UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

2017

Proceedings of 5th Annual CoMSIRU Colloquium

10 August 2017 - Old Mutual House,
Bishopscourt, Cape Town, South Africa

CoMSIRU

5th Annual CoMSIRU Colloquium

Proceedings of Annual
CoMSIRU Colloquium-2017,
Bishopscourt, Cape Town, South Africa
August 10, 2017

Edited by Valontino James

ACKNOWLEDGEMENTS

The Concrete Materials and Structural Integrity Research Unit (CoMSIRU) would like to thank all the students for the excellent research being conducted. Thank you to everyone who contributed to making the colloquium a success once again.

To the CoMSIRU directors Professor Pilate Moyo, Professor Hans Beushausen and Professor Mark Alexander, we thank you for facilitating such a fine research platform. We thank all the sponsors for their contributions. Last but not least, thank you to Old Mutual House for your superb hospitality during the 2017 CoMSIRU Annual Colloquium.

SYNOPSIS

The 5th Annual CoMSIRU Colloquium held on 10 August 2017 at Old Mutual House, Bishopscourt, provided a platform for postgraduate students and researchers to share their research and progress. Eleven students in total presented their research at the 2017 colloquium. During each session, presenters showcased their research during a 15 minute slot, after which an insightful discussion ensued enabling researchers to receive feedback, critique and advice that that could assist their research.

In addition to the academically beneficial presentations, the colloquium offered the opportunity for networking between supervisors and students where academics could share their intended research directions. Altogether it was a successful colloquium. All the presentations are documented in this report for future reference.

TABLE OF CONTENTS

1. Assessing the performance of a heavy haul railway viaduct through monitoring traffic loads and dynamic effects

Dr Fulvio Busatta

Abstract

Over the past decades, significant advances in all aspects of freight railway transport have made the operation of longer and heavier freight trains possible, thereby increasing the volume of bulk commodities conveyed from mines to dedicated export terminals. Owners and operators of heavy haul lines are constantly pushed to maximise the profitability during upturn periods or reduce the losses when downturns occur. Thus, advanced studies and simulations are generally performed to optimise the ratio "rail capacity-to-operating costs". Nevertheless, heavy haul railway transport significantly relies on the serviceability and safety of the civil infrastructure serving the lines.

However, the consequences of running longer/heavier trains on the service life of existing bridges have not been always well understood. Within this context, dynamic testing and monitoring can be effective tools to evaluate the effects of changing operating conditions, towards a knowledge-based management of the civil infrastructure. The presentation shows the investigation of the Olifants River Viaduct (ORV), a 23-span, 1 035 m long prestressed concrete (PSC) bridge located in South Africa. The ORV is the largest bridge serving the Iron Ore Sishen-Saldanha Export Line. It is in operation since 1976 and, at present, crossed by the longest HH train in the world (4.1 km long) with a sequence of up to 342 wagons.

Designed in an era when performance-based design philosophies were not fully established yet, the ORV has currently passed 40 years of its service life under changing environmental, structural and especially loading conditions. Thus, the two-fold objective of the research is i) characterising the current rail loading parameters, investigating the structural health state and assessing the dynamic response of the ORV after 40 years of operation, and ii) estimating the remaining service life of the bridge based on providing guidelines on the operating conditions as well as possible interventions on the structure. The presentation focuses on the first step of this ongoing research.

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Concrete Materials &
Structural Integrity Research Unit

Assessing the performance of a heavy haul railway viaduct through monitoring traffic loads and dynamic effects

Dr. Fulvio Busatta & Prof. Pilate Moyo

1.

Outline of the Presentation

- Introduction to Heavy Haul Railway Transport and Lines in South Africa
- The Olifants River Viaduct
- Dynamic Investigation of the Olifants River Viaduct
- Changing Railway Operating Conditions over 40 years
- The Transnet WIM-WIM system and Monitoring of the Railway Traffic and Loading
- The CoMSIRU Monitoring System and Monitoring of the Viaduct Girder
- Conclusions

2.

Introduction to Heavy Haul Railway Transport

Train Parameter	High Speed	Heavy Haul
Car/Wagon Static Axle Load (kN)	150-180	250-400
Operational Speed (km/h)	200-400	50-80
Number of Cars/Wagons	8-16	100-350
Car/Wagon wheelset distance (m)	18-20	5-10
Length (m)	150-300	1500-4000

3.

Heavy Haul Railway Transport in South Africa

Olifants River Viaduct (1973-74)

Iron Ore Export Line
"Sishen-Saldanha"
(1976, 861 km)

Coal Export Line
"Black Hill-Ermelo-Richards Bay"
(1976, 748 km)

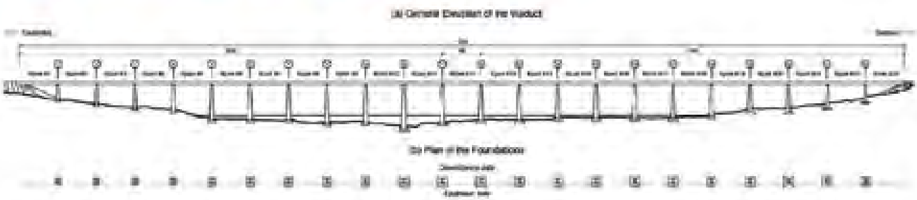
(Transnet Integrated Report 2016)

4.

The Olifants River Viaduct (1/3)

5.

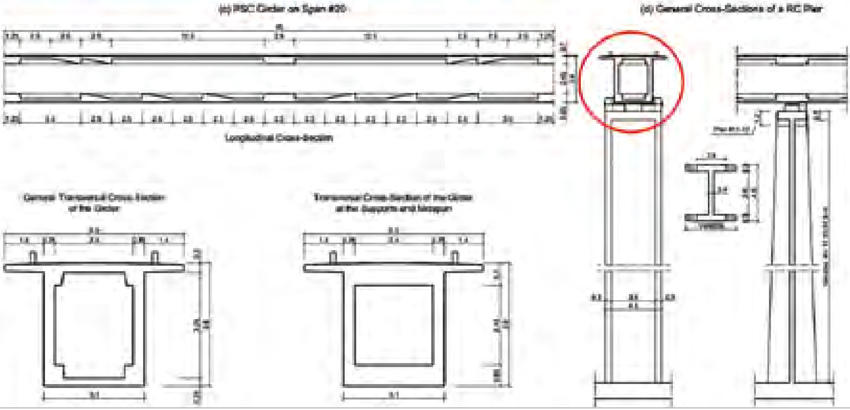
The Olifants River Viaduct (2/3)



- 1 035 m long girder (23 spans of length 45 m) with overall depth equals to 3.80 m, span slenderness ≈1/12;
- Single-box Cross-Section | Expansion joints at piers #11-12| A ballasted single-track railway line is hosted;
- Piers: H-shaped Cross-Section| Height from 17.85 (Pier #1) to 51.50 m (Pier #10);
- Foundations: Footings at Piers #1-4 and #20-22 | Piles at Piers #5-19;
- Prestressed Concrete Girder and Reinforced Concrete Piers and Foundations;

6.

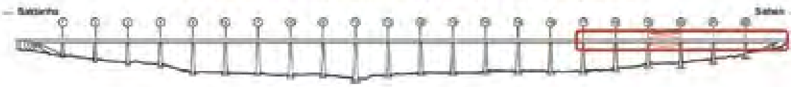
The Olifants River Viaduct (3/3)



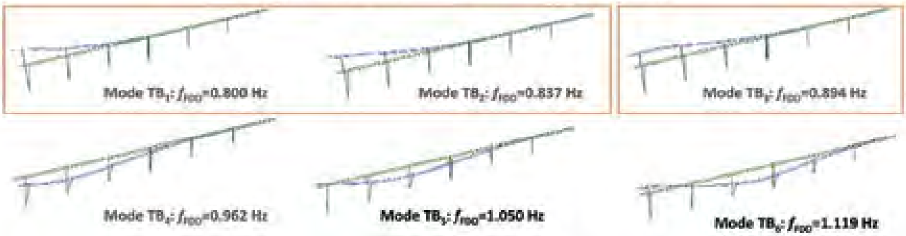
7.

Dynamic Investigation of the viaduct girder (1/4)

Ambient Vibration test in December-February 2016



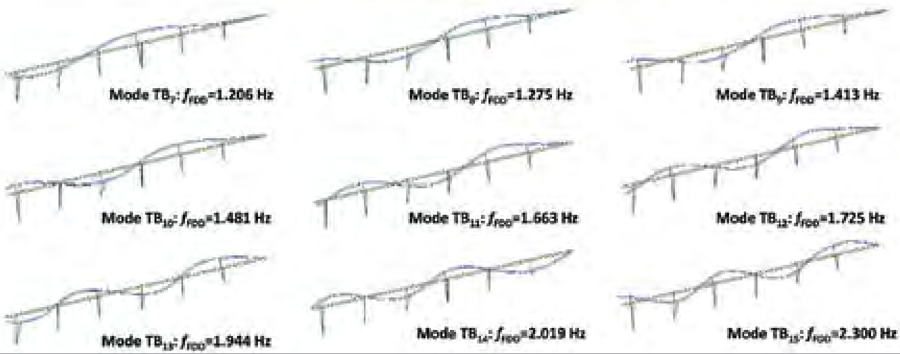
Identified Transversal Modes of Vibration



8.

Dynamic Investigation of the viaduct girder (2/4)

Identified Transversal Modes (continued)



9.

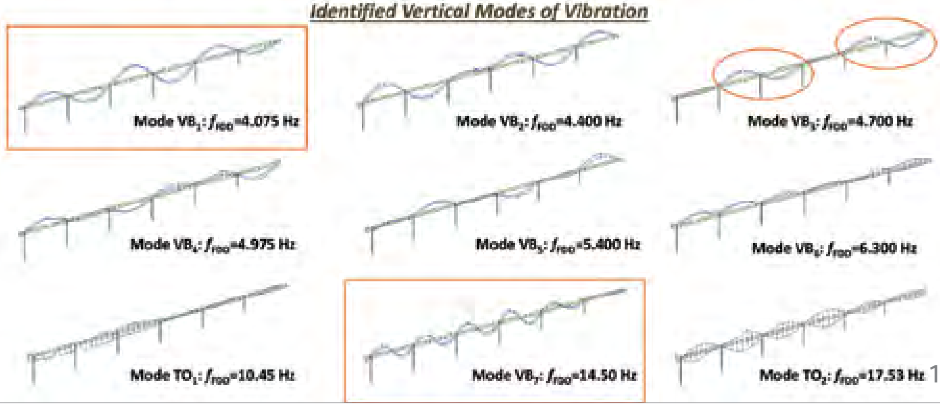
Dynamic Investigation of the viaduct girder (3/4)

Identified Transversal Modes (continued)

10.

Dynamic Investigation of the viaduct girder (4/4)

Identified Vertical Modes of Vibration



11.

Operating Conditions of the Viaduct (1/3)

Evolution of the railway traffic over 40 years

Parameter	1976	2016
No. of 4-axle wagons	100*	342
Wagon's static axle load (kN)	260	300
No. of loaded trains/week	21	38
Net capacity (mtpa)**	10	60

* 200 wagons in the late 1970s;
** mtpa stands for million tonnes of bulk commodities conveyed per annum

12.

Operating Conditions of the Viaduct (2/3)

Current train configuration and static axle loads:

LC "1" + 114 Ws + LC "2" + 114 Ws + LC "3" + 114 Ws + LC "4"

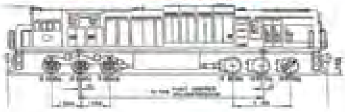
- LC stands for Locomotive Consist; Ws stands for Wagons;

- 4.1 km long freight train through employing the Radio Power Distributed (RDP) technology;

Locomotive 15E: 300 kN/axle

Locomotive 43D: 216 kN/axle

Locomotive 34D: 188 kN/axle



Wagon CR-13: 50 kN/axle (empty); 300 kN/axle (loaded)

13.

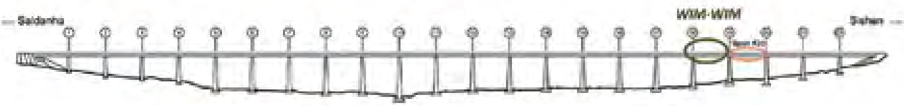
Operating Conditions of the Viaduct (3/3)

- The longest RDP train operated by TFR is around four times longer than the viaduct length;
- The current loaded wagon's axle load, 300 kN (30 t), was the upper value assumed in the static live load model at the design stage in the 1970s;
- Up to 18 wagon's axles can simultaneously load a 45 m single span i.e. 5400 kN (540 t);
- The ratio static live load per span-to-beam self weight equals 5400 kN/6000 kN = 0.90.

14.

The Transnet WIM-WIM System

32 strain gauges welded on the rail and a computer-based DAQ system



Train Database

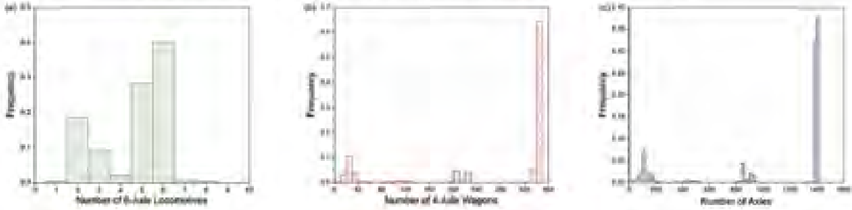
15.

Monitoring of Railway Loads and Traffic (1/2)

Analysis of 1225 trains running in 2016

Category	No. of Locomotives*	No. of Wagons	Type of Configuration**	%
A	1-2	12-54	LC"1" + *k* Ws	18
B	2-3	84-124	LC"1" + *l* Ws	2
C	3-4	196-228	LC"1"+ *m* Ws + LC"2" + *n* Ws	10
D	5-6	324-342	LC"1"+ *r* Ws + LC"2"+ *s* Ws+ LC"3" + *t* Ws + LC"4"	70

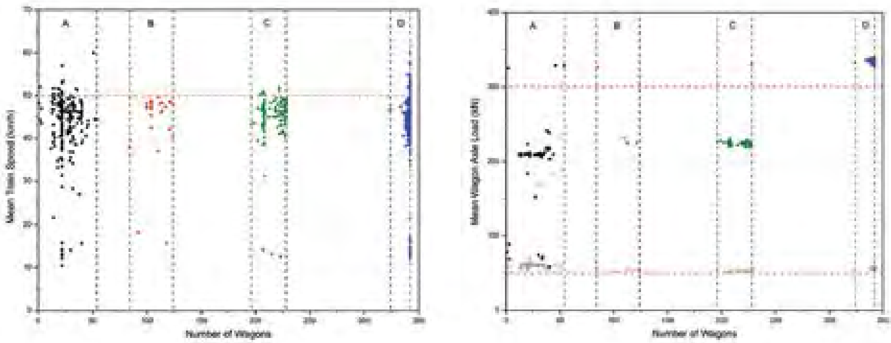
** Exceptions in the No. of Locomotives: 4 loco in A category; 5 loco in B; 2, 5-6 in C; 4, 7-8 loco in D;*
*** Notes on the No. of Wagons: k=2-54; l=84-124; m=99-124; n=90-104; r=108-114, s=110-114 and t=102-114;*



16.

Monitoring of Railway Loads and Traffic (2/2)

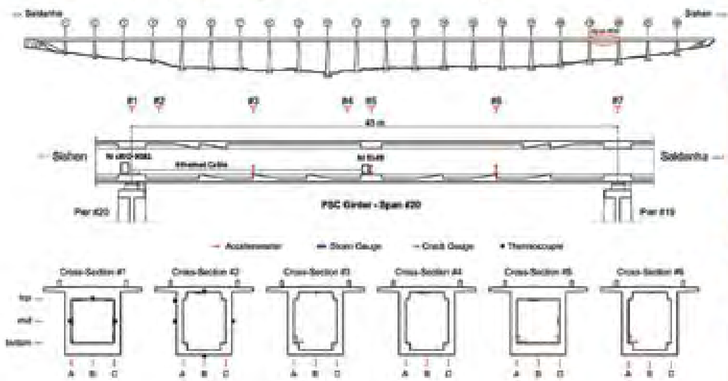
Analysis of 1225 trains running in 2016

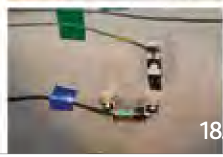


17.

