SSC412: FINAL YEAR RESEARCH PROJECT
TOPICS FOR 2017
8 November 2016

Programme

Time	Field	Staff member
13:45	Introduction	Prof E Kearsley
14:00	Advice from current 4th years	
14:10	Water Resources	Mr M van Dijk
14:20	Water Resources	Ms I Loots
14:30	Environmental/construction	Ms K Jansen van Rensburg
14:40	Structures	Prof C Roth
14:50	Structures	Prof W Burdzik
15:00	Structures	Ms S Skorpen
15:10	Transportation	Prof C Venter
15:20	Pavements	Prof W Steyn
15:30	Building Materials	Mr F van Graan
15:40	Building Materials	Dr M Kovtun
15:50	Building Materials	Prof E Kearsley
16:00	Railways	Prof H Grabe
16:10	Geotechnical	Prof G Heymann
16:20	Geotechnical	Prof E Rust
16:30	Geotechnical	Prof S Jacobsz
16:40	Conclusion	Prof E Kearsley

Topics for 2017

1 WATER RESOURCES

1.1 Supervisor: Mr Marco van Dijk

1.1.1 Energy generation using low head hydro technologies

In the South African agricultural sector, there are a number of canals and conduit systems that experience significant flow rates, velocities and/or pressures. The irrigation industry is the largest water user within the agricultural economic sector consuming about 60% of the total SA available water supplies.

Under the WRC/UP research project on Energy generation using low head technologies currently underway a hydropower plant was constructed at Zeekoegat WWTW which will provide an ideal opportunity for further testing and analyses.

The treatment of wastewater in the Gauteng Province alone is provided within some 52 treatment plants consuming significant amounts of electricity to sustain the treatment operations. There are hydropower generation opportunities on the upstream and downstream sides of these WWTW. The hydro energy generated at this specific site will be fed into an isolated electricity mini grid.

The student(s) will be looking at ways to determine the hydropower potential, what installation is the optimal (siphon or bottom outlet) and what the most practical ways would be to exploit this.

Students should have transport to conduct the tests at the Zeekoegat WWTW.

1.1.2 Developing of hydropower generation turbine unit for open channel flow

In the South African agricultural sector, there are a number of canals with significant flow rates or velocities. The irrigation industry is the largest water user within the agricultural economic sector consuming about 60% of the total SA available water supplies.

There is a need in the country to provide electricity in remote areas. Pico hydro installations are typically used in developing countries for energy provision to isolated communities where the national electricity grid is not available. In other cases it would be beneficial to provide electricity to allow remote monitoring and control of a water distribution system (in this case an open canal system). The focus of this proposed research initiative is the development/implementation of a hydro turbine to be located in an open canal.

It is believed that an affordable, working inline hydropower generation unit can be developed, supplying sufficient energy to meet the power requirements at a remote site.

1.1.3 Developing of pico hydropower generation turbine unit for water distribution systems

There is a need in the country to provide electricity in remote areas. Pico hydro installations are typically used in developing countries for energy provision to isolated communities where the national electricity grid is not available. There are some commercial hydropower systems available that provides power by using the pressure drop across a pressure reducing valve to run a generator. The focus of this proposed research initiative however is the development/implementation of an inline hydro turbine into a water distribution network.

It is proposed to develop an energy recovery solution that would enable local authorities to produce clean, reliable, low-cost electricity from the excess energy available in their water pipelines. An inline turbine that captures energy from fast-moving water inside of small diameter, gravity-fed pipelines with no impact on flow or operation will be developed. Depending on head pressure, flow and pipe diameter, the turbine installation would be capable of producing from a few watts to almost 1 kW of renewable, zero emissions electricity by extracting excess head pressure.

It is aimed to develop an inline turbine unit which can be rapidly and easily installed into a pipeline to provide energy for use on site to power various devices located within close proximity of the turbine unit e.g. motorised pilots, sensors, telemetry, cathodic protection, PLC, sump pumps and lighting.

The aims of this research topic are:

- To develop an inline hydropower turbine unit to provide electricity in remote areas.
- To develop criteria for implementation of the hydropower turbine units.
- To test the inline hydropower unit (pilot plant)

It is believed that an affordable, working inline hydropower generation unit can be developed, supplying sufficient energy to meet the power requirements at a remote reservoir site. Preliminary work has been done and results look very promising.

Students should have transport to conduct the tests at the Pierre van Ryneveld Reservoir.

1.1.4 Developing of a real small pico hydropower generation unit for a WDS application

Can a pico hydropower unit be developed which could be used for providing sufficient electricity for smart metering and control at a household level?

It is proposed to develop a small pico unit, connect it to a conventional municipal household water supply to generate electricity used to monitor, control and report on water consumption.

Students should have access to a house (and a willing owner).

1.1.5 Preventing cavitation in control valves

Experimental work will be conducted to determine the effectiveness of air induction to prevent cavitation in control valves. A radial valve at Lebanon will be investigated. The valve status will be monitored at site at Lebanon Reservoir (Rand Water). The site is located 20 km south of Johannesburg. The student will be required to determine the effectiveness of this modification that will be added to prevent the cavitation.

The experimental work could be supplemented with further testing at Queenswood reservoir. The valve will be operated at its limit and the cavitation damage will be measured/quantified. The valve will be replaced with a new modified control valve, which introduces air on the downstream side to reduce the cavitation. The student will be required to determine the effectiveness of this modification. This is a continuation of previous research work which showed promising results.

Data acquisition skills will be developed and the student should have access to a computer. Reliable transport is needed.

1.1.6 Mitigation options to ensure long-term hydraulic efficiency of pipelines

The design of pipelines is based on the notion that the absolute roughness is predominant under turbulent flow conditions. Various field investigations indicated that the presence of biofilm growth in pipelines has a major influence on the hydraulic capacity. The investigation will be conducted on a model setup where different options to inhibit biofilm growth will be investigated. An experimental set-up will be constructed on the Proefplaas and a comparison will be conducted between a control condition and a pipeline in which biocide has been introduced.

Students should have transport to conduct the tests at the Laboratories on the Proefplaas.

1.1.7 Development of hydropower assessment tool for retrofitting DWS infrastructure

The Department of Water and Sanitation (DWS) recently gazetted the Draft Policy document on Sustainable Hydropower Generation in which the process to obtain access to DWS infrastructure for hydropower generation is set out. An enormous opportunity thus presents itself as hundreds of potential dams, weirs canals etc. could now theoretically become feasible hydropower sites. The aim of this project report is to quantify this opportunity by developing a tool to assist in the evaluation of the potential sites and determine the overall country wide potential and feasibility of the sites.

1.2 Supervisor: Ms Ione Loots

1.2.1 The influence of catchment development on runoff on a catchment scale

It is widely accepted that urban development results in a decrease of permeability of a catchment and will therefore cause floods with higher and faster peaks. However, this assumption does not take into account the possibility of retention and attenuation caused by typical South African development trends. It may be that urban flooding is severely overestimated.

It is proposed to critically evaluate historical data and around major urban areas in South Africa to test the hypothesis and to recommend applicable run-off factors for different areas.

2 ENVIRONMENT AND CONSTRUCTION

2.1 Supervisor: Ms Karin Jansen van Rensburg

2.1.1 Waste management in South Africa

Identify major problems in landfill life-cycles and look for best environmental practice (BEP) solutions. DWAF has currently got Minimum requirements and the DEAT is busy with a new waste strategic plan and designs for landfill. How does the two fit in with each other and is it in line with BEP internationally.

2.1.2 Sustainable development

Look at different ways to create self-sustainable human settlements in South Africa. New drive from DEAT to develop self-sustained communities e.g Kgautsane community owned development centres where community is self-sustaining.

2.1.3 South Africa and Bio-Diesel

Look at existing bio diesel Plants and the viability of developing bigger plants, the positive and negatives of using bio diesel and the pshycology behind it.

2.1.4 Enterprise development programmes in Construction

Research existing programmes to determine whether they are practical. SAFCEC Enterprise Development programme – To mentor, guide and coach personnel of a sub contractor or JV Partner.

