost 4 years it has, until now, been predominantly used by the military (it was originally developed for the British Army as a means of upgrading defences in the harsh Afghan climate).

Only now, has it been discovered by a growing number of construction firms who are using it for a wide range of infrastructure projects in particular for ditching and drainage. Unrolling concrete is alot faster and simpler than pouring into formwork and it can be done whatever the weather!
The material works by trapping the dry concrete mix within a fibre matrix and sandwiching it between a waterproof membrane and a fabric skin. In its dry form it behaves like a thick carpet and can be unrolled in lengths up to 200 metres! The material is flexible enough to conform to complex curves and to be draped over

uneven surfaces. Once wet the rapid set concrete hardens to 80% strength within 24 hours and becomes a robust, durable, waterproof surface with a design life of over 25 years.

The early adopters of this technology have been impressed and see potential for a big impact in their industry. One such compnay is Network Rail who have already used it on 2 sites and are planning more. Andy Gurd, of Amco, the subcontractor's for the works, had this to say;
"Concrete Cloth is incredibly quick and easy to use. The time and expense saved, means I will have no hesitation in recommending Concrete Cloth for future projects."

Available in man portable or bulk rolls it can reduce the time on site from several days to just a few minutes. Costain, another early adopter, laid a 30 metre section of

ditch in only 45minutes, gaining a three day lead on their scheduled build time.

And if fast, durable and waterproof isn’t enough, the material also boats impressive fire resistance, wear resistance and environmental credentials. The innovation doesn’t stop here - the company is continually exploring new areas where this technology can have an positive impact – instant blinding, roofing, cladding and even flood defences!

Concrete Canvas have just started working with the Singapore government to investigate defence application of the cloth and the shelters over here.


## How it all began

The company started after the idea won support from the Concrete Centre. In 2004 it sponsored the 2 inventors to travel on a research trip to Uganda. At the time, William Crawford and Peter Brewin were studying at college and were developing Concrete Cloth for their other impressive invention ‘Concrete Canvas Shelters’. The research trip gave them the opportunity to present their concept to potential users and was the first step in establishing their current business Concrete Canvas Ltd. For more information visit www.concretecanvas.co.uk or email info@concretecanvas.co.uk.

# Ground Granulated Blast Furnace Slag, Green and Economical Substitute in Concrete

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Ground granulated blast furnace slag (GGBS or GGBFS) is obtained by quenching molten iron blast furnace slag (a by-product of iron and steel making) in water or stream, to produce a glassy granular product that is then dried and ground into a fine powder. For a long period of time, the application of GGBS was limited to production of blast furnace slag cement (BFSC) by intergrading of GGBS with cement clinker. Due to its less grindability, the surface area of production BFSC was even lower than commercial PC and this limited its reactivity. With development of concrete technology, the concept of superfine powder (defined as powder with average particle diameter less than 10 $\mu$m) was introduced [1]. GGBS is a green construction material used to make durable concrete structures in combination with Portland cement (PC). Manufacturing of Portland cement is a major contributor of greenhouse gases, responsible for about 5% of all global carbon dioxide emissions. By comparison, production of GGBS requires less than a fifth the energy and produces less than a tenth of the carbon dioxide emissions. High quality and durable concrete is required to reduce the rapid deterioration of concrete in severe conditions. In marine and coastal region the penetration of chloride ion is the major deterioration mechanisms [2]. Replacing PC with GGBS can significantly decrease the risk of sulfate attack, alkali silica reaction and chloride penetration. It has been proved that GGBS has perfect performance to resist the chloride induced corrosion [3]. Replacing PC partially by GGBS can improve the fluidity of fresh concrete, reduce its bleeding and postpone the setting [4]. To assess the effectiveness of GGBS in cementitious composites some of the parameters like the chemical composition, glass phase content and fineness are very important [5]. In this work the effect of replacing the Portland cement with various percentages of GGBS on various characteristics of concrete has been studied. This GGBS shows to improve the characteristics of concrete significantly and it's the good option for the coastal and humid regions with high concentration of chloride ions.

## Experimental Study

### 2.1 Materials:

In this study over 200 samples with various mix proportions with up to 50% GGBS replacement and with various w/c ratio and a/c ratio has been cast. The characteristic of GGBS was examined by particle size analyzer, X-ray diffraction test and chemical analysis test. Table 1 shows the result of physical and chemical analysis. From X-ray diffraction test, the number of the counts in the peaks is too low and in result no crystalline phase in this GGBS is detectable. As result of having the fine particle size and no crystalline phase this mineral admixture has high degree of reactivity.

### 2.2 Test procedures:

The pore structure, the moisture movement and the compressive strength of GGBS concrete has been studied in this experiment. Mercury intrusion porosimeter (MIP) 9400 Series was used for this

*Table1: Physical and chemical characteristics of PC and GGBS*

| | Cement (Type II) | GGBS |
|---|---|---|
| *Physical properties* | | |
| Particle Mean Diameter(μm) | 14.7 | 9.2 |
| Density(kg/m$^3$) | 3150 | 2720 |
| | | |
| *Oxide compositions (%)* | | |
| $SiO_2$ | 21.5 | 36 |
| $Al_2O_3$ | 5.5 | 9 |
| $Fe_2O_3$ | 4.5 | 1 |
| CaO | 63 | 44 |
| $SO_3$ | 1 | 1 |
| MgO | 2 | 8 |

The details of mix proportions in this experimental work have been presented in Table 2.

*Table 2: Details of mix proportion for concrete specimens*

| N | W/ (C+P) | a/c | p/ (c+p) | W $kg/m^3$ | C $kg/m^3$ | GGBS $kg/m^3$ | Sand $kg/m^3$ | Agg. $kg/m^3$ | SP (%) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.5 | 3 | 0 | 254 | 514 | 0 | 741 | 762 | 0 |
| 2 | 0.5 | 3 | 0 | 251.5 | 503 | 0 | 830 | 679 | 0 |
| 3 | 0.5 | 4 | 0 | 212 | 424 | 0 | 848.5 | 848.5 | 0 |
| 4 | 0.5 | 5 | 0 | 182.2 | 365 | 0 | 820 | 1002 | 0 |
| 5 | 0.4 | 3 | 0 | 210.5 | 526 | 0 | 710 | 869 | 0.25 |
| 6 | 0.6 | 4 | 0 | 244.2 | 407 | 0 | 976.8 | 651.2 | 0 |
| 7 | 0.5 | 3 | 0.1 | 250.5 | 451 | 50 | 751.5 | 751.5 | 0 |
| 8 | 0.5 | 3 | 0.3 | 249 | 348 | 150 | 747 | 747 | 0 |
| 9 | 0.5 | 3 | 0.5 | 248.5 | 248.5 | 248.5 | 894.6 | 596.4 | 0 |
| 10 | 0.5 | 4 | 0.5 | 209 | 209 | 209 | 836 | 836 | 0 |
| 11 | 0.6 | 4 | 0.5 | 241 | 201 | 201 | 804 | 804 | 0 |
| 12 | 0.4 | 4 | 0.5 | 174.5 | 218 | 218 | 872.5 | 872.5 | 0.5 |

experiment. Monitoring the weight loss during the drying process is the very good method to study the pore structure and moisture movement of concrete. Beside the fact that the concrete samples contain GGBS has better pore structure, it also has higher saturation degree. This property may be unrevealed in other test methods which contain the initial oven drying like the sorption test. Initial preconditioning can damage the pore structure and increase the pore connection. Finally, rapid chloride penetration test and rapid migration test have been done on the samples.

