Capacity Building and Skills Development Programme for the Laboratories of the Local Government Infrastructure and Transportation Research Centre (LoGITReC) in Tanzania

Final Report

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Cover photo: President's Office, Regional Administration and Local Government in Dodoma, Tanzania

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Executive Summary

The overall objective of this project "**Capacity Building and Skills Development Programme for the Laboratories of the Local Government Infrastructure and Transportation Research Centre (LoGITReC) in Tanzania"** is to equip the laboratory of LoGITReC, with the necessary skills and additional equipment to enable the facility to operate as a reference and quality control laboratory for the President's Office - Regional Administration and Local Government (PO-RALG) and as a research laboratory for LoGITReC.

Africa Community Access Partnership (AfCAP), a programme of research and knowledge dissemination funded by the UK government through the Department for International Development (DFID) provided the assistance for the implementation of this project, in response to the request from PO-RALG for support to carry out the training and skills development of LoGITReC personnel. The project was therefore aimed at addressing one of the needs of the country, to build the required capacity that will support the research activities by LoGITReC related to rural and urban roads network and therefore contribute towards improvement of the provision of transport infrastructure, particularly in the rural communities.

The project was designed and planned to be implemented through three main capacity building activities, namely: (i) capacitation of laboratory staff, through hands-on training of the technicians in laboratory testing according to the CML Laboratory Testing Manual (2000) of Tanzania and secondment of the Laboratory Manager to an ISO 17025 accredited research laboratory, (ii) development of operational systems for the laboratory and (iii) the procurement of additional equipment.

The outcomes of the project include:

- Staff with technical competence in routine laboratory testing for soils and gravel, aggregates, and concrete in accordance with the CML Laboratory Testing Manual (2000) of Tanzania and a laboratory manager with the knowledge and skills to manage a research laboratory;
- An electronic Lab Work Management System, to enhance quality management of data collection and storage and efficient processing of laboratory materials records, which will also be used by other laboratories under Tanzania Rural and Urban Roads Authority (TARURA);
- Standardised operational protocols/procedures for regulating everyday management of the laboratory in a consistent and sustainable manner to ensure a safe working environment, proper management of laboratory equipment, inclusive of maintenance and calibration requirements, to ensure results that are accurate and reliable.

The project benefits are already evident and the target indicator of providing laboratory and field testing services has been met in less than six months, following the enhanced training of the laboratory personnel. Twenty-four laboratory and field testing contracts have been completed for clients working on Government projects, including direct assignments from TARURA and Executive Director's Office, which previously would have been done by the regional TANROADS-CML. This has meant reduced waiting period for laboratory and field testing results and impacting positively on delivery of projects.

The project has influenced the initiative to implement a proficiency testing programme for civil engineering laboratories in Tanzania. The discussions held during the consultative meetings as part of the project implementation process, revealed there is no national-level standardised inter-calibration study programme for civil engineering laboratories in

Tanzania. As a result of this project, efforts are underway to initiate the inter-calibration study programme that will be implemented across civil engineering laboratories in Tanzania.

A critical mass of skilled laboratory personnel with a good understanding of the fundamental principles of testing in accordance with the CML Laboratory Manual 2000, has been created for the benefit of other Local Government entities. Three of the participants were from the city councils of Arusha, Mbeya and Mwanza and they will be establishing laboratories in their respective municipalities. Thus the impact of the capacity building and skills development programme goes beyond LoGITReC and it is an additional achievement of the programme specifically and the project in general.

Key words

Capacity building, laboratory equipment, laboratory quality management, laboratory process control, research laboratory, quality assurance.

AFRICA COMMUNITY ACCESS PARTNERSHIP (AfCAP)

Safe and sustainable transport for rural communities

AfCAP is a research programme, funded by UK Aid, with the aim of promoting safe and sustainable transport for rural communities in Africa. The AfCAP partnership supports knowledge sharing between participating countries in order to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources. AfCAP is brought together with the Asia Community Access Partnership (AsCAP) under the Research for Community Access Partnership (ReCAP), managed by Cardno Emerging Markets (UK) Ltd.