An Established Contractor must coach/guide/mentor a Developing Contractor (Protégé Company) through a structured development program. The objective is to help the protégé company to reach independence and to address all the development areas as mentioned in the Construction scorecard. Ideal mentoring period is between 3-5 years.

2.1.5 Are South Africa's built-environment professionals embracing green building practices

The ambition to lessen the carbon footprint associated with buildings and residences, especially by using design and technological innovation to decrease energy consumption and limit waste.

2.1.6 Is building conventional structures more feasible than aesthetically pleasing structures in South Africa?

2.1.7 Water shortage in South Africa – Can proper management of the water resources curb water shortages.

2.1.8 Water shortage in South Africa – Compare different water saving techniques to determine the most feasible solution

3 STRUCTURES

3.1 Supervisor: Prof Chris Roth

3.1.1 Use of cellphone accelerometer

Structural vibrations, possibly in Eng 3 building, will be measured and analysed to see if a cellphone accelerometer can capture data in sufficient detail to be useful for further structural analysis and design.

3.1.2 Use of thermal imaging camera

Steel connections are to be tested to see if a small thermal imaging camera connected to a cellphone can record temperature changes due to yielding.

3.1.3 Holding-down bolt pull-out in fibre-reinforced concrete

Holding-down bolts cast in fibre-reinforced concrete will be tested to determine the effects of various parameters on the pull-out force. The accuracy of current design methods can then be checked.

3.1.4 Dynamic testing of Young's modulus values for steel

Recent tests have indicated surprising variety in the Young's modulus value of steel. Normally it is assumed that the value is approximately 200 GPa for all types of steel. Some static tests were done last year. The student will do a dynamic test to determine the range of values and the consequences for design.

3.1.5 Anisotropy of thin steel plates

Normally it is assumed that steel is isotropic. Research has found some anisotropy, particularly in thin steel plates due to rolling. The student will test material properties such as Young's modulus and yield strength to determine if the steel is anistropic.

3.1.6 Distribution of basic input variables in reinforced concrete construction in Pretoria

Basic input variables for reinforced concrete design include material properties of concrete and steel, geometry of actual construction, quality control on site, etc. Although we assume fixed values for these variables in design, in practice the values vary. This work will be to quantify the variability in slab thickness and possibly other selected variables. Measured values must be analysed.

3.1.7 Rail defect distributions

Defects in steel rails, such as cracks or broken welds, can cause derailments and the prediction of defects is an important part of rail maintenance. This work will involve collecting data on rail defects and fitting models to the defects. Parameters for defects in tangents, curves will be fitted. This will require some interface with Transnet Freight Rail.

3.2 Supervisor: Prof Walter Burdzik

3.2.1 Timber Compression Members – Can one use lateral stiffness to predict buckling strength?

Research Projects in 2016 on the buckling strength of compression members showed that it was almost impossible to predict the buckling strength of these members, if one based it on the lateral stiffness of the individual components. It appears as if the equation for the strength of compression members may be incorrect and that knots, which do not change the lateral stiffness noticeably, may play a bigger part in the strength than anticipated. Slenderness ratios of between 36 and 52 were tested and the results showed that the curve that is being used dangerously overestimates the strength

It is necessary to investigate the buckling portion of the compression curve in the transition region of KL/b from 16 to 31 in increased slenderness of 5. This means that 2 students will choose a length; one will investigate the strength of the compression member with knots, the other without or at least small knots.

3.2.2 Investigating whether bolted moment or tension connections are better than nailed or screwed connections.

The question often arises when fixing a failed member in a truss, whether it is better to bolt it together, nail it or screw it. Various ways of connecting the members together using steel plates, shutter board or timber pieces will be investigated by the students

3.3 Supervisor: Ms Sarah Skorpen

3.3.1 Effective Bridge Temperatures

This skripsie topic involves calculating effective bridge temperatures from measured bridge temperatures and comparing these to design values given in various design codes.

3.3.2 Bridge Temperature Gradient

This skripsie topic involves calculating bridge temperatures gradients from measured bridge temperatures and comparing these to design values given in various design codes.

3.3.3 Heat of hydration in concrete bridge decks

This skripsie topic involves assessing measured heat of hydration temperatures in concrete bridge decks and assessing the effect on the design for temperature effects in the deck.

3.3.4 Deflection in high strength concrete beams / slabs

This skripsie topic involves assessing the deflection in high strength concrete (>150MPa) concrete slab and beams.

4 TRANSPORTATION

4.1 Supervisor: Prof Christo Venter

4.1.1 OPTIMAL STOP/GO TRAFFIC CONTROL AT HALF-WIDTH ROAD CONSTRUCTION SITES

During rehabilitation of two-lane rural roads, one lane is often closed and traffic is controlled by stop/go control that alternates use of the open lane between the two directions. Various strategies could be employed to determine the "green time" split between the two directions, including equal green times, complete queue discharge, or green times allocated proportional to arrival volumes. The effectiveness of various strategies will be tested by measuring delay and queue lengths using a Monte Carlo simulation implemented in Excel. The objective of the project will be to determine guidelines for optimal control strategies for various traffic and geometric conditions.

4.1.2 IINVESTIGATING THE SAMPLE BIAS POTENTIAL OF PROBE GPS DATA

Probe traffic data refers to data on travel patterns obtained from recording the movements of individual vehicles over some period of time, for instance with GPS tracking equipment (e.g. Tom-Tom or Tracker). This kind of data forms the basis of many traffic information services and, increasingly, traffic management strategies. A concern is however that tracked vehicles may not accurately represent the entire vehicle population, as high-value vehicles are more likely to be fitted with security trackers, thus underrepresenting the movements of lower-income drivers.

The project will investigate the potential for sample bias among probe vehicles by comparing a sample of Tracker data with an unbiased sample of vehicle tracks obtained from a separate study. If bias exists, we want to be able to quantify the extent of over- or underrepresentation of travel volumes and speeds on different road types, in different parts of Gauteng.

4.1.3 MEASURING PASSENGER CONVENIENCE AT PUBLIC TRANSPORT INTERCHANGES USING PERSONAL GPS DEVICES

Effective intermodal public transport interchanges where passengers transfer between different modes (e.g. Gautrain/bus or taxi/metrorail/BRT) require short walking distances, convenient walk routes (e.g. step-free), and short waiting times. This project will investigate the feasibility of collecting data on transfer convenience using GPS recorders carried by individual passengers as they travel through interchanges. Volunteers will be recruited to collect data on a sample of existing interchanges, and the data will be analysed to assess the reliability and feasibility of this data collection method.

4.1.4 UBER: DOES IT COMPLEMENT OR COMPETE WITH PUBLIC TRANSPORT?

Uber is growing very fast as an innovative addition to the menu of transport options available to people in addition to driving themselves. We know very little about how people are using Uber and, specifically, whether it is replacing public transport (i.e. people use Uber instead of the bus or train), or acting as a complementary mode to public transport. The project will start to answer this question by collecting and analysing travel information from a sample of Uber users, either obtained from Uber South Africa, and/or from a small survey of Uber users in Pretoria. The study will contribute to the identification of strategies that can be used to maximise the contribution of Uber to sustainable transport.

5 PAVEMENTS

5.1 Supervisor: Prof Wynand Steyn

5.1.1 Bitumen shrinkage due to ageing

Bitumen ages due to various factors, including increased temperatures and UV exposure. The ageing process cause the bitumen to loose volatiles, thereby causing a volume decrease. This project will evaluate methods to determine the volume change in different types of bitumen when exposed to different ageing factors, and relate these to the rheological properties of the bitumen. Most of the project will be conducted in a laboratory.

5.1.2 Modelling telematics-based gravel road deterioration data

The department is involved in a long-term project for the evaluation of road condition using telematics-based vehicle response data. Such data can be used, if collected consistently for the same route over a long enough period, to develop a road deterioration model that can be used for maintenance planning. In this project such data will be collected and analysed to develop a riding quality deterioration model for gravel road maintenance.