The CoMSIRU Monitoring System

36-channel wired system for continuous monitoring

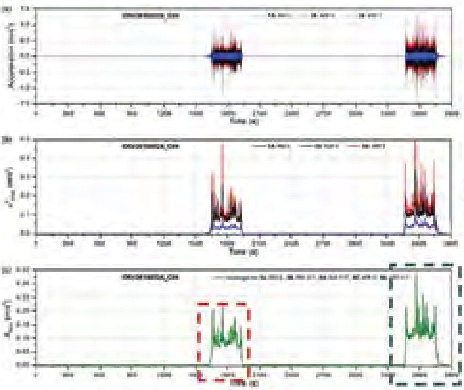


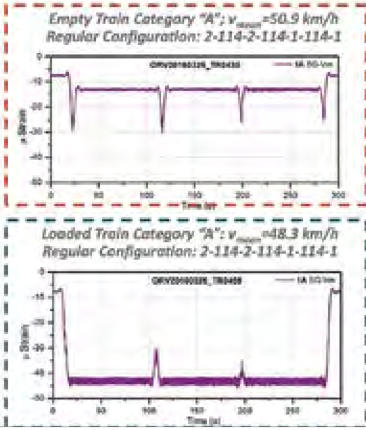


18.

Selected Results from Continuous Monitoring (1/4)

Acceleration signals and RMS values

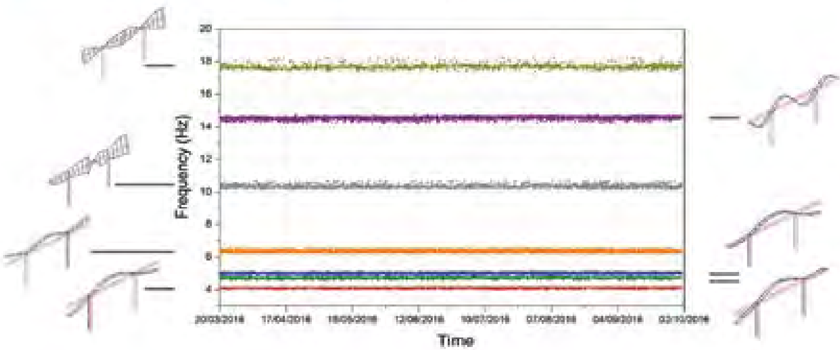




19.

Selected Results from Continuous Monitoring (2/4)

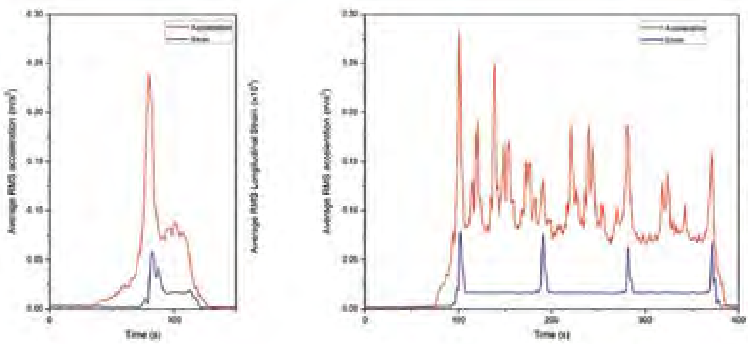
Automated Continuous Tracking of the Natural Frequencies



20.

Selected Results from Continuous Monitoring (3/4)

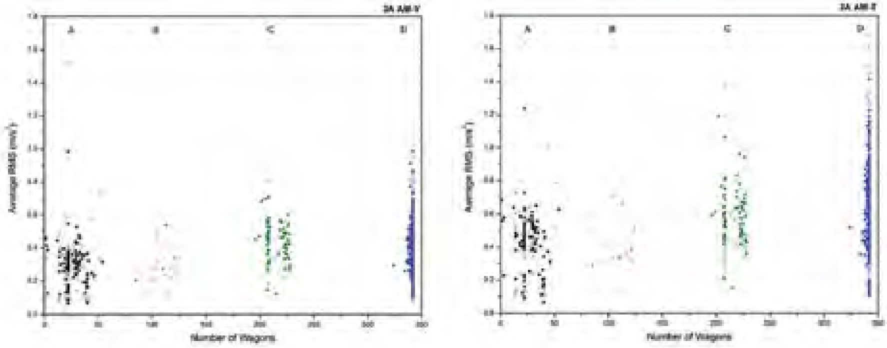
Average RMS functions of acceleration and strain



21.

Selected Results from Continuous Monitoring and WIM

Analysis of 1225 trains running in 2016



22.

Conclusions

- The ORV it is a highly critical structure because its repair, strengthening or replacement might be onerous and time consuming due to the large scale and continuous layout;
- The viaduct is currently crossed by the longest heavy haul train in the world; the current axle load equals the upper value assumed at design stage and leads to larger live load-to-dead load ratios;
- Periodic dynamic testing was performed to understand the girder behaviour affected by the periodic and multi-span layout. Local modes (i.e. pier modes) and modes involving the 23-span girder need to be better investigated to be separated from global modes;
- A train categorization has been investigated and established based on train (signal) length and configuration to better address the signal analysis and interpret monitoring data;
- Integrating data from the WIM-WIM system, the automated OMA (ambient response of the viaduct) and train signal analysis, taken into account the train category, might enhance the estimation of some performance indicators/factors.

23.

Thanks for Your Attention!

Acknowledgments:

TRANSNET freight rail

SA Heavy Haul

Concrete Materials & Structural Integrity Research Unit CoMSIRU

URCF

Questions?

2. Fatigue life of precast concrete sleepers when used on an open deck bridge

Andrew Goodhead

Abstract

Railway sleepers are integral components of a railway tracks. Due to better durability and larger loadbearing capacity precast concrete sleepers have largely replaced traditional hard wood sleepers, as an exception, wooden sleepers are still exclusively used on open decked steel bridges. For numerous reason many of which are not well documented in literature precast concrete sleepers have not been found suitable for use on open decked bridges. However due to the worldwide shortage of hard wood, it is increasingly difficult to replace deteriorated wooden bridge sleepers. It is thus out of urgent necessity that the use of precast concrete sleepers as replacement for wooden sleepers be thoroughly investigated.

A literature review reveals a limited understanding of a ballasted concrete sleeper's fatigue life however there is no recorded study on the fatigue life of a concrete sleeper supported on and open decked steel girder.

Experimental tests, simulating concrete sleepers near a bridge abutment will proved the majority of the data for this investigation. The experimental result will be used to try and select an appropriate constitutive relation for concrete fatigue mechanisms. Identifying and calibrating a concrete fatigue mechanism is a critical step in the process of numerical models of such systems.

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Concrete Materials &
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Fatigue Life of Precast Concrete Sleepers When Used on an Open Deck Bridge

1.

Contents

- Introduction
- Aims
- Methodology
- Results
- Conclusion

2.

Wood and Concrete Sleepers

3.

Title: Fatigue Life of Precast Concrete Sleepers When Used on an **Open Deck Bridge**

Open Deck

Closed Deck

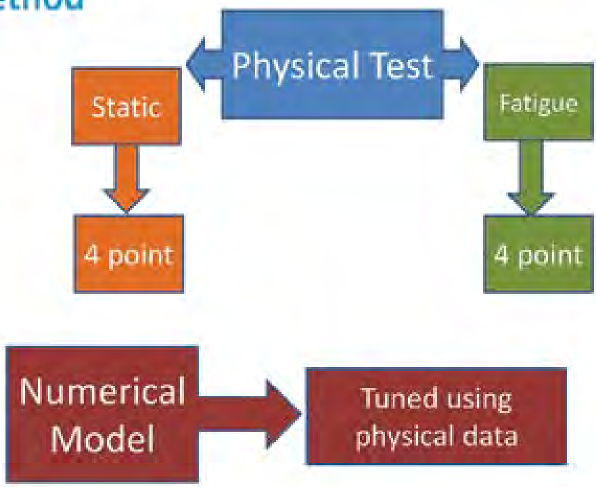
4.

Aims

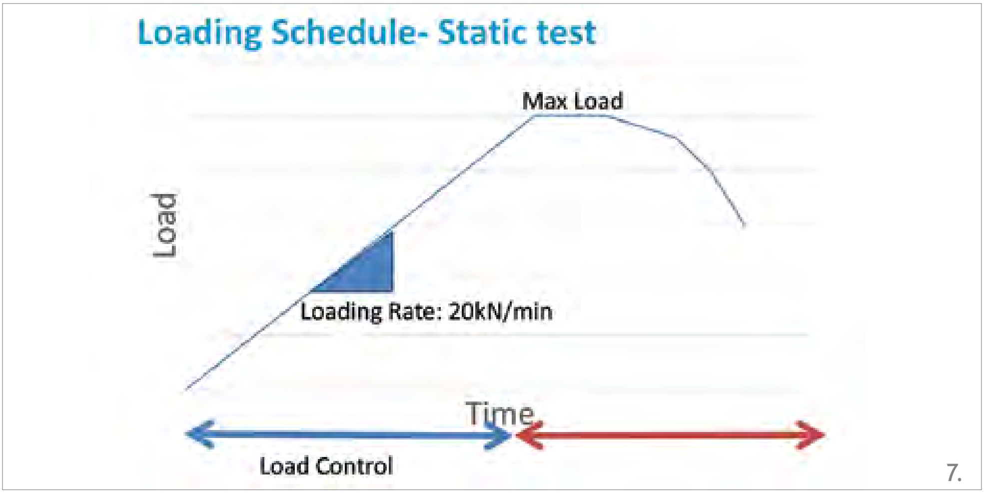
- To gain an understanding of the fatigue life of concrete sleepers
  - Specify the design life of the sleeper in terms of the number of repetitive loads
  - Identify the mode of failure

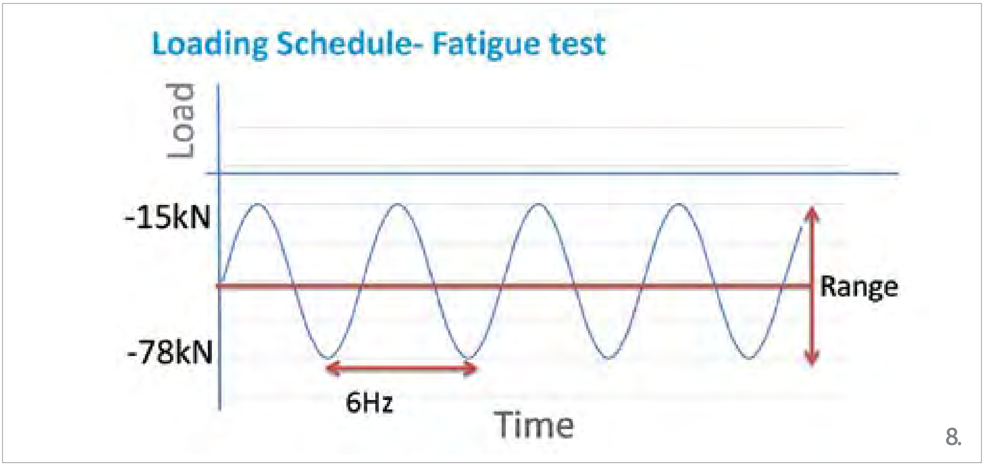
5.

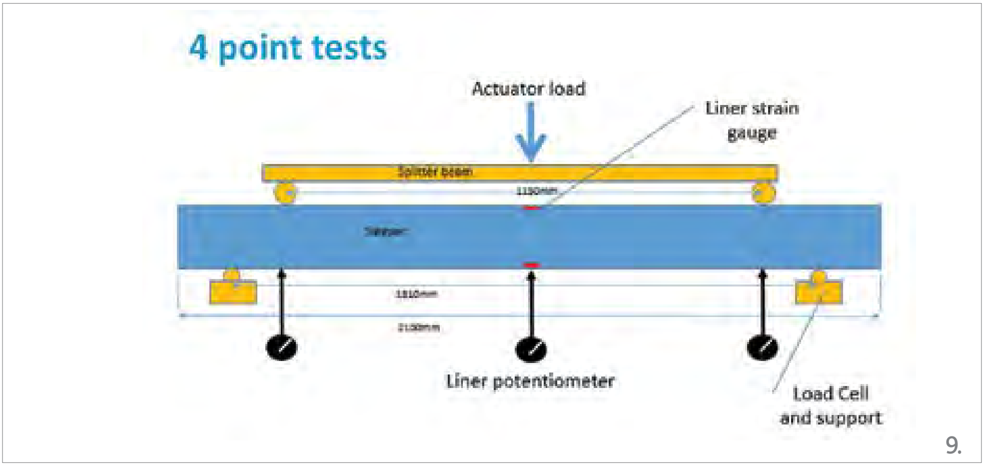
Method



6.


Loading Schedule- Static test
Max Load
Load
Loading Rate: 20kN/min
Time
Load Control
7.


Loading Schedule- Fatigue test
Load
-15kN
-78kN
Range
6Hz
Time
8.


4 point tests
Actuator load
Liner strain
gauge
Liner potentiometer
Load Cell
and support
9.

10.

Results

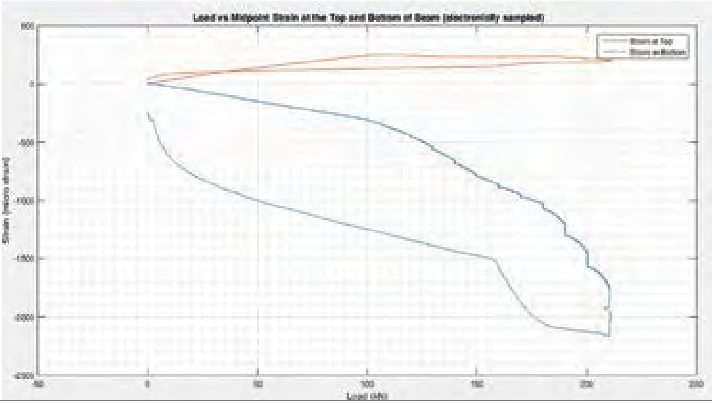
- Static Test
- Fatigue Test
- FEA Model

11.

Static 4 point test –Load Vs Displacement

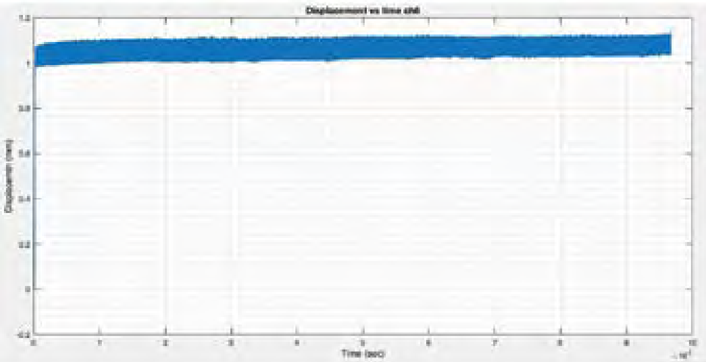
12.

Static 4 Point Test –Electically Measured Strain



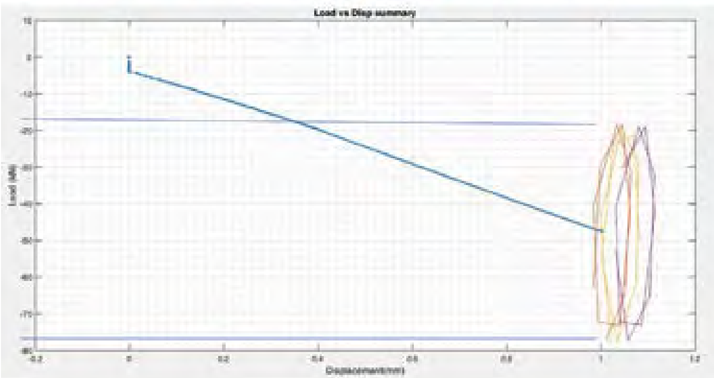
13.

Fatigue 4 Point Test – Midpoint Displacement vs Time



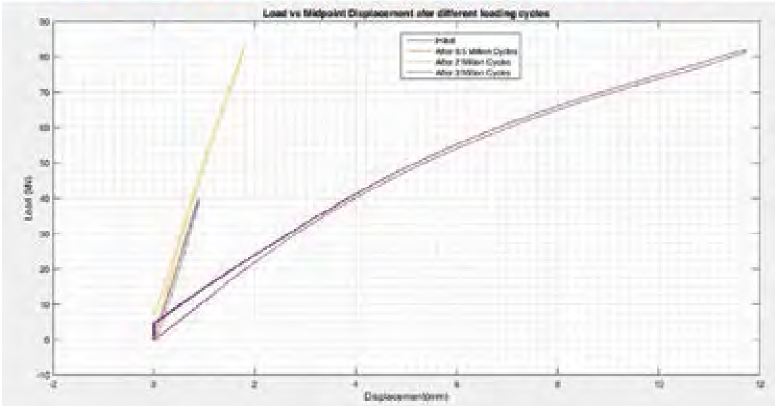
14.

Load vs Displacement Spanning 1 Million Cycles



15.

Static Load vs Displacement after Fatigue Loading Cycles



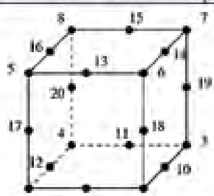
16.

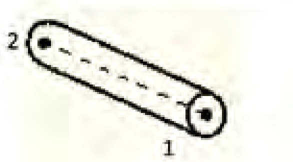
Compression Failure of Fatigued Beam at 225 kN

17.