## Results and discussions

As it has been mentioned previously, GGBS can improve fluidity of fresh concrete [4], the result of slump test for various percentage of GGBS replacement presented in Figure 1.

This GGBS showed to be effective in increasing the compressive strength of concrete even in early ages. In early hydration, the ordinary slag with bigger particle size will result in lower compressive strength.

The result of MIP test shows that, although the samples contain the GGBS have same total porosity but the pore size distribution is finer and the average pore size is much smaller compared to PC concrete.

A figure 3 shows the effect of various percentage of GGBS replacement on average pore diameter.

To highlight the effectiveness of GGBS replacement on pore structure of concrete, the average pore diameter for a/c=3 and various w/c ratio with and without 50% of GGBS compared in Figure 9.

As shown in Figure 4, in this experimental study the average pore diameter for the sample with w/c=0.6 and 50% GGBS was even smaller than the average pore diameter of PC concrete with w/c=0.4.

Figure 5 shows the effect of water curing period on average pore diameter of concrete with and without GGBS. As it shows the curing period can play significant role on activity of the GGBS.

Although the average pore diameter can be good parameter for comparision of the effect of GGBS on pore structure of concrete but still the MIP test can not show the effect of GGBS on pore connection of concrete. The main charactrestic of GGBS is to decrease pore connection as well as average pore size. Monitoring the weight loss during the drying process can high light the effect of GGBS in reduction of concrete pore connection.

Figure 6 shows the effect of different percentage of GGBS replacement on drying rate of concrete. As it has been presented in Figure 6, the higher GGBS replacement leads to smaller pore size. Then lower pore connection and lower drying rate is expected. The effect of 50% GGBS replacement with different curing period on drying rate in comparison with PC concrete samples has been presented in Figure 7.

As it shows in Figure 7, the effect of curing period is more significant on GGBS concrete and having the sufficent curing period for GGBS concrete leads to a very low pore connection concrete.This very low pore connection and finer pore size distribution leads to very dense pore structure. it has been proved that GGBS has very strong effect on improving the resistance of concerete against chloride pepenration[3] . Cheng [6] record the total coulomb passed in rapid chloride penetration test (RCPT) in concete reduced by 40% and 70% for 30% and 60% GGBS replacement respectivly. Also similar results pro-

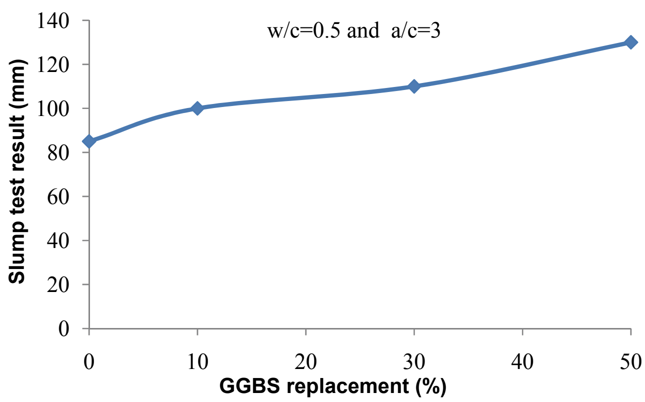


*Figure 1: Effect of different percentage of GGBS replacement on slump test result*

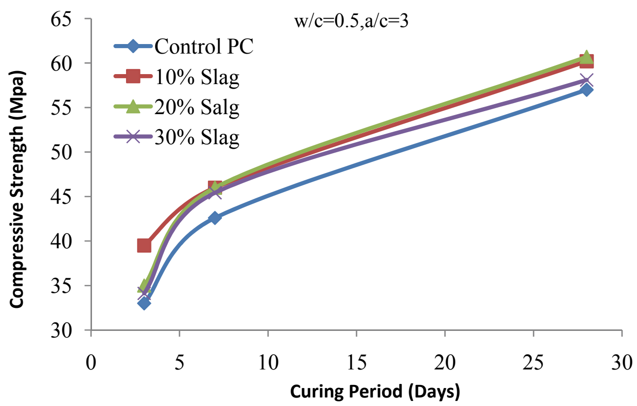


*Figure 2: The effect of GGBS replacement on compressive strength of concrete*

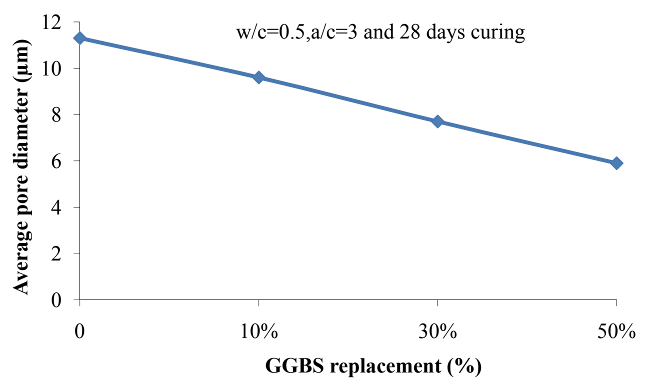


*Figure 3: The effect of GGBS replacement on average pore size diameter (µm)*

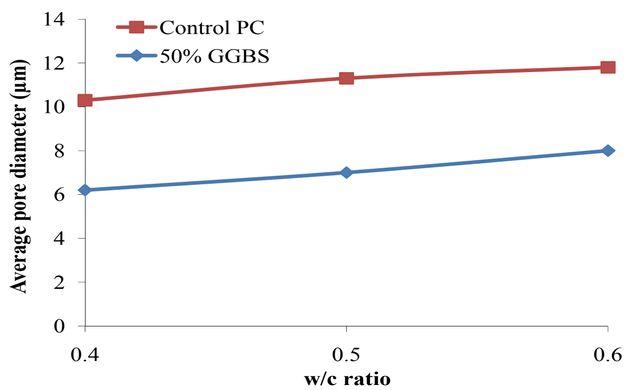


*Figure 4: The effect of GGBS replacement on average pore diameter in comparision of PC with different w/c ratio*

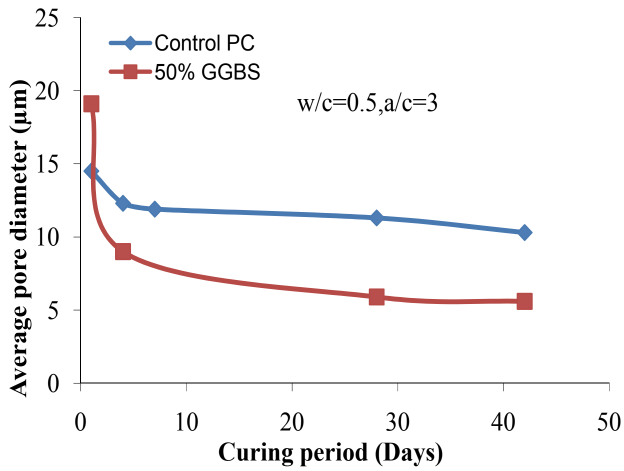


*Figure 5: The effect of curing period on average pore diameter of 50% GGBS replacement in comoparission to PC concrete*

