

The background of the slide is a high-contrast, abstract geometric pattern of grey and black shapes, resembling a 3D hexagonal lattice or a series of nested, perspective-viewed hexagons. A large, solid blue triangle is positioned in the lower-left quadrant, containing the title text.

# ANNUAL REPORT 2020/21

Concrete Materials and Structural  
Integrity Research Unit



UNIVERSITY OF CAPE TOWN  
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

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# MESSAGE FROM THE DIRECTOR

The Concrete Materials and Structural Integrity Research Unit (CoMSIRU) takes as a foundational philosophy the importance of developing high level human resources for industry, academia and research. We have always stressed the point that our highest research priority is to support young, talented engineers and help them grow academically and professionally.

In line with this priority, we have over the past few years continuously grown our postgraduate student cohort and are currently supervising a total of 46 postgraduate (PG) students (10 PhD, 13 MSc, 21 MEng) in their research. Another 20-30 MEng students are already in the pipeline, completing their coursework in the CIMM (Civil Infrastructure Management and Maintenance) PG programme, expected to register for their research project in 2022 or 2023. Similarly, the CIMM programme, which we established about 10 years ago, is attracting an increasing number of PG students from all over Sub-Saharan Africa, which allows to better prioritize the selection of our future research students.

The construction industry as a whole has been badly affected by the global pandemic that hit South Africa in March 2020 with full force. Similarly, our operations at UCT and in CoMSIRU were significantly affected. All undergraduate and PG teaching was shifted to an online format, which forced us to spend a major part of our time to redevelop our courses and rethink our curriculum. General crisis management in the department and the university consumed a large portion of our remaining time. Our laboratories were closed for a part of 2020, with the result that experimental research was delayed or research strategies had to be adjusted. However, despite all of these challenges, we managed to retain our productivity in terms of research output, PG student supervision, and industry liaison, as well as our involvement in local and international research leadership through industry associations such as CCSA, RILEM, and fib. It was tough - but with the help of our cohort of highly motivated PG students, we have so far managed to get through the crisis with little harm to our research enterprise.

Our postgraduate students have been back in the laboratories since August 2020 and our experimental research has now returned to pre-Covid levels of activity. However, we are now facing a very elemental crisis of a different kind. A range of factors, including the impacts of the pandemic on the construction industry, the restructuring in the local cement and concrete industry, and the continuous reduction in governmental funding have contributed to the situation where our research funding in 2021 has shrunk to about 10% of the 2018 levels. The local cement and concrete industry, which traditionally was one of our most trusted partners, shows a worrying tendency of assigning increasingly less value to the research done at local

universities. Consequently, we need to now rethink our purpose as the most active and largest concrete research unit in South Africa while we are trying to regain financial stability. In a way it is ironic that we came out of the pandemic with by far the largest research student cohort that we have ever supervised just to face a financial crisis that may lead to our extinction or severe curtailment if we cannot identify new avenues of funding very soon.

However, we remain hopeful that we can manage to return to a level of financial stability that will allow us to focus on our core business – contributing to cutting-edge local and international research, developing high quality engineering (wo)manpower for Sub-Saharan Africa, and supporting the local industry with the development and dissemination of relevant knowledge.

Lastly, I would like to thank Professor Moyo for successfully steering CoMSIRU as Director from 2016-2020. I look forward to another 5 productive years!



# INTRODUCTION

CoMSIRU is an active research unit in the Department of Civil Engineering at the University of Cape Town. The unit's research is focused on modern and advanced concrete technology, durability of concrete structures, structural health monitoring, structural integrity assessment, and repair and rehabilitation strategies for concrete structures. The guiding principle for CoMSIRU is developing high-level manpower for industry, research and academia, while engaging in innovative and impactful research. This is reflected in the strong integration between the unit's research, education and technology transfer activities. Based on student numbers and research output, the unit remains healthy and active, linking with industry through an advisory board, involvement in professional bodies and continuing professional development courses, as well as postgraduate training.

