CEMENT & CONCRETE SA

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Know your cement – in the interest of safety

Anchor connections in lightweight concrete

Reinforcement corrosion on RC bridges

Developments in low carbon cements


UNITY
RELEVANCE
LEADERSHIP

CONTENTS

COVER: Irene Precinct Building B – Entry in Buildings more than R 50 M value and Innovation & Invention of Concrete, Fulton Awards 2022.

6

24

33

34

We are often easily swayed by every morsel of (mis)information that comes our way in the professional world. With the digital and social media tsunami we lose our sense of direction and our ability to make responsible and well-informed choices.

More than ever before demands are made on our time, our resources, and specifically our ability to sift the wheat from the chaff. We are constantly being cautioned against scams to separate us from our hard-earned money, and advised to divulge personal information judiciously.

We are taught to prioritise; we are urged to set personal goals and performance targets in the work environment.

Four reliable criteria can assist the process to verify what we see and hear, and what is on offer in support of identified objectives and facts:

- Authority: Who is the author? Who is the publisher? Who is the presenter. What are their credentials?
- Accuracy: Compare the information to that which you already know is reliable.
- Context: Is the message part of a bigger study that is relevant to the underlying principles, and interactive disciplines of the subject?
- Currency: Is the topic constantly evolving away from empirically proven principles?

Concrete Beton always aims to bring content that can pass these verification steps.

Develop an enquiring mind to be able to evaluate what is correct, what is true, what can be useful and what is sustainable.

This message is certainly not a plea to stop innovation, but to move forward with caution, to be alert and to make accountable decisions and comments to guide our actions.

As we bid farewell to this year, my wish for all our readers is that 2024 will be the year for responsible decision-making and renewed focus on what is important, true and sustainable.

Concrete wishes

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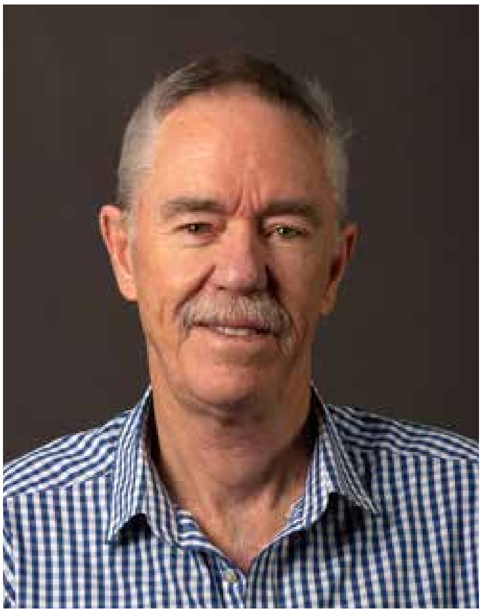


Cement & Concrete SA's commitment to a sustainable industry for all in South Africa, leads us along varied paths and requires involvement in many different spheres to influence, guide, and educate.

A critical segment remains the protection of our industry against cement dumping from overseas manufacturers and reviewing the ITAC application on general import tariffs and considering additional customs duties and anti-dumping measures.

Ongoing concerns regarding cement quality and bag masses are being addressed in engagement with NRCS. To make the public aware of potential problems with non-compliant cement, especially in rural areas, has led to the publication of a new leaflet to inform the public of the potentially life-threatening practice of buying cement from rogue suppliers, or using incorrect mix proportions for specific projects. (p.6)

CCSA is also in discussions with StatsSA regarding collection of cement sales statistics to be able to make these statistics available again to the various industries relying on cement statistics to be able to make forecasts for their own business, e.g., transport and logistics, packaging, vehicle manufactures, and entities looking at civil infrastructure spend to make economic projections for the country, and ultimately investors.

We are also well represented on various Government Project Steering committees, the Minerals Council and SABS to address issue pertaining to cement and concrete relating to legislation, the environment, health and safety, responsible use and management of resources, (both natural and human) and sound practices in South African standards.

CCSA staff further provide input in committees of Business Unity SA (BUSA), The National Business Initiative (NBI), Construction Alliance SA (CASA), Engineering Council SA (ECSA) and the South African Forum for Engineering (SAFE).

Cement and concrete, not only our current raison d'etre, but also our commitment to a sustainable future for the South African industry, for generations to come.

Yours in concrete,
Bryan Perrie, CEO

Know Your Cement – In the interest of safety

A house collapsed in Western Area.

The owner of the house called an engineer to come and investigate. The engineer conducted some tests and took core samples from the concrete foundation and sent these to a laboratory for testing. The test results showed that the strength of the foundation was only 3 MPa instead of the required 15 MPa.

The builder had used an incorrect or inferior cement type, or an incorrect mix for the foundations.

Many secondary blenders and unscrupulous importers are selling non-compliant cement, specifically into rural areas.

This example unfortunately is not an isolated occurrence and happens all over South Africa, and can cause failures in structures.

Uncertainty about the different cement types, or where dishonest contractors and builders use the wrong or non-compliant cement, and do not follow the correct mix proportions for a specific project, can all be potentially life-threatening.

Any project that involves concrete starts with the purchase of the correct cement. There are TWO main types of cement:

MASONRY CEMENT which should only be used for mortar and plaster. These bags have **MC** printed on it and should have the wording **"Masonry Cement, intended to be used for preparation of mortar and plaster only"**. (For example MC 22,5 X).

COMMON CEMENT which must be used for all structural concrete, and may also be used for mortar and plaster. Foundations, floors, columns, beams, and slabs are examples of structural concrete. These bags have **CEM** printed on it. (For example CEM II/B-M (V-L) 42,5 N).

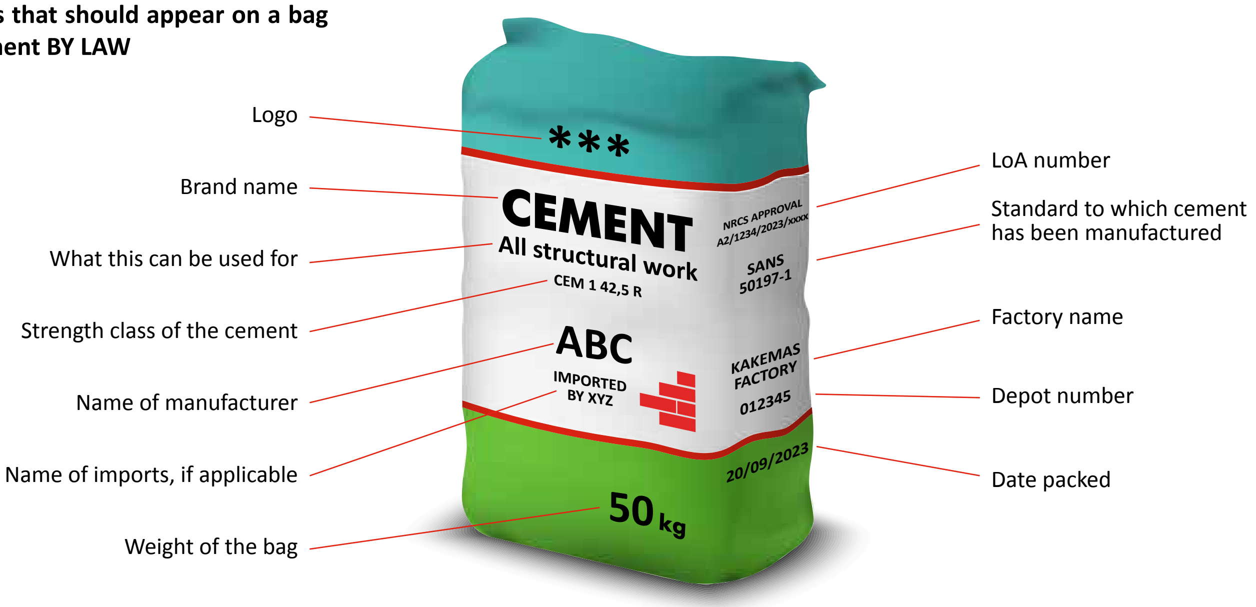
In South Africa, cement is regulated by a Compulsory Standard (VC 9085), administered by the National Regulator for Compulsory Standards (NRC), which means by law cement must meet certain performance specifications and outlines rules for the markings on the bags in order to protect human health and safety.

One of these rules is that **specific markings must appear on every bag of cement sold in South Africa**, to give the customer peace of mind about the quality and correct application of the cement. Most importantly, an LoA number (Letter of Authority) should be **printed** on the bag. Unfortunately, an LoA number appearing on a bag is no guarantee that a LoA has been issued! When buying a cement from an unknown source, always contact the NRCS to confirm whether the LoA is valid: Telephone: +27 12 482 8700.

Use of SANS compliant cements and masonry cements are important to:
- build safe, quality structures and buildings
- ensure that you do not break the law in South Africa
- prevent later liability if you have used a cement not having a valid LoA.

Always confirm the suitability of a particular cement for a specific application with your supplier, and also check that your builder is using a cement that meets the requirements specified above.

Details that should appear on a bag of cement BY LAW



Published by CCSA in the interest of safety.

CCSA Partner Members:

For more information about the different cements available in South Africa, and other guidelines on the use of concrete, download the free leaflets from Cement & Concrete SA's website: www.cemcon-sa.org.za

Accolades for CCSA Members

Professor Mark Alexander

Dr Yunus Ballim

Joanitta Ndawula

We congratulate CCSA Board member, Emeritus Professor Mark Alexander with his appointment as Distinguished Professor in Civil Engineering in the Department of Civil Engineering at the Indian Institute of Technology Madras, India. The appointment recognises his international academic standing in the field of cement and concrete technology and the many years of fruitful collaboration with IIT Madras.

Dr Yunus Ballim, Emeritus Professor at the School of Civil and Environmental Engineering at WITS, has been appointed as a CSIR board member. At the same time, he was honoured with the renaming of the Luka Jantjie Courtyard at the Sol Plaatje University in Kimberley to Yunus Ballim Square, in honour of his role as founding Vice-Chancelor and Principal of the university.

During the recent RILEM Week in Vancouver, the following CCSA members were honoured: Joanitta Ndawula being elected as a member of the RILEM Bureau - probably the youngest member ever so elected, Janina Kanjee being elected as a member of the RILEM Educational Activities Committee (EAC) and Prof Hans Beushausen continues as chair of the RILEM Development Advisory Committee (DAC), while Mark Alexander remains an active member on various RILEM committees.

Mary Chirwa, BSc (Hons) Civil Engineering Student at Wits received the Cement & Concrete SA prize in Concrete Technology Award at the Wits Faculty of Engineering and the Built Environment prize-giving ceremony.

Cement & Concrete SA proudly shares the achievement and recognition of our members. CB

Janina Kanjee

Prof Hans Beushausen

Mary Chirwa

Performance of slag-metakaolin-based geopolymer concrete (GPC) with recycled plastic eco-aggregate

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ABSTRACT

The high demand for concrete in the construction industry leads to a high cement production rate, thereby increasing carbon emissions (CO_2), resulting in global warming and detrimental effects on human survival. One-part "just add water" geopolymer binder is a potential sustainable binder that could substitute ordinary Portland cement. Currently, there are limited studies on the mechanical properties of one-part slag-metakaolin-based GPC with plastic waste as a substitute for fine aggregate. This paper presents the performance of a one-part slag-metakaolin-based geopolymer using anhydrous sodium silicate, sodium hydroxide and calcium hydroxide as activators. Also, the influence of 5 % and 10 % replacement of natural sand with RESIN8 (recycled plastic waste containing Resins 1-7) is also reported on the composite's fresh properties. Furthermore, the effects of two curing methods on the mechanical properties (compressive and flexural strength) are presented. Adding plastic waste as fine aggregate in concrete improved the workability, but there was a reduction in the mechanical strength of GPC as the percentage of RESIN8 increased. However, the compressive strength of 28 days water cured (WC) GPC with 5 % and 10 % RESIN8 were 25.6 MPa and 23.4 MPa, respectively, and ambient cured (AC) GPC with 5 % and 10 % RESIN8 were 24.1 MPa and 21.7 MPa, respectively.

Keywords: geopolymer concrete, RESIN8, metakaolin, slag, mechanical properties.

1. INTRODUCTION

Over the past few decades, due to global warming, there has been a high demand for sustainable concrete binder development. The intensified demand for concrete in the construction industry has led to a high cement production rate and increased Carbon emissions (CO_2). The International Energy Agency [1] and Wan-En et al. [2] reported that 7 % of the global CO_2 emission was generated by the cement industry and 0.83 kg of CO_2 per kg of ordinary Portland cement (OPC) [3]. According to Davidovits [4], the production of 1 tonne of cement generates an almost equivalent quantity of carbon emissions (0.99 tonne) during the calcination of limestone and combustion of carbon-based fuel. Furthermore, Andrew [5] reported that the global cement CO_2 emission in 2016 was 1.45±0.20 Gt out of the accumulated 39.3 Gt of CO_2 from 1900-2016, and South Africa emitted more than 6 Mt of CO_2 from 1950-2016. Hence the need for sustainable Portland cement (PC)-free binder.

Geopolymer is a new generation and PC-free binder for concrete production comprising aluminosilicate precursors and activators, with promising performance and capable of replacing PC in concrete. There are various aluminosilicate precursors, such as fly ash, ladle slag, red mud, metakaolin (MK), ground granulated blast furnace slag (GGBS), etc. However, the abundant availability (over 5000 Mt) [6] and physicochemical stability properties of MK have made it more suitable and recognised for engineering applications [7]. MK is produced by de-hydroxylation of kaolin between 650 °C and 800 °C [8], constituting an excellent amount of about 55 % of SiO2 and Al2O3 but deficient in CaO. On the other hand, ground granulated corex slag (CS) is rich in CaO; hence, it has been used in this study to fill the gap. GGBS is obtained in the metallurgical process of pig iron ore or ignition of coke at a temperature of 1500 °C with an approximate annual production of 270-390 million tonnes [6], while CS is obtained from the production of iron steel through the smelting reduction process.