5.1.3 Effects of road condition on fuel consumption

Road condition (riding quality, presence of anomalies, etc.) and driving behaviour affects fuel consumption. In general, as riding quality decreases and more anomalies are present in a road surface, fuel consumption deteriorates. Driving conditions such as congestion and aggressive driving habits further affect fuel consumption negatively. In this topic the effects of a number of selected road conditions and driving behaviour options will be measured and analysed to develop a better understanding of such phenomena and develop a model that can be used to evaluate the expected fuel consumption on specific roads.

5.1.4 Evaluation of telematics data for pavement condition analyses

This project will have several sub-topics where various applications of telematics data obtained from vehicle fleets in evaluating pavement condition and features will be studied. Typical sub-topics include use of telemetric gyroscope for measuring road geometry, use of telemetric accelerometer for evaluating dynamic bridge deck joint changes, calibration of telematics data with profile-based pavement riding quality, evaluation of current Vehicle Operating Cost (VOC) models versus actual VOC data, I2V options for road condition measurements.

5.1.5 Evaluation of pavement riding quality index issues

This project will have several sub-topics where the effect of a range of measurement and road features on the measured and perceived pavement riding quality will be studied. These

include the effects of vehicle speed, measurement interval length, pavement condition (paved vs. gravel), effects of individual wheeltracks on overall riding quality, and anomaly / feature detection.

5.1.6 Optimal spread rates for rolled-in chips in continuously graded asphalt to attain acceptable MPD values

Rolled-in chips are typically used on top of new asphalt layers to improve the skid resistance of the new asphalt. Many factors play a role in the effectiveness of this process, one of which is the chip spread rates. This project will evaluate the effect of a range of spread rates on the measured mean profile depth of the pavement layer and the resultant skid resistance attained.

5.1.7 Investigation of optimum placement of yellow-line road studs in terms of road safety and operational considerations

Yellow-line road studs are used to demarcate the edge of the road to drivers at night. Optimum location and frequency of placement is an engineering problem that requires safety, human perception, technical and cost inputs. In this project the factors affecting the location and frequency of placement will be investigated, and the effect of different layouts evaluated to develop a model for selection of optimum strategies.

6 MATERIALS

6.1 Supervisor: Mr Fritz van Graan

6.1.1 *Bepaling van die invloed van prosesparameters op die vashegting van PU aan metaal* / Determining the influence of process parameters on the bonding of PU to metal

Bonding of elastomers and in particular poly-urethane (PU) to metal is currently done on a basis of process experience. Process instructions should be very useful and therefore investigations and tests must be done to characterize adhesives in terms of process parameters like preparation of metal surfaces, time, temperature, etc. Test assemblies must be manufactured by changing only one parameter per test series, to determine its influence of the adhering force for three different hardnesses, namely 60 A-shore, 70 A-shore and 80 A-shore.

Vashegting van elastomere en meer in besonder poli-uretaan (PU) aan metaal, word tans op 'n basis van prosesondervinding gedoen. Prosesvoorskrifte sou baie nuttig wees en daarom sal ondersoeke en toetse baie help om kleefmiddels te karakteriseer in terme van prosesparameters soos die voorbereiding van metaaloppervlakte, tyd, temperatuur, ens. Toetssamestellings moet vervaardig word met slegs een parameter wat telkens verander, sodat die invloed daarvan bepaal kan word t.o.v. vashegtingskrag vir tipies drie verskillende hardhede, nl. 60 A-shore, 70 A-shore en 80 A-shore hardhede.

6.1.2 *Vashegting van PU aan metaal monteervlakke* /Adherence of PU to metal surfaces for mountings

Forced curing of Poly-urethane elastomer assemblies with relation to the bonding of it to the metal surfaces necessary for mounting purposes needs to be investigated. This is essential for manufacturing engine mountings and/or assemblies more reliable and to do better planning and design to eliminate failures.

Gedwonge stolling of "kuur" van Poli-uretaan elastomeer samestellings wat betref die vashegting aan metaalmonteervlakke moet ondersoek word. Dit is nodig sodat vervaardiging van tipies enjinmonteerstukke en/of samestellings, beter beplan en ontwerp kan word om falings te voorkom.

6.1.3 *Oordragmeganisme vir watergedrewe motorhek/* Transfer mechanism for water powered gate system

A model to move and control a motorway gate by using water pressure as supplied by water systems in the cities, instead of electric motors, already exists. A mechanism to magnify/multiply the necessary displacement is planned, built and tested to operate safe and reliable. The cylinder should operate with water pressure and control valves and moves in a range of 600 mm. The mechanism increases the displacement to approximately 2.5 m to conform to the requirements for a motor gate. The mechanism must be assembled properly to use it with the present range of gates for motorways and the available water supply equipment. The hydraulic (cylinder) part must be designed, built and integrated with the mechanism to function as a complete system.

'n Model wat 'n motorhek kan beweeg en beheer deur middel van waterdruk, soos voorsien deur die watersisteme van die stede, in die plek van elektriese motors, bestaan reeds. 'n Meganisme om die verplasing te vergroot/vermenigvuldig is beplan, gebou en getoets , sodat dit veilig en betroubaar funksioneer. Die silinder moet funksioneer dmv waterdruk en beheerkleppe met 'n reikafstand van ongeveer 600 mm. Die meganisme vergroot die beweging na ongeveer 2.5 m om te voldoen aan die vereistes vir 'n motorhek. Die meganisme moet deeglik saamgestel word, sodat dit aanpas by die huidige reeks motorhekke en beskikbare watervoorsieningstoerusting. Die hidroliese(silinder) deel moet ontwerp, gebou en geïntegreer word met die meganisme om as 'n volledige stelsel te funksioneer.

6.1.4 *Watergedrewe hidroliese hystoestel /* Water-driven hydraulic hoist

The planning, design and build of a scale model of a hydraulic unit using municipal water pressure, with a travel of 500 mm is already done. Optimization of the piston is done by using different profiles for the piston like grooves, cones, internal cavities, etc. Tests to determine bypass-leakage of the piston from high to low pressure sides in the cylinder are done to find the best solution .Experiments have to be done to lift heavy loads up to 500 kg to determine the performance, efficiency and stability.

Die beplanning, ontwerp en bou van 'n skaalmodel van 'n hidroliese eenheid wat met behulp van munisipale waterdruk werk en 500 mm reikafstand het is reeds gedoen. Die suierontwerp is reeds geoptimeer deur verskillende suierprofiele/vorms bv. met groewe, koniese vorms, binne-holtes, ens. te gebruik. Toetse wat lekkasie verby die suier van hoë- na laedrukkant bepaal, is gedoen om die beste oplossing te vind. Eksperimente moet gedoen word om swaar massas van tot 500 kg op te hys om die prestasie, effektiwiteit en stabiliteit te bepaal.

6.2 Supervisor: Dr Maxim Kovtun

6.2.1 Alkali-Silica reaction in Alkali-Activated materials

Alkali-silica reaction (ASR) is a big concern in South Africa. Many rocks used as aggregates in concrete production, contain reactive silica which causes ASR. Relatively high concentrations of alkalis are used in alkali-activated materials (geopolymers, alkali-activated slag, etc.) which can cause ASR. The aim of the project is a comparative study of ASR in alkali-activated materials and ordinal Portland cement.

6.2.2 Mitigation of shrinkage of alkali-activated materials

According to many researches, alkali-activated materials (geopolymers, alkali-activated slag, etc.) have increased shrinkage in comparison to ordinary Portland cement. The aim of the work is to mitigate shrinkage of alkali-activated materials.

6.2.3 Ternary alkali-activated mixes

Ternary concrete mixes containing ordinary Portland cement, fly ash and silica fume are well known. The aim of the project is to develop ternary alkali-activated mixes containing ≥50% fly ash and providing relatively high early strength at ambient temperature.

6.2.4 Infuence of mix composition and curing conditions on carbonation of alkali-activated concretes

Many scientists have questioned durability of alkali-activated materials (geopolymers, alkali-activated slag, etc.). Several previous research works have shown that alkali-activated materials can be susceptible to carbonation. The aim of the study is to investigate influence of concrete mix composition and curing conditions on carbonation of alkali-activated materials.