CoMSIRU's well-established international links provide opportunities for collaborative research and benchmarking, which enables the research unit to continuously evolve and strengthen its niche research focus. CoMSIRU recognises the impact of the emergence of "Industry 4.0" and its impact on both research and training needs in the construction materials and structural engineering industries. An underlying focus of the unit's research relates to sustainability principles and efficient use of resources in the construction industry. On a local and international level, CoMSIRU's research enjoys high impact as measured by scholarly productivity, inclusion in local standards, local and international awards, and the demand for its graduates in industry and academia.

## Objectives of the Research Unit



Expand and improve the pool of high-level skills in concrete materials and Structural Engineering in South Africa and the Southern African region.



Influence the culture and practice of engineering design of concrete structures.



Improve the management of civil infrastructure.



Embed durability and sustainability in all aspects of concrete structural/Civil Engineering.



Promote structural health monitoring as a key tool for structural performance assessment.



Embrace the opportunities and challenges of Industry 4.0.



Improve resilience of infrastructure to the effects of climate change.



# STAFFING



**PROF. HANS BEUSHAUSEN**  
DIRECTOR



**PROF. PILATE MOYO**  
CO-DIRECTOR



**EMER. PROF. MARK ALEXANDER**  
CO-DIRECTOR

## Research Associates

- Professor Manu Santhanam, IIT Madras, India
- Adjunct Associate Professor Vernon Collis, Collis and Associates

## Laboratory Assistant

- Mr. Leonard Adams

## Administrative support (part-time)

- Ms. Gill Verster

# CURRENT STUDENTS

## PhD Students

NAME	SUPERVISORS	RESEARCH TOPIC	
Nicholas Jarrat	HB	Structural contribution of patch repairs to RC elements	
Joanitta Ndawula	HB	MO	Mitigation of chloride-induced reinforcement corrosion propagation using hydrophobic impregnation
Ichebadu Amadi	HB	MGA	Enhancing the properties of fine recycled aggregate concrete
Saarthak Surana	HB	MGA	Conductivity in service life prediction of marine concrete structures
Emmanuel Leo	MGA	HB	Development of low-clinker concrete based on African raw materials
Alice Bakera	MGA	HB	Advancement of biogenic corrosion prediction model for concrete sewer pipes, based on the Life Factor Method (LFM)
Thalosang Tshireletso	PM		Impact of climate change on the behaviour of concrete arch dams in South Africa using non-parametric machine learning data-models
Bukhosi Nyoni	PM		Finite element model updating of concrete arch dams subjected to ASR
Valontino James	PM		Deep learning-based defect characterisation for concrete bridges
R. Heiyantuduwa	MGA		Improvement of chloride prediction models

# MSc (Eng) Students

NAME	SUPERVISORS	RESEARCH TOPIC		
A. Lekundayo	HB	Self-healing of cracks in concrete, technology and application		
Nicholas Elias	HB	Crack width models in RC and their relevance in durability design		
Areej Gamieldien	HB	MGA	The use of recycled fines as a binder in structural concrete	
Neema Kahabi	HB	MGA	Partial replacement of natural fine aggregates with recycled concrete	
Vafa Naraghi	HB		Structural concrete repair mortars	
Ameen Moola	HB	NJ	Bond strength of rebar in repair mortar	
Jaziitha Simon	HB	MO	Remote corrosion monitoring in RC structures	
Tais Soares	HB		Hydrophobic sealants to reduce carbonation-induced rebar corrosion	
Sean Alfred	MGA	HB	Integration of NDT permeability testing into SANRAL's quality control	
Mixo Ngwenya	PM		Heavy Haul Railway Bridge-track Interaction	
Emilia Mupwedi	PM		Assessment of a heavy haul railway viaduct through monitoring traffic loads	
S. Ndeutapo	PM		Economic evaluation of FRP's for bridge constr. in SA coastal areas	