The first invention of geopolymer started from a two-part application which required a corrosive, viscous and hygroscopic liquid activator that limited its practicability in cast-in-situ and mass concrete production to precast concrete [9]. Hence, the need to develop a one-part geopolymer which is user-friendly. One-part, otherwise referred to as "just add water" geopolymer requires anhydrous activators, which makes its application similar to PC and eradicate the transportation of large quantity of corrosive liquid activators for construction purposes. The most widely used anhydrous activators in one-part geopolymer are Na_2SiO_3 and NaOH. However, producing Na_2SiO_3 from the direct fusion of sand and sodium carbonate is energy-intensive, requiring 850-1088 °C [9] and generating a significant amount of carbon emission but lower than PC [10]. Therefore, there is a need to reduce the demand on Na_2SiO_3 by partially or fully replacing it with other viable activators; hence, NaOH and $Ca(OH)_2$ were used to replace anhydrous sodium metasilicate pentahydrate (Na_2SiO_3¬.$5H_2O$) partially.

The activation of MK-GGBS at equal proportion leads to the formation of C-S-H gel, which produces more stability in the matrix by filling the pores. Still, the high content of GGBS in the mixture reduces the durability properties through shrinkage cracks [11]. Hence, in this study, CS:MK at a proportion of 70:30 was chosen from trial mixes due to its performance over others while incorporating PVA fibre to avoid plastic shrinkage cracks.

The use of recycled aggregate is inevitable in concrete production based on the high demand for natural aggregates (fine and coarse aggregates). According to Babafemi et al. [12], aggregates amount to 75-80 % of the volume of the concrete, with fine aggregate constituting 35-45 %. Hence, the incorporation of recycled aggregate in concrete production has become crucial for sustainable

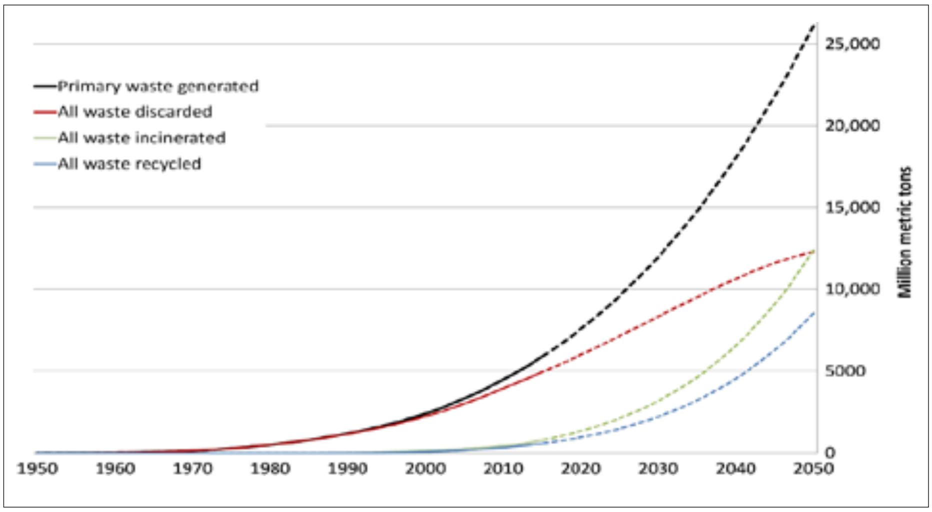

Figure 1: Global trend of plastic production and disposal in million metric tonnes from 1950-2015 and its projection to 2050 [13].

development in the construction industry and a solution to the shortage of natural sand. Geyer et al. [13] estimated the global plastic produced from 1950 to 2015 to be 8,300 Mt, of which 30 % was in use as of 2015, while 9 % was recycled, 12 % incinerated and 60 % discarded and ended up in landfill, oceans and rivers (see Figure 1). In addressing this challenge, researchers have investigated the performance of concrete using recycled aggregate [12,14]. Hence, incorporating recycled plastic waste in concrete to mitigate environmental pollution and develop sustainable and economical concrete holds potential [12].

2. EXPERIMENTAL PROGRAMME

2.1 Materials

The materials used in this study are MK and CS (aluminosilicate precursors), locally sourced Malmesbury sand and 13 mm Greywacke stone, recycled plastic waste (sub2 mm), activators (Na_2SiO_3¬.$5H_2O$, NaOH, and Ca (OH)2, water and admixtures. The MK was obtained from Kaolin Group, and the CS was produced by Arcelor Mittal Steel Plant and supplied by PPC Ltd, South Africa. The recycled plastic waste, patented as RESIN8, is a plastic aggregate that comprises all 7 types of plastics and has been modified to improve the performance of cement-based materials. It was supplied by Centre for Regenerative Design and Collaboration (CRDC), Cape Town. The chemical composition of the aluminosilicate precursors was determined by X-ray fluorescence (XRF) analysis, and the result is presented in Table 1. Figure 2(a-d) shows the precursors and aggregate used. The retarder (trisodium phosphate (NP)) and activators were purchased from Kimix Chemical Lab in Cape Town, South Africa. The specific gravities of MK, CS, sand and RESIN8 are 2.41, 2.90, 2.67 and 1.03, respectively. Polyvinyl alcohol (PVA) fibre having a specific gravity of 1.3 g/cm^3 was used to reduce the shrinkage of the mixes. The oxide molar ratio of the mix is 0.51, 4.45, 0.12, 0.76 and 21.38 for NaO_2/Al_2O_3, SiO_2/Al_2O3, NaO_2/SiO_2, $(Ca+Mg)O/SiO_2$ and H_2O/SiO_2, respectively, which are within the recommended molar ratio by Davidovit [15].

The moduli of sand, RESIN8 and Greywacke stone are 2.34, 2.53 and 6.75, respectively. Thorneycroft et al. [16] noted that the performance of plastic in concrete could be improved by matching the particle size distribution of plastic aggregates with the replaced sand. Hence, the plastic aggregate and sand used in this study were pre-treated to match the aggregate particle size distribution, which were both below 2 mm aggregate sizes, as shown in Figure 3.

2.2 Concrete Mix Proportion

The aggregate proportions and mix design were obtained by the packing density method [17], and the optimum proportion of the aluminosilicate precursors and activators was obtained through trial mixes using the Taguchi approach [18]. The proportion of CS

Figure 2: Aluminosilicate precursors and fine aggregates (a) corex slag (b) MK (c) Resin8 (d) Malmesbury sand

Table 1: Chemical composition of aluminosilicate precursors

Compound	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	SiO_2	others
CS	14.49	38.46	1.35	0.6	11.92	0.16	32.96	0.55
MK	24.52	0.04	1.88	3.89	1.03	0.33	67.14	0.87

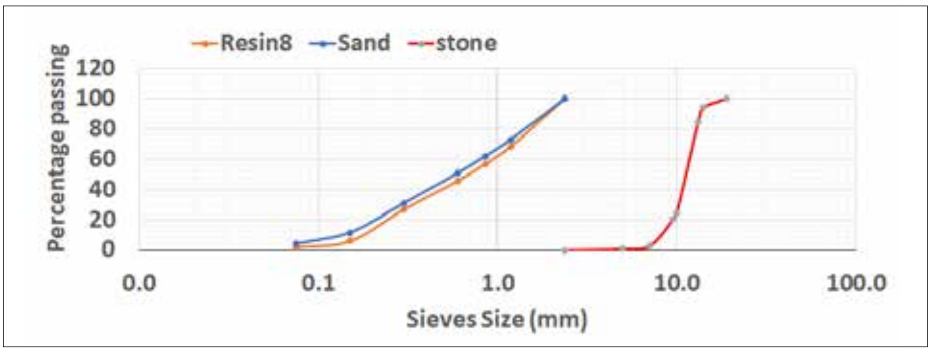

Figure 3: Particle size distribution curve of sand, RESIN8 and 13 mm Greywacke stone

Table 2: GPC mix design (kg/m3)

Mark	MK	SL	SS	SH	CH	NP	CA	FA	RESIN8	PVA	water
0%	94	265	21.60	12.96	8.64	9	1167	778	0	2.6	221.7
R5%	94	265	21.60	12.96	8.64	9	1167	739	15	2.6	221.7
R10%	94	265	21.60	12.96	8.64	9	1167	700	30	2.6	221.7

to MK was 70:30, and 12 % activator by weight of the binder was used. The optimum percentage combination of Na2SiO3: NaOH: Ca(OH)2, hereafter referred to as SS:SH:CH, obtained from trial samples was 6:3.6:2.4 (% by weight of the binder). The admixtures used were 1.2 % modified polycarboxylate superplasticiser and 1.5 % PVA by wt. of the binder. The reference mix (0 %) and RESIN8 mixes are presented in Table 2. The sand was replaced with RESIN8 by volume at 5 % and 10 %, which is denoted as R5 % and R10 %, respectively, and the targeted class of concrete for reference mix was C20/25 (strength of 20-25 MPa) with class S3 slump (100-150 mm).

3. EXPERIMENTAL TESTS

3.1 Fresh Properties

The workability and density of all the freshly mixed concrete samples were determined using a slump cone following BS EN 12350-2 [19].

3.2 Strength Tests

3.2.1 Concrete density and compressive strength

The concrete cube (100 mm) samples were cast and compacted using a vibration table in accordance with BS EN 12390-2 [20]. The concrete samples were cured for 7 and 28 days under ambient conditions and complete water immersion. The hardened concrete samples' densities were determined following BS EN 12390-7 [21], and compressive strength was determined following BS EN 12390-3 [22] using a KingTest Contest machine at a loading rate of 180 KN/min until the samples failed. The average failure loads of five samples were computed for each mix.

3.2.2 Flexural Strength

Three prismatic concrete replicates of 300 x 100 x 100 mm were cast per mix and cured for 7 and 28 days under ambient conditions as per BS EN 12390-1&2 [20, 23]. A four-point bending test was conducted on the specimens

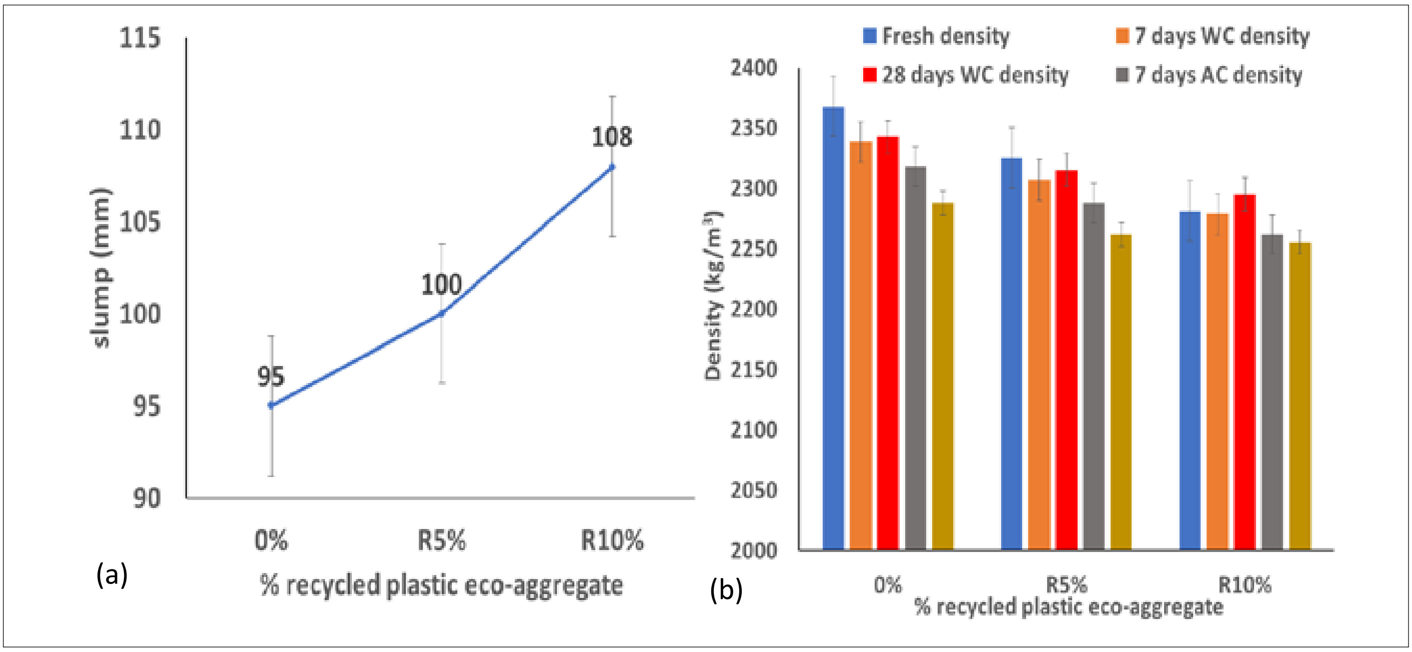

Figure 4. (a) Workability and (b) density of GPC with resin8

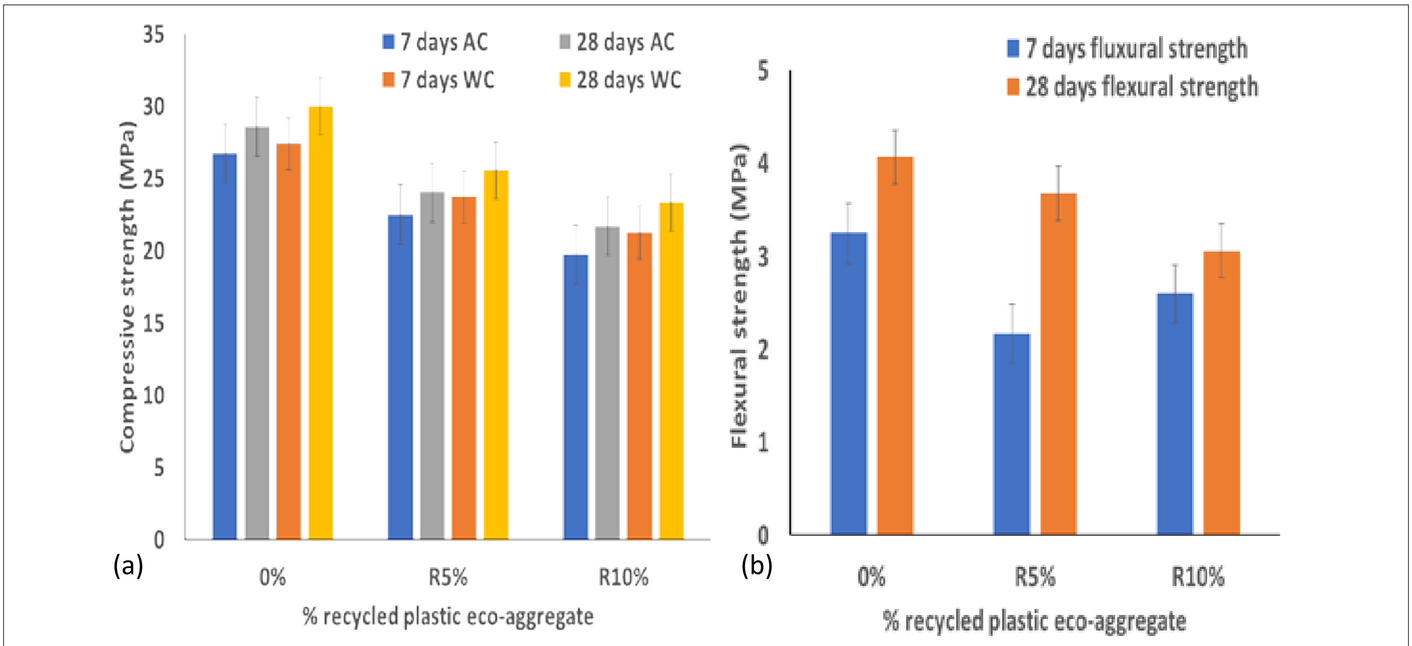

Figure 5. Mechanical properties of ambient and water-cured GPC (a) compressive strength (b) flexural strength (ambient cured).

using a Zwick Z250 material testing machine at a load rate of 0.06 MPa/s according to BS EN 12390-5 [24].