6.2.5 Engineering properties of alkali-activated concrete containing electric arc furnace slag as coarse aggregate

Electric arc furnace (EAF) slag is a by-product which can be utilized as aggregate in concrete. The aim of the study is to design alkali-activated concrete with coarse EAF slag aggregate and to study its engineering properties comparatively to ordinary Portland cement concrete.

6.2.6 Foam concrete with controlled volume change

Foam concrete is a versatile structural/thermal isolation material. Significantly increased shrinkage is the main disadvantage of the porous structure of foam concrete. The aim of the study is to mitigate shrinkage (or even ensure controlled expansion) of foam concrete.

6.2.7 Ultra-high strength fine-aggregate concrete

Modern infrastructure needs ultra-high performance materials. Ultra-high strength concretes can be used in transport systems, high rise buildings and so on. High quality coarse aggregates are scarce in many parts of the country. The aim of the project is to design ultra-high strength fine-aggregate concrete.

6.3 Supervisor: Prof Elsabe Kearsley

6.3.1 Pre-cast concrete element connections

The quality of concrete elements can be improved by manufacturing them in a controlled environment but the construction of structures made from pre-cast elements is complicated by connection details. In this project the student will investigate the use of high strength fibre reinforced concrete to limit the reinforcing bond length required in moment connections of pre-cast beams.

6.3.2 Bond between concrete and pre-stressed cables

In high strength pre-stressed concrete the cross section of elements can be so small that it is difficult to meet the detailing requirements of the design codes op practice (cover to pre-stressed bars must be more than 2.5 times the bar diameter. In this project the student will investigate the effect of cover on the slip of pre-stressed cables in flexural beams cast using

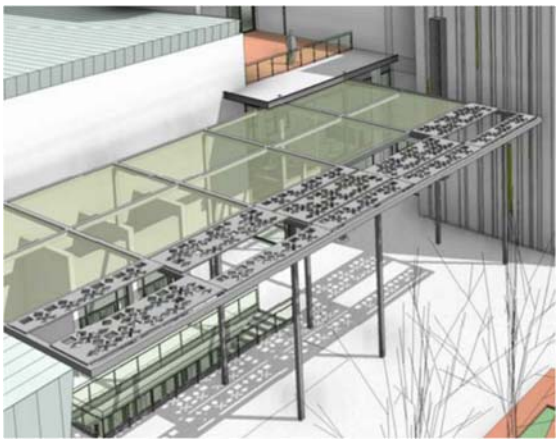
normal and high strength concrete. The use of fibre reinforcing to mitigate the slip can be considered for high strength concrete.

6.3.3 Loss in pre-stress of ultra-high strength concrete

Pre-cast concrete elements are manufactured by stressing steel cables and then casting concrete and releasing the cables once the concrete has gained sufficient strength. The stress in the cables is measured during the pre-stressing process, but significant losses takes place after stressing and the aim of this project is to instrument pre-stressed concrete beams to establish what percentage of the pre-stressing force is transferred into the concrete and how much of the force is lost due to early age deformation of the concrete.

6.3.4 Actual behaviour of thin pre-cast elements

Pre-cast panels are often designed to span in one direction with distribution steel perpendicular to the main reinforcing bars. In this project the student will investigate the effect of reinforcing layout and length to width ratio of panels on the stress and strain distribution in the panels.



6.3.5 Effect of split-cylinder support width on strength recorded

Different standard test methods require different support conditions for split-cylinder testing. The aim of this project is to determine the effect of support condition on the actual strength recorded for cylinders made from concrete with different compressive strengths.

6.3.6 Is concrete homogenous and isotropic?

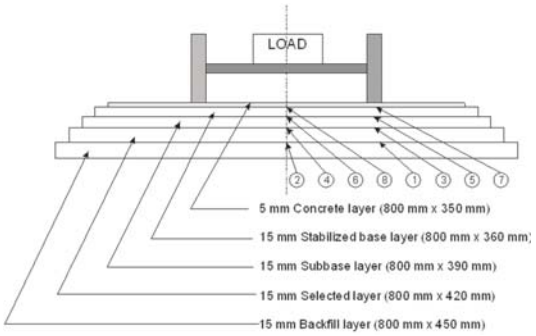
In this project the student will cast deep samples using different mix compositions. The properties of the concrete in the top and the bottom of the samples will be compared using various non-destructive testing techniques. The aim of this project will be to establish whether mixtures with high water contents are more prone to segregation and thus significant strength variations in deep sections.

6.3.7 Fibre reinforced concrete for Ultra-Thin Continuously Reinforced Concrete Pavements (UTCRCP)

UTCRCP is currently used in trail sections on the National Highways. These concrete layers are as thin as 50 mm and significant volumes of reinforcing are used to ensure ductile behaviour. Relatively high fibre contents are required for UTCRCP and different types, length and combinations of fibres should be tested to determine the optimum fibre composition for reinforcing these thin sections.

6.3.8 UTCRCP modelling

The behaviour of Ultra-thin continuously reinforced concrete pavement (UTCRCP) depends on the behaviour of supporting material. This project will look at the consequences of changing the layerworks used in UTCRCP. Scale models will be studied.



6.3.9 Expansion of materials used in UTCRCP

Local “buckling” of UTCRCP has taken place and on trial sections on the N12 the mesh “snapped”. At this stage these failures seem to take place on very hot days, when the concrete is saturated after rain. In this project the student will determine the actual expansion of concrete caused by variations in moisture content and temperature.

6.3.10 Cracking and early age tensile strength of concrete

Concrete cracks when the stress in the concrete exceeds the tensile strength. Concrete often cracks within hours after casting when the concrete temperature reduces and shrinkage takes place before significant strength development. In this project the student will determine tensile strength and crack development for different mix compositions.

6.3.11 Factors affecting the measured stiffness of concrete

It is known that the stiffness of concrete is not a constant and the stiffness is affected by the strength, load-level, aggregate type and sample size and shape. Different standard test methods use different testing frames to measure the E-value of concrete. In this study the student will determine the effect of gauge length on the measured stiffness.

6.3.12 Steel for reinforced concrete scale models

Geotechnical engineers have been using aluminum to model structures in scale models for centrifuge testing. Reinforced concrete is designed to crack under load, resulting in a reduced stiffness of concrete structures. This change in stiffness with increase in load cannot be simulated if aluminum is used in the models and therefor we have been scaling down concrete mix compositions and reinforcing bars for use in scale models. In this project the student will investigate the effect of scale on the bond between the concrete and the reinforcing bars.

6.3.13 Manufactured aggregate

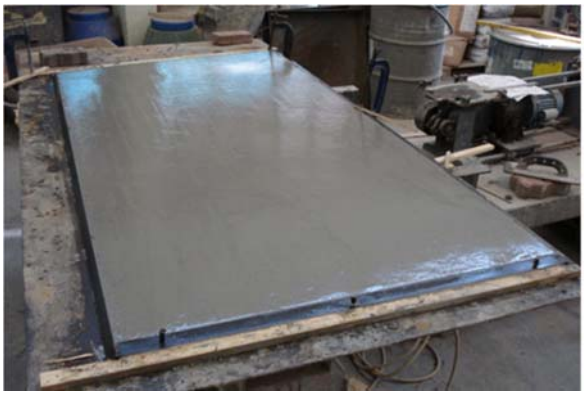
Coal fired power stations produce large volumes of fine ash as waste which is currently spoiled in landfill sites. This ash can be blended with clay, shaped into beads and fused at high temperature to manufacture lightweight aggregate for use in concrete with reduced own weight. In this project the student will investigate the effect of different combinations of raw materials and kiln temperatures on the properties of the man-made aggregate.

6.3.14 Recycled aggregate

It has been proven that 100% of the coarse aggregate in concrete can be replaced with recycled aggregate without any significant reduction in strength. There does seem to be an increase in long term deformation of concrete containing recycled aggregate. In this project the student will establish whether recycled aggregate concrete can be used to manufacture pre-stressed concrete.