See www.afcap.org

Acronyms

AfCAP	:	Africa Community Access Partnership
CML	:	Central Materials Laboratory
CMRL	:	Central Materials Research Laboratory
CSIR	:	Council for Scientific and Industrial Research
DFID	:	Department of International Development
DID	:	Division of Infrastructure Development
ISO	:	International Organisation for Standardisation
LGA	:	Local Government Authority
LGTI	:	Local Government Training Institute
LoGITReC	:	Local Government Infrastructure and Transportation Research Centre
PO-RALG	:	President's Office, Regional Administration and Local Government
ReCAP	:	Research for Community Access Partnership
TBS	:	Tanzanian Bureau of Standards
TSCP	:	Tanzania Strategic Cities Project
TANROADS	:	Tanzania National Roads Agency
TARURA	:	Tanzania Rural and Urban Roads Agency
RML	:	Regional Materials Laboratories

Contents

List of Figures

List of Tables

1 Background

The provision of reliable and cost-effective transport infrastructure is recognised as one of the essential strategic interventions to promote economic development of the country. An efficient national network should also provide sustainable access to economic and social opportunities for poor rural communities and links between rural areas and the main road network. In Tanzania "Rural Roads" and "Urban Roads" mean all District roads within Councils established under the Local Government (District Authorities) Act CAP 287 and under the Local Government (Urban Authorities) Act CAP 288, respectively. Until April 2017, the Local Government Authorities (LGAs) had the responsibility to manage rural and urban roads network, under the coordination and monitoring of President's Office, Regional Administration and Local Government (PO-RALG) through Division of Infrastructure Development (DID). This has since changed with the establishment of the Tanzania Rural and Urban Roads Agency (TARURA)[1].

The implication is that TARURA, established under the Executive Agencies Act Cap. 245, 2017 has taken over the operational roles and functions related to development and maintenance of rural and urban roads network. All operational work related to rural and urban roads network performed under the PO-RALG falls under TARURA, but the role of policy formulation and monitoring of development and maintenance of rural and urban roads network, implemented through the Division of Infrastructure Development (DID), remains with PO-RALG.

Thus it was in 2014 that the Local Government Infrastructure and Transportation Research Centre (LoGITReC) was established under then Prime Minister's Office – Regional Administration and Local Government (PMO-RALG), now known as PO-RALG, aimed at building the long-term capacity to address the needs of the country, to have qualified technical and managerial staff with the skills to manage operational functions of a laboratory that will support undertaking of relevant, high quality research in the country and therefore contribute towards improvement of the provision of transport infrastructure, particularly in the rural communities. In 2015, LoGITReC under PO-RALG, with assistance provided by AfCAP, produced a Five Year Strategic Plan.

As per terms of reference, the Five Year Strategic Plan was endorsed by the AfCAP National Steering Committee on 30 March 2015, following which LoGITReC established a Central Materials Research Laboratory, hereinafter referred to as CMRL, on the premises of the Municipal Council in Dodoma at a cost of Tsh 60 million. It was immediately established that the laboratory technicians had very little exposure to road material testing prior to joining CMRL. To address this, some basic training was provided by the Tanzania Roads Agency (TANROADS), Regional Laboratory in Dodoma during October to November 2015. The evaluation of the training revealed that further knowledge strengthening was required for the CMRL personnel to fulfil the requirement for a facility that will operate both as a reference laboratory and a research laboratory and to ensure delivery of credible test results. AfCAP accepted the request from PO-RALG for support to carry out the training and skills development of the CMRL personnel.

Thus the overall objective of this project is to assist LoGITReC to achieve its objective of capacity building and skills development for its laboratory staff at CMRL and to equip the laboratory, with the necessary additional equipment. Capacity building and skills development of laboratory personnel at CMRL required training of personnel at an established laboratory in Tanzania and the secondment of

[1] The Executive Agencies Act (CAP.245). Executive Agencies (Tanzania Rural and Urban Roads Agency) Establishment Order, 2017.

the CMRL Manager to an ISO 17025 accredited research laboratory, achieved through the Council for Scientific and Industrial Research (CSIR) and finally a hands-on training at CMRL in Dodoma. A research laboratory is expected to have a management system in place to strengthen the operational procedures of the laboratory and to provide the confidence to customers as a provider of quality service. In addition, for CMRL to fully function as a road materials testing laboratory, delivering credible test results as well as act as a reference and research laboratory, it should have appropriate and well maintained equipment. The need to equip CMRL with additional equipment was recognised and therefore forms part of this project.