# MEng Students

NAME	SUPERVISORS		RESEARCH TOPIC
Valentine Kaupa	HB	JN	Management of concrete water reservoirs in Malawi
N. Seketema	HB	JN	Railway Concrete Sleeper Maintenance in South Africa
Rendani Likhade	HB	JN	Condition Assessment for Prevention of Premature Structural Failure
Salmi Neshila	HB	NJ	Structural concrete repair
Ashfaaq Hoosain	HB	SS	Protective coatings for durability extension of RC structures
Shafiq Ismael	HB	SS	Self-healing of cracks in concrete
Christopher Adam	HB	SS	Using waste materials in concrete brick manufacture
Naashif Mowzer	HB	NJ	The effect of permanent formwork on the durability of RC structures
S. Balendra	HB	SS	Shrinkage prediction models for concrete
J. Takaindisa	HB		Development of rural infrastructure management and maintenance systems
E. Nyambalo	HB		Cathodic protection of RC structures
Ridwan Taiwo	MGA	EL	Efficiency of different supplementary cementitious materials and fillers
E. du Plessis	MGA	ATB	Making cube samples by using a rotary percussion drill

# MEng Students

NAME	SUPERVISORS	RESEARCH TOPIC
Ismael Hartley	MGA	Alternative building technologies and their practicality in Western Cape Human Settlements implementation
Gareth Gertse	MGA SS	A critique of international exposure zone classifications
T. Gwala	MGA SS	A critique of condition assessment strategies for port structures
B. Fredericks	HB	Cracking and crack width prediction in RC structures
Tina Namalima	PM BN	Review of Codes of Practice for the Design of Box Culverts for Recommendation for South African Bureau of Standards (SABS)
Nokwanda Sibisi	PM BN	Evaluating the Most Reliable Combination of Non-Destructive Test Methods for Concrete Uniformity and Relative Compressive Strength
K. Nare	PM BN	Validation of the Dynamic Behaviour of an Arch Bridge Structure using both Theoretical and Empirical Results
Paul Bakheit	PM	Comparative study on the behaviour of concrete reinforced with FRP and steel singly reinforced beams
Uthman Ramjaun	PM	Investigating vertical track deformations at railway bridge transition zones during approach of heavy-haul trains
Eric A. Rugemalira	PM	Identification of vulnerable zones on Steel Railway bridges

## KEY

MGA – Mark Gavin Alexander	JN – Joanitta Ndawula
PM – Pilate Moyo	NJ – Nicholas Jarrat
HB – Hans Beushausen	EL – Emmanuel Leo
MO – Mike Otieno	SS – Saarthak Surana
ATB – Alice Titus Bakera	BN – Bukhosi Nyoni

# GRADUATIONS

PhD	SUPERVISORS	RESEARCH TOPIC
Rakesh Gopinath	MGA HB	Carbonation-corrosion prediction model for SA conditions
Patrick Bukenya	PM	Structural performance evaluation of concrete arch dams using ambient vibration monitoring and GNNS systems
<b>MSc (Eng)</b>		
Sheila Ross	MGA	Bamboo construction as a sustainable building technology
Mandla Dlamini	MGA	Performance of geopolymers concrete subjected to mineral acid corrosion and related to microbially-induced corrosion (MIC) of concrete in sewers.
F. Akhalwaya	HB	Non-destructive testing technology for rebar corrosion detection
Amy Moore	HB MO	The influence of oxygen availability on rebar corrosion
H. Sohawon	HB	Hydrophobic treatments for service life extension of RC structures
Lele Fotso Harold	HB MGA	Carbonation Prediction and Modelling for Service Life Design
Daniel Govender	MGA	Data model for managing Durability Index (DI) results
James Valantino	PM	Fatigue Behaviour of CFRP Strengthened Reinforced Concrete Beams
Bright Dube	PM	A deep learning-based approach towards automated visual bridge inspection
<b>MEng</b>		
Martha Mwatile	MGA	Assessment of AAR avoidance measures and tests worldwide
B. Fredericks	HB	Cracking of concrete elements – prediction and prevention
M. Muhenje	HB JN	Performance Evaluation of NamWater's Asset Management System
K. Chirembo	HB JN	The state of Namibia's concrete infrastructure
Isaacs Benedict	PM	Review of Transnet National Ports Marine Concrete Infrastructure Asset Management and Maintenance
Matela Mou	PM	Vibration Serviceability of Long Span Slender Floors
Paiman Byron	PM	Visual inspection of concrete water reservoirs using a defects-based system
Alonzo Benjamin Allison	PM	Determining the dynamic responses of the non - overspill bridge decks of Van der Kloof Dam