4. RESULTS AND DISCUSSION

4.1 Workability of Mixes

The workability of the mixes increases with an increase in the percentage content of RESIN8, as shown in Figure 4a. The physical characterisation of the aggregates shows that sand has a high-water absorption (1.42 %) than RESIN8 (0.68 %) due to the hydrophobic nature of plastic, while sand is hydrophilic. Hence, the improved workability with the increase in RESIN8 [12, 25]. The fresh density of the mixes (Figure 4b) decreases with an increase in the percentage of RESIN8; this can be attributed to the light weight of plastic.

4.2 Hardened Density

Similar to the fresh density, the hardened density of the samples reduced with an increase in the percentage content of RESIN8, and this is attributed to the lightweight characteristic of plastic with a specific gravity of 1.03, compared to sand with 2.67. The density of the concrete samples with 5 % and 10 % RESIN8 decreased by 1.14 % and 1.4 % for AC and 1.15 % and 2 % for WC, at 5 % and 10 %, respectively, compared to the control samples at 28 days. The density reduction with an increase in the percentage of plastic was also reported by [25, 26].

4.3 Compressive and Flexural Strength

The compressive and flexural strength of GPC are presented in Figure 5. From the 7- to 28-day, the compressive strength of the control samples increased by 6.9 % and 9.4 % for AC and WC samples, respectively. This implies an early age strength development in GPC. However, there is a 15.9 %, 24.1 %, and 14.7 %, 22.2 % decrease in the compressive strength of AC and WC samples containing R5 % and R10 %, respectively, compared to the control sample at 28 days. This is attributed to the weak interfacial bond around the plastic aggregates (interfacial transition zone, ITZ), increased porosity and lower stiffness of plastic compared to sand. In contrast, according to Thorneycroft et al. [16], the strength of a conventional concrete sample with plastic waste increased when the fine sand and plastic particle sizes were matched. The decrease in strength was also reported by [12, 25, 27, 28]. However, structural strength is achieved at a R5 % content.

The flexural strength of the GPC samples decreased at R5 % and increased at R10 % at 7 days AC, but the strength at 28 days of AC samples decreased progressively with increased RESIN8 content. The flexural strength of the GPC samples at 28 days was 14.2 %, 15.3 %, and 14.1 % of the compressive strength for control (0 %), R5 %, and R10 %, respectively.

5. CONCLUSIONS

This study investigated the effects of plastic waste (RESIN8) as a partial replacement of natural sand (5 % and 10 % by volume) on the fresh and hardened properties of slag-metakaolin- based geopolymer concrete. The workability, fresh and hardened density, and compressive and flexural strength were investigated. The following conclusions are summarised from the investigation.

1. The addition of RESIN8 increases the workability of slag-metakaolin-based geo-polymer; however, it reduces the fresh density of the concrete mix.
2. Geopolymer can be effectively cured under ambient conditions and water curing methods. However, the concrete samples cured in the water exhibited higher compressive strength than those cured in ambient conditions.
3. The hardened density and the compressive strength of the geopolymer samples decreased with increased content of RESIN8 by 1.4 % and 2 % for density and 24.1 % and 22.2 % for compressive strength at R10 % at 28 days AC and WC samples, respectively.
4. The flexural strength also decreased with an increase in the percentage content of RESIN8.

However, RESIN8 can substitute fine aggregates up to 10 % by volume in slag (CS)-metakaolin-based non-structural geopolymer concrete and 5 % in structural geopolymer concrete. **CB**

ADEWUMI J BABAFEMI was appointed Associate Professor in Civil Engineering at Stellenbosch University after completing a PhD and Postdoctoral Research Fellowship investigating the time-dependent deformation of cracked macro fibre reinforced concrete, and mechanisms responsible for the behaviour.
He holds an MSc Building Structures from Obafemi Awolowo University in Nigeria and a PhD Civil Engineering from SU. While in private practice in Nigeria doing structural design and management of various building construction projects, he also lectured under-graduate and post-graduate students and supervised research theses at both levels at the Obafemi Awolowo University.
His research interests include Tensile creep of fibre reinforced concrete; Sustainable building materials; Concrete practice in general.

BABATUNDE LUKE AJAYI holds a BSc Civil Eng First Class Honours from the Federal University Oye Ekiti in Nigeria. He is currently a PHD Candidate, while holding a position as MEng (Research) & Teaching Assistant in the Civil (Structural) Engineering, Stellenbosch University (SU). Before coming to South Africa to further his studies, he worked in Nigeria as a site engineer.

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The design and analysis of anchor connections in lightweight concrete

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ABSTRACT

The recent developments in environmental studies show lightweight concrete as a suitable building material which aligns with sustainable principles. In terms of anchor design, concrete is the most preferred base material and is well-suited for anchoring; although the frequent use of lightweight concrete in the construction sector suggests the performance of fixing systems in lightweight concrete should be explored.

Anchor connections are used in all facets of the building and construction sector – namely household, structural and industrial fixings. This study explores the concept of anchor design and discusses the contributing factors that affect the overall performance of a fixing system. Innovative designs and alternate building materials prompt new development in the fixings industry, therefore in order to adapt and develop new fixings, one must understand the basics of anchor design.

Keywords: sustainable principles, lightweight concrete, anchor design, fixing

1. INTRODUCTION

It is known that solid concrete is the most preferred base material for anchors [3]. However, the importance for lightweight concrete to be identified as suitable base material in terms of anchor technology has been gaining traction within the anchor technology industry [2].

This study explores the theory of anchor design and demonstrates significant concepts through a case study [2]. Base materials, load-bearing capacities, failure modes and installation criteria are introductory concepts used to explore anchor design theory [1]. To showcase the industry development of concrete, an experiment which focuses on the performance of anchor technology in lightweight concrete is conducted.

2. THEORETICAL BACKGROUND

Anchor connections are generally used in steel to concrete connections to transmit loads from one element to another via anchor bolts [3]. The anchor bolts are used to distribute load actions into its base material and are influenced by key parameters such as its base material, load bearing capacities and anchor failures of the most unfavorable anchor [3].

2.1. Base Materials

There are various types of base materials available for anchoring. The most common types are concrete (cracked and uncracked), masonry (composite material composed of hollow or solid brick), boards and panels [4]. Each base material varies in compressive strength which has an influence on the anchor connection [3].

2.2. Load Bearing Capacities

The load bearing capacity of anchors refers to the tensile and shear (and combined tensile and shear) loads applied to an anchor connection [4]. Load actions are transferred via anchor bolts which function on two basic principles: Expansion/Undercut theory or Bonding theory [3].

2.2.1. Expansion/Undercut theory

This principle uses mechanical interlock and friction to hold an anchor into its base material [3]. Mechanical interlock of anchors transfers the load to the base material by locking against the base material [3]. Expansion anchors work on the principle of friction to create a force between the anchor and its substrate [3].

2.2.2. Bonding theory

Chemical anchors rely on bonding between the chemical, anchor and substrate [3]. In this case, the load is transferred from the anchor to the base material via the bond created by the chemical components. A chemical reaction occurs between the epoxy mortars which produce different strengths of chemical bonds [5]. Each chemical mortar has unique chemical components that require curing and drying times [5].

2.3. Failure Modes

Anchor connections fail when the load applied to the anchor connection exceeds its ultimate working capacity [4]. Anchor design is based on understanding the failure modes and providing sufficient resistance within a connection to prevent failures. Failures are classified into four modes: (a) Steel failure, (b) Pull-out failure, (c) Concrete cone failure, (d) Splitting failure. A description of each failure mode is given below [3].

2.3.1. Steel failure

Steel failure is a direct failure of steel, which occurs when the tensile load causes the steel to snap, whilst the contact between stud and base material remains intact [3].

2.3.2. Pull-out, pull-through and pry-out failure

Pull-out failure occurs when the anchor is pulled out of its base material, whilst pull-through failure occurs when the anchor disassembles at the expansion point and pulls out [3]. Pry-out failure occurs when the anchor is removed with excessive shear [3].

2.3.3. Concrete cone

Concrete cone failure refers to when a conical section is developed around the anchor and breaks out from its base material in this shape [3]. The cone is approximated to be 1.5 times the effective depth, with the tip of the cone being the part of stud that's furthest into its base material [6].

2.3.4. Splitting failure

Splitting failure refers to the cracking (or splitting) of a base material due to the incorrect embedment depths [3]. This failure mode is influenced by the spacing and embedment depths of an anchor connection.

2.4. Installation Dimensions for Anchor Bolts

Anchorage depth, spacings, and edge distances have an influence on the load bearing capacity of an anchor connection [3]. Figure 1 illustrates an overall description of the influencing dimensions considered when installing fixing systems: diameter of anchor bolt (d_0), effective depth (h_2), fixture thickness (t), Installation torque (T_inst) [3].

3. DESIGN OF ANCHORS

Anchor design involves applying engineering principles to determine safe-working conditions for anchor connections. This is calculated by using partial safety factors and the ultimate failure loads [4].

Partial safety factors are theoretical values which quantify the effect of the different parameters outlined above, on the overall anchor design. The equations shown in Table 1 are extracted from SANS: 51992 Part 4: Design of fastenings for use in concrete [5].

4. CASE STUDY

In order to learn more about the role of lightweight concrete as a base material, a case study is conducted to explore the working capacities of a sample of fixing systems through a series of mechanical tensile loading tests.

A sample of fixing systems, containing four different types of systems are installed in lightweight concrete blocks. A tensile load is applied to each system, and the mode and load at failure is recorded. Each system is installed and tested four times and an average performance result is determined. Using design concepts outlined in the previous section, a design analysis is calculated to determine the safe-working capacities of the various systems.

4.1. Methodology

The information presented in Table 2 shows critical data that describes the materials and equipment used for this case study.

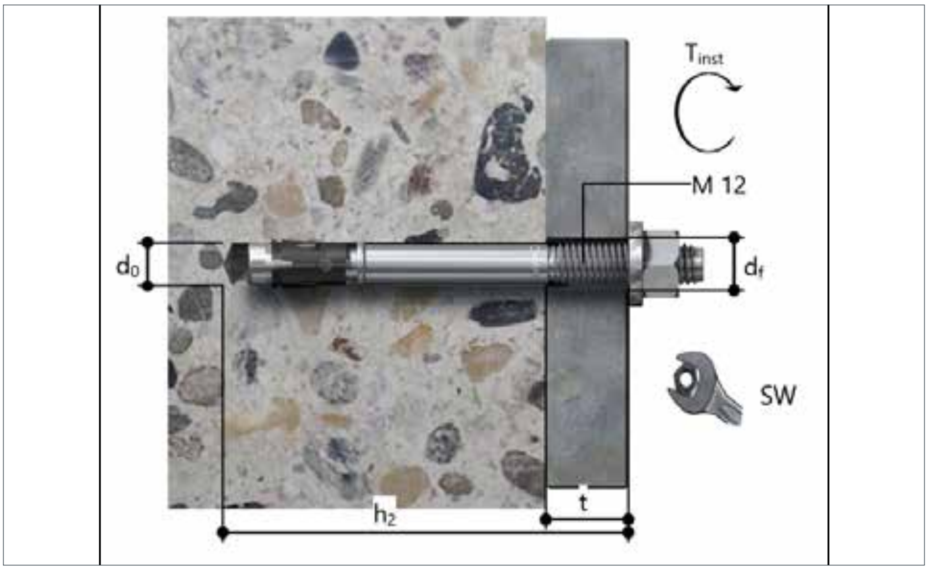

Figure 1: Influencing dimensions for typical anchor connection [3]

Table 1: Partial safety factors with correlating failure modes [5]

FAILURE MODES	PARTIAL SAFETY FACTORS Accidental design situations
STEEL FAILURE – Anchor fastenings	
1. Tension	$\gamma_{Ms} = 1.05 f_{uk}/f_{yk} \geq 1.25$
2. Shear	$\gamma_{Ms} = \frac{1.0 f_{uk}}{f_{yk}} \geq 1.25$ $when\ f_{uk} \leq 800N/mm^2 and\ f_{yk}/f_{uk} \leq 0.8$
CONCRETE RELATED FAILURE	
3. Concrete cone failure	$\gamma_{Mc} = \gamma_c \cdot \gamma_{inst}$
4. Concrete edge failure	$\gamma_c = 1.2$
5. Concrete pry-out failure	$\gamma_{inst} = 1.0$ $for\ fasteners\ in\ tension\ and\ shear$
6. Concrete splitting failure	$\gamma_{Msp} = \gamma_{Mc}$
7. Pull-out failure	$\gamma_{Mp} = \gamma_{Mc}$

where,

γ_{Ms} = partial safety factor for steel failure
f_{uk} = nominal characteristic steel ultimate tensile strength
f_{yk} = nominal characteristic steel yield strength
γ_{Mc} = partial safety factor for concrete cone, concrete edge, concrete blowout and pry-out failure modes
γ_c = partial safety factor for concrete edge failure
γ_{inst} = factor accounting for the sensitivity to installation of post-installed fasteners
γ_{Msp} = partial safety factor for concrete splitting failure
γ_{Mp} = partial safety factor for concrete pull-out failure