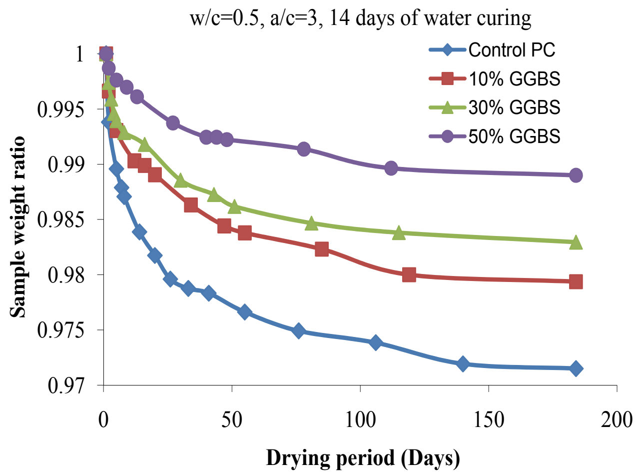


*Figure 6: The effect of different persentage of GGBS replacement on drying rate of concrete*

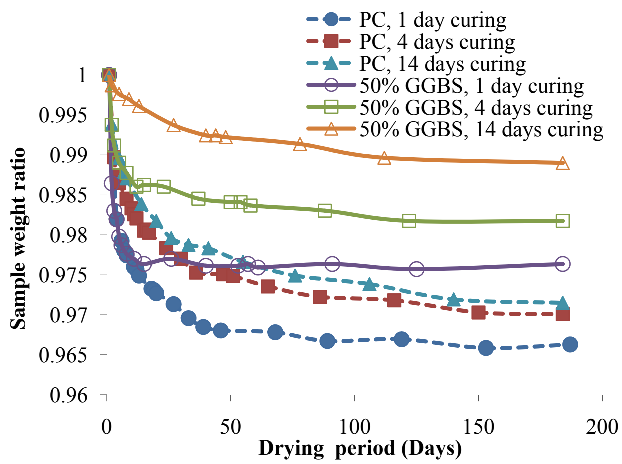


*Figure 7: The drying rate for PC and 50% GGBS replacement with different curing period*

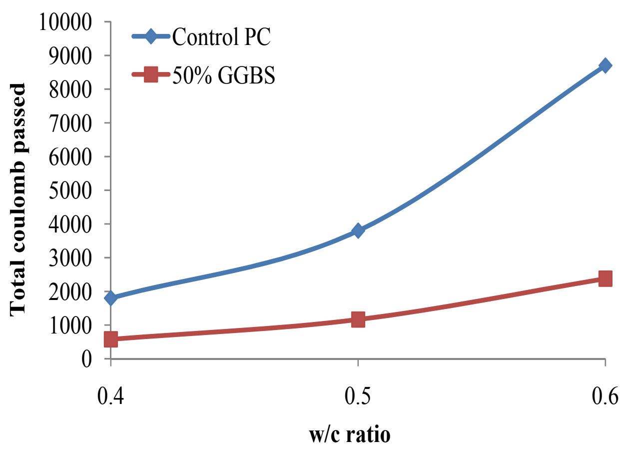


*Figure 8: The RCPT results for PC and 50% GGBS replacement with various w/c ratio*

posed by different research studies. As it has been mentioed above, the effectiveness of GGBS is affected by its particle size and chemical and mineral charactrestics. Figure 8 shows the effect of GGBS on reduction of total coulomb passed in RCPT test.

The result of RCPT is very much affected by drying period and the result must be concluded carefully. The result of rapid migration test shows penetration depth of chloride in GGBS concrete samples is very limited and it is much lower than PC samples.

## Conclusion

By considering the results of all this different tests, using PC partially replaced by GGBS is not only as ecological and environmental factors but as the effects on fluiditiy in fresh concrete, strength, durability and pore structure of hardend concrete is very usful. Especially in the marine srtuctures and in the high humidity and hot conditions, using PC partially replaced by GGBS in the most economical and safe option.

The particle size, chemical and mineral charactrestics of the GGBS and the duration of wet curing is very important to assure the full advantages of using GGBS in concrete. For this special GGBS, minimum period of 7 days curing for high humid environment is advised. For more information, please read the source paper [7].

## REFERENCES


[1] Quanlin Niu, Naiqian Feng, Jing Yang, Xiaoyan Zheng, "Effect of superfine slag powder on cement properties ", Cement and Concrete Research 32, (2002),615-621.

[2] Kyong Yun Yeau, Eun Kyum kim, "An experimental study on corrosion resistance of concrete with ground granulated blast furnace slag ", Cement and Concrete Research 35, (2005),1391-1399.

[3] Rui Luo, Yuebo Cai, Changyi Wang, Xiaoming Huang, " Study of chloride binding and diffusion in GGBS concrete", Cement and Concrete Research 33, (2003),1-7.

[4] Gao J.M., Qian C. X, Liu H. F, Wang B., Li L., "ITZ micro structure of concrete containing GGBS", Cement and Concrete Research 35, (2005),1299-1304.

[5] Ganesh Babu K., Sree Rama Kumar V., "Efficiency of GGBS in concrete", Cement and Concrete Research 30, (2000), 1031-1036.

[6] Cheng An, Huang Ran, Kuo Wu Jiann, Hsin Chen Cheng, "Influence of GGBS on durability and corrosion behavior of reinforced concrete", Material chemistry and physics 93 (2005) 404-411.

[7] Sabet Bahador, H.C. Jong, "Study on properties of concrete containing Granulated Blast Fornace slag", Recent Advances in concrete technology, 2007, 573-582.

# concrete products


## Pundit Lab ultrasonic test equipment

The ultrasonic test equipment Pundit Lab features online data acquisition, waveform analysis and full remote control of all transmission parameters. Along with the traditional transit time and pulse velocity measurement, the ultrasonic test equipment Pundit Lab offers path length measurement, perpendicular crack depth measurement and surface velocity measurement. Optimized pulse shaping gives greater transmission range at lower voltage levels. This, coupled with automated combination of the transmitter voltage and the receiver gain, ensures an optimum received signal level, guaranteeing accurate and stable measurements.

## PROFOSCOPE+

The Profoscope+ is a fully integrated rebar detector with data storage. To increase the efficiency on the construction site this enhancement of the Profoscope not only offers real time visualization of rebars, but also automatic data collection.
Writing down measuring results of testing series is a time consuming business that can be an unnecessary source of errors. The various data storage modes of the Profoscope+ make note taking obsolete. The cordless Profoscope+ is ideally suited for one-handed operations, keeping the other hand free for marking rebars.
The Profoscope+ has the same features as the Profoscope, but additionally offers the innovative memory function for data acquisition.

## SILVERSCHMIDT

Proceq has combined the best of Original Schmidt with the most advanced technology to create the new SilverSchmidt concrete test hammer.
The SilverSchmidt offers a virtually maintenance free, lightweight and compact construction.
This next generation tool combines an electronic display and advanced mechanics with true rebound coefficient that automatically converts to compressive strength.