# RESEARCH ACTIVITIES

CoMSIRU's research work is focused on developing a deep understanding of both the short-term and long-term behaviour of concrete and developing methodologies for producing durable and structurally sound concrete that minimises maintenance costs.

Thus, there is a strong emphasis on understanding the deterioration mechanisms of concrete structures, development of technologies for assessment of concrete structures as well as development of life extension of deteriorated concrete structures. This is achieved through two broad research thrusts: concrete materials and construction and structural integrity and monitoring.

CoMSIRU's research work is supported by state-of-the art laboratories for concrete technology and structural concrete. The research unit integrates laboratory work, field measurements and computational modelling of materials and structures, which places the research unit in a good position to develop realistic and practical engineering solutions.

An important consideration in deterioration science and renewal engineering is sustainability of materials and construction. To this end, the research unit has embarked on developing knowledge and technologies that may be used by structural engineers to ensure their designs are sustainable and in keeping with the developments in digital technologies

## Current Research Themes and Focus Areas

- Service life prediction models for reinforced concrete in the SA context
- Low-clinker cements for sustainable concrete
- Recycled aggregates and recycled fines for concrete production
- Durability and deterioration studies
- Sustainability and resource minimisation studies
- Fatigue reliability and long-term monitoring of railway bridges
- Bridge management systems
- Long-term performance of repaired reinforced concrete structures
- Effective corrosion prevention in existing concrete structures
- Ambient vibration monitoring of concrete dams
- Numerical modelling of the swelling effect of concrete structures
- Automated inspection of bridges
- Structural Health monitoring and prognosis using machine learning

## IMPACT OF RESEARCH

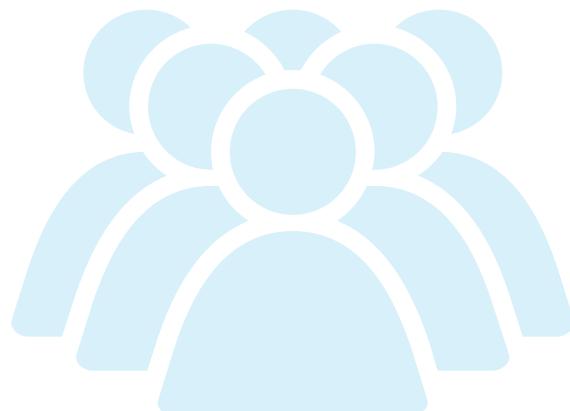
The unit's research in concrete durability has been on-going for more than two decades and has led to a better understanding of the deterioration mechanisms of concrete. Test methods for the durability of concrete developed by CoMSIRU researchers are now applied within the SANS system for acceptance as national standards. CoMSIRU's research has instilled a comprehensive approach to condition assessment, repair and strengthening of concrete structures, which may be noted by the input into national codes and standards, where research findings are being reflected.

New approaches from the unit's research continue to be applied in major national construction projects. As far as scientific papers are concerned, the output of CoMSIRU is substantial, and the vast majority appear in internationally respected journals and conferences.

One of the main research impacts is the development of (wo)manpower for the local and regional engineering industry, with well over 100 previous CoMSIRU postgraduate students working in industry and academia all over Southern Africa.