Table 2: Test materials & Equipment

MATERIAL/EQUIPMENT	DESCRIPTION
1. Lightweight concrete block	1.1. Dimension: 700x340x120 mm 1.2. Density: 480 kg/m^3 1.3. Compressive strength: 2.58 MPa
2. Fixing systems	2.1. Duo Power Plug & Coach screw 2.2. SXRL 2.3. UX 2.4. Nylon Hammer fix (Green) 2.5. Nylon Hammerfix (Standard)
3. Power tools	3.1. Percussion drill with masonry drill bit. Bit size: 9 mm Bit size: 7 mm
4. Hydraulic tensile tester	4.1. Hydraulic tester with 10 kN calibrated gauge

Table 3: Results obtained through tensile testing

FIXING SYSTEM		RESULTS	
Type	Dimensions	Failure Mode	Failure load
Duo Power (Duo Line)	ø size: 10 mm Length: 50 mm	1. Pull-out failure 2. Pull-out failure 3. Pull-out failure 4. Pull-out failure	0.2 kN 0.3 kN 0.2 kN 0.2 kN
Duo Power (Duo Line)	ø size: 10 mm Length: 80 mm	1. Pull-out failure 2. Pull-out failure 3. Pull-out failure 4. Pull-out failure	1.6 kN 1.6 kN 1.4 kN 1.4 kN
SXRL (Frame fixing)	ø size: 10 mm Length 80 mm	1. Pull-out failure 2. Pull-out failure 3. Pull-out failure 4. Pull-out failure	1.2 kN 1.4 kN 1.3 kN 1.0 kN
UX (Universal Plug)	ø size: 10 mm Length: 50 mm	1. Pull-out failure 2. Pull-out failure 3. Pull-out failure 4. Pull-out failure	0.8 kN 0.7 kN 0.8 kN 0.6 kN
Nylon Hammer fix (Standard)	ø size: 8 mm Length: 80 mm	1. Pull-out failure 2. Pull-out failure 3. Pull-out failure 4. Pull-out failure	0.1 kN 0.2 kN 0.2 kN 0.2 kN
Nylon Hammer fix (Green)	ø size: 8 mm Length: 80 mm	1. Pull-out failure 2. Pull-out failure 3. Pull-out failure 4. Pull-out failure	0.2 kN 0.2 kN 0.1 kN 0.2 kN

Figure 2: Fixing systems installed and tested: UX (10x80), N H/FIX G (8x80), N H/FIX S (8x80)

4.2. Test Setup and Procedures

Figures 2 and 3 illustrates the samples of fixing systems installed and tested until failure. The results are tabulated and shown in Table 3.

The sample set of fixing systems are selected according to the size and length of the plug and screw. The dimensions of each system are chosen with similar characteristics to ensure that the testing and recorded results are fair and unbiased.

5. DISCUSSION OF RESULTS

Figures 2 and 3 illustrate the failure modes of the relevant fixing system. Minor cracks developed in the lightweight concrete block, which questions the structural integrity of lightweight concrete as a base material. Physical inspection of each fixing system indicates that pull-out failure can be identified as the ultimate failure mode.

Partial safety factors are used to factor the ultimate tensile failure load, as shown in Table 4. The partial safety factors used in the calculations are given by the manufacturer and are adhered to according to each product's technical guidelines for installation [6]. It can be noticed that the Duo Power (10x80) fixing system is able to withstand 1.5 kN (±150 kg) tensile load which yields a safe-working load of 0.38 kN (± 38kg). This type of plug and screw is deemed the best performer in comparison with the remaining plugs and screws in the test sample.

6. CONCLUSION

It is important to discuss and explore the design of fixing systems, since these systems are used in all facets of the building and construction sector. The benefits of lightweight concrete align with sustainability principles and call for innovative fixing systems that are able to perform in variable base materials with high load capacities. The results prove that each fixing system is unique in design and each physical property of the system can be considered as contributing factors to the overall working capacity.

To showcase the recent development with lightweight concrete, various fixing systems are tested, and their performance is studied under tensile loading. For the purpose of this study, the pricing of different fixings systems isn't considered, however, in reality, price has a major influence over the type of fixing system used. This study contributes towards the research and development of anchor technology in lightweight concrete for the building and construction sector.

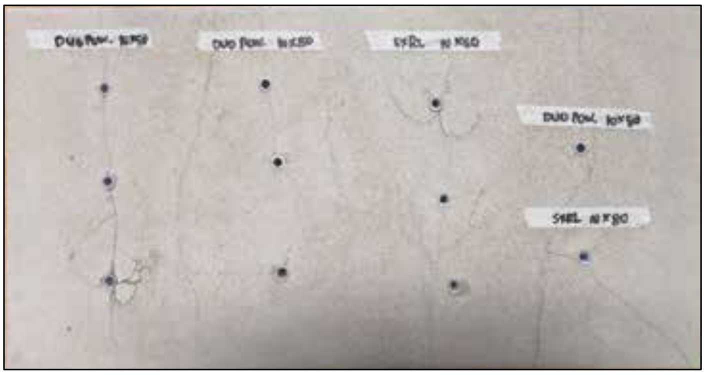

Figure 3: Fixing systems installed and tested: D/P (10x50), D/P (10x80), SXRL (10x80)

Table 4: Determination of safe working loads

FIXING SYSTEM	AVERAGE ULTIMATE TENSILE FAILURE LOAD	PARTIAL SAFETY FACTOR	SAFE-WORKING LOAD
Duo Power 10x50	0.23 kN	4	0.06 kN
Duo Power 10x80	1.5 kN	4	0.38 kN
SXRL 10x80	1.23 kN	4	0.31 kN
UX 10x80	0.73 kN	4	0.18 kN
Nylon Hammerfix (Standard) 8x80	0.18 kN	4	0.04 kN
Nylon Hammerfix (Green) 8x80	0.18 kN	4	0.04 kN

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Review of monitoring methods for chloride-induced reinforcement corrosion on reinforced concrete bridges

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ABSTRACT
Reinforcement corrosion is a serious durability problem that has been overlooked in the management of structures, as most Bridge Management Systems (BMS) primarily rely on visual inspection to determine the condition of bridges. The study aimed to identify monitoring methods for Reinforced Concrete (RC) bridges affected by chloride-induced reinforcement corrosion that can be included in the overall assessment jointly with visual inspections in the Struman BMS. The reviewed monitoring methods were categorised into visual inspections, Non-Destructive Testing (NDT), and remote monitoring. Monitoring technologies have the potential to allow for the early diagnosis of problems, resulting in better maintenance and damage prevention. They could also improve the speed and scope of condition assessments, offer reliable and comprehensive data, and eliminate traffic disruptions while taking measurements.

Keywords: chloride-induced reinforcement corrosion, Bridge Management System, Reinforced Concrete bridges, monitoring methods, condition assessment

1. INTRODUCTION
Reinforcement corrosion is a major cause of deterioration in Reinforced Concrete (RC) bridges, mainly caused by the ingress of chloride ions. This problem leads to a loss of structural capacity, concrete degradation, and increased maintenance costs. To manage and optimize allocated financial resources for bridge maintenance, repair, and rehabilitation, Bridge Management Systems (BMS) have been developed and implemented in different countries [1]. However, visual inspection remains the predominant method used in BMS to assess and monitor the condition of structures, despite the serious impact of corrosion.

2. CURRENT CORROSION MONITORING IN SOUTH AFRICA
The Struman BMS is commonly used in Southern African Development Community (SADC) countries. It was developed in South Africa to manage the maintenance of deteriorating bridges with limited budgets. The system uses visual inspections to rate defects on a scale of 1 to 4, based on their Degree, Extent, Relevance, and Urgency (DERU) [2]. The DERU rating data is used to prioritize bridges for repair and maintenance, and assessments are done every five years. However, there is a need for the use of appropriate monitoring systems, particularly for reinforcement corrosion, which is a significant cause of deterioration in RC structures.

3. MONITORING OF REINFORCEMENT CORROSION
Chloride-induced reinforcement corrosion happens in three stages namely: initiation, propagation, and acceleration. Detecting corrosion at early stages through monitoring methods is important to prevent severe damage and reduce repair costs. Research on technologies for the early detection of corrosion has been increasing since the 1990s, with most publications on corrosion monitoring published in the last decade. The review focused on visual inspection, Non-Destructive Testing (NDT), and remote corrosion monitoring methods to evaluate reinforcement corrosion damage in RC structures, particularly bridges.

3.1 Visual Inspection
Visual inspection is a common and cost-effective method to identify corrosion on RC bridges, but it has limitations when it comes to assessing reinforcement corrosion. This is because defects only manifest on the surface of concrete when significant damage has already occurred. Visual inspections do not quantify the damage or identify the effect, making it difficult to establish effective maintenance practices to prevent advanced corrosion damage. Additionally, visual inspections are subjective, relying on the experience and judgement of the inspector [3]. While visual inspections still provide useful information about the condition of bridges, they need to be complemented by other methods to address their shortcomings.

3.2 Non-destructive Corrosion Monitoring
NDT methods assess the degree, extent, and severity of deterioration in a structure without affecting its integrity. Several types of NDT methods include electrochemical, elastic wave, electromagnetic, and thermal methods.

3.2.1 Electrochemical methods
Electrochemical methods measure parameters such as corrosion potential, concrete resistivity, and polarization resistance. These parameters can be measured periodically using surface electrodes or sensors or continuously using embedded sensors. By monitoring these parameters, the extent and severity of corrosion can be assessed, and appropriate interventions can be taken to prevent further damage.

Half-Cell Potential (HCP) measurement involves measuring the potential difference between two half-cells, usually a metal in its solution, and an external Reference Electrode (RE). HCP measurements are done using surface or embedded REs, and new methods involving climbing robots and flying drones have also been developed [4].

HCP measurements can identify high corrosion risk before visible damage appears on the surface of the structure, allowing for appropriate interventions to be taken at the right time. However, HCP measurements are affected by factors, such as the availability of oxygen, cover depth, and the composition of the pore solution, which should be considered during interpretation [4]. Electrical Resistivity (ER) affects the flow of ions and the rate of corrosion in the concrete. ER measurements have been used to indirectly assess the quality of the concrete, chloride ion diffusion and degree of saturation. The Wenner Four probe is the most used device for measuring ER [5]. ER measurements can identify high corrosion risk areas but must be used in conjunction with other parameters such as HCP. However, ER measurements are influenced by various factors such as moisture content, temperature, concrete composition, curing conditions, cover depth, and probe contact during testing [4, 6]. Even though this method is fast, non-intrusive, and does not require connection to embedded steel, it does not indicate whether corrosion has occurred or to what extent active corrosion has occurred. Linear Polarization Resistance (LPR) is a technique used to measure the corrosion rate of steel by monitoring corrosion activity over time. It works by correlating the HCP of corroding steel to the externally applied current. New technologies such as Gecor 8TM and CorroMap simplify the measurement process by automatically evaluating and displaying data [7, 8]. These technologies are considered non-intrusive as they only require a connection to the reinforcement without damaging the structure. The Giatec iCOR is a wireless device that can measure corrosion rate, corrosion potential, and electrical resistivity without needing a connection to the steel in concrete [9]. Using one device for all three parameters saves time and reduces costs. This device also allows easy reporting, exporting, and sharing of results, enabling fast and efficient condition assessment. However, temperature, concrete resistivity, and relative humidity can affect the accuracy of measurements and should be considered.

3.2.2 Elastic wave methods

Elastic wave methods are used to estimate the mechanical properties and heterogeneous characteristics of concrete. They can detect damages caused by reinforcement corrosion, such as internal cracks, voids, delamination, and corrosion products. Examples of these methods include Impact Echo (IE), Ultrasonic Pulse Velocity (UPV), and Acoustic Emission (AE).

The IE method is based on the propagation and reflection of elastic waves in concrete. It works by inducing a low-frequency stress wave using a mechanical impact into the concrete, which reflects off internal cracks, voids, or changes in material characteristics. The resulting displacement-time curves are analysed in the frequency domain to detect anomalies. IE has been used in several studies to detect flaws such as internal cracks, voids, and delamination, as well as to determine the thickness of concrete elements and measure crack depth [10, 11].

The UPV method measures the propagation time of an ultrasonic pulse through concrete to determine its properties and detect internal flaws such as cracks, voids, and delamination caused by reinforcement corrosion [12]. Laboratory-based studies have attempted to relate UPV measurements to reinforcement corrosion. Amplitude attenuations correlate well with corrosion damages, while internal cracking results in wave attenuations and a decrease in UPV. UPV measured by the first wave peak describes the reinforcement corrosion process from the formation of corrosion products to the visibility of corrosion damage indicators on the concrete surface [13]. Even though UPV is less reliable in detecting shallow defects, it can estimate concrete strength, determine member thickness, and measure crack depth. Its results are influenced by pulse attenuation, concrete composition, and aggregate sizes.

The AE method is a technique that detects elastic waves generated from localised sources in concrete, such as internal crack growth and corrosion product generation [5]. The emitted elastic waves are detected using AE sensors. Detecting active cracks at an early stage makes it suitable for long-term monitoring. AE analysis can also identify different stages of corrosion, including corrosion onset and nucleation of corrosion-induced cracking [13, 14]. However, there are currently no critical standards for its procedures, installation, or interpretation of results in terms of corrosion, and it has mainly been used in laboratory settings.

3.2.3 Electromagnetic methods

The cover meter and Ground-Penetrating Radar (GPR) are electromagnetic methods used to locate reinforcement and cover thickness. They are used to mark out the measurement grid which is essential to other monitoring methods such as ER, HCP, and LPR. Cover meters have been used for cover measurements because they are portable, lightweight, and easy to use. They are also established and standardised. The ACI 357 specifies a minimal cover of at least 50 mm for RC members subjected to seawater, which applies to submerged and atmospheric-exposed structural elements. SANS 10100-2, however, recommends a cover of 65 mm for members in contact with seawater [15].

GPR works by emitting and receiving high-frequency electromagnetic waves that can penetrate concrete and reflect when they encounter changes in material properties. GPR is also used to detect other subsurface features, such as voids and delamination, which can provide additional information about the condition of the structure [16]. This method is usually preferred because it can cover large areas of measurement in a short time. However, it can only be used on horizontal structural elements such as decks and slabs. Its use in corrosion evaluation is still in progress. GPR was found useful in providing bridge condition ratings in the BMS [16]. It can detect early reinforcement corrosion during the propagation period; larger wave transit times and lower amplitude zones were associated with increased chloride content and the presence of corrosion products [17, 18]. The GPR signal can thus be associated with changes within the concrete during the corrosion process, particularly from the formation of corrosion products to internal crack formation and propagation.