To achieve the objectives of the project, the strategy on capacity building addresses issues relating to the individual staff members, infrastructure and the organisation arrangements. Thus this project approached capacity building through: (i) capacitation of laboratory staff, (ii) development of operational systems for the laboratory, and (iii) procurement of additional laboratory equipment.

This Final Report captures the key elements of the project implementation to achieve the objectives of the project "**Capacity Building and Skills Development Programme for the Laboratories of the Local Government Infrastructure and Transportation Research Centre (LoGITReC) in Tanzania"** and highlights the achievements and the impact of the project.

2 Capacity building

2.1 Training at TANROADS-CML

The first stage of the capacity building programme involved training conducted at TANROADS-CML in Dar es Salaam to enhance knowledge of testing procedures in all areas of the materials laboratory and strengthen required competencies of staff at CMRL. However, three additional participants from the city councils of Arusha, Mbeya and Mwanza, who were also establishing local government laboratories under the Tanzania Strategic Cities Project (TSCP), attended the training. Table 1 shows all who took part in the training.

Table 1: List of participants

Name of Participant	Institution	Position
Lwanda, Vincent	PO-RALG	Engineer, LOGiTReC Lab Manager
Mbunda, Geofrey	PO-RALG	Technician, LoGITReC
Kamba, Ahsante,	PO-RALG	Technician, LoGITReC
Tuka, Vestina	Arusha City Council	Engineer
Jackson, Ndairagije, J	Mbeya City Council	Civil Technician
Manguye, Jacob, P	PO-RALG	Technician, LoGITReC
Mkumbo, Peter, J	PO-RALG	Technician, LoGITReC
Juma, Nassoro, S	PO-RALG	Technician, LoGITReC
Mtalasi, Daudi, M	Mwanza City Council	Technician

The training programme was prepared by TANROADS-CML senior staff with intimate knowledge of testing procedures detailed in the CML Laboratory Testing Manual (2000)[2] of Tanzania. However, the complete and individual hands-on training was scheduled to be conducted at CMRL in Dodoma.

One key expected outcome of the project was well-trained laboratory staff capable of carrying out the various test methods and having an understanding of the meaning of the obtained results. Phase 1 of the training was designed to be delivered through three components in order to facilitate: (i) knowledge building on fundamental principles, (ii) an understanding of the application of the tests and (iii) development of laboratory skills. Table 1 presents the objectives of the training components.

Table 2: Components of training

Training Components	Description	Objective
Basic Principles	Test Objective	Provide background on test method and clarify terms
	Test equipment	Familiarise the participants with the required equipment for the test
	Test procedures	Explain to participants methods of testing
	Test application	Explain to participants to understand application of the test to practical problems
Practical Exercise	Materials testing	Familiarise participants with sample preparation for specific test method and analysis
		Provide the particpants the opportunity to demonstrate ability to conduct test
		Allow participants to demonstrate individually/team undertstanding to record data
Synthesise	Synthesise knowledge acquired	Assess level of achieved understanding and areas of improvement
		Discuss lessons learnt
		Provide participants the insight into the linkage to specification requirements, materials design.

[2] Laboratory Testing Manual 2000. United Republic of Tanzania, Ministry of Works.

The training was held as follows:

- Classroom sessions were first held to make presentations aimed at providing the participants with a knowledge base on fundamental principles in material testing, specifically on the tests they were going to conduct on that day.
- Basic theoretical background, step-by-step test procedures, and list of equipment required for the test and how to record the data on standardised data sheets were presented and discussed.
- Participants were divided into groups of four for the laboratory sessions, based on test equipment availability and safety considerations, but also guided by previous training experiences.
- The equipment to be used for the test was presented with further explanations to link with classroom presentations.
- The full test procedure was then demonstrated to allow the participants to familiarise themselves with the correct procedures in conducting the test.
- The participants were then allowed to conduct the test with supervision by TANROADS-CML personnel and direct observations by the project team leader.
- Second classroom sessions were undertaken after the laboratory sessions aimed at wrapping up the day's training through discussions.
- An evaluation of the sessions was also conducted which included discussions on the highlights of the days' training programme. The discussions were facilitated by the Project Team Leader.