Numerical Model

Material	Element name	Element length (mm)
Concrete: Concrete Damage Plasticity	C3D20R: An 20-node quadratic brick	30
Steel Tendon: Elastic Plastic	T3D2: A 2-node linear 3-D truss	30





18.

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Numerical Model –Mesh sensitivity

Element size (mm)	Mid point deflection (mm) 70kn 20node reduced integration - no steel	% difference
80	-1.32194	-0.0197
50	-1.32220	-0.0151
40	-1.32240	-0.0295
30	-1.32279	-0.0257
25	-1.32313	-0.0325
20	-1.32356	

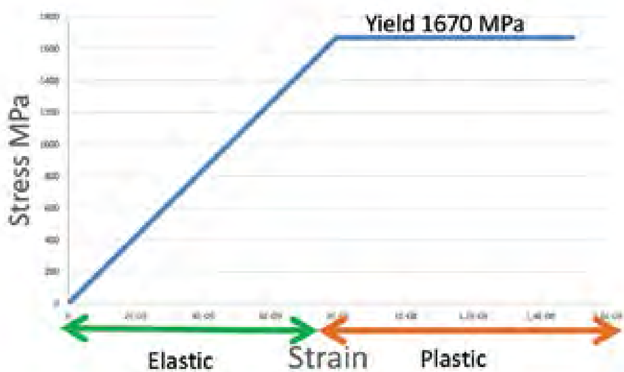
19.

Numerical Model-Material Properties

- Steel:
  - Perfectly elastic/Plastic
- Concrete:
  - Concrete Damage Plasticity Model (CDP)

20.

Steel: Perfectly Elastic/Plastic



21.

Numerical Model-Material Properties

- Steel:
  - Perfectly elastic/Plastic
- Concrete:
  - Concrete Damage Plasticity Model (CDP)

22.

Concrete Damage Plasticity

Concrete Damage Plasticity Input Parameters	
Compressive Strength (MPa)	60
Dilation Angle (degrees)	31
Eccentricity	0.1
fb0/fc0	1.16
Kc	0.66
Viscosity Parameter	0.0001
Element length (mm)	30
Crack Energy (N/mm)	0.156

23.

Viscosity Parameter

- Viscosity Parameter of 0.0001 was chosen so as to match the 13 distinct crack locations seen in the experimental beam.

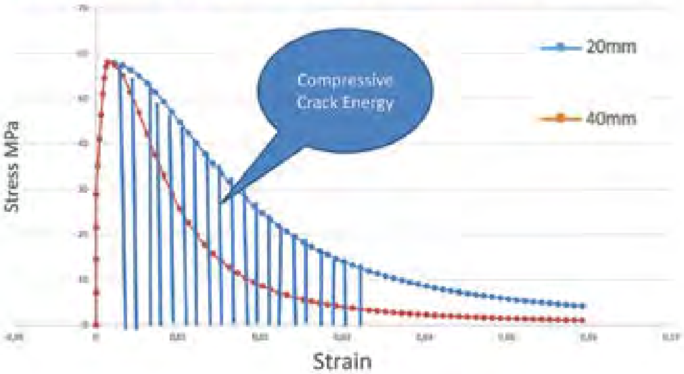
24.

Where to go from here

1. More Sleepers will be experimentally tested to achieve statistical reliability
2. CDP Model needs to be refined and tuned
3. Use the Abaqus model and experimental results to try and determine the likely mode of fatigue failure
4. Relate the fatigue life (number of cycles) to a sleepers life span in years

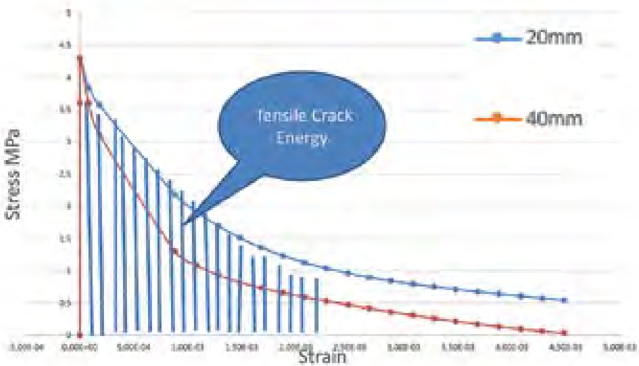
25.

Concrete Properties- Compressive



26.

Concrete Properties- Tensile



27.

3. Carbonation predictions for modern South African concretes

Nabeel Omar

Abstract

Concrete is regarded as the most used construction in the world. The consumption of this material is exponentially increasing as immense pressure is being posed onto the construction industry to supply more infrastructure to support the development of urbanisation, which can result in significant environmental consequences. One of the solutions to combat this problem was achieved by the introduction of partially replacing Portland cement (PC) with supplementary cementitious materials (SCM) in order to achieve sustainable construction. This practice is becoming prevalent within modern concretes worldwide.

Carbonation is one of the main mechanisms, which induces reinforcement corrosion. It involves carbon dioxide reacting with the alkaline constituents within concrete, which passivates the embedded steel to produce calcium carbonate. A decrease in alkalinity results in the depassivation of the steel, which in turn makes the steel vulnerable to corrosion. Alkaline concrete constituents, mainly calcium hydroxide is responsible for the relatively high pH environment within the concrete. It forms during the hydration reaction and its quantity is proportional to the amount of calcium oxide within the cement. This inclusion of SCMs results in the decrease in pH due to its lower calcium oxide content to produce calcium hydroxide.

In South Africa, the Durability Index (DI), a performance-based approach was adopted to quantify the durability of a concrete structure. This consists of three tests (oxygen permeability, sorptivity and chloride conductivity index tests). Each test relates to a specific transport mechanism, which contributes to the deterioration of the concrete structure. The results obtained from these tests (i.e. OPI and CCI) can be used as input parameters within the appropriate service life prediction model to determine the expected life span of the structure. However, the concrete mix designsused to formulate the models are significantly different to ones presently used within construction, thus the expected service life of modern concretes cannot be adequately determined. Therefore, the purpose of this research seeks to improve the DI approach by determine the relationship between DI values and the performance of modern concrete structures, specifically with regard to carbonation-induced deterioration.

The OPI test has a good correlation to carbonation depths and sensitive to various concrete parameters such as w:b ratio, binder type, curing condition and so forth. Furthermore, it is used as an input parameter to define medium-term carbonation depths i.e. accelerated carbonation, which are then used to determine long-term results of carbonation i.e. the carbonation service life model equation. As previously stated, the purpose of this research is to determine carbonation predictions for modern South African concretes. This will achieved by investigating various concrete mixes. The variables that will be investigated are the following: w:b ratio, SCM type (GGBS, GGCS, y ash and limestone) and the SCM partial percentage level. Finally, the laboratory experiments that will be conducted are the compressive strength test, OPI test, and the accelerated carbonation test.

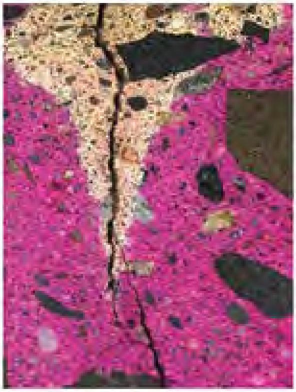
Carbonation Predictions

for modern South African concretes

Nabeel Omar

MSc Civil Engineering 2017 Candidate
Supervised by: Prof H. Beushausen

10 August 2017



1.

Aims & Objectives

- Identify need for carbonation predictions of modern SA concretes
- Carbonation Mechanism
- Explanation of the Carbonation Prediction Model
- Methodology
- Results

2.

Problem Statement

3.

Problem Statement

4.

Problem Statement

DI tests used to predict the performance and service life of structure.

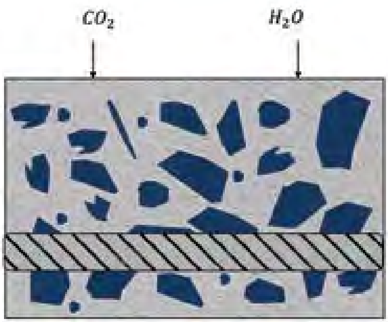
Vast research in durability predictions for common binder replacements:

50% Slag 30% Fly Ash

"What about replacements levels of 20, 40, 65%?"

5.

Carbonation Mechanism

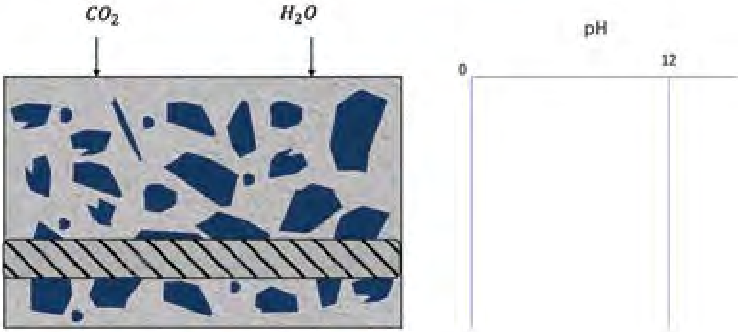


Carbonation Reaction

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

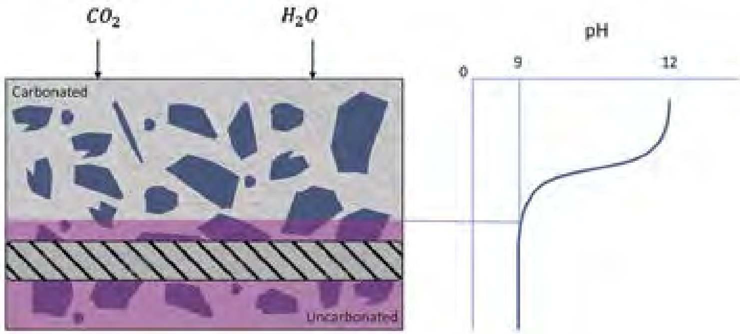
6.

Carbonation Mechanism



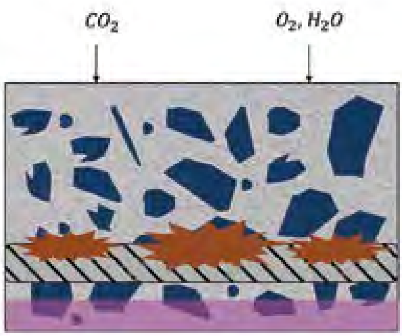
7.

Carbonation Mechanism



8.

Carbonation Mechanism



Anodic:

$2Fe \rightarrow 2Fe^{2+} + 4e^-$

Cathodic:

$2H_2O + O_2 + 4e^- \rightarrow 4OH^-$

Rust formation:

$2Fe^{2+} + 4OH^- \rightarrow 2Fe(OH)$

9.

Aim & Strategy

- Investigate the most commonly used binders in SA
- Test concrete with varying binder replacement percentages.
- **Determine a relationship between OPI values & carbonation for modern concretes.**
- Understand principle of the carbonation model
- Improve the pre-existing model of carbonation for modern concretes.

10.

Methodology

- Compressive Strength Test (28 Day)
- Oxygen Permeability Test (OPI)
- X-ray Diffaction test (XRD)
- Accelerated Carbonation Testing
- Carbonation Prediction Model proposed by Salvoldi

11.

Variables

Type	Variables
GGBS (BS)	20, 30, 40, 50, 60%
GGCS (CS)	20, 40, 60%
Fly Ash (FA)	20, 30, 40, 50%
Limestone	10, 20%
Commercial	CEM II 52,5N A-L + CEM II 42,5 B-M
Silica fume (SF)	5%
Ternary Mixes	SF + FA, SF + BS, SF + CS (5% + 25%)

w/b ratio: 0.5 & 0.65

12.

New Carbonation Model

New Carbonation Model (Salvoldi, 2010):

$$x = \frac{2D_{dry}\beta t_e}{a}$$

$$\beta = 23{,}32\ \beta_r\ \times \beta_D$$

Relative humidity (RH) factor diffusion: $\beta_D = \left(1 - \frac{RH}{100}\right)^2$

RH-reaction coefficient: $\beta_r = \left(\frac{RH}{100}\right)^{2,6}$

Effective exposure time: $t_e = \left(1 - \frac{ToW}{365}\right)$

13.

Carbonatable Material

$$[CH] = \frac{3}{2}[C_3S] \times F_{C_3S} + \frac{1}{2}[C_2S] \times F_{C_2S} - 4[C_4AF] \times F_{C_4AF} - [C_3A] \times F_{C_3A} + [CSH_2] + [C] \times P_c - \frac{3}{2}[S] \times P_s - 4[A] \times P_A$$

[CH] = Hydration reaction

Consumed by gypsum (hydration reaction)

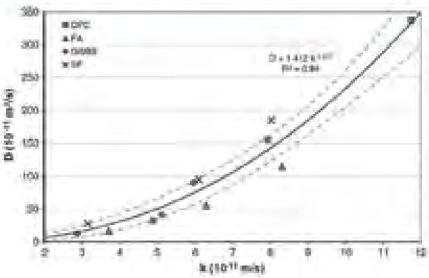
Pozzolanic reactions

- Degree of hydration (F_i)
- Composition of cement and binders
- Degree of pozzolanic activity (P_i)

14.

New Carbonation Model

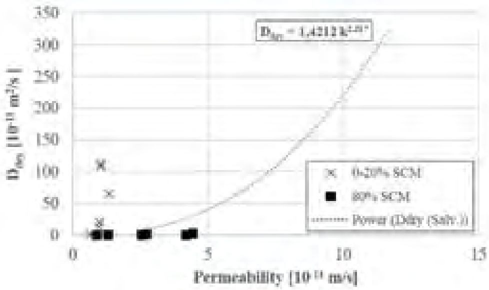
$$D_{eff} = \frac{A^2 a}{2c} \div \beta_D$$



$$D_{dry} = \left(1{,}4 \times \left(\frac{k}{10^{-11}}\right)^{2,2}\right) \times 10^{-11}$$

15.

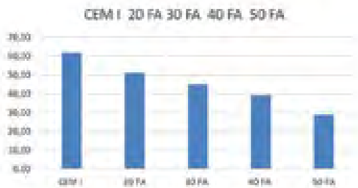
Limitations of Models

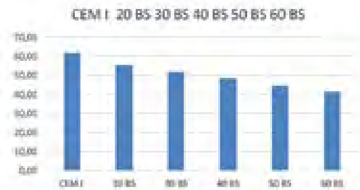


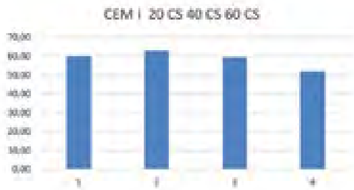
- No power relation
- Negative CH content

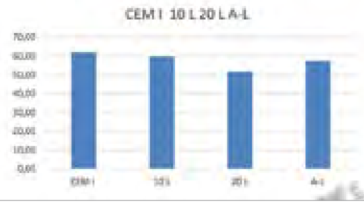
16.

Compressive Strength (w/b = 0,5)



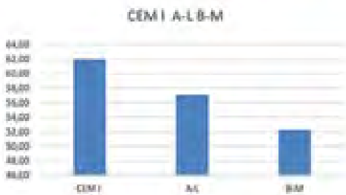




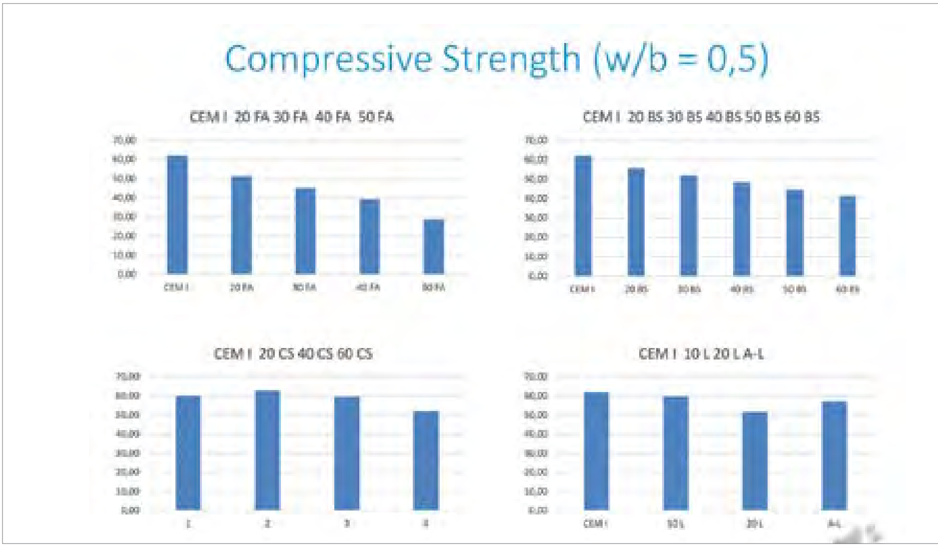


17.