3.2.4 Thermal methods

Infrared Thermography (IRT) is a method used to detect radiation emitted from materials, including concrete. IRT can be passive or active. Passive IRT is commonly used, where specimens are artificially heated before testing to induce temperature differences. Defects disrupt heat transfer, causing localised differences in surface temperature [19]. IRT is preferred for bridge inspection and evaluation due to its high speed, reliability, accuracy, and cost-effectiveness [20]. It can detect sub-surface defects without requiring direct access to the element being inspected, which eliminates the need for traffic disruption and lane closures. Its application in detecting early reinforcement corrosion is still in the development stage. IRT has been used to detect reinforcement corrosion and delamination in RC bridges, but surface-related and environmental factors can affect the test results [16, 21].

3.3 Remote Monitoring

Remote monitoring systems for bridges use sensors connected to a data acquisition system and can be installed in new or existing structures. They are particularly useful for bridges that are difficult to access for regular inspections. These systems provide data that can help with planning and implementing required interventions to prevent premature deterioration. Six different remote monitoring systems are discussed, including their application, principle, and parameters measured, as shown in Table 1.

Table 1: Summarized comparison of the remote monitoring systems

System characteristics	ALS*	ERS*	MRE*	CW*	CR*	ISE* sensors
Application						
Used in new structures	X	-	X	X	-	-
Used in existing structures	-	X	X	-	X	X
Principle						
Anodes placed at various depths in the	X	X	X	X	X	-
HCP technique (measurement of anode vs cathode)	X	X	-	X	-	X
Measured corrosion parameters						
Potential voltage (V)	X	X	-	X	X	X
Electrical current (µA)	X	X	-	X	X	-
Concrete resistance (kΩ)	X	X	X	-	-	-
Temperature (◦C)	X	X	-	-	-	-
Moisture content	-	-	X	-	-	-
Chloride concentrations	-	-	-	-	-	X

*ALS – Anode Ladder System; ERS – Expansion Ring System
MRE – Multi-ring Electrode; CW – CorroWatch
CR – CorroRisk; ISE sensors –Ion Selective Electrode sensor

3.3.1 Time to corrosion monitoring systems

Time to corrosion monitoring systems measures the time to corrosion initiation by monitoring the ingress of aggressive agents, such as chlorides. These systems use a macrocell reinforcement corrosion approach and involve the measurement of current flow between separate anode and cathode areas [22]. Several anodes are placed at different depths within the concrete cover to determine the time to corrosion initiation continuously. The anodes are the same composition as the reinforcing steel to ensure they corrode at the same time. The onset of corrosion of the anodes is determined at any time, provided the cover to reinforcement is known. The depassivation of the anodes is related to an increase in electrical current and a decrease in potential using the specified thresholds [23]. Four methods (Anode-Ladder System, Expansion-Ring System, CorroWatch, and CorroRisk) use this principle.

The Anode-Ladder System (ALS) is used for long-term chloride-induced corrosion monitoring, typically embedded in new RC structures between the reinforcement cage and the concrete surface. The ALS determines the critical depth of chloride content when the six steel anodes that form up the anode ladder depassivates sequentially. The system has been used successfully in various countries to monitor corrosion in new structures [24, 25]. The ALS is durable and typically designed for a service life of more than 100 years [23]. However, it cannot be used in submerged structures because it needs to be installed near the concrete surface where sufficient oxygen is available.

The Expansion Ring System (ERS) developed by Sensortec [26] is used in existing structures before corrosion initiation. In structures where the propagation period has begun (when the critical depth of chloride content is reached), the corrosion potential and resistance indicate corrosion risk. The ERS comprises an expansion-ring anode (with six circular steel anodes), a titanium oxide cathode bar and a temperature sensor drilled into the concrete. This system has been tested in the laboratory and on-site, and it was found unsuitable for submerged elements [27].

CorroWatch (CW) and Corrorisk (CR) sensors were developed by Force Technology to provide early warning on corrosion initiation in RC structures. CW sensors are used in new structures, while CR sensors are installed in existing structures that are exposed to aggressive environments or are inaccessible for inspection. Measurements of potential and current in these systems are carried out continuously using a remote monitoring modem or automatic data logger attached to the system. Though these systems have been used in some projects [28], their research is very limited.

3.3.2 Moisture content monitoring systems

Monitoring moisture content in concrete is important for controlling reinforcement corrosion, as a significant drop in electrical resistivity indicates the vulnerability of the concrete to corrosion. The Multi-Ring Electrode (MRE) system is a new technology that can be used to monitor moisture content, and it measures electrical resistance and provides a profile across the sensor depth. The resistivity readings are converted to moisture profiles using concrete-specific calibrated curves [29, 30]. This technology is installed before concrete placement in new structures and drilled and anchored with mortar in existing structures. The sensors need to be connected to a measuring device which records data automatically. Moisture content governs the initiation and progression of reinforcement corrosion, and reducing it to below 40 % can stifle corrosion. The MRE is beneficial because it provides electrical resistance measurements in case NDT methods are not used.

3.3.3 Chloride content monitoring systems

New non-destructive methods have been developed to continuously monitor chloride concentration in concrete. One of these methods is using potentiometric sensors or Ion Selective Electrodes (ISE), which can determine free chlorides in RC. The system consists of an ISE sensor and a reference electrode that measures the change in potential between the two, allowing for the estimation of chloride activities and subsequently, the determination of chloride concentration using the chloride activity coefficient. This method can be used in existing structures, especially in inaccessible areas. The ISE sensors are commercially available and have been used in various studies to detect chlorides non-destructively in concrete [27, 31]. They have also been tested in laboratories, in which they were found to successfully measure chloride activity [32]. Some of the sensors include but are not limited to Ag/AgCl-ISE and the ERE 20 reference electrodes.

4. CONCLUSIONS, REMARKS AND FUTURE TRENDS

Reinforcement corrosion poses a significant challenge to the durability of RC structures, often going unnoticed in visual inspections and leading to costly repairs. To address this issue, monitoring technologies are needed to detect corrosion damage throughout the lifespan of RC bridges and enable proactive maintenance. The Struman BMS currently relies mainly on visual inspection, but it needs to incorporate corrosion monitoring methods to detect damage earlier. While progress has been made in developing NDT and remote monitoring methods, further refinement is necessary to effectively incorporate them into the BMS for condition assessments. By incorporating various monitoring methods, including cover depth and chloride measurements, HCP measurement, LPR, and other corrosion onset sensors, the Struman BMS can provide a comprehensive condition assessment, reduce maintenance and repair costs, and improve the speed and scope of condition assessment. It is recommended to use multiple monitoring methods in conjunction to effectively detect and quantify relevant defects in reinforcement corrosion damage. **CB**

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Developments in low carbon cements – a South African perspective

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Extended Abstract

The greatest existential threat currently facing the global community is arguably climate change, with the associated environmental and infrastructure challenges. The imperative is to reduce CO_2 emissions in all areas of the economy and society, as rapidly as possible, to levels where global temperature rise does not reach catastrophic levels. The cement and concrete industries are major contributors to global CO_2 emissions, both by way of cement production and by way of the construction industry and its reliance on, for example, materials transport and construction energy usage. The two most promising ways of reducing the carbon footprint of concrete are to a) reduce the clinker content in cement, and b) reduce the overall binder content in concrete. This paper outlines option a), which involves use of supplementary cementitious materials (SCMs), in particular a ternary binder called limestone calcined clay cement (LC_3), which is a promising option for both southern and eastern Africa. This is particularly relevant in view of the possible shortages of conventional SCMs such as fly ash and slag in the future.

A suitable clay for LC_3 system is one with a kaolinite content of at least 40 % [1,2]. Kaolinite clays produce reactive minerals when calcined at a temperature of around 800 °C [3]. Analyses of the samples of clay investigated at the University of Cape Town [4] show that all clays were composed mainly of quartz, kaolinite, and illite in varying proportions. The Bronkhorstspruit clay (B-Clay) in Gauteng provinces has about 70 % kaolinite content, the Hopefield clay (H-Clay) in the Western Cape about 40 %, and Pugu clay (PH-Clay) in Tanzania, as reference clay in this case, about 50 % kaolinite content, making them potentially suitable for use in cement and concrete production.

The performance of LC_3 mixes with clinker contents of 45 %, 55 %, and 65 % was assessed and compared with two conventional concrete mixes: a mix with 100 % CEM II/A-L 52.5 N, and a recommended mix for South African marine environments with 50 % cement replaced by GGBS. Overall, it was concluded that LC_3 mixes are characterised by reduced penetrability, increased electrical resistivity, higher chloride ingress resistance, and increased carbonation rates, indicating superior durability performance for marine exposure conditions. Results also indicate that the performance of these mixes is not directly related to the kaolinite content. Other factors such as the specific surface area of the clay and the alkali content also come into play and these aspects require further study to better understand their influence. **CB**

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Sydney's spectacular showcase of creative concrete turns 50

by Jan de Beer

Sydney Opera House – a showcase of the creative use of concrete in 20th century architecture – recently celebrated its Golden Anniversary. Officially opened on 20 October 1973, after a painstaking 14 years of construction, the remarkable building stands proud in Sydney Harbour as a symbol of supreme concrete innovation.

Danish architect, Jørn Utzon's concept for the building in 1957 won an international design competition ahead of 222 other entries from 28 countries. Ironically, the creator of this remarkable building never saw the completion of his work. Furiously resigning from the project in 1966 after budget conflicts with the government, Utzon fled home and died in Copenhagen in 2008 at the age of 90. He never returned to Sydney again.

Sydney Opera House is today Australia's premier tourism destination and one of the world's busiest performing arts centres. The site attracts over 8 million visitors and hosts more than 2 000 performances, attended by 1.5 million people, every year.

The Opera House, acclaimed for its remarkable application of exposed structural concrete, in 2007 received World Heritage listing by UNESCO in recognition of Utzon's masterpiece. UNESCO called it "a great urban sculpture set in a remarkable waterscape, at the tip of a peninsula - an extraordinary interpretation and response to the setting in Sydney Harbour".

The realisation of the building's complex design called for close collaboration between engineering and architecture designers. The complex's precast sail-like roof structures had never been built on such a scale before. The global civil engineering company, Ove Arup & Partners, provided the structural engineering for all the elements of the building, including the foundation, those iconic roof "sails", the concourse and glass walls.

Architect Utzon and structural engineers, Ove Arup, working with the building contractors, Civil & Civic (Stage 1), and M.R. Hornibrook (Stage 2), had to invent new technologies and materials to create Utzon's vision. His design was so revolutionary that there were no existing construction techniques that could be directly applied. New engineering and construction methods had to be developed and this not required extensive research and experimentation but also prolonged the period of construction. Originally expected to cost US $7 m, it ended up at US $102 m.

Sydney Opera House aerial view

Sydney Opera House tiles on roof.

Sydney Opera House close-up view of its sails

Another challenge was politics. There were changes in government leadership during the construction period, and the project – and its cost - became the subject of controversy and debate. This led to delays and complications in the decision-making process as well as dissent within the project team. Labour strikes by construction workers further delayed the project to add to the overall construction costs and extend the time on site to a staggering 14 years. Sydney's unpredictable and often severe weather conditions also posed challenges during construction, as the exposed site was exceptionally vulnerable to the elements. Engineering and technological feats developed during the design and construction of the Opera House include:

- Ove Arup designed folded concrete beams to support the podium structure. By integrating the techniques of folded plate structures and pre-stressing, Arup's innovations enabled the creation of expansive open spaces within the podium, such as the Box Office Foyer, without the need for structural columns.
- The Opera House was one of the first buildings in the world to make use of computers in design. The exacting geometric calculations necessary to build the sails could only have been achieved using what was then revolutionary technology.
- Ove Arup & Partners became pioneers of wind tunnel testing for buildings during the design of the Opera House's rooftop sails. The system developed is now common practice in design for large buildings all over the world. The building's unique arched white roofs - shaped like the sails of boats - is basically the design feature that lifts this structure out of the ordinary. The design called for 2 194 pre-cast concrete sails weighing up to 15 tonnes each.

During construction, the pre-cast rib sections of the sails were cast with ducts to carry the steel stressing cables. In all, 4 100 individual ducts with a total length of around 113 kilometres. were created. The rib sections are bonded with a special epoxy developed for the purpose during construction.

After post-tensioning was completed, the ducts were pumped with grout to seal the steel cables from the outside elements. The rib structures were clad in 3 382 chevron-shaped prefabricated concrete tile lids, supporting around an amazing one million self-cleaning ceramic tiles. The tiles are kept clean by rainwater that washes away dirt so manual cleaning of the soaring sculptural arches is not required.

The Sydney Opera House is estimated to have needed approximately 187 000 cubic metres of concrete for its construction. Built on a narrow peninsula of land on the south shore of Sydney Harbour, the Western Broadwalk and Northern Broadwalk rest on 588 reinforced concrete piers embedded into the harbour floor 25 m below. Granite aggregate slabs were used to clad the Broadwalks.

The building covers 1.8 hectares of land and is 183 m long and 120 m wide at its widest point. The highest roof point is 67 metres above sea-level – as high as a 22-storey building.

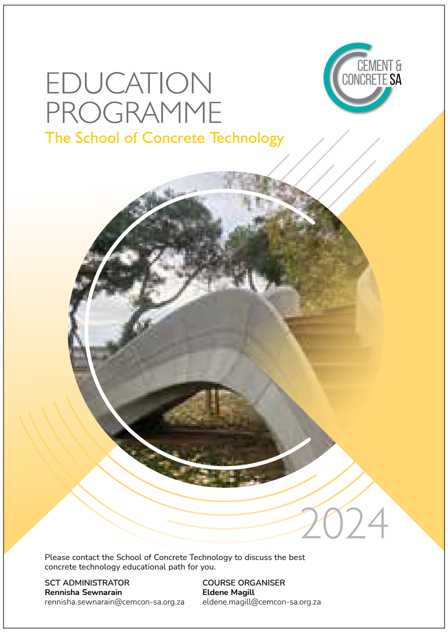
The points from which the sail ribs rise from the podium, and connect to the foundation columns, are known as the Pedestals. The Pedestals are made of reinforced concrete, cast in-situ, and can be seen on the building's exterior below the line of ceramic tiles, and in the interiors of the foyers to the Concert Hall and Joan Sutherland Theatre. The concrete in the Pedestals is completely exposed to weather and the marine environment, and human contact.