During the classroom training**,** the reference test methods for soils and gravels and for testing of aggregates and concrete were presented in detail, and are presented in the project Capacitation of Laboratory Staff: Phase 1 Report[3]. There were two overarching learning objectives for the training programme. It was envisaged that upon successful completion of the training participants should be:

- Familiar with the scope of CML reference test methods;
- Familiar with the principles and procedures of CML reference test methods.

The specific learning objectives for the referenced test methods were provided for each learning module at the beginning of the presentation. Each participant was provided with the CML Laboratory Testing Manual (2000).

The overall purpose of the practical sessions was to increase knowledge and confidence of the participants in carrying out the laboratory tests. The practical sessions were therefore designed to provide an opportunity for each participant to be active when carrying out the tests, following the demonstrations. Each practical session was started by explanation and demonstration of the test procedure by the CML senior staff, to ensure that the participants understood the techniques and

[3] M B Mgangira and D Ventura. **Capacity Building and Skills Development Programme for the Laboratories of the Local Government Infrastructure and Transportation Research Centre (LoGITReC) in Tanzania. Capacitation of Laboratory Staff: Phase 1**. CONTRACT REF NO. AfCAP/TAN/2095A. January 2017.

procedures to conduct the tests effectively. Safety requirements were also highlighted. To ensure active participation of the participants, an interactive approach was adopted during the demonstration sessions.

The demonstration offered the opportunity for the participants to observe and acquaint themselves with sample preparation, type of equipment, the methods of testing, including how to clean equipment and working areas after conducting the tests. The participants then carried out the testing procedures according to the respective CML test method scheduled for that day or a particular session. The tests were conducted under supervision of CML senior staff, to provide guidance. Interventions were immediately made with explanation to ensure that participants took appropriate measures to correct mistakes. The hands-on training at TANROADS-CML was limited to group work, but was aimed at ensuring that all participants achieved the minimum required standard and level of competence, to prepare them for conducting the specific tests independently, during Phase 2 of the training at CMRL in Dodoma.

2.2 Hands-on training at LoGITReC-CMRL

The overarching learning objective for the hands-on training programme was that upon successful completion of the training, participants should be familiar with the scope, principles and procedures of reference test methods according to CML Laboratory Testing Manual of 2000. The hands-on training was aimed at preparing each technician to be capable of conducting specific test methods and to allow for participants to be individually evaluated. The hands-on training was conducted by the Laboratory Management Specialist for the project, the Manager of the CSIR Built Environment Advanced Materials Testing Laboratories, over a period of four weeks, but conducted in two-week-block sessions.

The hands-on training programme is deemed one of the critical processes of capacity building for the technicians, during which they can demonstrate how familiar they are with the principles and procedures of CML reference test methods. The hands-on training was structured in a way that it created a realistic testing process to develop the capability to conduct the specific test methods as undertaken during Phase 1 of the training programme at TANROADS-CML in Dar es Salaam. Each participant therefore individually demonstrated capability to carry out the various test methods according to the CML Laboratory Testing Manual of 2000 and was individually assessed on how he/she conducted the tests.

To ensure test precision and repeatability, all testing was done in a similar manner by all the participants in accordance with the standard test procedures. The hands-on training consolidated each participant's ability and confidence in carrying out the test methods to achieve the specific learning objectives for each reference test method. Where inadequacies were observed, participants were allowed to repeat the test under the supervision of the Laboratory Management. The technicians carried out the following principal tests, which were dictated by the available laboratory equipment:

- Sample preparation;
- Sieve analysis;
- Determination of Atterberg Limits;
- Compaction tests – Optimum Moisture Content (OMC and Maximum Dry Density (MDD) both done according to British standards;
- California Bearing Ratio (CBR).

- Aggregate Impact Value (AIV); Flakiness and Elongation
- Concrete cube crushing
- Block crushing,
- Unconfined Compressive Strength (UCS),
- ACV and 10% FACT (10% FCV).