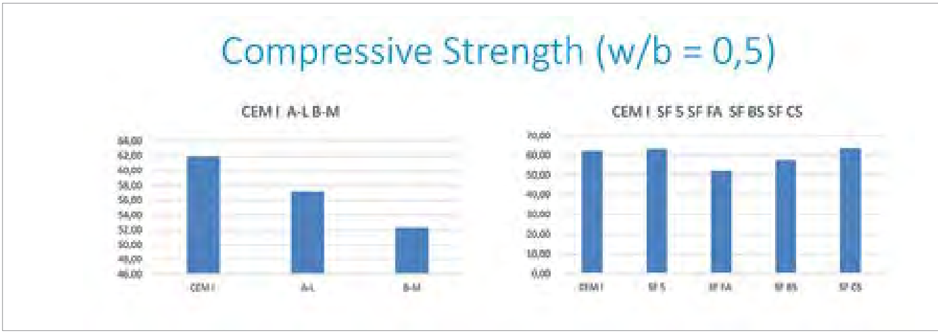
Compressive Strength (w/b = 0,5)



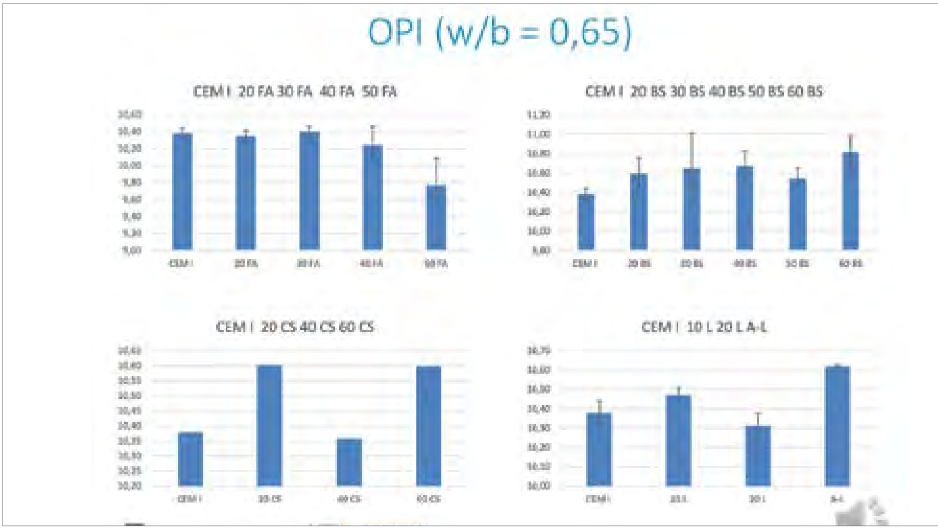
18.


Compressive Strength (w/b = 0,5)
CEM I 20 FA 30 FA 40 FA 50 FA
CEM I 20 BS 30 BS 40 BS 50 BS 60 BS
CEM I 20 CS 40 CS 60 CS
CEM I 10 L 20 L A-L

17.

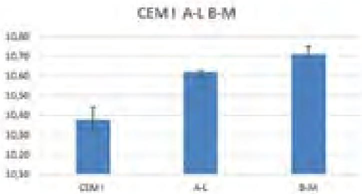

Compressive Strength (w/b = 0,5)
CEM I A-L B-M
CEM I SF 5 SF FA SF BS SF CS

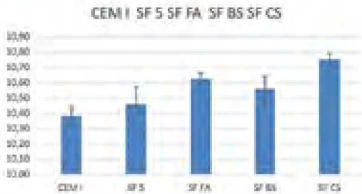
18.


OPI (w/b = 0,65)
CEM I 20 FA 30 FA 40 FA 50 FA
CEM I 20 BS 30 BS 40 BS 50 BS 60 BS
CEM I 20 CS 40 CS 60 CS
CEM I 10 L 20 L A-L

19.

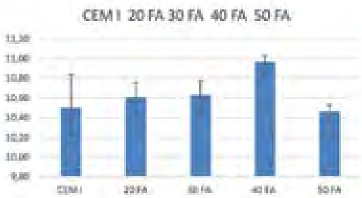
OPI (w/b = 0,65)

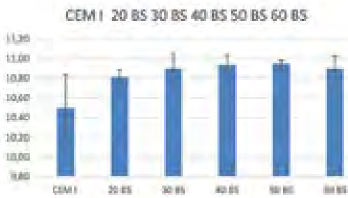




20.

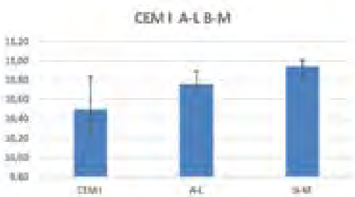
OPI (w/b = 0,5)

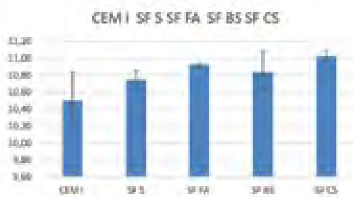




21.

OPI (w/b = 0,5)

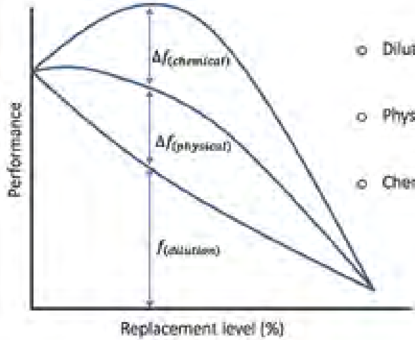




22.

Effects of SCM/fine fillers

$$f_{(addition)} = f_{(dilution)} + \Delta f_{(physical)} + \Delta f_{(chemical)}$$



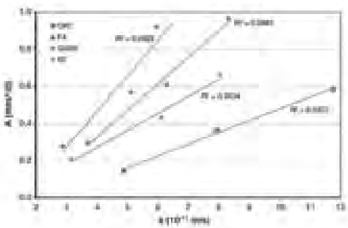
- Dilution: removal of cement
- Physical: heterogeneous nucleation & particle packing
- Chemical: Latent hydraulic binders & pozzolanic reactions

23.

Old Carbonation Model

Old Carbonation Model: $x = At^n$

Carbonation coefficient $A = \frac{x}{\sqrt{t}}$



24.

Thank you for your attention!

4. Potential admixture for concrete technology made from the sap of Trimfetta Pendrata A. Rich.

Dr Ines Ngassam

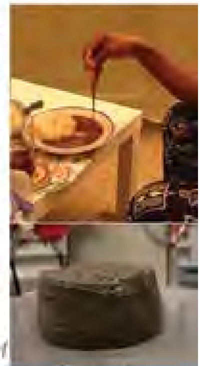
Abstract

The African continent is experiencing an enormous economic boom, which mainly puts pressure on the entire continent to develop infrastructures. Infrastructure development is accompanied by a significantly higher demand for cement and concrete. However, to date Africa is the continent where cement and concrete are by far the most expensive and in conjunction with the economic purchasing power of the population the least affordable in the world. For instance, a US citizen needs only 0.5 working days to afford 1T of cement while a Rwandan citizen needs 191 days to afford this same amount of cement. The high price of cement is largely responsible for the high price of concrete, but there is also an ecological issue: to use too much cement in concrete in general due to the energy intensive processing and transportations as well as the carbon emissions. A more efficient use of cement could reduce the cost of concrete as well as the environmental impact. However, the more efficient use is limited in Africa by the limited availability and high prices for admixtures. This is largely induced by the fact that most of the admixtures used in concrete technology are manufactured outside Africa. However, Africa is also known for its biodiversity which offers vast possibilities in terms of research and potential solutions.

It is in this spirit that many studies have started to focus on natural materials for their application in civil engineering, such as this introductory study. The most interesting benefits of the use of natural materials are their availability, their environmental appropriateness, and the potential to use waste materials such as husks, cassava peels or starch. This extended abstract presents first results of some preliminary tests that have been carried out on the sap of a tree called Triumfetta Pentandra A. Rich. The local name in Cameroon, where it comes from, is Nkui. Nkui is known especially in the western part of Cameroon as a festive meal for women that just gave birth. Nkui itself is a sticky brown sauce (due to the 19 spices used to cook it) which is eaten with maize couscous. It is obtained by the extraction of the sap of the tree rod. Triumfetta Pentandra is a plant which grows in various modifications in all tropical areas of Africa. Hence it is an available resource.

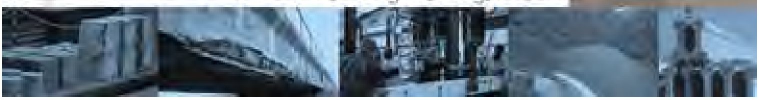
This study presents some basic tests that have been conducted on cement paste made with different ratios of Nkui solution with the aim to see if this sticky solution could affect some properties of the cement paste. The observations presented here are on the flowability, the density and the setting time. The first results show that the nkui gives to cementitious materials a thixotropic behaviour that reduces their workability, without affecting their hardening and their mechanical properties.

Potential admixture for concrete technology made from the sap of triumfetta pendrata A. Rich



KEYS

Dr Ines TCHETGNIA NGASSAM



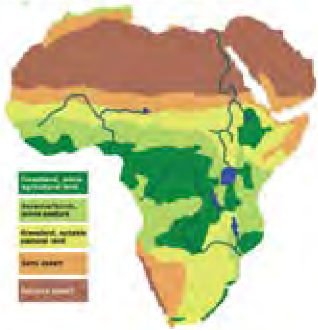
1.

Some observations

- High cost of concrete in Africa
- Increase of the demand of cement and admixtures
- Unexploited potential of waste and bio-materials in Africa
- High capacity to produce waste and bio-materials in Africa
- Ect.

2.

What is the Triumfetta pendrata A. Rich?



Properties*	
Weed Potential	Yes
Habit	Shrub
Height	4.00 m
Growth Rate	Fast
Pollinators	Bees
Cultivation Status	Wild

3.

Triumfetta pendrata A. Rich = Nkui

http://fryou-maison.over-blog.fr/article-les-benedictions-2-48072105.html

4.

How can Nkui affect properties of a cementitious material?

5.

Approach of study

1. Extraction of the Nkui sap

Bark kneading in hot Water

6.

Approach of study

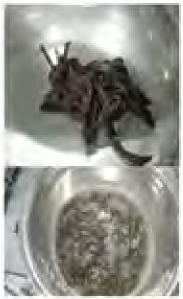
1. Extraction of the Nkui sap

7.

Approach of study

1. Extraction of the Nkui sap

Bark kneading in hot Water



8.

Approach of study

2. Sample preparation

Tests	Cementitious mix	Solution/cement ratio	Sand/cement ratio	Mix process
Workability	Cement paste	0.8	-	Manual
Porosity				
Setting time		0.4		5L mixer
Mechanical properties	Mortar	0.55	3	

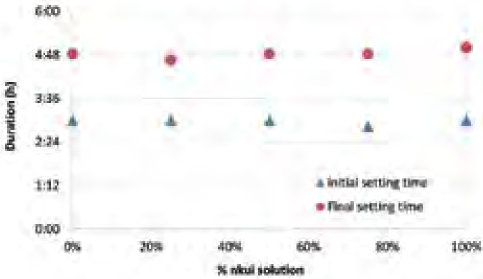
- *Cement: CEM II / B-M (L) 42.5N*
- *Sand: dune sand*
- *Solution: water + nkui solution*

9.

Results

1. Setting time

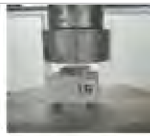
Measured with a Vicat device according to EN 196-3:2008



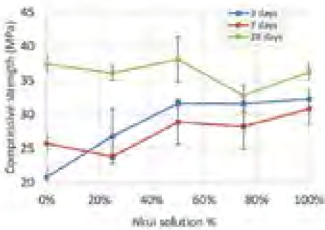
10.

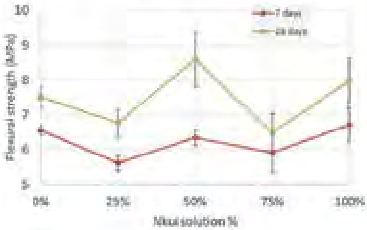
Results

2. Hardened state



Measured on 40x40x160 mm prisms samples, based on the EN 196-1:2008





11.

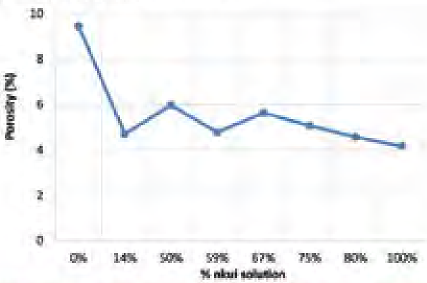
Results

3. Porosity

On 2 pieces of the hardened cement

- md, mass before the saturation
- ms, mass after the saturation

$$\%p = \frac{ms - md}{md} \times 100$$



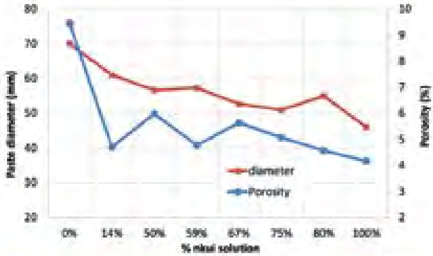
Decrease of the porosity of the cement paste with the increase of the amount of nkui solution

12.

Results

4. Flowability

Cement paste drops from 10mL syringe



Decrease of the flowability of the cement paste with the increase of the amount of nkui solution

13.

Results

Combination of nkui and superplasticiser

w/c = 0.3

w/c = 0.3
0.08% Nkui

w/c = 0.3
0.35% PCE

w/c = 0.3
0.35% PCE
0.08% Nkui

Rheology modifying admixtures for concrete taken from nature | 26. Kolloquium | Rheologische Messungen an mineralischen Baustoffen | OTH Regensburg

Nkui solution has a thixotropic behaviour in cement paste

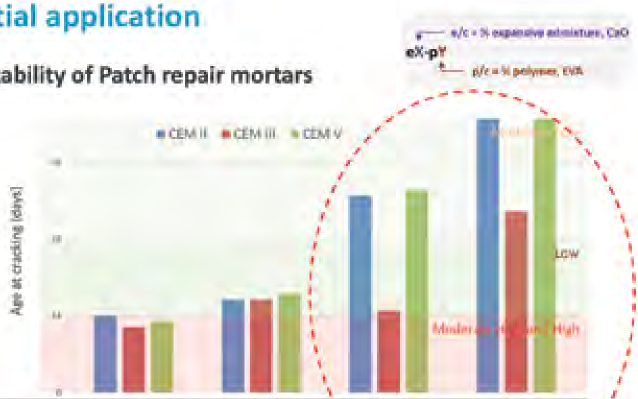
14.

Applicable cement admixture for sub-Saharan Africa (?)

15.

Potential application

Workability of Patch repair mortars



	e0-p0	e10-p0	e0-p20	e10-p20
SP (mL/Kg)	5	7,5	-	-
Slump (mm)	120	90	200	235

16.

Summary

- Triumfetta pendrata A. Rich - Nkui sap – does not affect the setting time and the mechanical properties of cementitious materials
- Triumfetta pendrata A. Rich - Nkui sap – reduces the porosity and the flowability
- Triumfetta pendrata A. Rich - Nkui sap – acts as an thixotropic admixture on cement pastes

Future actions

- Nkui sap effects on durability. Curing
- Dig deeper in to the rheological behaviour
- Nkui chemical composition

17.

18..

5. Alkali aggregate reaction: current Western Cape concrete

Zubair Mahomed

Abstract

Alkali-aggregate reaction, AAR, is an adverse chemical reaction between the alkaline pore solution and reactive silica in concrete. The reaction can be categorised in one of three classes based on the type of aggregate involved. In the Western Cape, the prominent use of greywacke and granite aggregates implies that alkali-silica reaction, ASR, will be the main concern. However, ASR has been mostly studied from a scientific perspective and standardised tests, which are broad in context, have been established. The main concern is that the most common tests do not accommodate for the concurrent use of both 'reactive' coarse and 'reactive' fine aggregates, which is generally present in 'real-life' situations. This occurrence is what has been investigated in this study.

The study was thereafter segmented into three phases. Phase 1 of this research was dedicated to investigating any behavioural pattern which may arise with the simultaneous use of reactive fine and reactive coarse aggregates. In this effect, the AAR-2 AMBT was slightly modified and conducted on nine mixes. From the results of Phase 1, it was found that a pessimum effect occurs when approximately 40 to 60% of the fine aggregate blend is constituted of greywacke crusher sand. Moreover, all the mixes tested in this phase were deemed 'slowly reactive' in terms of ASR as the expansion measured was in the range of 0.1 to 0.2%. Additionally, it was found that the formation of the gel product does have a negative impact on compressive strength as cubes whereby the reaction was encouraged had a lower strength than normally cured cubes. Phases 2 ensues whereby the critical mix from Phase 1 (50% crusher sand in sand blend) was complemented with cement extenders with the aim of mitigating the expansion due to ASR. As expected, both the Class F fly ash and Corex slag proved to be effective mitigation measures, that is reduced expansion to less than 0.1%, when dosed correctly. It was also found that the fly ash was relatively more effective than the corex slag. Finally,

Phase 3 delved into the mechanisms of the mitigation processes involved when using cement extenders. It is theorised that the extenders reduce the expansion by firstly reducing the total available alkali content from the binder (dilution process) and secondly by binding free alkalis into compounds from the pore solution. As such, in this phase an inert filler was used instead of the cement extenders but in the same proportions as in Phase 2. Comparison between the results show that the limestone filler does reduce the expansion but to a much lesser extent than the cement extenders, therefore confirming the occurrence of the reaction effect.