With a building of this stature comes a great responsibility to ensure its proper upkeep and smooth functioning. The Sydney Opera House Trust, a non-profit agency in charge of the site, manages the structure's conservation management plan, an active programme currently in its fourth iteration.

Being aware of the need to consider the effects of weathering on the building from a marine environment and climate change, the Trust—with the Getty Foundation's support—is engaged in a two-year project, Sydney Opera House Concrete Conservation, that involves working with a team of heritage experts and students from the University of Sydney to analyse the building's concrete, test non-invasive conservation techniques, and develop a management system to monitor the condition and performance of this great building now and into the future. **CB**

Jan de Beer

We live in exciting times… especially in the field of concrete technology



These exciting times are being brought about by climate change and new technologies.

Climate change is now a reality, revealing itself with the ever-increasing occurrences of extreme weather events, rising sea levels, loss of ice cover in the arctic and northern hemisphere, warming oceans, rising temperatures, and changing rainfall patterns. Extreme weather events such as flooding, storm surges, high winds, heat waves and droughts with frequent and severe wildfires, requires a resilient and pro-actively designed and built infrastructure.

Concrete will play a vital role in the mitigation of these adverse effects.

Climate change unfortunately presents a double edge sword for the concrete industry. Durable concrete infrastructure is needed for the mitigation of extreme climate change events while at the same time there is an associated carbon footprint with the use of more concrete. Herein lies a second exciting challenge for concrete technology, which is the drive towards carbon neutral concrete.

Striving for a lower concrete carbon footprint involves interesting challenges in mix design, material use and structural design covering the whole life cycle of concrete. Something that, only a few years ago, truly little time and thought was assigned to.

New technologies are evolving in the concrete industry.

The deployment of drone technology, thermal imaging, remote sensing, admixture advances are all examples, but by far the newest and biggest kid on the block is 3D concrete printing.

It is in its infancy and currently can be likened to the 'brick like' cell phones of yesteryear, but given the phenomenal advances in cell phones, we can easily say, regarding 3D concrete printing, in words borrowed from Bachman-Turner Overdrive "You ain't seen nothin' yet!". The potential for 3D concrete printing is quite staggering, providing juicy work for those involved in concrete technology and structural design. The concrete 'ink' mix design requires a whole new innovative look at materials and admixtures to meet the unique properties required of 3D printed concrete.

To take advantage of these 'exciting times' a solid foundation in concrete technology education is needed. The School of Concrete Technology (SCT) has a structured progression of course levels that will allow a prospective student to join at a level that matches his or her competency. There can be no short cuts to becoming a good concrete technology practitioner and the SCT has all the educational requirements to help you meet your goals.

Please contact the School of Concrete Technology to discuss the best concrete technology educational path for you.

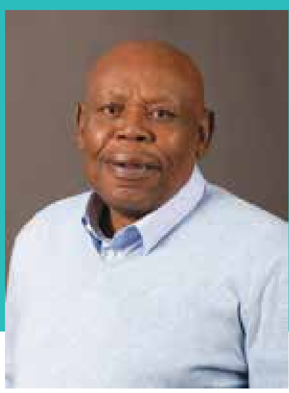
The school would like to thank all clients and students that supported us during 2023.

We look forward to continuing your concrete education in 2024. **CB**

John Roxburgh, Technical Specialist

Rennisha Sewnarain, Course Administrator

Gary Theodosiou, Technical Consultant



Matthews Magwaza, Technical Specialist

Eldene Magill, Course Organiser

Concrete progress: Colossal concrete products reopens De Aar plant, boosts revival of rail and infrastructure development

An innovative range of dust suppressants available from CHRYSO Southern Africa, continues to be a gamechanger in the mining and quarrying sectors, providing substantial benefits and enhancing operational efficiency.

Colossal Concrete Products, a Level 1 B-BBEE company and the largest manufacturer of railway sleepers in Southern Africa, with a proud 64-year track record, reopened its mothballed De Aar factory in October.

This eagerly anticipated move follows the recent conclusion of a 1-year contract with Transnet Freight Rail (TFR) to supply precast concrete railway sleepers for the parastatal's national freight rail network upgrade.

The De Aar facility is strategically located in the Northern Cape, near one of the arterial railway junctions connecting the Cape Town, Johannesburg and Kimberley lines. Through its manufacturing facility reopening, the company will not only provide a much-needed boost to the regional economy through the creation of jobs - and additional upstream and downstream manufacturing and supply opportunities – but is now in a position to reach its inherent capacity, with the production of over 1 million railway sleepers per annum.

Parallel tracks of growth and development

This will pave the way for growth in South Africa and beyond, according to Chief Executive Officer (CEO), Gwen Mahuma-Madida.

"Africa is rich in natural resources, but much-needed growth and progress are often hampered by lack of finance and the required infrastructure. Colossal Concrete Products understands the pivotal importance of infrastructure development - and the impact that this has on the economic development of any country. In line with our precast concrete manufacturing capacity, skills and our Pan-African growth strategy, Colossal can play a significant part in the roll-out of rail, civils and general infrastructure development – improving the overall prosperity of the continent," Mahuma-Madida explains.

The company has grown substantially over the past two years, taking over from a listed entity and entrenching its own style and culture, while maintaining a sound client base and expanding its market share both locally and cross-border.

This followed the June 2021 acquisition - by a consortium made up of Colossal Africa Group, Mafoko Holdings, Clone Capital and Randvest Capital - of Aveng Infraset's Brakpan and De Aar facilities for their rail, telecommunications, civil engineering and specialised precast concrete manufacturing capabilities and intellectual property (IP).

Mahuma-Madida says that even though the De Aar facility had in fact been mothballed prior to the 2021 acquisition, its potential was always extremely evident: "The TFR contract has been the catalyst for the reopening, and there are now further plans to keep the operation sustainable. The acquisition of an adjoining property in De Aar will also assist us in growing our footprint within the renewable energy space, which is on the cusp of significant growth following the publication of the final draft of South Africa's Renewable Energy Masterplan in July this year," she explains, adding that the De Aar facility is close to the current Northern Cape hub of many renewable energy projects - and is expected to be pivotal in supplying products such as precast wind turbine towers, amongst others."

Concretising job creation

"De Aar, like many areas in the Northern Cape, has been economically depressed in recent years. It is with this in mind that one of the most important elements in the rejuvenation of the manufacturing facility is the creation of some fifty jobs. No employment opportunities have been available since the plant was mothballed by the previous owner over three years ago, and we have been inundated with job applications. We are also collaborating closely with the local mayor and municipal manager, who are extremely excited about the plant reopening and what this means for the town as a whole, " says Executive Director Chris 'CK' Klagsbrun.

Jobs include mixer operators, team leaders, boom scraper, line feeder, crane operators, boiler operators, wire feeders, fork lift drivers, grinder operators, wire cutters, slot washers, preppers and quality controllers.

"Preference is being given to those previously employed in the above positions at our De Aar facility, and I am confident that a fair percentage of former employees will be re-employed," he advises.

Mahuma-Madida adds that not only are she and her team extremely pleased to have a contract which necessitated the plant reopening; but also that all Colossal's products have met the safety and technical requirements required when implementing projects for TFR.

"The foundational concept here is that infrastructure development and job creation go hand-in-hand: when TFR – or any other public or private sector entity - chooses Colossal as their precast concrete products provider, this means that we can create jobs," she emphasises.

Further down the track

Mahuma-Madida notes that the company's 64-year track record as a supplier of precast products in rail, telecommunications, civil engineering and mining - as well as its valuable intellectual property (IP) - were a critical part of the original decision to acquire Aveng Infraset's Brakpan and De Aar precast concrete manufacturing plants.

Currently, Colossal Concrete Products is recognised internationally as one of the world's most innovative and diverse concrete sleeper producers, with a highly experienced research and development division having developed over 40 rail-related products. In addition, Colossal manufactures other precast concrete products including culverts, poles and masts, for use in the mining, civil engineering, construction and renewable energy sectors, to name but a

few. There are furthermore plans manufacture wind turbine towers moving forward.

"We are still the only company locally that has such a large range of railway products. To retain that leadership position is critical. While our competitors do manufacture a selective range of main line sleepers, we are the only ones to make the entire range," she says.

Already, there are plans to move manufacture of all turnout sleepers to De Aar. These are highly specialised and supplied to VAE which adds rails.

Technically, Klagsbrun points out that Colossal has maintained its high manufacturing standards with all specifications remaining in line with original technology provided by its Swedish licensor. The company also consistently invests in research and development, which remains a very crucial element of the business.

"Our vision is to constantly bring innovative new solutions to the rail, mining, renewable energy, civil engineering and construction sectors – among many others. Taking this a step further, we also plan to replicate what Colossal does across Africa. We have already grown our consulting division close to home; and we are working closely with our Swedish partner on Pan-African rail projects. There have been two recent enquiries around establishing new manufacturing plants which we have participated in, where Colossal could either oversee construction or conclude service level agreements to manage these facilities," Klagsbrun explains.

A new platform for De Aar

As the company is a major player in the precast concrete space supplying the mining, construction, civils and general infrastructure sectors, Mahuma-Madida says every Colossal facility will always produce a variety of products servicing multiple sectors: "Not only is the De Aar plant strongly positioned for projects in the renewable energy space - but it is strategically and operationally well placed to fill the gap left by the closure of companies serving the construction sector in the Northern Cape," she points out.

"Therefore, once we have a solid base and increasing revenue, we will resume marketing to the civil engineering and construction sector once again, selling our culverts, pipes and more. When the De Aar and other plants serving the construction sector closed in the Northern Cape, it left a void. Construction companies were forced to import precast products from Gauteng and other regions. So, we will fill that gap - and save them transport costs!" she enthuses.

The same goes for Colossal's strategy in neighbouring countries: "We will use rail as a base to move into adjacent countries. Once this is set up, we can introduce other products. For us, it is very important to be a Pan-African player as well as a South African player. Although South Africa still has some way to go, that is where a lot of the infrastructure development stems from - and we really need to be part of that!

In summary, we are very sincerely committed to the future not only of rail, but also of infrastructure development – and therefore also of South Africa and the rest of the continent, and are proud to play our part in moving this forward," Mahuma-Madida concludes. **CB**

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a.b.e. has extensive range of products to preserve S.A.'s concrete infrastructure

South Africa's diverse climate, from the arid regions of the Karoo to humid coastal areas, presents unique challenges to concrete structures. Factors such as moisture, temperature fluctuations, and aggressive environmental conditions can lead to concrete degradation, including cracking, spalling, and corrosion of embedded steel reinforcements.

Leading supplier of construction chemicals, a.b.e. Saint-Gobain, believes timeous concrete protection and repair are vital to preserve the established infrastructure and create durable new projects for the future.

Elrene Smuts, Product Manager, General Construction and Concrete Repair, says South Africa's infrastructure, including bridges, dams, and buildings, relies on extensive application of time-proven sealants, coatings, adhesives, repair mortars and corrosion inhibitors. "The a.b.e. product range of these products play a crucial role to guard against moisture ingress, chemical attack, and destructive environmental exposure," she explains.

"In addition to failure prevention, concrete repair and rehabilitation are also indispensable practices in South Africa's construction industry. Skilled contractors, with the technical support of a.b.e.'s consultants, have for decades carry out crack injection, patching, fairing and reprofiling, and structural adhesion and repair to address existing damage and restore the structural integrity of concrete. From roads and bridges to airports and ports, with a growing emphasis on maintaining and upgrading existing infrastructure, these practices are critical and contribute to cost savings compared to the construction of entirely new structures," Smuts adds.

Some a.b.e. products regularly specified for concrete repair and protection include:

- For crack injection: epidermix 365 and 389 as well as PU injection filter foam;
- For fairing and reprofiling: durarep FC and epidermix 505;
- For priming and adhesion: epidermix structural adhesives, products, durabond GP and SP, durarep 2R primer, duralatex and also durafibre system;
- For concrete protection: duracote WB and FT, abecote SF217 and SF 356, duraflex, dura fibre, durasil and silocoat;
- For steel protection, the abecote range;
- For concrete repairs: various durarep and epidermix mortars.

Smuts says these products have been used for many years on infrastructure projects like:

- Val De Vie River Bridge, Northbound carriageway to North Coast Toll road N2, N17-1 Regents Park Bridge, Grayston Bridge, N14 Bridges, Komatipoort Bridge and Fish Ladder.
- Ndlambe Bulk Water Supply, Mndwaka Dam, Vredenburg WWTW, Fish Water Flats Sewage Works, Savana City Reservoir, Kruisfontein WWTW.
- ACSA PE Airport, Northam Plats Mine Cooling Towers, Saldanha Tippler, Kanengo Silos, Impala Platinum Cooling Towers.

"In South Africa, concrete protection and repair represent a dynamic field that bridges the past and the future. By preserving historical landmarks, maintaining vital infrastructure, and embracing innovation, a.b.e. Saint-Gobain is forging a path towards a sustainable and resilient built environment. As the industry continues to evolve, the role of concrete protection and repair remain vital in shaping a brighter future for South Africa and a.b.e. Saint-Gobain will remain a key player," Smuts adds. **CB**

Contact: www.abe.co.za

SAVE THE DATE

CONCRETE WORKING FOR WATER

Organised by: CEMENT & CONCRETE SA

CAPE TOWN Thursday, 22nd February 2024 – Lagoon Beach Hotel
DURBAN Tuesday, 27th February 2024 – Mt Edgecombe Country Club
JOHANNESBURG Thursday, 29th February 2024 – Premier Hotel OR Tambo

Cement & Concrete SA is excited to announce a CPD-accredited roadshow which will take place in February 2024 on the role of concrete in providing infrastructure to address the looming water crisis in South Africa.

Stable water services, together with the provision of uninterrupted electricity, have become the two major risks for both individual households and businesses in South Africa, with the cumulative economic challenge of retaining, and attracting foreign investment. The water crisis carries a potentially devastating threat to our whole country.

It has become imperative that water issues be addressed swiftly and widely to avert disaster.

Cement & Concrete SA believe that we need to facilitate discussions on this critical issue to identify and highlight durable responses from our industry. The presentations will deal with concrete (literally and figuratively) solutions for fresh water supplies, as well as wastewater treatment plants.

Keynote presenters are:

- **Dr Anthony Turton** (Environmental Advisor | Speaker | Author) – South African Water Supply Dilemma.
- **Bryan Perrie** (CEO, CCSA) – Cement & Concrete Standards update.