6.3.15 Ultra high performance concrete

It is possible to make concrete with strength in excess of 150 MPa. By reinforcing this concrete with high strength steel fibres a matrix with properties similar to steel can be obtained. In this project the student will investigate the optimum composition for thin panels made from this type of composite.



6.3.16 Stress distribution in concrete cylinders

Concrete strength and stiffness is measured on samples in uniaxial compression. The effect of confinement on the central part of samples is neglected and the ridged platens of concrete presses ensure that the strain through the whole sample is constant – does that mean that the stress in the centre of the sample is higher than that on the edges? For this project the student will use strain gauges in different locations and positions on the sample to determine the effect of the boundary conditions on the measured concrete properties. Triaxial tests can be conducted to compare behaviour.

7 RAILWAY ENGINEERING

7.1 Prof Hannes Gräbe (assisted by Mr. David Mpye)

Please note:

- All Railway Engineering research topics are linked to industry needs and are sponsored or supported in different ways by Transnet Freight Rail, The Railway Safety Regulator and other industry partners.
- Students choosing Railway Engineering should discuss the topics with (or email) Prof. Gräbe (Eng 1, Room 13-7) before submitting their choices. There are transportation, time and various other terms and conditions that apply.
- Most of the research will be carried out on the Experimental farm Test track, the newly installed MTS testing frame in the Civil Engineering laboratory and on selected railway lines in the Tshwane area.

7.1.1 Conventional Track Performance and Characterization

During November 2012, a 30 m section of railway line was constructed on the Experimental farm (Proefplaas), University of Pretoria. Loading on the track is provided by a specially designed bogie with a capacity of 80 ton or by using the loading frame with which vertical and lateral axle loads can be simulated. A number of projects (defined or new and original) will be available to investigate various aspects related to the performance of the conventional track structure:

7.1.1.1 The longitudinal stress in Continuously Welded Rail (CWR) depends on the relationship between air and rail temperature. This relationship was empirically determined years ago and has not been verified recently, especially in the light of climate change and global warming. The student will use new instrumentation to investigate and quantify the relationship between rail and air temperature, wind chill, radiation and other environmental effects.

7.1.1.2 On test sites and in the field, engineers use strain gauges to measure the wheel loads of passing trains. This method is time-consuming and requires calibration with heavy equipment and track occupation time. The student will use visual methods to carry out full-strain measurement of the rail under vertical loading and thereby calculate the applied vertical loading.

7.1.1.3 Own topic as defined by the student in consultation with the supervisor.

7.1.2 Non-Conventional Track Structure performance

Tubular Modular Track (TMT) and PY Track Slab are both South African inventions and ballast-less alternatives to conventional track. TMT modules are pre-casted in a factory and then transported to site where installation takes place. TMT and PY Track Slab have specific advantages over other track structures which include lower maintenance cost, slower track deterioration and higher stability. A number of topics are available which include laboratory tests on components of TMT, field tests at an appropriate site as well as numerical analysis. TMT and PY Track Slab topics include the following:

7.1.2.1 The effect of different rail pads on noise and vibration measurements near Tubular Modular Track and/or PY Track Slab in comparison to ballast track behaviour. Noise pollution is becoming a very important aspect to be considered in all track construction, especially in urban areas.

7.1.2.2 The effect of lateral forces on rail deflection and a comparison of lateral rail head rotation between fastenings (TMT vs. Conventional track). Lateral rotation is important as it carries a high safety risk with regard to derailments.

7.1.2.3 Own topic as defined by the student in consultation with the supervisor.

7.1.3 Resilient and Permanent Deformation Behaviour of Track Substructures

An existing research test site has been in use for several years on the Coal Line between Vryheid and Richards Bay. Instrumentation already installed includes multi-depth deflectometers (MDDs) and strain gauges. Field tests will be carried out to model the resilient and permanent deformation behaviour of the track foundation by using new techniques and novel instrumentation.

7.1.3.1 Characterizing seating and loaded stiffness of track ballast by using Remote Video Monitoring (RVM). Conventional methods are costly and time-consuming. The student will use RVM methods and software to characterize track performance by measuring and calibrating RVM results against conventional methods. RVM technology will be used to calculate the deflection, velocity and acceleration of different track components. A similar experiment can also be carried out in the laboratory under controlled conditions.

7.1.3.2 Establishing the Young's modulus of a multi-layered track formation. A method developed by pavement engineers uses the shape of the deflection bowl caused by vehicle loading to derive the individual E-values of a multi-layered track formation. In this research the student will use this approach to determine whether this is accurate or possible at all by comparing calculated E-values with measured E-values from MDDs.

7.1.3.3 Track Characterization using geophysical techniques (e.g. geophones or PSPA). The student will use geophysical instruments to measure track response to train loading and relate that to standard deflection measurement methods. Track characterization is important when upgrades for higher axle loads and when track formation failure is eminent.

7.1.4 Formation/Ballast/Sleeper performance and design life prediction

The newly acquired MTS loading actuator in the Civil Engineering laboratory enables us to carry out accelerated testing on all kinds of track components under controlled conditions. The following laboratory experiments are available.

7.1.4.1 Under-sleepers pads (USP) are now being developed to lower the contact stress and increase the contact area between the sleeper and the ballast. Previous research has shown that ballast settlement can be reduced significantly by introducing this technology. The student will carry out laboratory tests to evaluate the design life and deterioration of USPs on railway lines, especially heavy haul.

7.1.4.2 Ballast becomes rounded when subjected to repetitive loading. As the ballast loses its angularity, it also reduces its shear strength, resulting in increased settlement rates and track geometry deterioration. Tests will be carried out to determine the limits that govern the replacement/screening of ballast.

7.1.4.3 Sleepers become rounded due to repetitive hand tamping at the same location. This process takes place on the underside of sleepers and is hidden from normal sight. At some stage in this process of degradation, the sleepers have to be replaced. Currently no guidelines or limits exist

to manage this replacement intervention. Laboratory tests and possibly also numerical modelling will be required to quantify and relate sleeper rounding to track performance.

7.1.4.4 Ballast becomes fouled with time as a result of ballast breakdown and external contamination from spillages from the wagons or from fouling material blown into the ballast by wind. The student will investigate the effect of fouling material type and the degree of fouling on the settlement of ballast by carrying out applicable ballast box tests.

7.1.4.5 Rigid-foam polyurethane can be used to reinforce ballast at track transitions to reduce settlement and undesirable vehicle dynamics. The student will perform a series of laboratory tests to evaluate methods to improve the prediction of settlement when using reinforced ballast on railway track transitions.

7.1.5 The study of railway formation under unsaturated soil conditions and cyclic loading

In a semi-arid country like South Africa, shallow foundation structures, such as railway formations are subjected to cyclic loads under unsaturated soil conditions during their day-to-day operations. From a geotechnics' point-of-view, formations are designed to withstand the impact of dynamic loads by trains. However, these models do not take into account the presence of partial saturation of the soil. Recent field tests have indicated that railway cyclic loads have an influence on the pore-pressures, which in turn influence the shear strength of the soil and subsequently both the long- and short-term stability of the track. This project is part of a broader research study aimed at understanding the behaviour of railway formations under cyclic loading.

7.1.5.1 The variations of the pore-pressures (excess or suction) under the influence of cyclic railway loads and unsaturated soil conditions by means of field tests on a railway line, coupled with the characterisation of the prevailing soil conditions during testing. The candidate will also be involved in the manufacturing and utilisation of pore-pressure measuring devices such as tensiometers.

7.1.5.2 The prospective candidate will have to undertake a research project focusing mainly on the variations of the pore-pressures (excess or suction) under the influence of cyclic railway loads and unsaturated soil conditions by means of laboratory tests, coupled with the characterisation of the prevailing soil conditions during testing. The candidate will also be involved in the manufacturing and utilisation of pore-pressure measuring devices such as tensiometers.