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

Concrete Materials & Structural Integrity Research Unit

Alkali Aggregate Reaction:

Current Western Cape Concrete

Zubair LALL MAHOMED

Supervised by: Prof Alexander

1.

1.

Outline of presentation

- Problem statement
- Aim & strategy
- Methodology
- Results (to date)
- Conclusions

2.

Problem statement

3.

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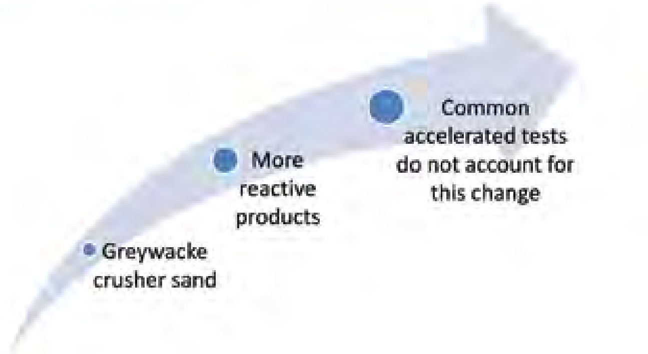
IYUNIVES

Local industry



4.

Aim & strategy

5.

Objectives

1. Investigate the effect of crusher sand
2. Investigate the ASR mitigation extent of SCMs
3. Investigate the dilution and reaction effect of SCMs

6.

Methodology

7

Test methods

1 Indicator test – Accelerated mortar bar test (AMBT)

2 Microscopic analysis

3 Co

8.

Test review of AMBT

Standard	ASTM C227-10	ASTM C1260-14	ASTM C1567-13	SANS 6245	RILEM AAR-2
Cement type	Job cement	Low alkali cement	Job cement	Low alkali cement	High alkali
Aggregate grading	Graded	Graded	Graded	Graded	Graded
Mould size (mm)	25×25×285	25×25×285	25×25×285	25×25×285	25×25×285 or 40×40×160
Testing period (days)	Up to 6 months	16	16	14	16
Temperature (°C)	38	80	80	80	80

More desirable to least desirable →

9.

Modifications to AAR-2

1. CEM II/A-L 52.5N – boosted alkali content
2. Ungraded aggregates
3. Use of 40×40 mould for micro-concrete

10.

Test phases

Phase 1

- Varying crusher sand content
- 9 mixes
- AAR-2, compressive strength, microscopy

Phase 2

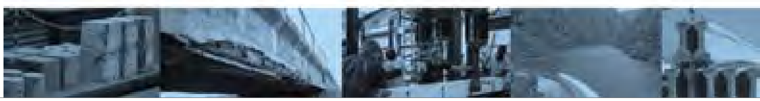
- Varying cement extender content
- 6mixes
- AAR-2, compressive strength, microscopy

Phase 3

- Varying limestone content
- 6 mixes
- AAR-2, Pore expression method microscopy,

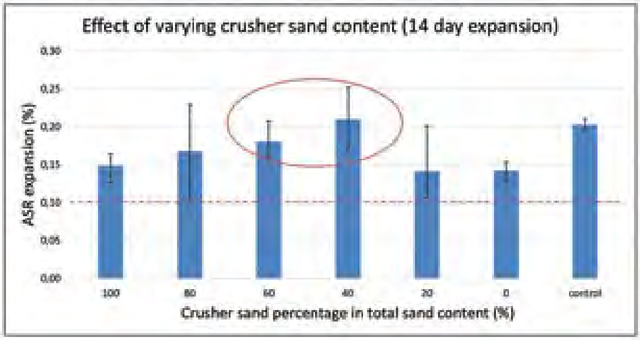
11.

Results



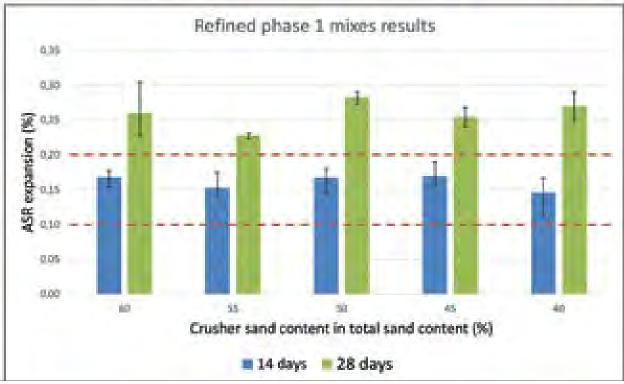
12.

14 days AAR-2 results (Phase 1)



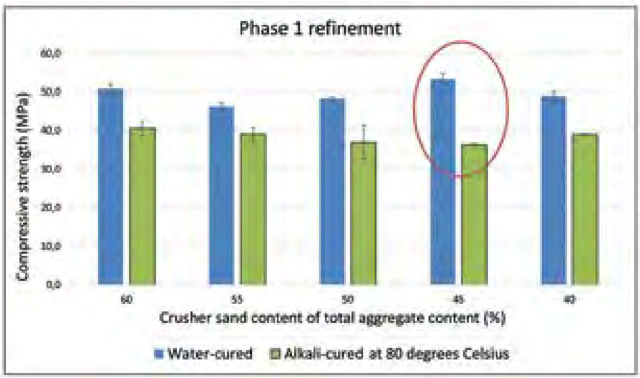
13

14 days AAR-2 results (Phase 1 refined)



14.

Compressive strength results (Phase 1)



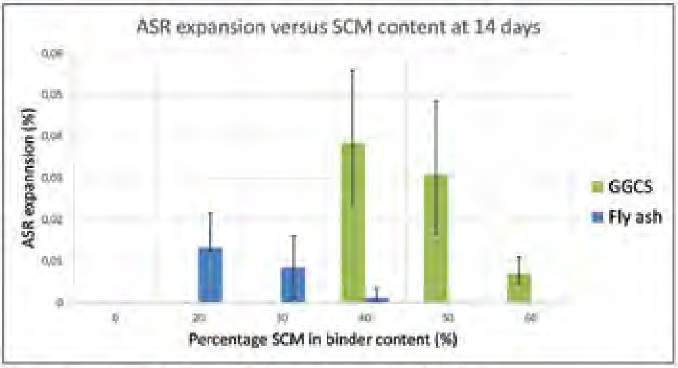
15.

Phase 1 – Main findings

- All the mixes can be classified as slowly reactive;
- Pessimum effect between 40-60% crusher sand content;
- Use of crusher sand alone is more detrimental than micro-concrete;
- No correlation between crusher sand content and compressive strength; and
- Biggest reduction in strength was 31% (45% crusher sand content)

16.

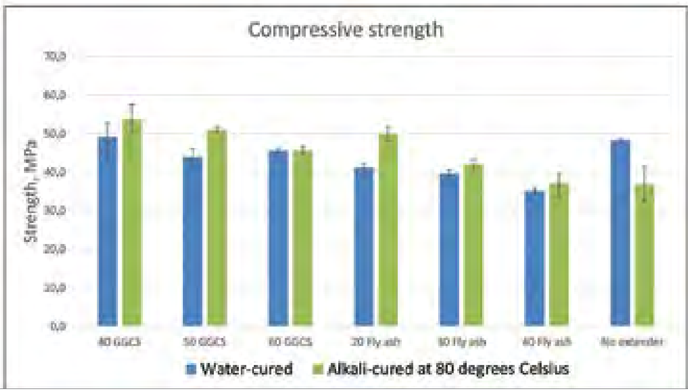
14 days AAR-2 results (Phase 2)



Note: Control with 0 % extender had an expansion of 0,167%

17.

Compressive strength results (Phase 2)



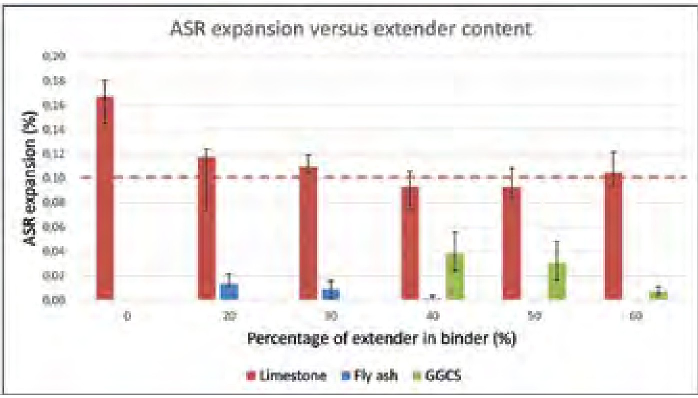
18

Phase 2 – Main findings

- All mixes below the 0,10% expansion limit;
- Maximum reduction using 40% fly ash;
- Fly ash more effective than Corex slag;
- Compressive strength decreases as we increase SCM content; and
- We may infer that the hydration process takes precedence for alkali-cured specimens.

19

14 days AAR-2 results (Phase 3)



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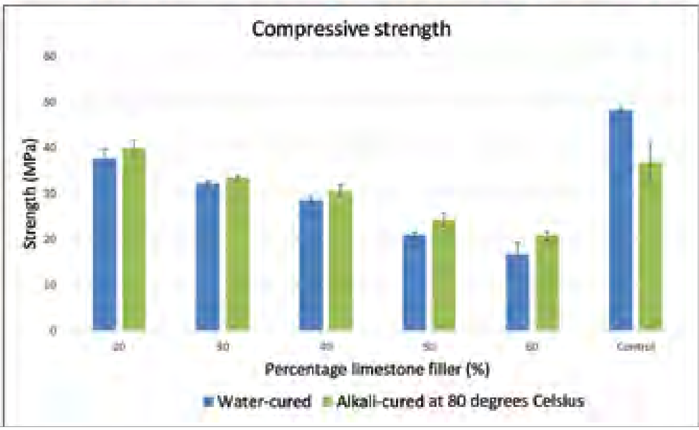
Compressive strength results (Phase 3)



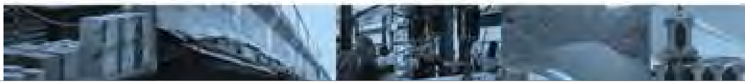
21.

Phase 3 – Main findings

- All mixes around to the 0,10% expansion limit;
- Reduction is marginally lower than when using FA or GGCS;
- Maximum reduction using 40% limestone filler;
- Compressive strength decreases as we increase SCM content; and
- We may infer that the hydration process takes precedence for alkali-cured specimens.

22.

Conclusion



23

Conclusions

- The use of reactive fine aggregate and coarse aggregate in conjunction affects the ASR expansion;
- A pessimum effect was observed, inferring that grading of aggregates in tests may produce inaccurate results;
- Cement extenders such as fly ash and corex slag are effective in mitigating ASR expansion if appropriately dosed; and

24

23

6. Assessing the conformity of South African Patch Repair Mortars (PRMs) to the EN 1504-3 performance specifications

Brian Abala

Abstract

Currently, there exists many repair products in the market which has resulted in a challenge in the specification of repair products by engineers. There exists no readily available and well established procedures that would guide the ranking of the existing commercial non-structural concrete patch repair mortars (PRM) to how they meet the performance requirements. This ranking will be based on the cracking tendency. The performance of patch repair mortars with respect to cracking and bonding depends to a large degree on material properties such as tensile strength, elastic modulus, creep, and rate of hydration (Beushausen and Alexander, 2006). To determine the age of cracking of these repair mortars, ring tests cast in accordance to the ASTM C 1581 were used. Mechanical properties are also measured with the use of the compressive strength test, tensile strength and tensile relaxation. Durability index based performance tests i.e. Oxygen Permeability Index (OPI), Water Sorptivity Index (WSI) and Chloride Conductivity Index (CCI) are determined.

PRMs from the following suppliers will be tested; Sika, Pro-Strut, BSF, a.b.e and Mapei. This study will rank the commercial PRMs using the ring test to ASTM standards. The age at cracking will be determined. Guidelines /limiting values for the ring test age at cracking will be followed. As a minimum, two electrical resistance strain gages will be used to monitor the strain development in the steel ring.

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Concrete Materials &
Structural Integrity Research Unit

Assessing the conformity of South African Patch Repair Mortars (PRMs) to the EN 1504-3 performance specifications

Presented by: Brian Vukindu

Supervisor: Prof. Hans Beushausen

1.

Presentation outline

- ❖Introduction
- ❖Problem statement
- ❖Research objectives
- ❖Research methodology
- ❖Research significance & scope

2.

Introduction

3.

Problem Statement

❖Existence of many PRM products

4.

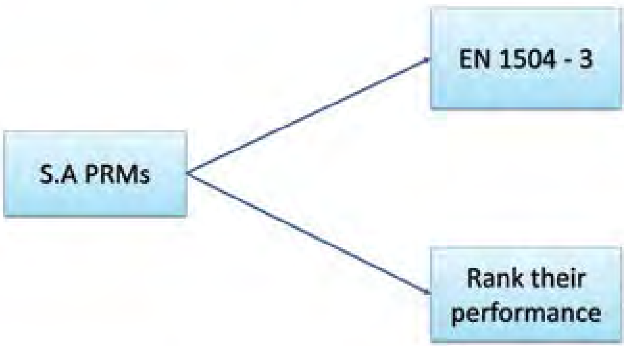
Problem Statement

❖Lack of standards and guidelines in S.A

❖Lack of procedures of ranking of the existing commercial products

5.

Research Objectives



6.

Research methodology

- ❖ Literature review
- ❖ Material selection & collection
- ❖ Test methods
- ❖ Analysis & discussion of results
- ❖ Conclusion

7

Methodology

❖ Test methods (Performance characteristics)

- Compressive strength
- Adhesive bond – Bond strength test
- Restrained shrinkage/expansion – Ring test
- Durability
  - Durability index tests
  - Bulk diffusion
  - Acc. Carbonation test

8.

Research significance & scope

- This study will assist the industry on specifying PRM products in S.A
- This work is limited to commercial non-structural PRMs available in S.A.

9.

Thank you.

10.

7. The packing of powder materials for a reduction in the clinker content of concrete

Matthew Holmes

Abstract

Globally, concrete is the most widely used construction material. Its embodied energy is relatively low yet, due to the vast quantities that are produced annually, there are substantial emissions associated with it. Of the concrete material constituents, the manufacture of clinker, the basis of all conventional cements, contributes the most significant emissions. Therefore, with the hope of reducing the emissions associated with concrete manufacture, there has been extensive research into how the clinker content of concrete can be reduced without neglecting desired engineering properties.

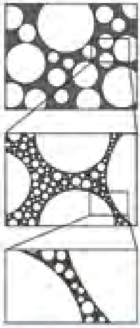
Methods for the reduction of clinker have included the partial replacement of clinker by various supplementary cementitious materials (SCMs) as well as the consideration of alternative binders with lesser global warming potential. However, so far, the use of SCMs are subject to their availability and many alternate binders are only applicable to niche markets. Further methods have considered the modelling and particle packing optimisation of concrete materials. Initially, this was done for the coarse and fine aggregate components but subsequently, the largest potential for the reduction in the clinker content of concrete was found to be the optimisation of the powder material phases. The influences on the packing of powder materials are not the same as those for coarser particles and therefore coarse particle packing models cannot be directly extended to powder phases. Instead, they need to include influences specific to powder materials such as van der Waals and electrostatic interparticle forces.

This research entails an investigation into the application of powder-particle packing modelling for the reduction of clinker content in concrete. Objectives comprise the maximisation of powder packing density to enable a reduction of clinker content without detrimentally affecting desired engineering properties. The investigation comprises the analytical modelling of various material combinations, aiming to find optimal combinations which maximise packing density. Modelling includes the application of two theories: discrete (Compaction Interaction Packing Model (CIPM)) and continuous (Modified Andreasen and Andersen Curve (MAAC)) poly-disperse particle systems. Modelling outputs will be verified experimentally, allowing the comparison of the accuracy of the two models and their theories. Furthermore, experimental findings will also allude to the effects of the optimised material combinations on fresh concrete properties and how the outputs from modelling might need to be further adjusted.

Ultimately, this research aims to address the applicability of powder-particle packing modelling for the reduction of clinker content in concrete. Practically, this will be assessed by the extent that the parameter of strength per kilogram clinker per cubic meter of concrete can be maximised.

Powder packing optimisation for clinker reduction in concrete

Matthew Holmes
University of Cape Town, South Africa



1.

Outline of presentation

- Background
- Introduction
- Methods
  - Particle packing modelling
  - Experimental assessment of packing density
- Preliminary results
  - Assessment of most appropriate experimental procedure
- Comments and observations
- Way forward
- Questions

2.