100+

*Postgraduate Alumni working  
in industry & Academia*



# TEACHING ACTIVITIES & POSTGRADUATE TRAINING

CoMSIRU is integrally involved in two postgraduate programmes within the Department of Civil Engineering namely, the Structural Engineering and Materials (SEM) Programme and the Civil Infrastructure Management and Maintenance (CIMM) Programme. CIMM was developed by the research unit to offer a broad range of knowledge and skills including

asset management, maintenance, repair and rehabilitation of civil infrastructure in line with South African Government's Immovable Asset Management Act of 2007. Courses offered in these programmes are also open to industry for continuing professional development (CPD).



# POSTGRADUATE COURSES / CONTINUED PROFESSIONAL DEVELOPMENT

## **CIV5002Z Structural Concrete Properties and Practice**

The aims of the course are to provide structural engineers with fundamental and practical knowledge in concrete materials technology, to establish an understanding on modelling and designing concrete properties relevant to structural design and to create awareness of chemical and physical material characteristics of cementitious construction materials.

## **CIV5138Z Durability and Condition Assessment of Concrete Structures**

This advanced course aims to develop an understanding of durability aspects, service life design and non-destructive testing of concrete structures.

## **CIV5113Z Structural Dynamics with Applications**

This course aims to introduce the concepts of structural dynamics and its applications in structural engineering. Specific applications considered include applications to seismic design of structures, blast and impact effects on structures and wind engineering.

## **CIV5119Z Structural Performance Assessment and Monitoring**

This course introduces concepts of structural health monitoring of civil infrastructure through static and dynamic field measurements as well as finite element modelling.

## **CIV5115Z Bridge Management and Maintenance**

This course introduces the principles of bridge management and maintenance, with a focus on both highway and railway bridges. The course expands on the basic philosophies behind bridge management systems, the structure of a bridge management system and the implementation of bridge management system. Key to this course is practical bridge inspections and case studies.

## **CIV5138Z Repair and Rehabilitation of Concrete Structures**

This course deals with the repair and rehabilitation of concrete structures and covers

repair materials and strategies, durability and repair audits, economics of repair and life-cycle costing, practical and contractual aspects of concrete repair, and maintenance planning.

## **CIV5140Z Strengthening and Retrofitting of Concrete Structures**

This introduces structural condition surveys and assessment of concrete structures and covers materials and strategies for structural strengthening, structural requirements and procedures for rehabilitation, practical and contractual aspects, strengthening systems, design procedures, and analysis of strengthened concrete structures.

## **CIV5118Z Safety of Special Structures**

The course introduces students the governance and management of special structures. The particular focus of the course is adjusted to current industry needs and may include concrete dams, nuclear facilities, mining structures, and coastal infrastructure.

## **CIV5151Z Non-Destructive Testing of Concrete Structures**

The course addresses the detection and quantification of concrete degradation and associated mechanical, physical and chemical processes, dealing with non-destructive testing methods (NDT) in civil engineering for quality control and condition assessment.

## **CIV5141Z Condition Assessment and Remedial Action on Steel Structures**

The course develops an understanding of durability aspects, service life design, condition assessment and non-destructive testing of steel structures, including material characteristics and properties, structural behaviour of steel, deterioration of steel structures, and protection, strengthening and repair of steel structures.

## **CIV5067Z Advanced Infrastructure Management**

This course exposes the student to the concepts of municipal infrastructure management. These concepts include the context, process and implementation of Infrastructure Asset Management Planning.

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# ORGANISATIONAL ARRANGEMENTS

## Governance

CoMSIRU is overseen by its two directors, Prof Hans Beushausen and Prof Pilate Moyo. Emeritus Prof Mark Alexander plays the role of senior advisor to CoMSIRU. Regular meetings are held by these three directors to discuss teaching, research, administration and budget issues.