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proceq

# Launch of the versatile ultrasonic pulse velocity test equipment Pundit Lab

(Schwerzenbach / Switzerland, April 2010) Proceq is pleased to announce the sales release of the Pundit Lab. With this new ultrasonic test equipment the Swiss based company is continuing the success story of the Pundit family.

Along with the traditional transit time and pulse velocity measurement, Pundit Lab offers path length measurement, perpendicular crack depth measurement and surface velocity measurement.

Optimized pulse shaping gives greater transmission range at lower voltage levels. This coupled with automated combination of the transmitter voltage and the receiver gain ensures an optimum received signal level, guaranteeing accurate and stable measurements.


The Windows based software Pundit Link unlocks the full capabilities of the Pundit Lab providing online data acquisition to reduce the testing time significantly. With the Pundit Link the user is able to view and analyze the received waveform on the PC. The measured data can also be viewed on a connected oscilloscope. Moreover, full remote control of the instrument, including data logging, is possible via a USB connection.

Even though Pundit Lab was designed with laboratory use in mind, its robust design and exceptionally long battery life make it equally suitable for on-site use.

Pundit Lab supports a wide range of transducers, to provide the solutions not only for concrete and rock, but also other materials such as carbon fibre.

# Proceq presents the new industry standard – the SilverSchmidt ST / PC

Proceq is pleased to announce the sales release of the new SilverSchmidt ST / PC.
"ST" stands for the standard version, "PC" for the version with additional features, such as the Hammerlink software for your PC.

For decades, Proceq's Original Schmidt Concrete Test Hammer has been the industry standard for a rapid assessment of the condition of a concrete structure. Test objects to which this method is applied may range from freshly prepared test cubes to historical wall segments. Now, Proceq has taken a significant step forward by launching a hammer that is even more accurate and user-friendly. Independent testing at the renowned Federal Institute for Materials Research and Testing, BAM Berlin (Bundesanstalt für Materialforschung und –prüfung, Germany) has confirmed that the SilverSchmidt has less dispersion than all of its predecessors over the entire compressive strength range.
Below is a summary of the benefits of the SilverSchmidt Concrete Test Hammer:

**Ergonomics**: The SilverSchmidt body lies very comfortably in the hand. The display is highly readable under any conditions.

**Robustness**: A two-layer seal prevents dust and dirt from penetrating to the interior of the instrument.

**Impact direction independence**: The forward and the rebound velocity of the hammer mass are both measured in close proximity to the point of impact. The rebound value requires no angular correction.

**Measurement accuracy and repeatability**: The new measurement principle and the redesign of the mechanics enable the SilverSchmidt to outperform its predecessors.

**Objective evaluation**: A larger number of measurement points can be easily collected by the instrument and automatically evaluated according to statistical criteria.

**PC connection**: The application "Hammerlink" allows all data to be uploaded via USB (PC version only). Firmware upgrades are also possible over this connection.

Proceq is confident that the SilverSchmidt hammers will become the new industry standard, just like their Original Schmidt Hammer has been for the last 50 years.

# Advances In Concrete Imaging Using A 2.6 Ghz Gpr Antenna

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Ground penetrating radar (GPR) is a non-destructive evaluation method that is commonly used to locate reinforcing in concrete structures. The popularity of the method grew significantly after introduction of GPR antennas with center frequencies greater than 1 GHz in the late 1990's. Reinforcing in concrete is a strong reflector of radar waves, hence detection of isolated rebars is typically not a problem down to depths of 15 cm (6 in) in cured concrete. However, much of the poured concrete in buildings contains dense mats of reinforcing and conduits yielding reflection patterns in GPR data that exceed the horizontal and/or vertical resolution of the standard GPR antennas necessary to image the reinforcing and conduits. This limitation provided the incentive to construct a higher-frequency antenna with a center-frequency of 2.6 GHz. A prototype antenna was constructed and data obtained on cured concrete blocks to compare with the standard GSSI 1.6 GHz antenna. In addition to a higher center-frequency, the smaller transmit and receive antenna elements in the prototype enclosure were separated by 4 cm compared to the 5.8 cm separation in the 1.6 GHz antenna. The combination of higher frequency and closer antenna pairs was expected to significantly enhance GPR vertical and horizontal resolution. The following sections of this paper contain data comparisons between the 1.6 and 2.6 GHz antenna.

## DATA COMPARISON

Data were obtained on a 1.2x2.4x0.20 m (4x8x0.6 ft) concrete block built in 2001. The concrete block, shown in Figure 1 prior to being poured, contained numerous rebar, post-tensioning cables, and PVC targets.

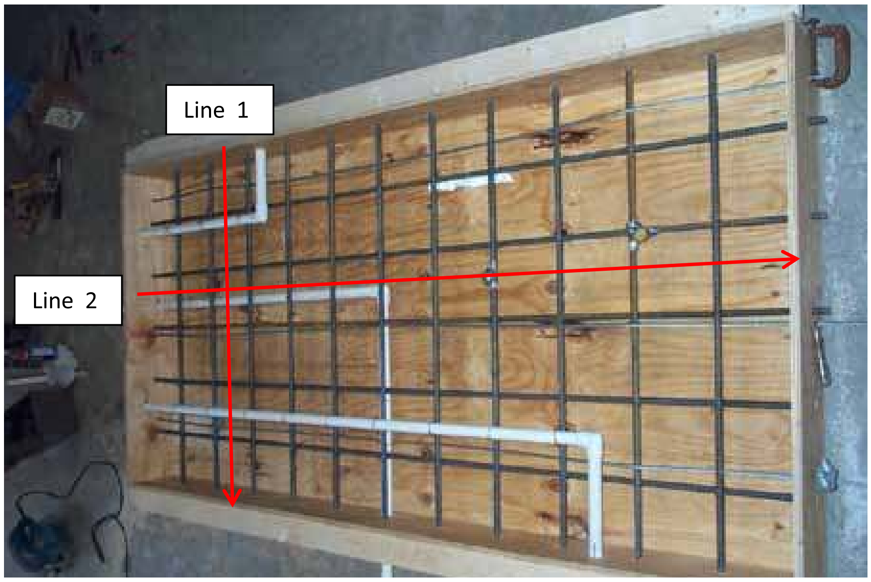



*Fig. 1 Target orientation in concrete block prior to pouring in 2001. Data collection profile line locations with respect to the targets are indicated by the red arrows.*

Two profiles, designated as Lines 1 and 2 were obtained over the concrete block. The first line was collected over 10 targets covering a distance of approximately 100 cm (40 in). Figure 2 shows raw data obtained with the 1.6 GHz antenna. Two out of the three PVC pipes can be observed in the data. The reflection from the PVC pipe positioned beneath the mesh is much lower amplitude than all the other targets. The post-tensioning cable reflections constructively and destructively interfere with the reinforcing reflections.

All data shown in the following figures was obtained with no vertical or horizontal filters and constant, fixed gain. The display gain and color tables of the unmigrated data shown in the figures are the same to allow for direct comparisons. This type of display permits a visual comparison of the scattering relative to the noise floor of the system.