7.1.6 Numerical modelling of track structures

STRAND7 and CivilFEM are useful finite element software packages that can be used to create 3D models of track components and track structures. The student can choose his own topic and create an FEA model to investigate a particular aspect in the field of conventional or non-conventional track structures. Field measurements will be carried out to calibrate the FEA model. The aim of the study will be to enhance track design and to optimize performance. Possible topics:

7.1.6.1 Track transitions (e.g. tunnel, viaduct, bridge and TMT transitions to conventional track). The developed models will be calibrated with and verified against track response measurements from test tracks on the Gautrain, PRASA or TFR networks.

7.1.6.2 Slab track design for different axle loadings. The student can choose between Tubular Modular Track (TMT) and PY Track Slab systems to investigate a range of aspects that could improve the design of these track structures.

7.1.6.3 Investigation the effect of track parameters (i.e. sleeper size, spacing, rail size and ballast depth) on the induced formation stresses in a track structure. This will allow engineers to optimize track design and save on capital investment costs.

8 GEOTECHNICAL

8.1 Supervisor: Prof Gerhard Heymann

Geotechnical engineering is a challenging and rewarding field of study and many aspects of soil behaviour are still poorly understood. During this year you were introduced to a wide range of soil mechanics topics including seepage, consolidation theory, strength of soil and engineering applications such as design of shallow foundations, retaining structures, slope stability as well as embankment and tailings dams. This is an open invitation for students who have an interesting soil mechanics related question or problem that they want to investigate as a final year project.
Projects must be pre-approved by prof Heymann and he will give you a project number.

8.2 Supervisor: Prof Eben Rust

8.2.1 Evaluation of tailings dams in terms of risks and liabilities.

Tailings dams consist of mine residue. They are an asset as well as a liability to the mine. An asset in terms of the gold still contained in the residue and liability in terms of pollution, health and safety. They are subjected to regular seismic activity as well, which may lead to liquefaction of a dam. All these risks need to be evaluated.

- Evaluate the stability of a tailings dam from in-situ tests with emphasis on seepage anisotropy.
- Consider other risks such as pollution or liquefaction. Evaluate these risks using in-situ tests.

8.2.2 Soils identification via the Piezocone.

Soils ID in tailings is problematic due to the highly layered nature of the material. Several methods exist to carry out the identification. The student will be required to **compare** these **methods** and possibly come up with a **new** method.

8.2.3 Determining the permeability and liquefaction of layered tailings in the lab.

This skripsie has been an on-going project in our labs and is currently researched by a PhD student. Carry out your own version of this test in a hydraulic column. Additionally, demonstrate liquefaction in the column. (Lots of instrumentation).

8.2.4 Own subject.

The student could propose a research topic in **Geotechnical or Environmental Engineering** which will be evaluated by the leader. Alternatively the student could carry out research in collaboration with outside consultants under the guidance of the leader.

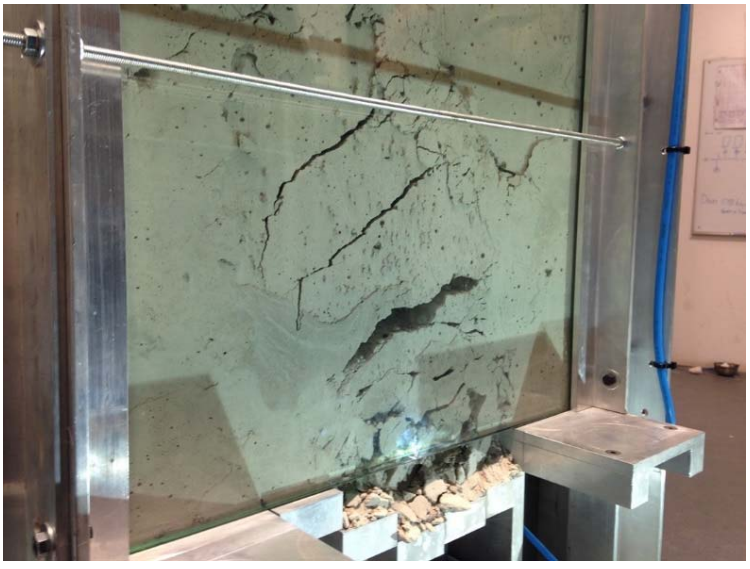
8.3 Supervisor: Prof SW Jacobsz

8.3.1 Segmental block retaining walls

Segmental block retaining walls, as shown below, are very common, but failures are very common. Model blocks made from polyurethane are available for students interested to carry out physical models tests to investigate conditions causing failure of these walls.

8.3.2 Modelling cave mining in the centrifuge

In some mining projects it is possible to undermine the ore body and allow it to fracture and collapse gradually under its own weight by removing support. If done correctly, the ore body does not need to be blasted, resulting in a very economical mining operation. We have modelled cave mining in the TUKS geotechnical centrifuge for the first time in the world in collaboration with the Australian Centre for Geomechanics based in Perth for one of their PhD students. The development of a relatively weak and brittle material that collapses realistically in the centrifuge to model cave mining was a major challenge but has been achieved. We are now ready to continue the study with this more brittle material and require students to assist with the centrifuge testing to model cave mining in this material.



A model rock mass in the geotechnical centrifuge after modelling of cave propagation.

8.3.3 Moisture absorption of soil samples (effect of temperature)

When measuring the moisture content of soil sample, the samples are weighed, dried, allowed to cool down and weighed again to calculate the moisture content. Prof Jacobsz does not understand why it is necessary to cool down the samples after drying in an oven before weighing them and is not even convinced that it is necessary. Please help to clarify this riddle once and for all! We will test a range of granular materials with and without cooling down to get to the bottom of this question.

8.3.4 Window preparation to prevent stuff sticking to window

In the centrifuge we often test physical models that we observe through a class window. We have found that under certain circumstances sand sticks to the glass window which means that our observations are of poor quality. We need to investigate various means to reduce the tendency of sand to stick to the window. These will include a set of centrifuge tests in which we observe a foundation being loaded in tests in which we have applied different treatments to the glass window to prevent sand from clinging to it.

8.3.5 The use of tensiometers to measure suctions in tailings and soils

A tensiometer is a piezometer that measures negative pore pressures. We make our own from small electronic pressure sensors, stick a ceramic filter on them, seal around them with an epoxy, saturate and calibrate them and then use them to measure both positive and negative pore pressures in soils.

8.3.6 How hard can plants suck? Implications for soil strength

When saturated soils dry out, suctions are generated in the soil. If the suctions become too large when the soil dries too much, vegetation are unable to extract moisture from the soil and dies. Soil scientists working in agriculture study the effect of suction on vegetation. On the other hand, vegetation extracting water from soils impose suctions in the soils and these suctions result in increased effective stress in soil and hence soil strength.

This study will use tensiometers to measure suctions in soil slopes and soil columns with and without vegetation to see if vegetation can increased suctions in a slope which can improve slope stability and will be carried out in consultation with the University's Soil Sciences department.

8.3.7 Settling slurries: Consolidation or sedimentation?

A tailings slurry has a higher density than water due to the solids it contains. When this relatively heavy slurry is discharged on a tailings dam or poured into a cylindrical column two processes take place, i.e consolidation and sedimentation. The heavy fluid results in an initial pore pressure distribution with depth that exceeds that of water. As the slurry settles and consolidates, the initial pore pressure distribution will change to eventually be hydrostatic. Consolidation usually takes place at an approximately exponentially reducing rate. Particles settle at an approximately linear rate according to Stokes law (when spherical). However, the finer particles settle must slower than the coarse. The consolidation and sedimentation processes take place together and affect each other. A series of column experiments will be carried out by pouring different tailing slurries into transparent tubes and measuring the pore pressure response using very sensitive piezometers while observing and timing the sedimentation process through the transparent column. This will enable us to gain a better understanding of the settlement and consolidation of tailings slurries. More information is available from a PhD thesis (Lebitsa 2016).