Background

Van Den Heede & De Belie (2012)
Witi & Stevens (2014)

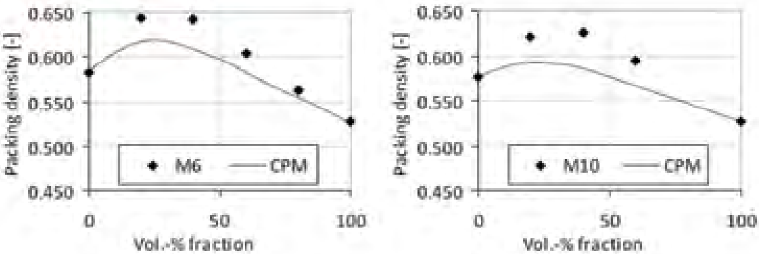
3.

Introduction

- Efficient use of Portland cement clinker
- Increased packing density enhances concrete microstructure
- Allowance for clinker reduction without detrimentally affecting strength
- Application of particle packing modelling and increased filler content

4.

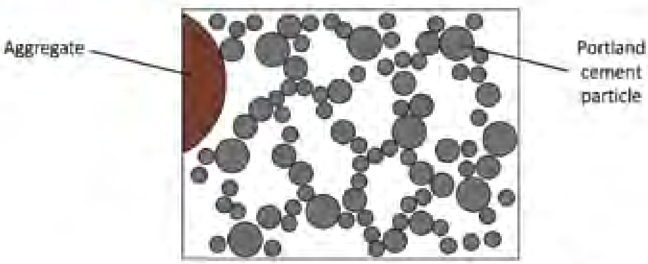
Introduction



Failure of Compressible Packing Model to accurately predict the packing density of various quartz powders M6 and M10

5.

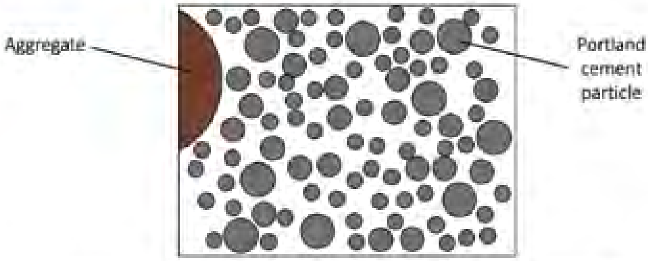
Introduction



Poor packing of Portland cement particles in water

6.

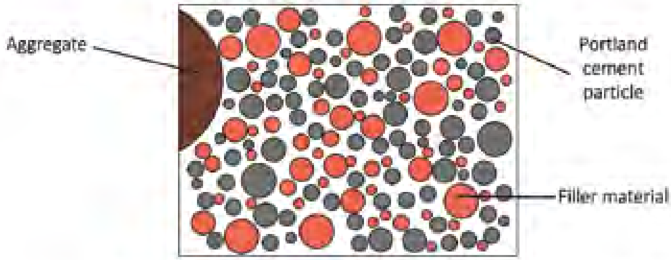
Introduction



Increased dispersion of particles with the use of superplasticiser

7

Introduction

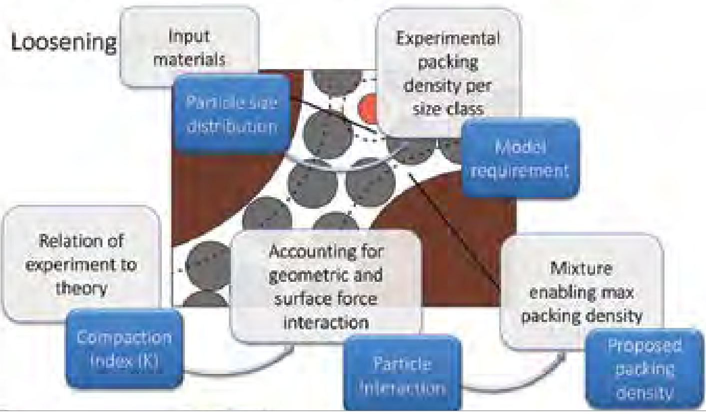


Increased packing capability due to proper dispersion and use of effective filler material

8.

Compaction Interaction Packing Model

An analytical packing model accounting for particle interactions



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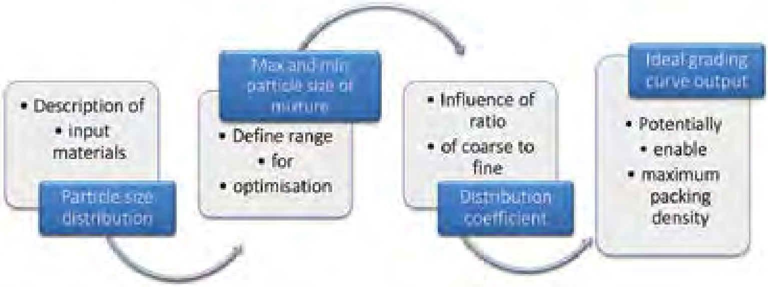
Modified Andreasen and Andersen Curve

An ideal grading curve



10.

Experimental Investigation

- Wet packing method (Wong and Kwan, 2008)
- Centrifugal consolidation (Miller et al., 1996)
- Mixing energy test (Marquardt, 2002)

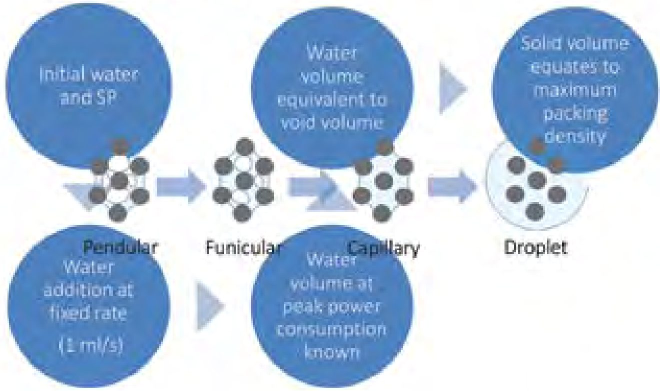
11.

Mixing energy test

- Indirect measure of packing density from water demand
- Power consumption with the addition of water at a constant rate (approx. 1ml/s)
- Water volume at peak power consumption corresponds to void volume

12.

Mixing energy test



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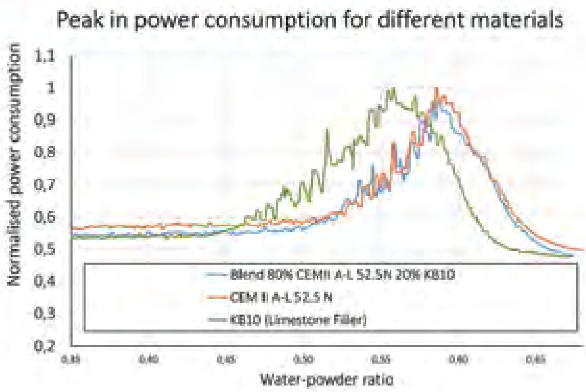
Experimental setup

14.

Preliminary mixing energy results



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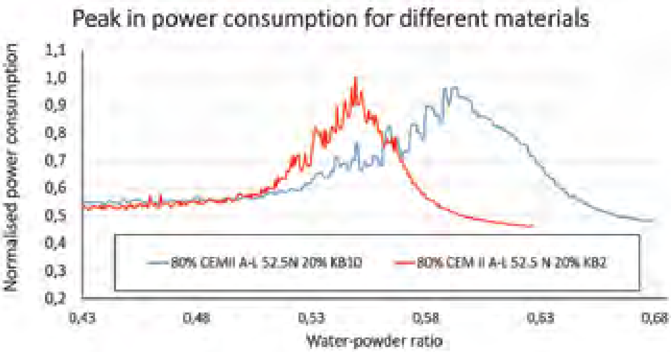
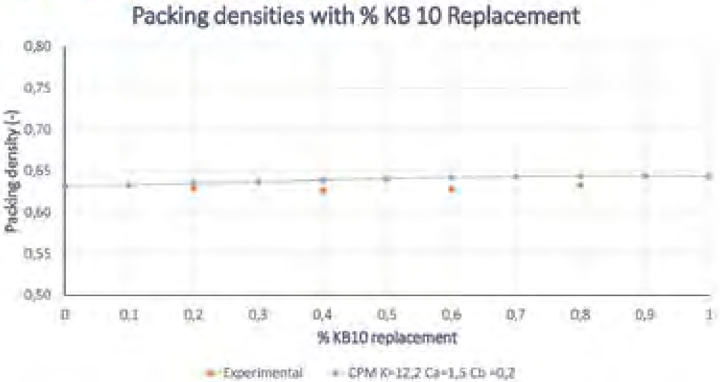
Preliminary mixing energy results



16.

Packing density results



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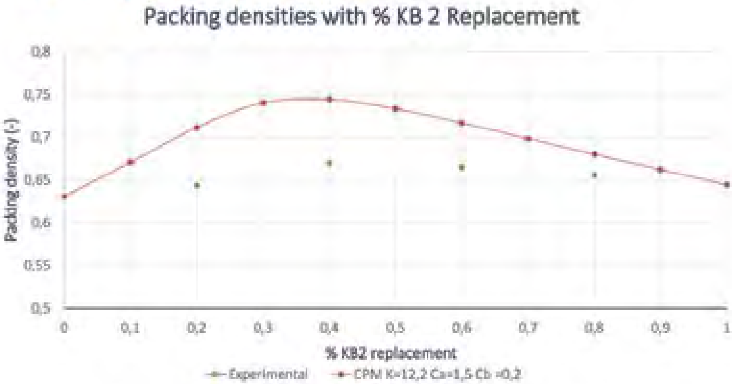
Packing density results



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Comments and observations

- The mixing energy test has provided the most repeatable results
- The influence of assigning a single K value to describe compaction is being further investigated
- The degree of clinker reduction possible is still being investigated

19

Way forward

- Validation and calibration of models, acceptable margin of error
- Manufacture of mortars and/or micro-concretes for assessment of properties
- Conclude on applicability of powder optimisation for clinker reduction

20.

Questions?

21.

8. Multiphase modelling of reinforced concrete corrosion using the Theory of Porous Media (TPM)

Joanitta Ndawula

Abstract

Concrete durability has become a major concern in recent years as maintenance costs often exceed construction costs. Various current research efforts are being focused on understanding and subsequently predicting and mitigating the mechanisms that result in deterioration.

A significant form of concrete degradation is the chloride-induced corrosion of steel in reinforced concrete especially in marine environments. Due to the porous nature of concrete, it is evident that transport mechanisms play a vital role in corrosion and other deterioration mechanisms.

Although the products of corrosion are known to create expansive stresses within the concrete, it has been observed in the past that the rust is first deposited in the concrete pores within the vicinity of the reinforcing steel. It is for this reason that this work aims to develop a multiphase model of rust transport in reinforced concrete using the Theory of Porous Media as a first step towards a complete model of chloride-induced corrosion. The model will be implemented in SESKA by modifying the existing cardiac mechanics model so that it may be applied to concrete.

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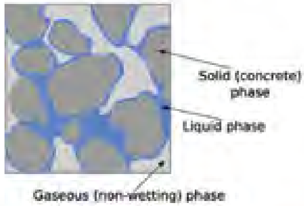
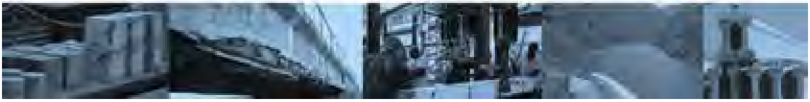
Concrete Materials &
Structural Integrity Research Unit

Multiphase modelling of reinforced concrete corrosion using the Theory of Porous Media (TPM)

Presented by: Joanitta Ndawula

Supervisors: Dr Sebastian Skatulla
& Prof Hans Beushausen





1.

Background

2.

Introduction

Objectives of this work

1. Investigate the relationship between transport mechanisms and rust development and transport.
2. To express this relationship mathematically
3. To modify the existing framework for TPM in *Sesko* for corrosion in reinforced concrete.
4. To validate the model using experimental data.

3.

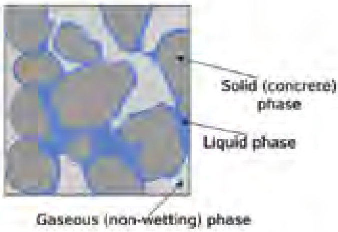
Transport mechanisms in concrete

- Permeation
- Absorption
- Diffusion
- Migration

4.

Concrete as a multiphase material

- Solid skeleton with voids(pores)
- Gel pores, **capillary pores,** micro-pores and macro-pores.
- Liquid water: **capillary water, adsorbed water,** chemically combined water



Representative Volume Element for concrete

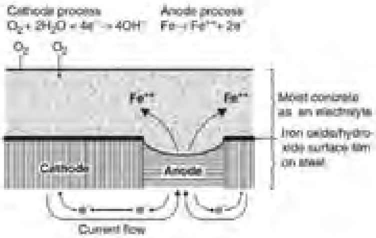
5.

Chloride-induced corrosion

6.

Chloride-induced corrosion

Half-cell reactions



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7

Chloride-induced corrosion

- Chloride ions catalyze the reaction

$$2Fe^{2+} + 6Cl^{-} \leftrightarrow 2\,FeCl_3^{-} + 4e^{-}$$

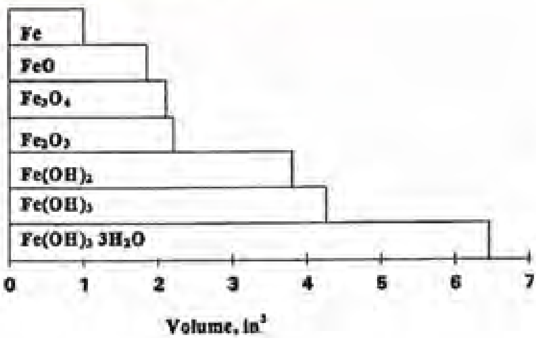
$$2FeCl_3^{-} + 4OH^{-} \leftrightarrow 2Fe(OH)_2 + 6Cl^{-}$$

8.

8.

Chloride-induced corrosion

Products of corrosion



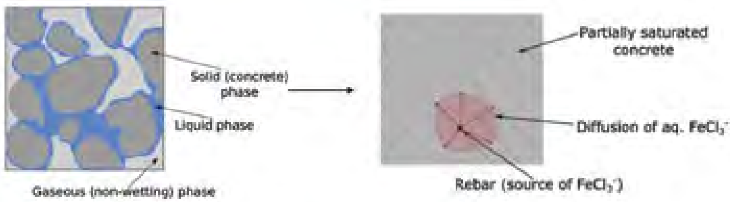
9.

Rust transport in RC concrete

- Rust products have very low solubility
- Iron-chloride complexes are known to be relatively soluble.
- These complexes are transported away from the steel surface by the pore solution.
- They further react with hydroxyl ions yielding the final corrosion product(s)

10.

Rust transport model



11.

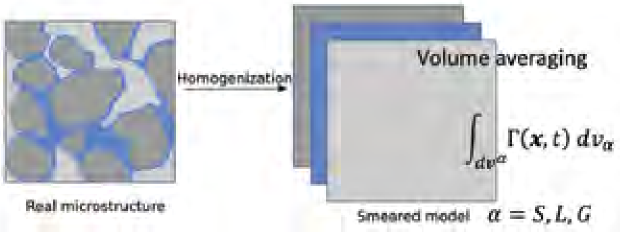
Theory of Porous Media

- Combines mixture theory with the concept of volume fractions.

12.

Theory of Porous Media

- Combines mixture theory with the concept of volume fractions.



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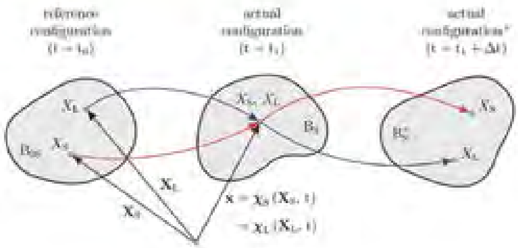
Theory of porous media



14.

Three phase material model

Assumptions

- Solid & liquid phase – incompressible.
  Gas phase – compressible.
- Non-isothermal process
- All phases are in a quasi-static state.
- Free Helmholtz energy:

15.

Three phase material model

Assumptions

- Solid & liquid phase – incompressible.
  Gas phase – compressible.
- Non-isothermal process however:

$$\theta^S = \theta^L = \theta^G = \theta$$

$$\boldsymbol{q}^S = \boldsymbol{q}^L = \boldsymbol{q}^G = \boldsymbol{q}$$

$$\hat{e}^S = \hat{e}^L = \hat{e}^G = 0$$

16.

Three phase material model

Assumptions

- Solid & liquid phase – incompressible.
  Gas phase – compressible.
- Non-isothermal process
- All phases are in a quasi-static state.

$$\boldsymbol{x}''_\alpha = 0 \qquad \text{for all } \alpha = S, L, G$$

17.