A background removal filter was applied to most of the data in this paper to remove the direct-coupling clutter that obscures scattering from the top two inches of con-

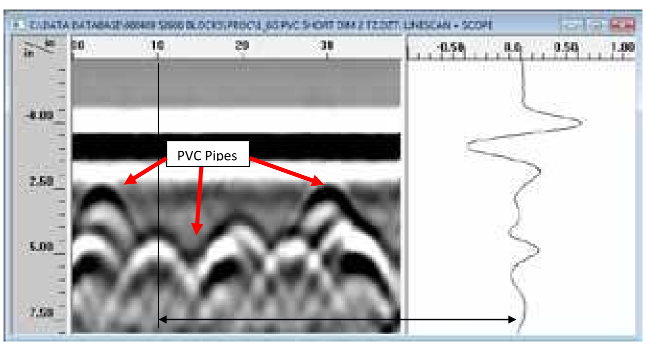



*Fig. 2 Raw data obtained from 1.6 GHz antenna over concrete block built in 2001 containing rebar, post-tensioning cable and PVC pipes.*

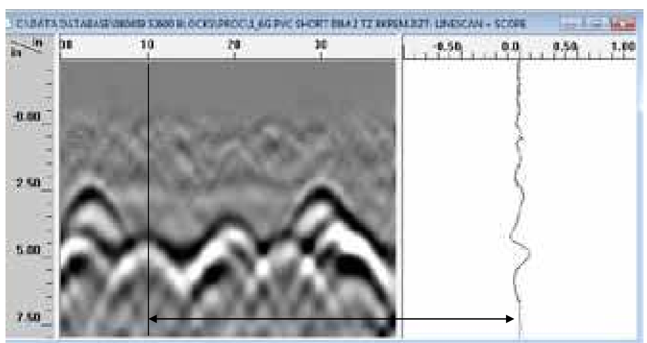


*Fig. 3 Processed data obtained from 1.6 GHz antenna over concrete block built in 2001 containing rebar, post-tensioning cable and PVC pipes. Background removal applied to data.*

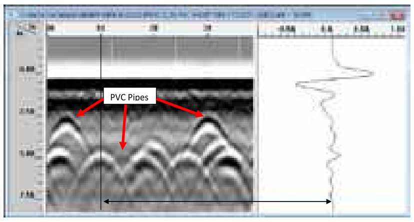



*Fig. 4 Raw data obtained from 2.6 GHz antenna over concrete block built in 2001 containing rebar, post-tensioning cable and PVC pipes.*

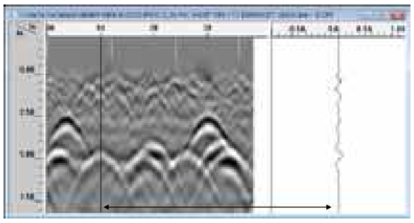


*Fig. 5 Processed data obtained from 2.6 GHz antenna over concrete block built in 2001 containing rebar, post-tensioning cable and PVC pipes. Background removal applied to data*

*(a) 1.6 GHz data along Line 1 after migration and background removal.*

*(b) 2.6 GHz data along Line 1 after migration and background removal.*

*Fig. 6 Data from (a) 1.6 GHz antenna and (b) 2.6 GHz antenna over line 1 after migration and background removal.*

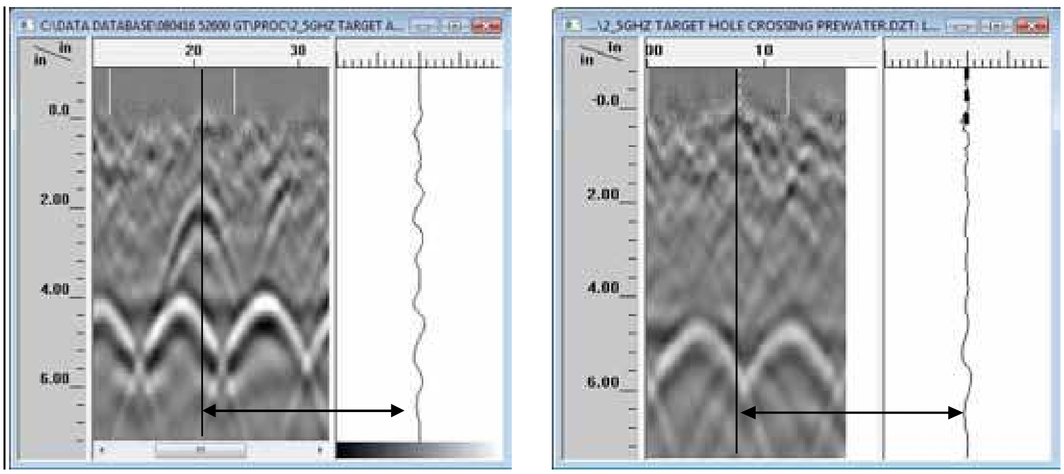

*(a) 1.6 GHz data along Line 2 after migration and background removal.*

*(b) 2 .6 GHz data along Line 2 after migration and background removal.*

*Fig. 7 Data from (a) 1.6 GHz antenna and (b) 2.6 GHz antenna over Line 2 after migration and background removal.*

crete. The data from Figure 2 with the background removal filter is presented in Figure 3. Examination of the figure reveals some very weak scattering from the concrete that is near the noise floor of the data. Data obtained with the 2.6 GHz antenna along the same profile are presented in Figure 4. The increased vertical and horizontal resolution is immediately apparent. The PVC pipe beneath the reinforcing mesh is observable in the raw data. The data following application of a background removal filter are shown in Figure 5. Close examination of Figure 5 reveals significant scattering from the voids and aggregate in the top two inches of concrete. This was an unanticipated finding and can have interesting implications regarding characterization of concrete that will be discussed in the next section of the paper.

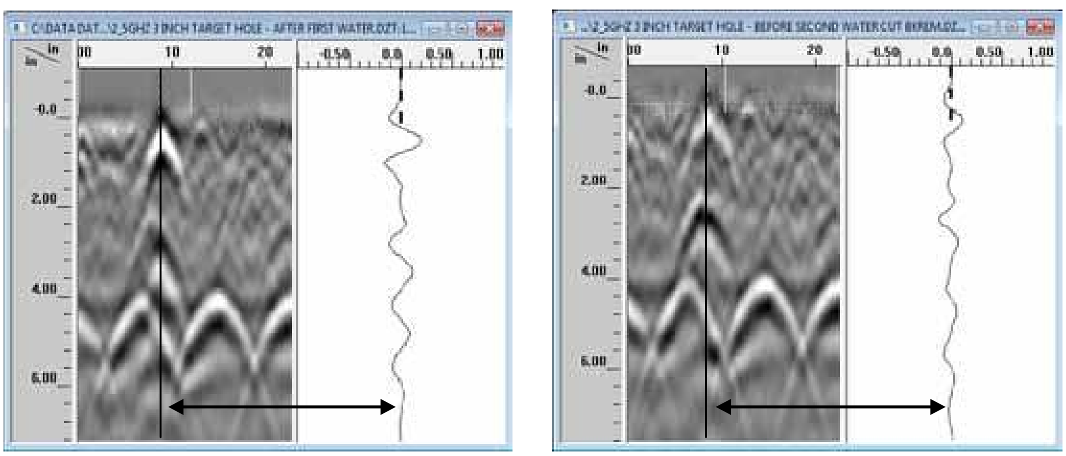
Migration is a processing technique com-