8.3.8 Suction generation in tailings dams

Linking to the previous topic, once tailings had settled out and consolidated, evaporation takes place resulting in the development of suctions. Work carried out using settlement columns in the Geotechnical Group has shown that consolidation of newly placed tailings layers occur rapidly after placement and that dissipation of excess pore pressures alone does not explain why some tailings dams can be constructed at very high rates of rise. It is believed that over-consolidation due to drying out and desiccation of tailings is responsible for much of the strength. Very limited data is available on the changes in pore pressures (positive and negative) during the construction of tailings dams.

Skripsie students in 2015 and 2016 modelled the construction a tailings dam a by placing layers of tailings slurry in containers and allowing them to dry out under lights while measuring pore pressures using tensiometers, as well as the strength of the tailings using a vane shear apparatus. It was found that the negative pressures generated during drying out over-consolidated the material, providing much strength. This strength was not destroyed when a further layer was placed. This important study needs to be taken further by placing more layers and using different types of tailings to study the factors contributing to tailings strength gain.

8.3.9 Over-steepening of seawalls and recovery of the water table. What happens?

At a certain diamond mine at the ocean, massive and deep excavations are carried out along the beaches to expose the diamond bearing formations at bedrock. Reliance is placed on large sand embankments to keep the ocean out of the mining areas. After mining, the mined areas are flooded and eventually rehabilitated. Due to the moisture in the sand, suctions allow the embankments to be constructed at angles somewhat steeper than the angle of repose of 34°. The rising water level results in these suctions dissipating, reducing the strength of the sand, leading to quite substantial and dangerous sloughing failures along the embankments. This becomes especially problematic when the water level reaches its original level, i.e. sea level. A series of model studies will be carried out in seepage tanks in the laboratory, building moist sand slopes of different angles and allowing the water table to rise to study the effect on over-steepened seawall slopes. It may be possible to use tensiometers to measure the effect of a rising water table on the suctions in the slopes. The aim is to formulate recommendation to the mine to avoid the sloughing problem.

8.3.10 Calibrate Tekscan pressure mats on sand

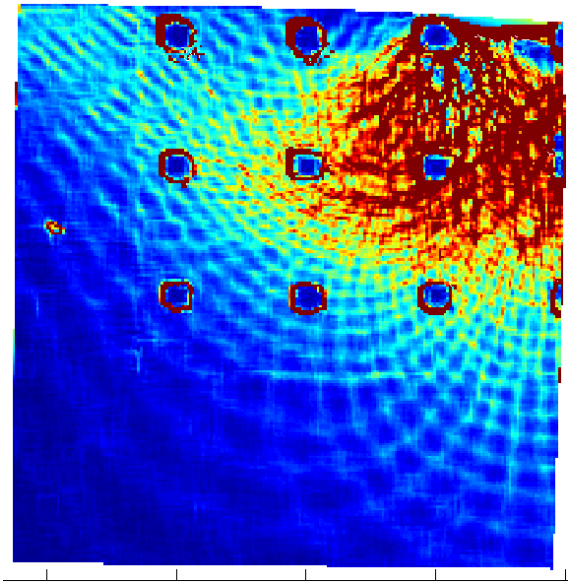
In geotechnical centrifuge models we regularly use pressure sensors looking like small mats to measure the total stress distribution over the surface area of the mat. These sensors enable us to visualise pressure distributions in real time. The output is however highly non-linear and it is important that the sensors be calibrated against the surfaces on which they are used. Up to the present we have only used their results qualitatively to get an idea of the shape of the pressure distribution, but not the actual values.

Tests will be carried out by placing the sensor mats on a surface of steel, wood, sand etc and then placing a known mass on top and then accelerating the entire set up in the centrifuge to a known acceleration. From the known acceleration the weight of mass can be determined and the average pressure underneath calculated and compared with the output from the pressure sensors to enable them to be calibrated.

8.3.11 PARTICLE IMAGE VELOCIMETRY

PIV stands for Particle Image Velocimetry and originated in the field of fluid dynamics. Small particles are injected into fluid stream, high-speed photos are taken and the movement of

the particles are tracked to study the movement of the fluid. A modification of this method applicable to certain geotechnical and structural problems was developed at the University of Cambridge between 1999 and 2002, with improvements becoming available in 2015: If photos can be taken of a soil body or a structure being deformed by, for example, the loading of a foundation, the photos can be compared with one-another to find the displacement vectors in the soil below the foundation. From the displacement vectors, the strains in the soil can be calculated. The technique is versatile, very accurate, easy to apply and creates impressive displacement and strain graphs (see below). The only instrument required is a conventional digital camera. You are welcome to suggest a topic of your choice in which you observe soil movement through a glass window and analyse the deformation field using PIV. Examples include foundation, retaining walls, soil anchors, developing sinkholes etc. Another interesting possibility is described below.



Maximum shear strain field under a foundation on sand.

8.3.12 PIV as surveying tool

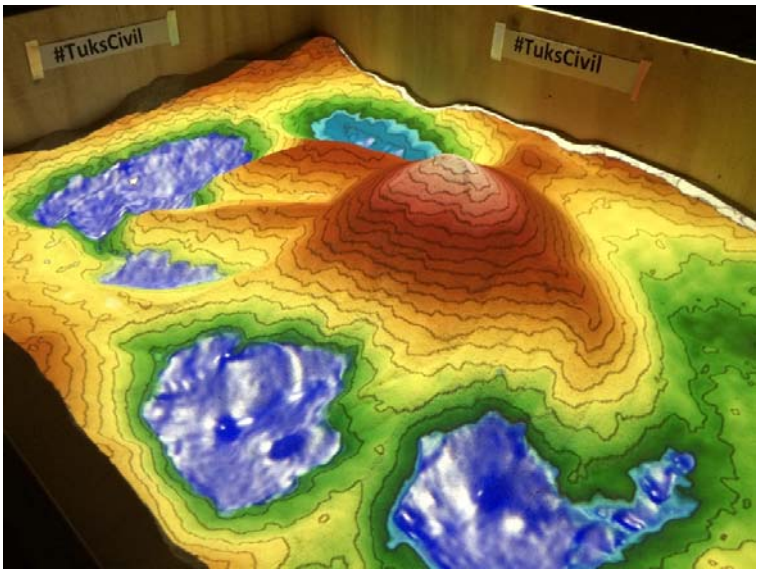
A pile test being carried out with displacement monitoring using PIV.

The figure above shows a pile test being carried out using PIV to monitor movement. The technique has also been used to measure ground settlement on, for example, a consolidating landfill site. We want to investigate the suitability of using PIV for monitoring ground movements. A camera will be set up and targets positioned at different locations. These targets will then be displaced by known amounts after which the displacement will be calculated from photos using PIV to investigate the accuracy of this monitoring method. Targets comprising single black spots or a combination of spots as shown in the figure will be evaluated.

8.3.13 Stereographic mapping

Using an Xbox 360 Kinect stereo sensor, a surface can be mapped to create a digital terrain model (DTM). Contours can be generated and the resulting contour map projected back onto the surface using a data projector to create an augmented reality model. Software developed at the University of California at Davis to achieve this is available free of charge and runs off a Linux platform. (This includes the C++ source code.) The result is illustrated below. In addition to the contouring function, the software includes a computational flow dynamics module to model fluid flow. The combined package can have useful application in the fields of surface mapping and hydrology (by modelling runoff after rainfall).

A project is to be undertaken to evaluate the accuracy and resolution of this 3D mapping tool to assess whether it can be used to track the deformation of surfaces in soil models due to various types of loading. The student will require a knowledge of programming in C++ and the Linux environment. Applications in hydrology can be studied in collaboration with our Hydraulics Group.