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# AWARDS, ACHIEVEMENTS, HIGHLIGHTS

## CoMSIRU scored twice for Innovandi Partner Projects

CoMSIRU was invited to become a scientific member of Innovandi in 2019 and to participate in their Innovandi Partner Projects. Innovandi, the Global Cement and Concrete Research Network of the Global Cement and Concrete Association (GCCA), is an industry-led consortium of 30 companies and 40 scientific institutions that draws together the cement and concrete industry and academic institutions to stimulate innovative and actionable research worldwide. Innovandi's scientific members are the leading research entities for cement and concrete globally, and therefore being part of this network is very prestigious

The Innovandi Kick-Off Week was held online in June 2020, where the various partners presented their project proposals. CoMSIRU was the only academic partner to receive approval for not one, but two partner projects. Both Emer. Professor Mark Alexander and Professor Hans Beushausen were awarded to lead a unique research project.

### **Research Project 1: Combining performance-based carbonation and reinforcement corrosion rate models for service life prediction of RC structures**

Competencies developed: Knowledge of concrete performance based design, material property optimization, testing of durability properties, durability modelling and service life design. Novelty: This study uses a performance-based approach to predict both reinforcement corrosion initiation and propagation in concrete structures.

### **Research Project 2: Enhancing the Properties of Fine Recycled Aggregate Concrete**

Competencies developed: Knowledge of concrete mix design, material property optimization, testing of mechanical, physical and durability properties, durability modelling. Novelty: This study uses a performance-based approach to improve the properties of FRA in order to optimize its performance in concrete production.

## **Emeritus Professor Mark Alexander editor of the 10th edition of Fulton's Concrete Technology**

The 10th edition of the Fulton's concrete technology was launched in June 2021 by Cement & Concrete SA (CSSA). The handbook is divided into 37 chapters (10 more than the 9th edition), authored by professionals of various backgrounds including academics, researchers, material specialists, concrete producers, and consulting engineers. This edition was edited by CoMSIRU's Emer. Professor and co-director Mark Alexander and places great emphasis on the issue of sustainability while addressing topics such as the

properties, manufacture, and quality control of concrete materials.

### UCT and India's IITM to collaborate in civil engineering

The civil engineering departments of the University of Cape Town (UCT), South Africa and Indian Institute of Technology Madras (IITM), India signed a memorandum of understanding to secure further research cooperation and engagement between the two universities in the field of civil engineering.

The collaboration was coordinated by CoMSIRU's Emer. Professor Mark Alexander and IITM's Professor Manu Santhanam. The agreement will facilitate the exchange of students, faculty, staff and research scholars, as well as organization of seminars, workshops such as the Open Indo-South African Workshop on the Use of Recycled Aggregate in Concrete which was held online on 21 August 2020 and other academic events for training and research purposes.

### CoMSIRU provides video lectures for Europe's concrete industry

Professor Hans Beushausen was selected by the European Ready-Mixed Concrete Organization (ERMCO) to educate professionals in Europe's concrete industry on durability of concrete structures through a series of lecture videos.

There were a total of ten videos covering topics including Alkali-Silica Reactions, chemical attack on concrete, common construction defects, shrinkage cracking of concrete and reinforcement corrosion. The videos focussed on deterioration mechanisms, the effects of deterioration on the service life of the affected structures, and the prevention of premature deterioration. The videos are freely accessible on ERMCO's YouTube channel.

### Expert briefing on limestone calcined clay cements

CoMSIRU was proud to host the LC<sup>3</sup> Information Day in Cape Town on 19th November 2019, at the UCT Graduate School of Business, V&A Waterfront. The workshop brought leading international researchers to Cape Town, and participants were updated on the latest developments in low carbon cements, specifically limestone calcined clay cements (LC3), and applications in concrete. There were also inputs from local experts and practitioners as well as information on ongoing research at UCT in this field.



The background of the image is a close-up, high-angle view of a wall or floor made of large, light-colored concrete blocks. The blocks are arranged in a staggered, interlocking pattern that creates a complex, three-dimensional geometric texture. The lighting highlights the rough, textured surfaces of the concrete.

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