*(a) 2.6 GHz data over anomaly*

*(b) Perpendicular 2.6 GHz profile data over anomaly*

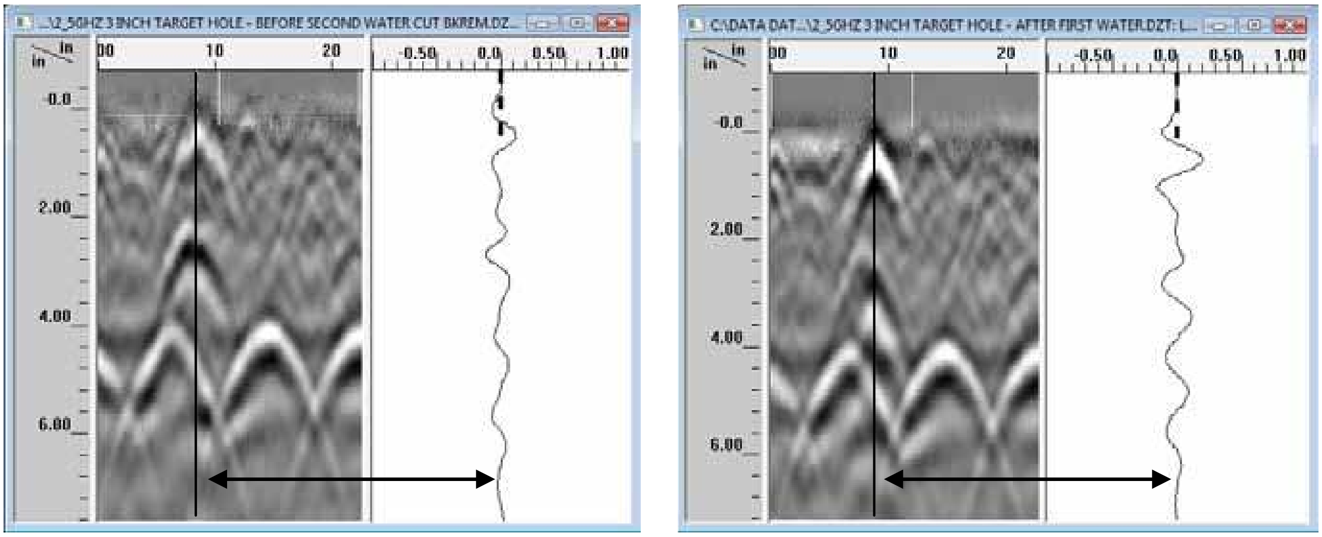
*Fig. 8 Data from 2.6 GHz antenna over drill hole from profiles crossing at right angles.*



*(a) 2.5 GHz data obtained over anomaly immediately after adding water to hole a second time*

*(b) 2.5 GHz data obtained over anomaly prior to adding water to hole a second time*

*Fig. 9 Data from 2.6 GHz antenna over drill hole at anomaly location (a) before and (b) after filling 0.8 cm (5/16 in) diameter hole with water.*




(a) 2.5 GHz data obtained over anomaly-free location prior to adding water to hole a second time

(b) 2.5 GHz data obtained over anomaly-free location immediately after adding water to hole a second time

*Fig. 10 Data from 2.6 GHz antenna over drill hole where no anomalies were located (a) before and (b) after filling 0.8 cm (5/16 in) diameter hole with water.*

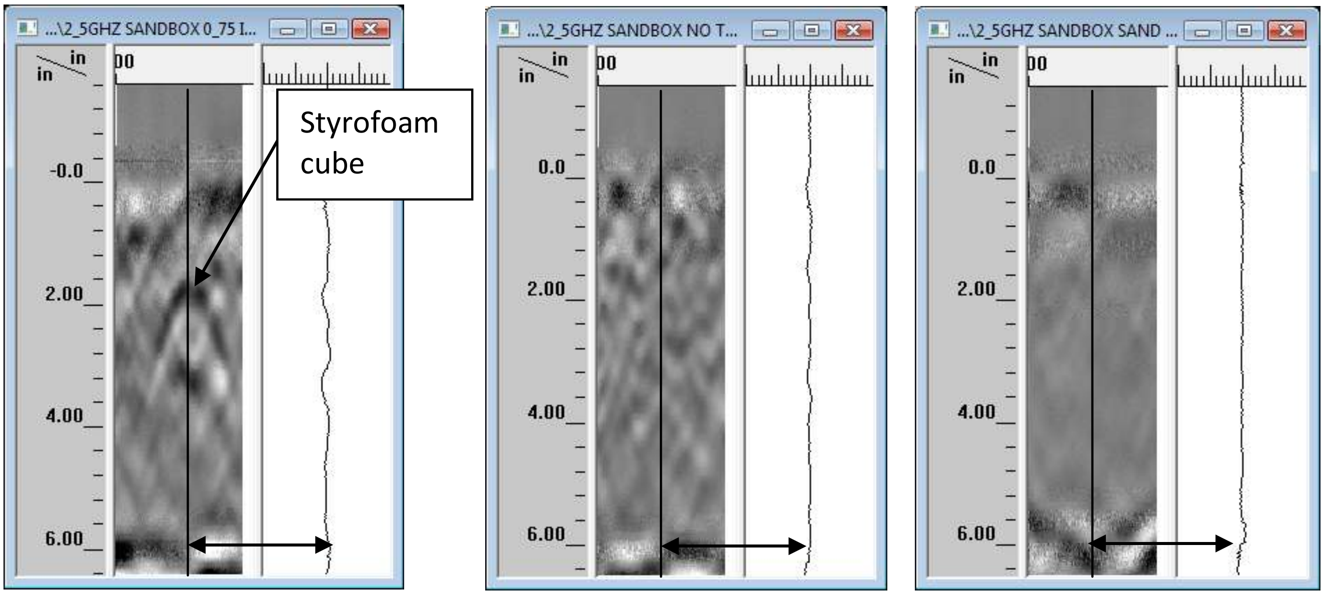
monly applied to data to focus the reflections from targets. The migrated data from the two antennas is presented in Figure 6. The PVC pipe buried beneath the reinforcing mesh is observable in both processed datasets. In addition, migration effectively focused scattered energy from the voids and aggregate in the 2.6 GHz data (Figure 6(b)). One example is the hyperbolic reflection at approximately 2 cm (0.75 in) depth located 50 cm (20 in) along the profile in Figure 5. This hyperbola is collapsed in Figure 6(b). The amplitude of this focused reflection is approximately 50% of the amplitude of the reflection from the reinforcing buried at 10 cm (4 in) depth.

The concrete block contained two ping pong balls that were duct-taped to the reinforcing. Data were obtained along Line 2, which crossed over one of the ping pong balls. The migrated and background removed data from the 1.6 and 2.6 GHz antennas are shown in Figures 7(a) and (b), respectively.