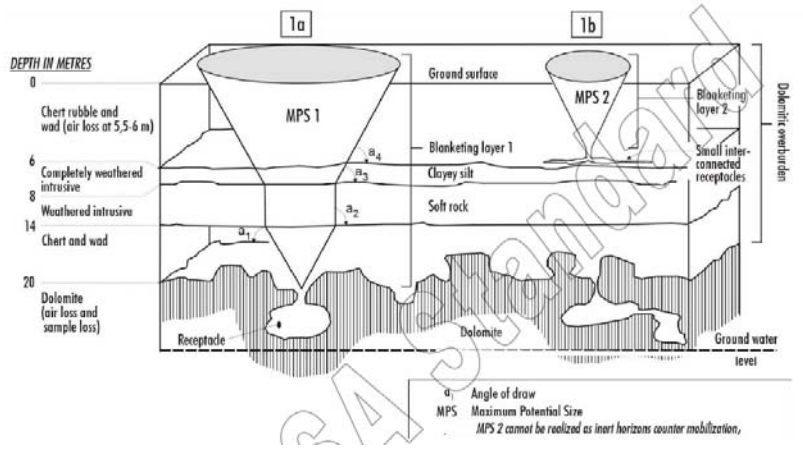
A contour map projected in real time on a sand surface using Xbox 360 Kinect stereo sensor and data projector.

8.3.14 DOLOMITIC SINKHOLES

Studying dolomite sinkhole development:

The figure below taken from the National Standard for the development of dolomitic land (SANS 1936) suggests a method for the estimation of the maximum size of a sinkhole. The method basically comprises the extrapolation of a funnel from bedrock to the surface at various slope angles in the different soil layers. The method is known to give over-conservative results, resulting in costly design solutions because of the large sinkhole size that developers have to cater for when using this method.

Recent centrifuge experiments suggest that the diameter of a sinkhole is controlled by the size of the zone in the subsoil over which support is removed, i.e. if support is removed over a diameter of 3m wide, the diameter of the depression appearing at the surface will also be 3m. The propagation of sinkholes to the surface can be studied using physical models in 2D by means of a trap-door experiment in which the trapdoor is slowly lowered, causing the overhead material to collapse.



Estimation of sinkhole size from SANS 1936 (2012).

8.3.14.1 Cavity propagation experiments

Observe cavity propagation to the surface in soils of various strengths under the controlled lowering of a trapdoor at depth. Different types of soil at various moisture contents will be tested with different trapdoor widths in models at 1g to observe cavity propagation. At nearly all real-life sinkholes that appear a leaking pipe can be found. Cavities in soils will be stable indefinitely until disturbed. The disturbance can be vibration, but much more often, it is caused by leaking services. The effects of leaking services on the stability of a cavity at depth in a soil mass will also be investigated.

We use Particle Image Velocimetry (PIV) to track soil movement around and above the growing cavity. PIV can be used to measure the displacement field in the entire soils mass and from the displacements the strain distribution in the soil can be calculated. The student will set up a camera in front of a box with a glass window through which photographs of the sand behind the window will be taken as the cavity grows. Existing software is available for the image analysis.

All physical models will initially be carried out at 1G in the laboratory. Only models judged by the supervisor to be of sufficient merit might be tested on the centrifuge.

8.3.14.2 Modelling micro-gravity surveys numerically

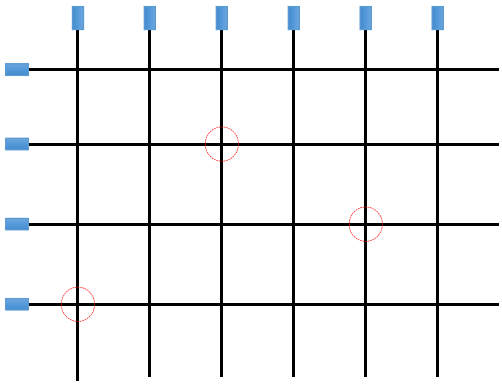
During geotechnical investigations on dolomite land microgravity surveys are often done to try to identify areas where there is a potential for sinkholes to form. These surveys comprise very accurate measurement of gravitational acceleration, usually in a grid pattern, over the area of interest. Should there be cavities in the ground, the gravitational acceleration can be expected to be less than normal. The question arises how fine you need to make the grid to identify features of a certain size and shape and depth. Finer grids give results at a higher resolution than coarse grids, but they cost more. We will investigate the required grid spacing by means of a spreadsheet modelling exercise in which we will artificially create a certain irregularity in bedrock and then carry out calculations of gravitational acceleration in a grid over it. Microgravity contour maps will be generated from calculations done at various grid spacing to find out what grid spacing is required to pick up irregularities of what size. Irregularities of various shapes and sizes will be investigated. The outcome will be valuable information for the geotechnical community.

8.3.14.3 Evaluation of the performance of a subsidence detection system (sinkhole warning system)

An envisaged ground subsidence detection or warning system will comprise a buried grid of sleeved tensioned cables covering the area of interest. Soil subsidence due to the propagation of a cavity towards the surface is likely to result in a change in the tension in the cables. By monitoring the tension in the cables, the location of the subsidence event can be detected. However, the performance of such as system has never been tested and is therefore uncertain. We intend to investigate the behaviour of such a system. Aspects to be addressed include:

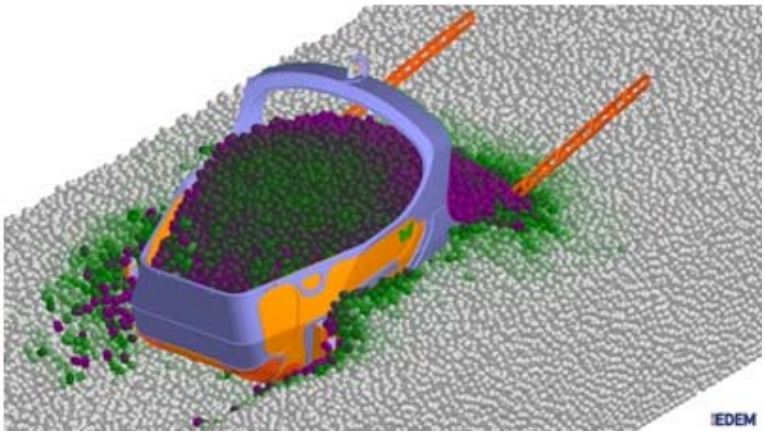
- How early will be system provide warning against sinkhole collapse?
- What are the factors controlling the performance of the system, e.g. effects of soil type (purely frictional / frictional-cohesive), depth of installation, thickness of soil overburden, etc.
- Can the system distinguish between large and small sinkholes?

The problem will be investigated by means of a model study, possibly involving the geotechnical centrifuge.



Plan view of a grid of cables attached to load cells to detect surface settlement above sinkholes.

8.3.15 DISCRETE ELEMENT MODELLING



Students may be aware of finite element modelling that allows stress-strain analysis of complicated structures to be done using computers. These methods are very effective in analysing a continuous material (referred to as continuums) like metals and allow impressive stress and strain distributions to be plotted. Soils comprise of particles and using continuum models for geotechnical analysis involves many assumptions and approximations. Discrete element modelling is now available in which the interaction between individual grains can be fundamentally analysed using Newton's laws of motion, applying friction etc. An example of a video of this process can be found online at the link below. Numerous others exist. We believe that the propagation of a cavity from bedrock to the surface to form a sinkhole can be modelled using discrete element modelling which will allow us to gain a more in-depth understanding of the factors controlling this process. The student is welcome to suggest other processes to investigate using discrete element modelling. The program to be used is likely to be StarCCM+, Abacus or EDEM (all on campus). Freeware is available online.

See https://www.youtube.com/watch?v=r2sUPDzDVmQ

Key reference: P.A. Cundall, O.D.L. Strack. 1979. A discrete numerical model for granular assemblies. Géotechnique, 29 (1) (1979), pp. 47–65.

For more ideas for geotechnical projects look at the videos at the following link:

http://ascelibrary.org/doi/suppl/10.1061/9780784413920.video

One liner topics:

8.3.16 Soil water characteristic curves for unsaturated soils. Investigate hysteresis during a number of wetting and drying loops.

8.3.17 Tailings dam breaks modelled in the centrifuge at high stress.

8.3.18 Measuring suctions in unsaturated soil samples being sheared.

8.3.19 Measuring suctions in unsaturated samples being loaded in the oedometer

8.3.20 Effect of sample size on tensile strength of unsaturated soil samples