Other confirmed speakers include Willie de Jager, Leisel Bowes, Matteo Angelucci, Dr Frank Denys, Alan Chemaly and Dr Rod Rankine.

Projects and topics of regional interest will be presented; the programme will vary in the 3 venues.

1 ECSA CPD point will be applied for.

Local admixture, polymer facilities put Chryso at leading edge

Admixture specialist CHRYSO Southern Africa has invested extensively in its local production facilities, giving its customers a cost advantage and quick access to revised formulations. The polymer plant at its Jet Park facility has played a particularly important role in the company's success – and promises to open more doors into Africa.

CHRYSO Southern Africa has manufacturing plants in Jet Park, Cape Town and Durban, as well as warehouses in Gqeberha and Bloemfontein. While the facilities in Cape Town and Durban produce about 70 % of their requirements, there are certain specialised products that are supplied to them out of the Jet Park operation.

Among the company's forward-looking infrastructure is its polymer production facility, which began operating in 2015. It produces four polymers for the manufacture of plasticisers and superplasticisers that are used in concrete mixes. It also has the capacity to produce four more different polymers, according to Andries Marais, Operations Director at CHRYSO Southern Africa.

"We were the first Southern Hemisphere company in the CHRYSO group to manufacture these specific polymers," says Marais. "We used to import them from the group's facility in France, when we would bring in around 38 containers every month; now we are able to import the raw materials and require only one container of specialised product each month."

He highlights that having the polymer plant in South Africa has reduced logistical costs substantially, allowing savings to be passed on to the customer. It also allows much more flexibility in the manufacturing process. These polymers can be combined in any ratio required by customers to suit specific site conditions – addressing vital factors like workability and water demand.

"Every project location will have different environmental conditions, different construction materials and even different cement – so the concrete is not going to perform in the same way," he explains. "With the production flexibility with our polymers, we can locally customise the solutions for each specific requirement, which really benefits our customers."

The local facilities give CHRYSO Southern Africa the ability to make immediate changes to its admixture ingredients by varying the proportion of the different polymers – which are readily available in their plants. So responsive is this system that the company can have the necessary product ready for the customer within 24 to 48 hours.

"If you are reliant on imported polymers, it takes three months to import the necessary stock," he says. "Then, if a customer's cement chemistry changes, you might not have the required polymers to make the necessary adjustments to the admixture."

Keeping the plants up to date and efficient takes continuous investment, emphasises Marais. CHRYSO South African reinvests 3 to 5% of its annual turnover into the facilities, to allow for regular strategic upgrades. For example, the mixer at the Jet Park plant is being upgraded at a significant cost, specifically to support the needs of the mining sector – a project that he expects to complete by the end of 2023. This was done in response to approaching 100 % of the current capacity for a specific mining product.

Andries Marais, Operations Director at CHRYSO Southern Africa, at the polymer plant's SCADA Control System.

"As we expand into Africa, we see considerable opportunity for growth in the mining industry – and so we need extra capacity to meet this expected demand," he says. CHYRSO Southern Africa has been moving into various new countries since 2010. Markets in Zimbabwe, Botswana, Mozambique, Namibia and Zambia are already being serviced, and an office and toll manufacturing facility has been opened in Kenya.

The investment in the polymer plant alone has been doubled in the past three years, he points out, to increase its efficiencies and to grow its capacity by 100 %. This will also allow the company to export polymers to Latin America in 2024, where the necessary formulations can be manufactured. He highlights how CHRYSO Southern Africa's local facilities have opened up opportunities for businesses in the construction and other sectors.

"We have created the volumes and cost effectiveness to allow producers of concrete products to thrive," he says. "We also nurture skills by employing post-graduates in our Jet Park plant, as well as to develop our research and development capacity to investigate formulations. We rely on concrete technologists in developing the products themselves."

The manufacturing process is conducted at atmospheric pressure and below 80 degrees Celsius, which assists in addressing efforts by CHRYSO Southern Africa and its customers to reduce their carbon emissions. Marais says that the company has been monitoring its carbon footprint in recent years and is committed to steadily reducing this factor to 50 % of current levels by 2030.

Quality is also a key consideration in all three plants countrywide, where the ISO 9001 quality management system is rigorously applied. He adds that the same attention is paid to environmental management through ISO 14001, and to safety through ISO 45001. **CB**

Concrete roof tiles outperform metal sheeting on cost, comfort and creativity

Over the years the Concrete Manufacturers Association (CMA) has commissioned several independent surveys which demonstrate how concrete roof tiles outperform their rival materials across a host of performance criteria.

More recently, Port Elizabeth's Eagle Roof Tiles commissioned its own cost comparison study between a concrete tile roof and a corrugated metal roof. The company has had a longstanding relationship with the CMA and uses its certification arm, CMACS, to certify Eagle's tiles which are produced to SANS 542 specifications.

"We focus on three Cs when comparing the performance of concrete roof tiles with metal-sheeted roofing, namely, Cost (initial cost and maintenance), Comfort (peace of mind, thermal and noise dampening performance) and Creativity (style and beauty)," says Tarn Derman, general manager of Eagle Roof Tiles.

"We decided to re-visit the cost aspect in an updated appraisal and to that end we commissioned an ITC SA certified truss fabricator, Africa Timbers, to run a comparative cost study between a concrete tile roof and a metal sheeting roof in September 2023.

"Africa Timbers followed a common roof design to allow for the most accurate and fairest cost comparison and the use of MiTek design software validated the engineered design and material costs of both roofs. The costing exercise covered complete roof structures from the wall plates and above, but excluded facias and bargeboards.

"The study was based on an average-sized house of 161m² with an intersecting gable and hip-roof design pitched at 25°. Double Roman through-colour roof tiles and 0.47 corrugated sheeting F/H, the cheapest acceptable sheeting for this type of house, were the two materials chosen for the comparison.

The total cost for the metal roof was R 154 748.38, comprising R 76 468,34 for roof trusses and fixtures and R 78 280,04 for the roof sheeting. The total cost for the concrete tile roof was R 116 216.34, comprising R 88 254,97 for roof trusses and fixtures and R 27 961,37 for the concrete tiles.

"This represents a substantial saving of just under R 40 000, or 33 % less for the concrete roof tile house, an amount which could be used towards countering load-shedding or to contribute to a child's education.

Covered with Eagle Roof Tile's slate tile, modern elegance gives way to crisscrossing angles and framed gables at The Waves in Wilderness, Western Cape.

A Plettenberg Bay house where Eagle Roof Tile's Tuscan profile tile was used on this Spanish-inspired hip-roof with exposed eaves and verges

One of the Western Cape's most-loved concrete roof tiles, Eagle Roof Tile's Shingle profile lends itself to the sharp triangular lines on this exposed intersecting gable roof.

"It is clear from the above that concrete roof tiles are the most economical roof cover and the savings will be even greater over the lifetime of the roof as the maintenance on concrete roof tiles is virtually zero.

"A major comfort factor with concrete roof tiles is the associated peace of mind in knowing that they almost never have to be replaced. Since they were first introduced to the South African market over 70 years ago they are still protecting homes with minimal fuss. Due to their large thermal mass, they absorb high levels of energy when it is warm and then slowly release the accumulated heat at night when it is colder, ensuring a comfortable interior," says Derman.

In order to prove that concrete roof tiles are considerably more thermally efficient than metal sheeting, in 2012 the CMA commissioned the AAAMSA Group to run a series of tests comparing the thermal performance of metal sheeting roof with a concrete tile roof. One of the tests, which involved roofs with ceilings, revealed R-values of 0.38 for the metal roof as against 0.49 for the concrete tile roof, a 29 % comfort factor improvement.

"Concrete roof tiles are also vastly more efficient noise insulators. Metal roofing, especially when used in working environments such as schools and government buildings, have to be installed with far more insulation material to damp down noise from rain, hail and wind to reach tolerable levels.

"Creativity with concrete roof tiles is only limited by one's imagination and really broadens one's design horizons. Tiles can be cast in innumerable colour choices for enhanced beauty and they allow designs with hips, gables, mono or duo-pitch, modern or traditional which add individuality and value to any house. They are definitely the best roofing material available, and can convert any house into a home" concluded Derman. **CB**

Zenzele precast products cemented with AfriSam quality

Zenzele Pavers and Cladding, a family-run Pretoria-based manufacturer, credits its unwavering commitment to quality and its lasting partnership with leading cement supplier AfriSam for its successful growth. Today, the business serves both local homeowners in Pretoria North, Ga Rankuwa, Soshanguve and broader regions, as well as large developers and construction contractors.

AfriSam supplies its 42.5R High Strength CEM II high strength cement to Zenzele, which gives early age strength to the product.

Since its inception in 2007, Zenzele has specialised in precast products from concrete pavers and bricks to cladding, kerbs, blocks, and tiles. "The backbone of our success is high-quality cement, ensuring consistency in results and colour," says Founder and Owner Wendel Krook. "Our enduring relationship with AfriSam, who mirrors our dedication to quality, reliability and consistency, plays a significant role in our growth."

The company's core principle of delivering a product that is 'good enough for their own home' has attracted a diverse clientele, ranging from local families to large commercial customers. Zenzele Co-Founder Hengelene Krook says, "Our loyal customer base is built upon quality, service and the trust that our products will pass the test of time."

Very low staff turnover and many employees already having a decade of service ensures attention to detail in technical and other aspects.

This commitment to quality extends to Zenzele's workforce, marked by low staff turnover and retention of skills and experience, ensuring attention to detail in all business aspects. General Manager Jacqueline O'Kelly, Zenzele's first employee, applauds AfriSam's support and reliability in meeting Zenzele's high-quality standards.

Sales and Marketing Representative Tinus Redelinghuys emphasises AfriSam's vital role in the success of phased construction projects. "With AfriSam's quick service, we maintain a consistent supply of cement, facilitating efficient production and ex-stock deliveries," says Redelinghuys.

AfriSam's consistent service and high-quality cement, including the 42.5R CEM II High Strength Cement, has notably benefited Zenzele's inventory management and delivery efficiency. Wendel Krook comments, "AfriSam's cement consistency and quality allow us to accurately predict our paver supply and promptly deliver to our customers."

Praising the partnership, Hengeline Krook says, "AfriSam genuinely values our relationship, a sentiment we greatly appreciate as a smaller business."

Adele Wentzel, AfriSam's Sales Manager Manufacturing for Gauteng, further emphasises the importance of their collaboration. "We provide technical support, share information and interact regularly to strengthen our partnership. We are proud to be associated with such a caring and well-respected company."

Zenzele's collaboration with AfriSam continues to contribute significantly to its growth and success, underscoring the value of quality and service consistency in the precast product manufacturing sector. **CB**

Contact: www.afrisam.com
Facebook: @AfriSamSA, Twitter: @AfriSam, LinkedIn: AfriSam

Localised infrastructure upliftment with local community participation

Local infrastructure development isn't just about laying roads or erecting bridges; it's about creating sustainable avenues for growth, development and integration. The localised upliftment of local road infrastructure connected to the Msikaba bridge Project is a shining example of how infrastructure can be a catalyst for community transformation..

Bridging Gaps - Literally and Figuratively

Laurence Savage, Project Director for the Concor Moto-Engil Joint Venture (CMEJV) – the main contractor – says the primary intention behind this project was to provide secondary access routes to and from the Msikaba Bridge for the CMEJV. While this was a pivotal logistical move for the construction phase, it bore more profound implications, he says.

"Firstly, these routes provide seamless access for the local communities, eliminating previous barriers and promoting integration. Secondly, they pave the way for potential economic upliftment. With enhanced connectivity, sectors like tourism now stand to gain immensely, opening the region to new possibilities," Savage continues.

Local infrastructure development, as exemplified by the Msikaba Bridge Project, is a catalyst for sustainable community growth and transformation.

Scope and Span

The upliftment projects were divided between the North Bank and South Bank of the Msikaba Bridge Project, embracing a wide spectrum of road types. From the rehabilitation of surfaced roads on the R61 to re-graveling existing sandy terrains, the need for these improvements was apparent. But beyond the physical work, the incorporation of stormwater facilities in multiple areas denotes meticulous planning.

However, Savage says, the real triumph lies in the project's socio-economic impact. "Over 40 local subcontractors were involved, illustrating an unwavering commitment to integrating local expertise and manpower."

A Commendable Effort by SANRAL

Notably The South African National Roads Agency Limited (SANRAL) deserves recognition according to Savage who says the involvement of SANRAL and the CMEJV brought a ray of hope to a place where economic activity has been bleak. "SANRAL has not just driven the development of roads but have also actively contributed to job creation in a region that desperately needs it," he says.

Key Achievements

The R61 stretch from Port St Johns, passing through Lusikisiki and Flagstaff to the Bazana turnoff, spanning nearly 100 km, has seen transformational change. From immediate pothole repairs to complete surface replacements in sections, the road has been revamped from a hazardous path to a user-friendly roadway.

Between Lusikisiki and the Msikaba Bridge, a combination of re-graveling and the innovative usage of geo-cell concrete roads has made travel safer and more reliable. Especially noteworthy are the taxi routes that were previously inaccessible in unfavourable weather conditions, which have now been made approachable.

Similar advancements can be observed on the Msikaba Bridge's North bank, where re-graveling, geo-cell installations and stormwater systems have been integrated to better serve the rural communities.

Savage says that an environment-friendly approach was adopted with bush clearing activities, again involving local SMMEs, further pushing the agenda of job creation.

"It is significant that through these projects over 400 jobs have been generated, especially in the geo-cell projects domain. Furthermore, the CMEJV's approach to training, mentoring and uplifting SMME's is commendable," he says. "This initiative not only imparts technical skills but also fosters a culture of quality, financial responsibility and adept project management."

While the Msikaba Bridge Project and its ancillary developments are still a work in progress, what's undeniable is the positive change it has heralded. The CMEJV's pride in this endeavour is palpable and rightly so. Over the past two years, the region has seen more than just infrastructure development; it has witnessed the laying down of the foundation for a brighter, more connected future. **CB**

Contact: www.concor.co.za, Twitter: @ConcorConstruct, LinkedIn: @concor-construction-pty-ltd, Instagram: @concorconstruct Facebook: @ConcorConstruction

Development of local infrastructure is about creating sustainable avenues for growth.

The Msikaba Project has deeper implications for community integration and development.

Upskilling and upliftment of local communities is an important cornerstone of the Msikaba Bridge Project.