The ping pong ball reflection is not obvious from examination of the 1.6 GHz antenna data. The reflection is obvious in the 2.6 GHz data. However, in the 2.6 GHz data the ping pong ball reflection obscures the reflection from the rebar directly beneath it.

It is readily apparent that there is considerable scattering associated with the concrete composition in the top 6 cm (2.5 in) of the 2.6 GHz data. Especially strong scatterers are located within 0.5 cm (0.2 in) of surface at 62 cm (25 in) and 100 cm (34 in) along the profile. There is also a strong scatterer at approximately 5 cm (2 in) depth at 105 cm (36 in) along the profile. Several holes were drilled at this location in an attempt to ground truth the anomaly. Figure 8 shows data obtained at the location of the drilled hole along orthogonal profiles.

It is immediately apparent from examination of Figure 8 that detection of the anomaly depends on the polarization of the antenna. Data from different concrete blocks contain some anomalies similar to the one




(a) Data over sand-aggregate mix containing 1.9 cm (0.75 in) cube buried 4.2 cm (1.7 in).

(b) Data over sand-aggregate mix

(c) Data over sand

*Fig. 11 Data from 2.6 GHz antenna with background removal applied. Data obtained over (a) sand, (b) a sand-aggregate mix, and (c) sand-aggregate mix with buried 1.9 cm Styrofoam cube.*

shown in Figure 8(a) possessing similar polarization sensitivity.

The anomaly shown in Figure 8(a) could not be verified from visual examination of the hole drilled to a depth of approximately 8.2 cm (3.25 in). Additionally, all of the concrete dust could not be removed from the holes using the available commercial grade vacuum. Consequently water was introduced into the hole drilled over the anomaly and a control hole drilled at a location with no apparent anomaly. GPR data were obtained at both locations. A noticeable change was observed in the appearance of the anomaly before and after the hole was filled with water. The water in the holes completely permeated into the concrete within 10-20 minutes. Subsequent data obtained 2 hours later revealed that the anomaly was substantially "recovered" from the initial amount of water. That is, the reflection from the anomaly was substantially similar to the anomaly prior to the addition of water. The holes were subsequently refilled and more GPR data were obtained. Figures 9 and 10 show data obtained immediately before and after filling the anomaly and control holes the second time, respectively.

There is a clear change in the anomaly before and after adding water, as shown in Figures 9(a) and 9(b), which indicates that void space is being filled with water. In contrast, there is no indication of the presence of water in the control hole, Figure 10(b), except at the top of the hole.

The effect of scattering from aggregate with a low dielectric contrast relative to the host medium in a controlled environment was examined using sand and a mixture of sand and 2 cm (0.75 in) crushed granitic rock. Data were obtained using the 2.6 GHz antenna in contact with approximately 15.9 cm (6.25 in) of material in a container with dimensions 57.9x42.4 cm (22.8x16.7 in) placed on top of a 60x60 cm (24x24 in) metal plate. Figure 11 shows data obtained along a 23.4 cm (9.2 in) long profile over the container filled with (a) sand, (b) sand and gravel mixture, and (c) sand and gravel mixture with a 1.9 cm (0.75 in) cube of Styrofoam buried at a depth of 4.2 cm (1.7 in). A background removal filter was applied to the data to resolve the faint scattering from the inhomogeneities.

Close examination of Figure 11(a) reveals that there is very low amplitude scattering from the slight differences in compaction in the data obtained over the sand. This scatterering is near the noise floor of the system. Much stronger scattering from the aggregate is observed in Figure 11(b). The 1.9 cm (0.75 in) Styrofoam cube is clearly evident in the data in Figure 11(c). However, the constructive and destructive interference of arrivals from aggregate scattering weaken and strengthen the hyperbolic reflection at different locations along its extent.

## DISCUSSION

It is clear from the data presented in this paper that the 2.6 GHz prototype antenna data provides higher resolution of closely spaced targets than the 1.6 GHz antenna. It is not shown in this paper, but the cost of the higher resolution is less depth penetration.

The scattering from aggregate and voids in the concrete is an unanticipated finding from analysis of data obtained with the 2.6 GHz antenna. Close inspection of the 1.6 GHz antenna data indicates that some of the scattering is also apparent, but much lower amplitude.

Data obtained with the 2.6 GHz antenna over other concrete blocks of different ages and different aggregate both indoors and outdoors contain scattering patterns similar to the patterns observed in the block data presented in this paper.

## CONCLUSION

The prototype 2.6 GHz antenna provides greater horizontal and vertical resolution than the 1.6 GHz antenna. The data also contain a scattering pattern associated with void and aggregate scattering within the concrete. This scattering pattern can potentially be very useful for assessing the moisture profile of the concrete, aggregate related issues such as aggregate settling, and honeycombing.

# Concrete Repair Products and Systems based on EN1504

## - structural and non-structural repair of concrete structures

BASF
The Chemical Company

Over the past 30 to 40 years the industry's understanding of the technical performance requirements of concrete repair and protection products has increased significantly.

The new European standard EN 1504 represents the culmination of over 15 years of consultation and committee work by professionals from all sectors of the concrete repair industry. It is the first concrete repair code. The European standard EN 1504 is entitled: "Products and systems for the repair and protection of concrete structures", and is aimed at all those involved with the repair of concrete.
For the first time in the industry, EN 1504 deals with all aspects of the repair and / or protection process including:
- definitions and repair principles;
- the need for accurate diagnosis of dete rioration causes before specification of the repair method;
- detailed understanding of the needs of the client;
- product performance requirements and test methods;
- factory production control and evaluation of conformity, including CE marking
- site application methods and quality control of the works

When followed, this complex, but comprehensive document, should ensure good quality repair and protection work on the jobsite, which will result in increasing satisfaction of the building owners.

The European standard EN 1504 consists of 10 parts, each covered by a separate document. This provides a resource which helps specifying engineers, contractors as well as material manufacturing companies. It will give the structure owner an increased level of confidence as, for the first time, all issues of concrete repair and protection are addressed by a single integrated European standard.

In this article, we would like to focus on Part 3, which provides the specification for the structural and non-structural repair of concrete structures. It covers repair mortars and concretes, possibly used in conjunction with other products and systems, to restore and / or replace defective or contaminated concrete and to protect reinforcement, in order to extend the service

| Document No | Description |
|---|---|
| EN 1504-1 | Describe terms and definitions within the standard |
| EN 1504-2 | Provides specifications for surface protection products/systems for concrete |
| EN 1504-3 | Provides specifications for the structural and non-structural repair |
| EN 1504-4 | Provides specifications for structural bonding |
| EN 1504-5 | Provides specifications for concrete injection |
| EN 1504-6 | Provides specifications for anchoring of reinforcing bars |
| EN 1504-7 | Provides specifications fro reinforcement corrosion protection |
| EN 1504-8 | Describes the quality control and evaluation of conformity for the manufacturing companies |
| EN 1504-9 | Defines the general principles for the use of products and systems, for the repair and protection of concrete |
| EN 1504-10 | Provides information on site application of products and quality control of the works |

| | | | |
|---|---|---|---|
| Principle 3 | Concrete restoration | Method 3.1 | Applying mortar by hand |
| | | Method 3.2 | Recasting with concrete |
| | | Method 3.3 | Spraying mortar or concrete |
| Principle 4 | Structural strengthening | Method 4.4 | Adding mortar of concrete |
| Principle 7 | Preserving or restoring passivity | Method 7.1 | Increasing cover to reinforcement passivity with mortar or concrete |
| | | Method 7.2 | Replacing contaminated concrete |

life of a concrete structure exhibiting deterioration.