Three phase material model

Assumptions

- Solid & liquid phase – incompressible.
  Gas phase – compressible.
- Non-isothermal process
- All phases are in a quasi-static state.
- Free Helmholtz energy:

$$\psi^S = \hat{\psi}^S(\theta, \boldsymbol{C}_S), \quad \psi^L = \hat{\psi}^L(\theta), \quad \psi^G = \hat{\psi}^G(\theta, \rho^{GR})$$

18

Three phase material model

Balance equations for the immiscible constituents $(\alpha = S, L, G)$

- Balance of mass

$$\frac{(1-n)}{\rho_S}\frac{D\rho_S}{Dt} - \frac{Dn}{Dt} + (1-n)\, div\, \boldsymbol{x}'_S = 0,$$

$$\frac{n}{S_\beta \rho_\beta}\frac{DS_\beta \rho_\beta}{Dt} + \frac{Dn}{Dt} + n\, div\, \boldsymbol{x}'_\beta + \frac{1}{S_\beta} div[nS_\beta(\boldsymbol{x}'_\beta - \boldsymbol{x}'_S)] +$$

$$\frac{1}{S_\beta \rho_\beta}\, \text{div}\, [nS_\beta \rho_\beta(\boldsymbol{x}'_\beta - \boldsymbol{x}'_S)] = 0$$

with $\beta = L, G$

19

Three phase material model

Balance equations for the immiscible constituents $(\alpha = S, L, G)$

- Balance of mass
- Balance of linear momentum

$$div\, \boldsymbol{T} + \dot{\rho}\boldsymbol{G} = 0$$

Where

$$\boldsymbol{T} = \boldsymbol{T}^S + \boldsymbol{T}^w + \boldsymbol{T}^g$$

$$\dot{\rho} = (1-n)\rho^S_{0S} + (nS_l)\rho^l_{0l} + n(1-S_w)\rho^g_{0g}$$

20.

Three phase material model

Balance equations for the immiscible constituents $(\alpha = S, L, G)$

- Balance of mass
- Balance of linear momentum
- Balance of energy

$$\sum_{\alpha=1}^{K}[\rho^\alpha(\varepsilon)'_\alpha - \boldsymbol{T}^\alpha . \boldsymbol{D}_\alpha - \rho^\alpha r^\alpha + \text{div}\boldsymbol{q}^\alpha] =$$

$$\sum_{\alpha=1}^{K}[\hat{e}^\alpha - \hat{\boldsymbol{p}}^\alpha . \boldsymbol{x}'_\alpha - \hat{\rho}^\alpha\left(\varepsilon^\alpha - \frac{1}{2}\boldsymbol{x}'_\alpha . \boldsymbol{x}'_\alpha\right)]$$

21.

Three phase material model

Balance equations for the immiscible constituents $(\alpha = S, L, G)$

- Balance of mass
- Balance of linear momentum
- Balance of energy

Entropy inequality

$$\sum_{\alpha=1}^{\kappa} \frac{1}{\theta}\{-\rho^{\alpha}[(\psi^{\alpha})'_{\alpha} - \theta'_{\alpha}\eta^{\alpha}] - \hat{\rho}^{\alpha}\left(\psi^{\alpha} - \frac{1}{2}\mathbf{x}'_{\alpha}.\mathbf{x}'_{\alpha}\right) + \mathbf{T}^{\alpha}.\mathbf{D}_{\alpha} - \hat{\mathbf{p}}^{\alpha}.\mathbf{x}'_{\alpha} - \frac{1}{\theta}\mathbf{q}.\mathrm{grad}\theta + \hat{e}^{\alpha}\} \geq 0$$

22

Three phase material model

Balance equations for the solute

- Balance of mass

$$(n^{L}c^{LQ}M^{Q}_{mol})'_{LQ} + n^{L}c^{LQ}M^{Q}_{mol}\, div\, \mathbf{x}'_{LQ} = \hat{\rho}^{LQ}$$

- Balance of momentum

$$div\, \mathbf{T}^{LQ} + n^{L}c^{LQ}M^{Q}_{mol}(\mathbf{b} - \mathbf{x}''_{LQ}) = \hat{\rho}^{LQ}\mathbf{x}'_{LQ} - \hat{\mathbf{p}}^{LQ}$$

- Balance of energy

$$n^{L}c^{LQ}M^{Q}_{mol}(\varepsilon^{LQ})'_{LQ} - \mathbf{T}^{LQ}.\mathbf{D}_{LQ} - n^{L}c^{LQ}M^{Q}_{mol}r^{LQ} + div\, \mathbf{q}^{LQ} = \hat{e}^{LQ} - \hat{\mathbf{p}}^{LQ}.\mathbf{x}'_{LQ} - \hat{\rho}^{LQ}(\varepsilon^{LQ} - \tfrac{1}{2}\mathbf{x}'_{LQ}.\mathbf{x}'_{LQ})$$

23.

Progress
Completed
✓ Derived the balance equations and evaluated the entropy inequality
Currently working on….
• Formulating the governing equations and weak forms
Still to do
• Adapt the existing code in SESKA for the model • Validate using experimental data

24.

9. Properties of Western cape concretes made with metakaolin

Alice Titus

Abstract

One of the key constituents of concrete is cement, whereby approximately 12 billion of concrete produced in the construction industry uses 1.6 billion tons of Portland cement (Kumar Mehta 2004). This is associated with a high fuel expenditure which causes high production costs, and high carbon dioxide (CO2) emission to the atmosphere which leads to the greenhouse effects. The cement industry produces 0.8 tons of CO2 per each one ton of cement produced (Rashad 2013) that accounts for 5-8% of worldwide CO2 emission (Scrivener & Kirkpatrick 2008).

Therefore, the use of supplementary cementitious materials (SCMs) has been adopted for the purpose of reducing the use of Portland cement in construction, but also improving strength and enhancing durability of concrete (Siddique & Khan 2011). The reduction of cement quantity reduces the production of clinker, and hence a substantial decrease in CO2 emission and production costs. (Lothenbach et al. 2011).

In the Western Cape construction industry, Corex slag is currently used as an SCM to produce cement. However, it is difficult to guarantee the availability of this material since it is a by-product of steel production industry (Saldanha Steel). It is possible that the decline of steel production or other global factors may lead to scarcity of this material. In the second hand, fly ash produced at Eskom electricity power station may take over during the scarcity of Corex slag. However, emphasizing the use of fly ash has the negative environmental impacts. Its production involves burning coals which produces more of greenhouse gases (Scrivener & Kirkpatrick 2008).

Therefore, there is a need to consider alternative SCMs for use in the Western Cape. A possible candidate for this material could be metakaolin. Metakaolin is a new high reactive pozzolanic material which is abundantly available in Western Cape. It is commonly known as metakaolin K40. It is manufactured from the kaolin clay deposit at Atlantis by a company called Kaolin group, and supplied by Serina Trading company.
The main objective of this study is to investigate the properties of this locally available metakaolin K40 for use as an alternative supplementary cementitious material in the Western cape concrete. The following specific objectives are assessed in order to meet the main objective.

i. To characterize metakaolin in terms of its physical properties, chemical properties, and pozzolanic activity.
ii. To assess the influence of metakaolin on fresh concrete and hardened concrete properties, and to compare with the properties of concrete with corex slag.

iii. To evaluate the durability properties of concrete containing metakaolin by assessing its potential to mitigate alkali silica reaction (ASR), and to reduce concrete penetrability.

The study methodology is divided into two stages; a substantial and critical literature review of the use of metakaolin in concrete, and laboratory experimental investigations. The experimental investigations are conducted at UCT Civil Engineering laboratory, whereby six aspects are studied, namely; physical and chemical properties of metakaolin, pozzolanic activity of metakaolin, properties of fresh concrete, properties of hardened concrete, deformation and volume change of hardened concrete, and durability properties of concrete especially metakaolin mitigation potential of ASR. The variable considered in the concrete mix design are the metakaolin replacement level at 0%, 10%, 20%, and 30%, and water/binder ratio of 0.4, 0.5, and 0.6. The water and aggregate content are kept constant to all mixes, whereby a superplasticizer (CHRYSO ® Plast Omega 103) is used to regulate the slump of 100 mm.

The pozzolanic activity of metakaolin is tested by two test methods; the strength activity index test and semi-adiabatic calorimeter test method. In both tests, the mortar is used to prepare their specimens. Their results will be compared and the conclusion of its reactivity potential will be made. The properties of fresh concrete with metakaolin are assessed into two terms, setting time and workability. The setting time is determined by the Vicat apparatus test, whereby the cement paste of different replacement levels is tested. The workability of fresh concrete mixes is determined by the consistency test (slump test).

The properties of hardened concrete which are tested are; compressive strength, tensile strength, elastic modulus and pore size distribution. The age of curing is 7, 14, 28, and 56 days. The mix shows the desired results will be compared to the properties of concrete mix of 50% corex slag. The aim of doing this is to observe the possibility of using metakaolin as a substitute of corex slag in the construction industry.

The deformation and volume change of the hardened concrete with metakaolin is also assessed to determine the creep and shrinkage behaviour of the concrete. This will assist to predict the long-term deformation behaviour of the concrete. The creep test will be conducted to the concrete mixes with 0.5 water/binder ratio and different replacement levels of 0%, 10%, 20%, and 30%. The drying shrinkage test is assessed relative to the unloaded creep samples (control).

Finally, durability properties of concrete with metakaolin are assessed into two terms; the concrete penetrability and metakaolin potential to mitigate ASR. The concrete penetrability is assessed by the durability index tests, which are oxygen penetration index test, water sorptivity test, and chloride conductivity test, while accelerated mortar bar test described by ASTM C1567-13 (2008) is performed to determine the potential alkali silica reactivity of metakaolin and the reactive aggregate named greywacke.

Thereafter, the test results in each aspect will be analysed and discussed, finally, the conclusion and recommendation will be drawn. This study has its significance in the western cape construction society which is adding to the body of knowledge of metakaolin use as an SCM. Thus, it will lead to awareness on the potential use of metakaolin in South Africa, particularly in the Western Cape.

Properties of Western cape concretes made with metakaolin

By

Alice Titus Bakera

Supervisor: Professor Mark G Alexander

1.

Presentation outline

- Introduction
- Challenges
- Literature review
- Research objectives
- Research methodology
- Selected results
- Conclusion

2.

Introduction

- Western Cape concrete
  - Granulated ground corex slag (GGCS); Most common used Supplementary cementitious materials (SCMs)
  - Fly ash; less used

3.

Challenges

- Corex slag; Difficult to guarantee its availability

4.

Challenges

- Fly ash; Eskom Power Stations, Mpumalanga - approx. 1500 km from Cape Town; uneconomical
- Need to explore an alternative SCM
  - More reliable
  - Economical
  - Can assist durability

Such a material could be METAKAOLIN

5.

Literature review

KAOLIN CLAY
$Al_2Si_2O_5(OH)_4$

Dehydroxylation process → 500°C – 900°C

METAKAOLIN
$Al_2O_3.2SiO_2$

Pozzolanic reaction
$Ca(OH)_2 + Al_2O_3.2SiO_2$ → More Cementitious matrix

6.

Literature review

Kaolin clay distribution in Western Cape (Cole et al. 2014)

Kaolin deposit location	Abandoned mines	Unexploited deposits	Quantity of unexpl. deposits
Noordhoek – Fish Hoek Valley	5	3	4.5 Mt
Brackenfell – Kuils River area	2	3	3.5 Mt
Stellenbosch – Somerset West	1	3	12.8Mt
Southern Namaqualand	2	7	11.5 Mt
Vredenburg		3	0.6 Mt

Plastic clay

- Found in Buffelsfontein (435.3 km from east of Albertinia)
- Rich in kaolinite, enough for 50 years to come

7

Literature review

(Cole et al. 2014)

Abandoned mine at Noordhoek since 2008

Plastic Clay Mine on the Buffelsfontein farms

8.

Research objectives

- **Main objective:**

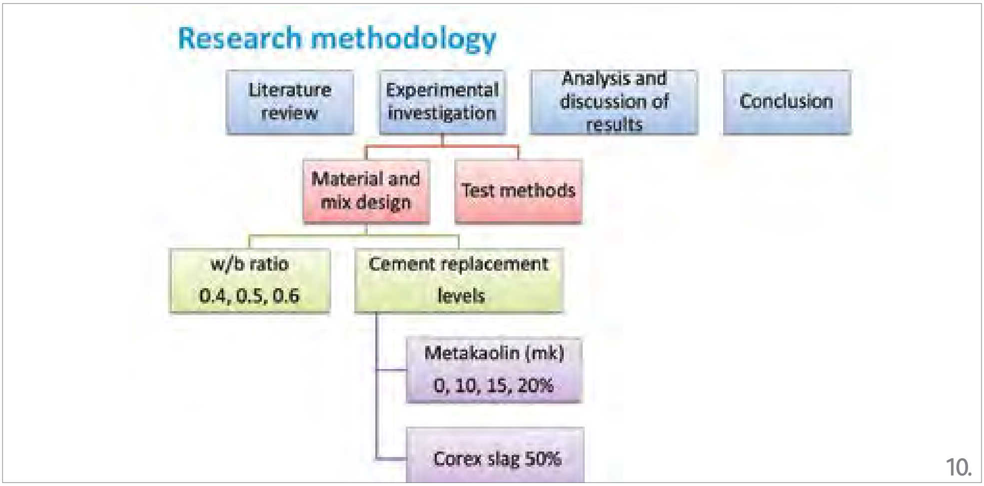
  To investigate the performance of Western Cape concrete with metakaolin

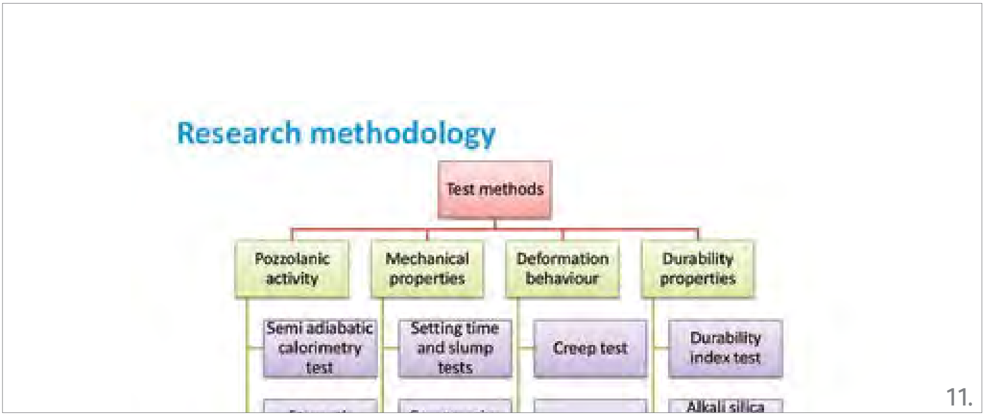
  – Properties of metakaolin; physical, chemical, and pozzolanic activity

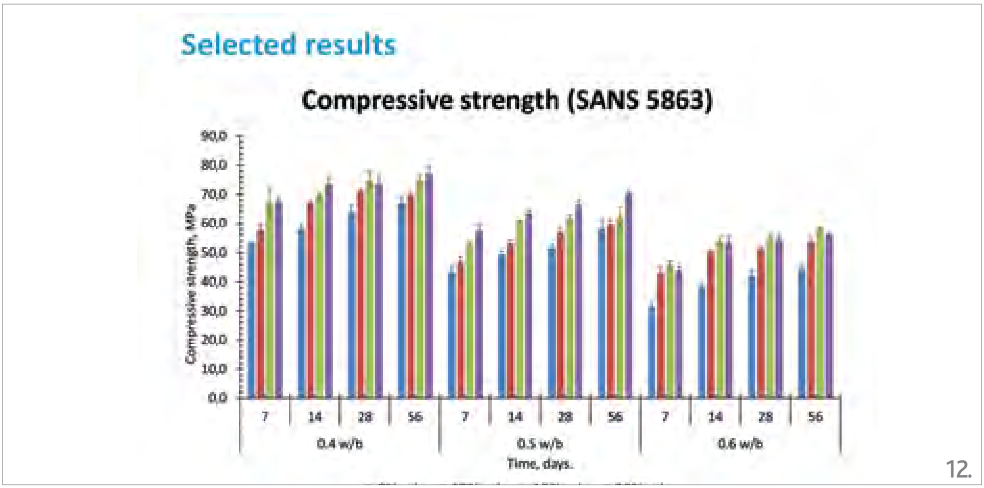
  – Influence of metakaolin on fresh and hardened concrete properties and compare to concrete with Corex slag.

  – Durability properties of concrete containing metakaolin

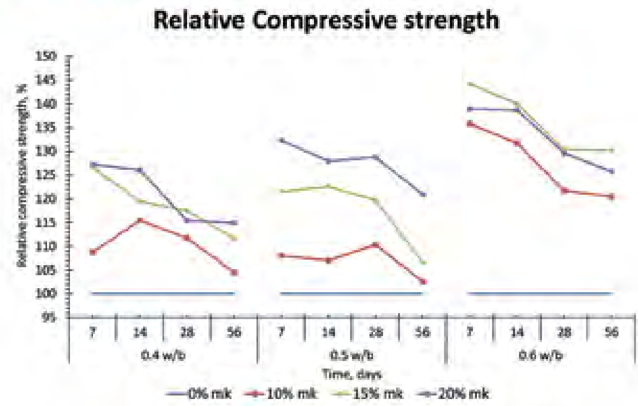
9.