Quality training paves the way forward for construction SMMEs

The improvement of a 27,5 km portion of Section 2 of the R510 from Bierspruit and Thabazimbi created hundreds of new construction jobs when the project peaked. This is in addition to the many local small, medium and micro enterprises (SMMEs) who have been appointed to work alongside and received quality training in various road construction trades from principal contractor, Raubex.

Tjeka Training Matters was again appointed by this leading infrastructure development group to train construction workers and SMMEs on its behalf.

To date, Tjeka Training Matters has trained SMMEs in the installation of open-lined V drains; precast-concrete kerbs and concrete channels; subsoil drains; gabions; and guardrails. About 60 people – around 12 individuals per course – have already benefited from the training. These are short courses of between eight and five days in duration. Comprising both theoretical and practical training, they are designed to have an impact by imparting sound road-building knowledge quickly and efficiently. Upon completion of the training, individuals receive a certificate from Tjeka Training Matters that confirms that they are competent in their fields.

Bernard Vos, Site Manager of Raubex, says that the overall workmanship of the various SMMEs attests to the quality of training that they have received from Tjeka Training Matters. “Our sub-contractors are productive, efficient and accurate workers who have played a large part in the success that we have achieved on this project thus far. However, investing in quality training has also empowered many people with important road construction knowledge that will enable them to participate in more of these projects moving forward. Certainly, we will also harness these skills again for future road construction projects in the vicinity if available, while also making skills development and training opportunities accessible to more SMMEs in the area,” Vos says.

SMMEs and employees were recruited via the Project Liaison Committee (PLC), nominated by the Thabazimbi Local Municipality. In doing so, the PLC worked closely with Mpho Dijane, Raubex’s Community Development Facilitator. Dijane undertook the skills audit analysis, as well as identified work packages for the various SMMEs and gaps in proficiencies that would need to be addressed via quality training.

Upon completion of the training, individuals receive a certificate from Tjeka Training Matters that confirms that they are competent in their fields.

He is also impressed with the overall performance of the SMMEs. “Equipped with the correct knowledge, our sub-contracting teams have been improving steadily. This is both in terms of productivity and quality of workmanship. Understandably, there will be issues here and there that need to be addressed, but they have been minor and far and few between. This is part of the learning experience for SMMEs and comes with our role as a mentor, which we take very seriously” Dijane says.

SANRAL Contract R510-020-2016/1 for the improvement of National Route R510 is now approximately 90 % complete and on track to be handed over to the South African National Roads Agency Limited (SANRAL) in mid-March 2024. By then, 30 % of the contract value will have been spent on targeted enterprises and 8 % on local labour. This is in line with SANRAL’s focus on ensuring that all of its road construction projects benefit surrounding communities via employment, as well as skills development and training opportunities.

The work being undertaken to this section of the R510 will improve road safety and provide shorter travelling times. Working alongside Royal HaskoningDHV, the consulting engineer, Raubex is widening the existing carriageway and providing surfaced shoulders and passing lanes. This is in addition to strengthening the existing pavement and improving drainage. Moreover, the construction company is upgrading intersections and lengthening existing minor and major structures where necessary.

Both Dijane and Vos have nurtured a long professional relationship with Tjeka Training Matters. Considering Raubex’s intense focus on skills development and training across the group and its worksites, they value the high quality of Tjeka Training Matters’ civil-engineering construction training. The company also ensures that its training pertains to the project, taking into consideration typical challenges that SMMEs will encounter on the worksite. This focus includes imparting knowledge of the typical health and safety risks that are present so that precautionary measures can be undertaken.

Frans Toua, CEO of Tjeka Training Matters, says that the company is proud to be associated with one of the country’s foremost road construction companies. “Raubex’s projects go beyond delivering top-notch road infrastructure that forms the backbone of our economy. Our client’s focus on providing the best training opportunities to participants in its projects is also equipping individuals with quality skills that will enable them to grow and develop. This is also driving up quality across the industry. Considering the company’s large national footprint, it is also extending access to quality skills development and training in the road construction industry,” Toua concludes. **CB**

Contact: www.tjeka.co.za

Groundwork laid for the innovative Betrams Multipurpose facility

The Johannesburg Inner-City Eastern Gateway is witnessing a transformative moment as the excavation works for the highly anticipated multipurpose centre are underway. The Johannesburg Development Agency (JDA) has made significant progress in the construction of the Bertrams Multipurpose Centre on the eastern edge of the Inner-City Central Business District. The JDA is implementing the facility for the City of Johannesburg Social Development Department. The progress of the construction work is at 20 %, and mass excavations are taking place with the project team working diligently to lay the foundation for this transformative community asset. The state-of-the-art facility will be a beacon of hope and empowerment for the community in offering social development services and foster community growth for residents of Region F.

Upon completion, the facility will offer a wide range of services and amenities designed to uplift and enrich the lives of residents. Key features of the Betrams Multipurpose Centre:

Community Hall: A versatile space for gatherings, events, and community meetings.

Senior Citizens Support: A dedicated area to cater to the needs and well-being of our senior citizens.

Women's Empowerment Centre: A hub for programs and resources aimed at empowering women in our community.

Childcare Facilities: A safe and nurturing environment for the youngest members of our community.

Social Development Offices: Offices to facilitate essential social services and support.

Youth and Skills Development Facilities: Spaces for skills development, education, and recreational activities for our youth.

Basketball Courts: A sports facility to promote physical fitness and community engagement.

The site of the Bertrams Multipurpose Centre is adjacent to the Greater Ellis Park. The sports precinct is part of the revitalisation project by the JDA to transform the area into an eye-catching, accessible hub linking sport, education, residential and transport sectors.

The Betrams MPC is conveniently located adjacent to public transport like Rea Vaya BRT service, numerous buses, and taxi routes to the CBD and eastern suburbs of Jeppestown, New Doornfontein, Troyeville and Kensington to access the facility.

"The City of Johannesburg is committed to enhancing the quality of life for its residents by providing essential services and infrastructure while fostering community development, sustainability, and inclusivity," JDA acting CEO Siyabonga Genu said.

"The Bertrams Multipurpose project aligns with the JDA's objective to efficiently, effectively and economically deliver sustainable social and economic infrastructure projects", he said.

"It also aligns with the JDA objective to support the growth and development of strategic economic nodes into high-quality, investor friendly and sustainable urban environments," he noted.. **CB**

Contact: www.jda.org.za

Complete lubrication solutions for cement and heavy industry

A leading supplier of lubricants and services for the cement industry, FUCHS Lubricants South Africa offers diverse products such as STABYL HD, high-performance grease for roller bearings in kilns and mills. "The cement industry has specific requirements for lubricants," explains Astin Allin, Cement Local Business Segment Lead.

These include high temperatures, heavy loads, dust and water contamination, and long service intervals. FUCHS meets such challenges with innovative solutions that provide high performance, reliability, and efficiency. It also offers technical support, condition monitoring, and customised service packages to optimise the lubrication of cement plants.

STABYL HD, in particular, is a heavy-duty lithium soap grease containing a highly viscous base oil and wear-reducing EP additives and solid lubricants. It is mainly used in heavy equipment engineering to lubricate large, self-aligning roller bearings in roller mills and presses and plain bearings subject to high surface pressures.

The product has approval from major global OEMs such as KHD Humboldt Wedag International, Koyo Australia, Loesche, Maschinenfabrik Köppern, Outotec, and ThyssenKrupp Industrial Solutions AG. It means that, apart from the cement industry, it is perfect for construction, machinery and equipment, power generation, mining, quarrying, and exploration.

Allin highlights that FUCHS is able to support its customers throughout the cement manufacturing process. Right from the quarrying stage, equipment such as crushers, trucks, and excavators operate in arduous conditions and are exposed to vibration, massive loads, and dust. FUCHS supplies a range of special lubricant solutions from blending beds to grinding units. It even provides chain oils and special oils and greases as well as lubricants for gearboxes and synthetic heavy-duty oils.

Kayla Van Vught

When it comes to the kilns and clinker coolers involved in hot processing, FUCHS offers open gear and high temperature lubricants, lubricants for thrust and support rollers, and even cleaners to degrease metal parts. The vertical roller mills used in the final grinding process require high performance oils for trunnion bearings and gearboxes, and special open gear lubricants for spray bath and circulation lubrication.

"Our customers also benefit from our global expert network, which offers the best technical expertise based on our extensive experience in the cement and other heavy industrial sectors," concludes Allin.

FUCHS LUBRICANTS SOUTH AFRICA
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NON-MAGNETIC CONCRETE – CONCRETE TIP

by F.S. Fulton

It is necessary for certain purposes that concrete should be entirely non-magnetic. Unfortunately, as all who have used an electromagnetic covermeter are aware, many aggregates are slightly magnetic or contain magnetic constituents.

Thus magnetite, which is highly magnetic, occurs in granites and norites.

In reef quartzites there may be as much as 2 – 3 % of pyrite. Although neither pyrite nor any of its decomposition products is magnetic, pyrrhotite, which commonly occurs in pyrite is amounts of about 1 % by mass is sufficiently magnetic to prohibit the use of these aggregates for certain purposes.

Probably the safest aggregates to use in non-magnetic concrete are dolomites and limestones, but the presence of tramp metal1 must be strictly guarded against.

Non-magnetic concrete is essential for hardstandings of aircraft requiring compass adjustments.

NB. Milled granulated blastfurnace slag has been known to contain fairly high percentages of metallic iron and should not be used in the binder for non-magnetic concrete.

1. Tramp metal is any scrap metal introduced into the aggregate or binder from the production process. Examples of where it comes from are conveyors, grinding aids, chains, crushers, bucket teeth, and metallic tools. CB

PPC and CAMM launch socioeconomic impact report

Tangibly demonstrating the consequences of substituting local cement production with imports

PPC - a leading provider of quality building materials and solutions in sub-Saharan Africa - and the Centre for African Management and Markets (CAMM) at the Gordon Institute of Business Science (GIBS) today launched a report on the social and economic impact of cement imports on the local economy.

The report, titled "The socioeconomic impact of substituting local cement production with cement imports" was based on a study commissioned by PPC and independently conducted by CAMM. The study provides an overview of PPC's contribution to the South African economy and forecasts the potential social and economic impacts of a significant displacement of local cement production in favour of imported cement.

"As a business that has sustained for more than 130 years, purpose and people remain at the heart of all we do. We are proud of the depth of our value chain and recognise that the success of thousands of families, communities, and businesses are interlinked with that of PPC," said Njombo Lekula, PPC MD: South Africa and Botswana. "The report evidences PPC's significant contribution to the South African economy and society and tangibly demonstrates the serious and complex threats that cement imports pose to our industry, society, and country's development. This study, undertaken by CAMM, based at GIBS Business School, aimed to consolidate these dimensions into the impact analysis."

Based on the scenario modelled in the report, some of the more sobering estimations on the impact - across the entire PPC value chain – include more than 2,200 jobs potentially at risk - primarily across marginalised communities; and a potential R 2.6 billion annual loss in economic value in an already-strained economic environment.

The report evidences PPC as a major economic contributor in South Africa, as the business's operations added R 8.8 billion to the national GDP last year through its vast value chain –equivalent to 0.13 % of the country's total GDP. Despite the subdued economic climate and infrastructure backlog South Africa experiences, PPC's purchased goods, services, and capital equipment from local suppliers was valued at over R 4.7 billion.

PPC's commitment to operating a sustainable business is also reflected in the various provinces it functions in, with purchased inputs such as fuel, electricity, and raw materials all playing a significant role in creating additional jobs in the upstream supply chain. PPC's Western Cape-wide employment is estimated at 2,667 jobs. Based on information from the government's public works programmes, it is estimated that annual public sector spending of R 410 million would be required to achieve the same employment contribution.

In this vein, while the findings of the report demonstrate the significant economic and social contribution made by PPC to South Africa, the report also shows the material impacts and implications that follow from the displacement of domestic production by imported product.

The report was launched as part of a panel discussion that unpacked the urgency of enabling policies for building a conducive, local production environment. Hosted by Professor Adrian Saville, director of CAMM, the panel of trade and industry experts included CAMM Research Associate, Francois Fouche'; PPC MD: South Africa and Botswana, Njombo Lekula; Cement & Concrete South Africa (CCSA) CEO, Bryan Perrie; Business Unity SA (BUSA) CEO, Cas Coovadia; and Industry Insight CEO, Elsie Snyman. What came across clearly from the discussions was the imperative to establish robust policies which are critical in levelling the playing field for local producers. Despite the intensifying challenges faced, what remains encouraging is the host of measures the construction industry has taken to ensure innovative, sustainable development that is responsive to evolving market dynamics.

"We are delighted to have worked with PPC on this report," said Professor Saville. "The report provides valuable insights into the socioeconomic contribution of the cement industry, and the impact that would be experienced through displacement by cement imports in South Africa – disproportionately impacting economically vulnerable towns and having substantial impacts across provinces that are home to PPC's plants. This study bears out the interconnectedness of industries, individuals, communities, and the state. None of these can truly succeed in the long term unless each of the others functions properly. An economy is more like a living organism than a dispersed archipelago."

Professor Saville highlighted some of the key findings in the report, "The quantitative portion of the study applied an established modelling tool to capture the totality of the economic value that the activities of a single firm or industry contribute to society. On-the-ground interviews with a variety of stakeholders provided rich context within which we should interpret the numerical analysis."

The panellists noted that the local cement industry faces a number of compliance costs that do not affect foreign suppliers, such as carbon taxes and adhering to the Mining Charter. Mr Lekula added that the local cement industry has time and again shown its commitment to innovation and ongoing improvement through its decarbonisation efforts. In the face of massive challenges, including low infrastructure spending, poor transport infrastructure and increased energy costs, the sector has worked hard to stay competitive. However, it needs an enabling policy environment to keep effectively serving South Africa's economic, social and developmental needs.

Francois Fouche, CAMM Research Associate and an author of the report, said that protecting the local cement industry is not just a question of employment. For instance, if production were to shut down in the Western Cape, employment would be decimated, but so would the complexity of local economic activity. Importing materials is considerably less complex than producing – which involves advanced technology, processes and complex activities. We risk losing those skills in the economy, which we cannot afford. Fouche explained that the literature is clear that more economic complexity, and more diverse skills, are associated with better economic performance. South Africa is currently highly proficient at producing cement and we manage the complex value chain well – why compromise that by permitting dumped imports? **CB**

The report is available for download from the PPC website - https://www.ppc.africa/media/jtikrwcr/ppc-sei-report.pdf

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