The method of application is covered in EN1504-9 (general principles for the use of products and systems, for the repair and protection of concrete)

## Concrete repair mortar classification according EN 1504, part 3

The European standard defines 4 classes of repair mortar R4, R3, R2, R1. These are then divided between structural and non-structural repairs, i.e. those applications where load transfer has to be considered in the design of the repair specification, or alternatively for cosmetic works. Furthermore the standard classifies the repair products for each type of application, in a high strength or high E-modulus and low strength or low E-modulus mortar.

This approach has been developed as a result of 30 years experience in the use of cement mortars for concrete repair. It allows the specifying engineer to select the right quality of repair material for the jobsite specific concrete quality, in order to repair "like with like". It is well known that incompatibilities between repair mortar and host concrete can lead to premature failure, e.g. through differential thermal expansion / contraction.

The different classes do not imply bad, mediocre, good or excellent performances of the repair products. All repair materials meeting the norm are of a high quality. The norm only indicates which repair mortar class should be used for which kind of application. e.g.
- high strength concrete exposed to heavy loads should be repaired with a high strength / high E-modulus repair product, thus a class R4 mortar
- a lower strength concrete exposed to loads should be repaired with a structural repair mortar with medium strength and / or E-modulus, thus class R3
- all concretes in a non-structural situation, i.e. where loads are not to be transferred through the repair zone, can be repaired with a higher quality non-structural repair mortar, class R2

In addition to considering the appropriate classes, it is of utmost importance to recognize and specify the exposure conditions to which the product will be exposed. These exposure classes and the relevant repair mortar testing will determine the durability of the applied mortar systems. e.g.
- a mortar tested for restrained shrinkage / expansion only can not be used on structures exposed to freezing and thawing
- a mortar approved for use in freeze / thaw conditions (including salt exposure) can be used in all conditions

These additional commonly needed performance requirements, e.g. freeze / thaw resistance, should be specified, for each and every jobsite, from the performance characteristics list named "certain intended uses" in the standard.

## Performance characteristics of structural and non-structural repair products

| Performance characteristics | Repair principle | | | |
|---|---|---|---|---|
| | 3 | 3 | 4 | 7 |
| | Repair method | | | |
| | 3.1; 3.2 | 3.3 | 4.1 | 7.1; 7.2 |
| Compressive strength | ■ | ■ | ■ | ■ |
| Chloride ion content | ■ | ■ | ■ | ■ |
| Adhesive bond | ■ | ■ | ■ | ■ |
| Restrained shrinkage / expansion | ■ | ■ | ■ | ■ |
| Durability – carbonation resistance | ■ | ■ | ■ | ■ |
| Durability – thermal compatibility<br>Freeze / thaw; thunder / shower; dry cycling | □ | □ | □ | □ |
| Elastic modulus | □ | □ | ■ | □ |
| Skid resistance | □ | □ | □ | □ |
| Coefficient of thermal expansion | □ | □ | □ | □ |
| Capillary absorption ( water permeability) | □ | □ | □ | □ |

■ For all intended uses    □ For certain intended uses

Note:
- carbonation resistance is not required when the repair system includes a proven carbonation resistant surface protection system
- restrained shrinkage / expansion not required if durability – thermal cycling is undertaken
- choice of thermal cycling test depending on the exposure conditions, e.g. exposure to freezing and thawing, drying and wetting, hot and cold etc

BASF has the complete range of concrete repair mortar that meets the EN1504 specification for structural and non-structural repair products. The new Emaco Nanocrete range represents the next generation of concrete repair mortars with exceptional properties :
improved bond strengths

- improved densities and impermeability
- improved tensile strengths and reduced cracking tendency
- improved thixotropy
- reduced application problems
- reduced shrinkage
- improved compatibility with concrete
- easier and quicker application and finishing
- reduced costs

## Performance requirements for cementitious structural and non-structural repair products

| Performance characteristics | Test method | Requirements (Table 3 in EN 1504, part 3) | | | |
|---|---|---|---|---|---|
| | | Structural | | Non-Structural | |
| | | Class R4 | Class R3 | Class R2 | Class R1 |
| | | Emaco Nanocrete R4 | Emaco Nanocrete R3 | Emaco Nanocrete R2 | Emaco R1 |
| Compressive strength | EN 12190 | ≥ 45 MPa | ≥ 25 MPa | ≥ 15 MPa | ≥ 10 MPa |
| Chloride ion content | EN 1015-17 | ≤ 0.05% | | ≤ 0.05% | |
| Adhesive bond | EN 1542 | ≥ 2 MPa | ≥ 1.5 MPa | ≥ 0.8 MPa | |
| Restrained shrinkage / expansion | EN 12617-4 | Bond strength after test | | | No requirement |
| | | ≥ 2 MPa | ≥ 1.5 MPa | ≥ 0.8 MPa | |
| Durability – carbonation resistance | EN 13295 | $d_k$ ≤ control concrete | | No requirement | |
| Durability – thermal compatibility Freeze / thaw | EN 12617-4 | Bond strength after 50 cycles | | | Visual inspection |
| | | ≥ 2 MPa | ≥ 1.5 MPa | ≥ 0.8 MPa | |
| Durability – thermal compatibility Thunder / shower | EN 12617-4 | Bond strength after 30 cycles | | | Visual inspection |
| | | ≥ 2 MPa | ≥ 1.5 MPa | ≥ 0.8 MPa | |
| Durability – thermal compatibility Dry cycling | EN 12617-4 | Bond strength after 30 cycles | | | Visual inspection |
| | | ≥ 2 MPa | ≥ 1.5 MPa | ≥ 0.8 MPa | |
| Elastic modulus | EN 13412 | ≥ 20 GPa | ≥ 15 GPa | No requirement | |
| Skid resistance | EN 13036-4 | Class I: > 40 units wet tested<br>Class II: > 40 units dry tested<br>Class III: > 55 units wet tested | | Class I: > 40 units wet tested<br>Class II: > 40 units dry tested<br>Class III: > 55 units wet tested | |
| Capillary absorption ( water permeability) | EN 13057 | ≤ 0.5 $kg/m^2$-$h^{0.5}$ | | ≤ 0.5 $kg/m^2$-$h^{0.5}$ | No requirement |

## Reference

EN1504 Part 1-10, Products and systems for the repair and protection of concrete structures.

## A leading solution provider

BASF's Construction Chemicals division is the leading supplier of chemical systems and formulations for the construction industry. Continuous innovation and tailor-made solutions ensure that its customers are provided with the best services. Its Admixture Systems business unit specifically helps customers in the ready-mix, precast, manufactured concrete and underground construction industry. The Construction Systems unit offers a wider range of products for industrial flooring, specialist repair and structural systems, waterproofing membranes, protective coatings and expansion joint sealants.
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