Research methodology
Literature review
Experimental investigation
Analysis and discussion of results
Conclusion
Material and mix design
Test methods
w/b ratio
0.4, 0.5, 0.6
Cement replacement levels
Metakaolin (mk)
0, 10, 15, 20%
Corex slag 50%
10.


Research methodology
Test methods
Pozzolanic activity
Mechanical properties
Deformation behaviour
Durability properties
Semi adiabatic calorimetry test
Setting time and slump tests
Creep test
Durability index test
Alkali silica
11.

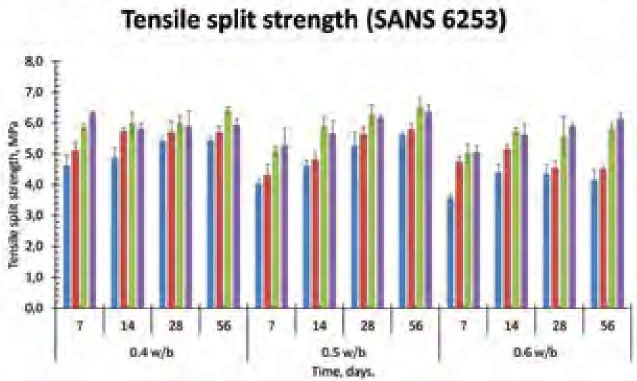

Selected results
Compressive strength (SANS 5863)
Compressive strength, MPa
90,0
80,0
70,0
60,0
50,0
40,0
30,0
20,0
10,0
0,0
7
14
28
56
0.4 w/b
0.5 w/b
0.6 w/b
Time, days
12.

Selected results



13

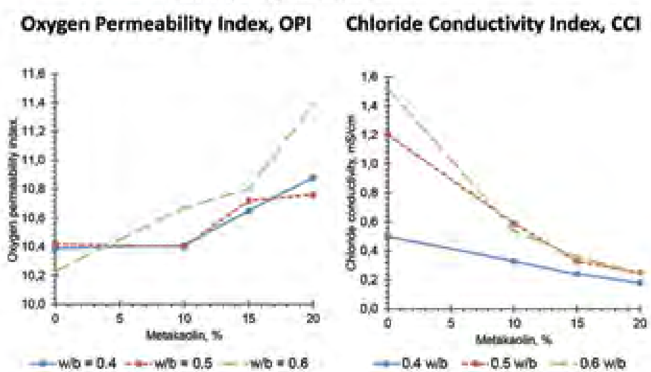
Selected results



14.

Selected results

Durability indexes

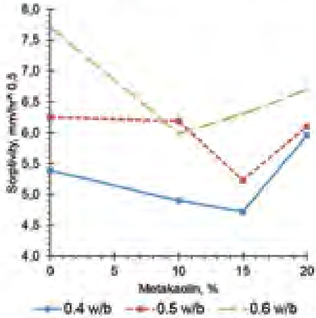


15.

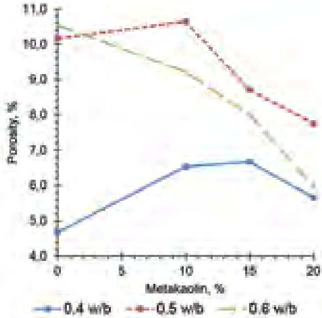
Selected results (to be confirmed)

Durability indexes

Water sorptivity Index, WSI



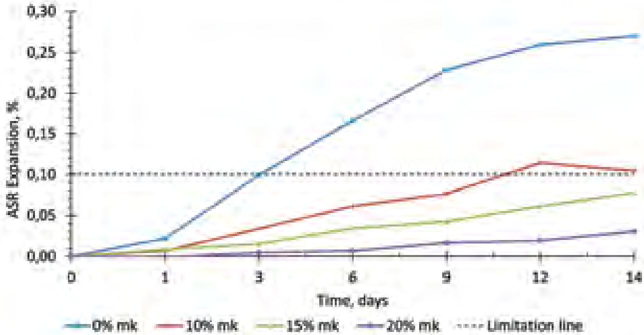
Porosity



16.

Selected results

ASR expansion (ASTM C 1567)



17.

Conclusions

- Metakaolin
  - Improves mechanical properties of concrete
  - Produces concrete with good to excellent quality as per DI results
  - Has a greater influence on concrete with a higher w/b ratio
  - Can supress ASR expansion in concrete at 15% and 20% replacement levels.

18

10. An evaluation of concrete shrinkage test methods towards better design

Siphesihle Marrengane

Abstract

Shrinkage cracking and shrinkage deformation in concrete structures continue to be very relevant issues in the construction engineering industry. In an effort to minimise the risk of shrinkage cracking, structural engineers often tend to specify shrinkage testing. However, test interpretation is difficult and the relevance of the results is not fully understood.

This research aims at evaluating current commonly-specified shrinkage testing methods and developing interpretation guidelines for these testing methods. This is to be done by investigating the correlation between accelerated shrinkage and atmospheric (long-term) drying shrinkage; the correlation between shrinkage results and concrete cracking; and to further investigate the repeatability and reproducibility of test results and test method sensitivity to known intrinsic factors (related to mix design) influencing shrinkage.

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Concrete Materials &
Structural Integrity Research Unit

An evaluation of concrete shrinkage test methods towards better design

Siphesihle Mamengana, Prof. Hans Beushausen
University of Cape Town, South Africa

August 2017

1.

Outline of Presentation

- Research Background
- Research Significance & Objectives
- Research Methodology

2.

Background

Shrinkage in concrete is the loss of volume in the concrete as a result of a loss of moisture.

Three types of shrinkage:

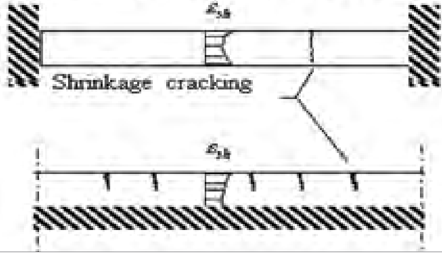
- Plastic shrinkage
- Autogenous shrinkage
- Drying shrinkage

3.

Background: Structural effects of shrinkage

- Cracking in concrete

Occurs under restrained conditions, when the shrinkage strain exceeds the concrete's tensile strain capacity



4.

Background: Structural effects of shrinkage

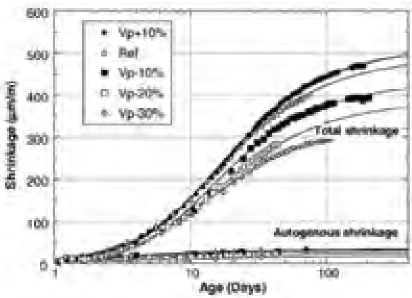
- Deflections in concrete (Curling)

Occurs as a result of differential rates of shrinkage between compression and tension zones in flexural members

5.

Background: Factors influencing shrinkage

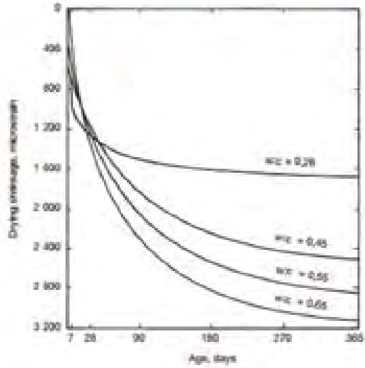
Paste content



6.

Background: Factors influencing shrinkage

Water-binder ratio



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Background: Factors influencing shrinkage

Water content

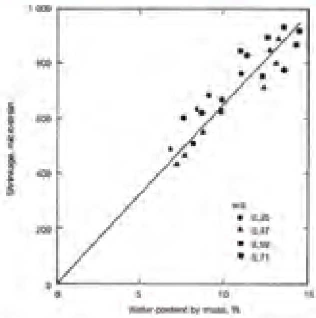
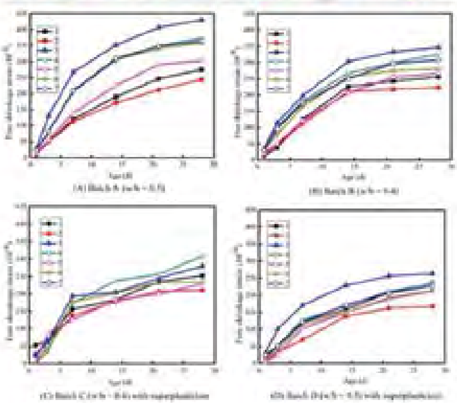


Figure 8.30: The linear relation between shrinkage and water content for a variety of mix proportions

8.

Background: Factors influencing shrinkage

Binder type



9.

Background: Factors influencing shrinkage

Aggregate content and type

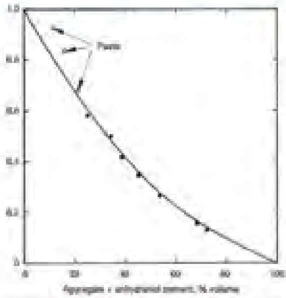


Figure 6.26 Effect of aggregate concentration on shrinkage of concrete

10.

Research Significance & Objectives

Develop interpretation guidelines for concrete shrinkage test methods to provide practical guidelines for industry by:

- Determining the correlation of shrinkage results with concrete cracking
- Determining the correlation of accelerated shrinkage with drying shrinkage
- Determine test method sensitivity to the factors known to influence shrinkage
- Determining repeatability of the test methods

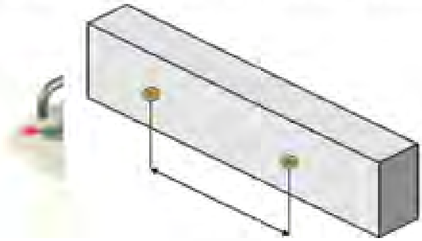
11.

Research Methodology

12.

Research Methodology

- Accelerated shrinkage testing
- Long-term drying shrinkage testing
- Restrained drying shrinkage cracking testing



13

14.

11. Fatigue behaviour of corrosion damaged, patch repaired and FRP strengthened RC beams

Valontino James

Abstract

Infrastructure deterioration is a growing concern all around the world, whether it be premature deterioration due to inadequate material design or because the structure experienced higher loads than it was designed for. It is a major concern firstly because of the significant cost associated with building new structures or upgrading structures and secondly, very often a brand new structure is out of the question due to logistical nightmares of rerouting traffic or relocating occupants from a building, in order to demolish and rebuild.

Two of the major causes of infrastructure deterioration, specifically bridges, are corrosion damage and fatigue damage. Considerable research has been conducted in these two fields, considering them in isolation. However if, combined they can be quite destructive and significantly reduce service life of the affected structure.

Corrosion damage is a twofold problem in that it firstly causes cross-sectional loss of reinforcing steel in the form of either uniform corrosion or pitting corrosion, where the latter is more critical, as is causes a larger, localized cross-section loss. Secondly, corrosion damage causes damage to cover concrete, because the corrosion reaction products occupy a larger volume that the original steel, which exerts tensile forces on cover concrete, resulting in cracking, delamination and eventually spalling of cover concrete.

Fatigue is related to characteristic micro-cracking and eventual rupture of a structural component under cyclic loading. As a structure experiences fatigue mid-span deflections increase with the number of fatigue cycles it experiences.

Corrosion damage coupled with fatigue behaviour reduces the service life of RC structures in that it facilitates fatigue failure at lower fatigue stresses. Pitting corrosion not only reduces the ultimate limit state (ULS) design moment due to cross-section loss, but it also creates an ideal location for formation of micro-cracks which have a shorter propagation distance to rupture.

If detected early enough there are a few methods that can be employed to ameliorate the damage. The most common repair method for corrosion damaged structures being: removing the damaged concrete, treating the corroded steel and applying a concrete repair mortar. If the steel has corroded excessively strengthening may be required and most recently FRP is being used extensively to that end. This repair method has been proven to be quite effective in restoring structural durability and capacity.

The problem is that this creates a multiple interface system between the concrete substrate, repair mortar, reinforcing steel, FRP epoxy and the FRP strip itself. The resulting composite structure has four interfaces, where each interface is susceptible to multiple failure modes. The long-term behaviour of structures repaired in this manner is a relatively unexplored area. The problem is further exacerbated by the constant evolution of construction materials. Modern concretes vary considerably to concretes used half a century ago, due to the availability of cement constituent components. Also, advances are constantly being made in improving construction material properties. Nonetheless, an understanding of the long-term behaviour of corrosion damaged, patch repaired and FRP strengthened RC structures remains vital.

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Concrete Materials &
Structural Integrity Research Unit

Fatigue behavior of corrosion damaged, patch repaired and FRP strengthened reinforced concrete beams

VALONTINO JAMES

Supervisor: Professor Pilate Moyo

1.

Contents

- Problem statement and significance of research
  - Corrosion damage
  - Patch repair
  - FRP strengthening
  - Multiple interface system
  - Fatigue behaviour
- Research objectives
- Research methodology
- Progress

2.

Problem statement and significance of research

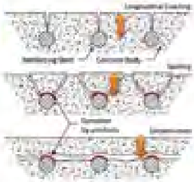
- Premature infrastructure deterioration growing concern
- Multifaceted problem

Source: Google Images

3.

Corrosion damage

- Damage to cover concrete reduced durability
- Compromised structural integrity due to reduced reinforcement cross-section



Source: Google Images

4.

Patch repair

Corrosion Damage → Patch Repair

- Widely used repair method
- Importance of surface preparation
- Matching material properties

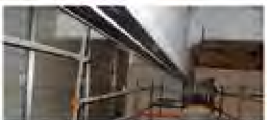
Source: Google Images

5.

FRP strengthening

Corrosion Damage → Patch Repair

Corrosion Damage → Patch Repair & FRP Strengthening

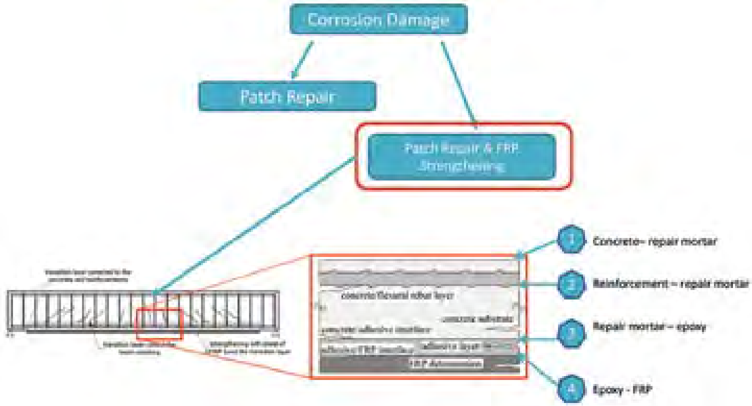


- Considerably effective in restoring structural properties short-term
- Preferred strengthening option due to strength to weight ratio
- Failure modes

Source: Google Images

6.

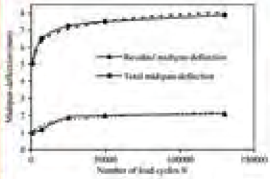
Multiple interface system



7

Fatigue behaviour

- Cycles during design life
- Reduced Stress due to corrosion damage



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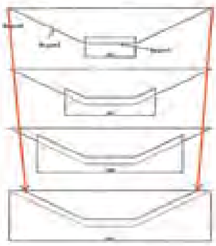
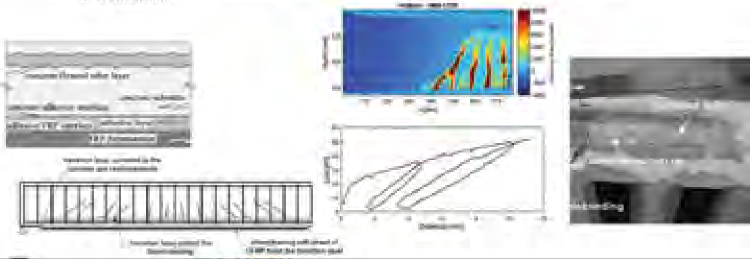


Source: Tlabize Okello

8.

Research objectives

- Investigate the mode of failure of the composite system considering all interfaces
- Evaluate the crack behavior of patch repaired and strengthened system relative to the control beams
- Analyze the fatigue behavior of the beams under cyclic loading with the aid of Digital Image Correlation in terms of mid-span deflection relative to number of loading cycles
- Determine the effect of damage extent on the fatigue performance and failure mechanisms



9.

Research methodology

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Beam design and casting	Accelerated corrosion	Patch repair	FRP strengthening	Fatigue testing	Data analysis & reporting

10.

Progress

Source: Valantino James

11.

THANK YOU!

Any questions?

12.

RETREAT GROUP PHOTO

FUNDERS

2017

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