There are a number of possible tests as listed in the CML testing Manual that can be conducted. The core tests that should have been added had the equipment been available, include the following:

- **Soils and Gravels**: Hydrometer analysis; Triaxial testing; pH value; Initial consumption of lime/cement.
- **Aggregates**: Relative Density and Water Absorption; Los Angeles Abrasion.
- **Asphalt and Bituminous Materials**: Density of Binders; Thin Film Oven Test (TFOT); Penetration; Ductility; Softening Point; Brookfield Viscosity; Production of hot bituminous mixtures and all the testing associated with hot mix asphalt – listed in CML Laboratory Testing Manual.

The outcomes of the training sessions are discussed in Section 2.5. It should be noted that, while testing of bitumen and bituminous materials was also included during the training in Phase 1, it was not undertaken in Phase 2 as this was only added to complement knowledge on material types used in pavement construction. It was not one of the training requirements needing to be addressed immediately under the current assignment.

2.3 Synthesis of laboratory training programme

This session was scheduled at the end of the day to summarise the most significant learning points of the day by highlighting key issues, which included discussions on the relevance of the tests performed to standard specifications for road works and to underscore the linkage between the manuals with respect to the laboratory tests with pavement and materials design as illustrated in Figure 1 and Table 2. The importance of conducting tests according to the procedures and implications of inaccurate interpretation of results were also illustrated during the discussions, this included examples of applications of the test methods in the execution of road works.

Time was provided to encourage the participants to ask questions for further clarifications on the test procedures and any other issues related to the training and the day's activities. On the days that the tests required more time, it was not possible to have these sessions on the same day. In such cases, some time was spent for the purpose of reflecting on the key issues of the previous day, before a new module was presented. This session was presented and facilitated by the Project Team Leader.

Table 3: Linkage between CML test reference and Specifications

TABLE 3903/1
COMPACTION REQUIREMENTS FOR BASE COURSE OF CRUSHED AGGREGATE

Material class specified	Minimum dry density, nominal value.
CRS	100% of BS-Heavy (*CML test 1.9*)
CRR	88% of the aggregate's apparent density (*CML test 2.2*)

The Engineer may allow that the BS-Heavy compaction is used as reference value for class CRR materials. In such case the minimum nominal field density requirement shall be 104% MDD of BS-Heavy.

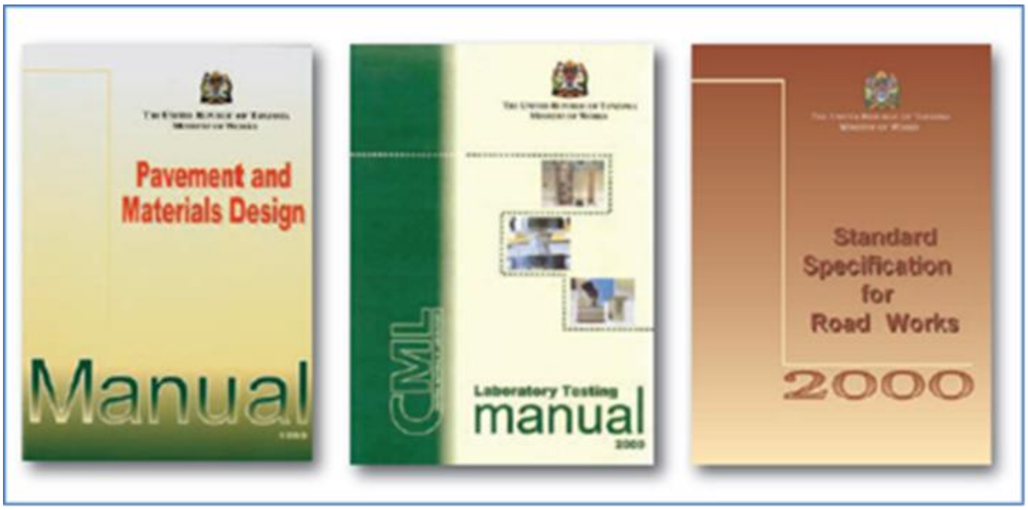

Figure 1: Illustration of linked documents

2.4 Secondment of CMRL Manager

The experiential learning for the CMRL Manager at an ISO 17025 accredited research laboratory was embedded in the capacity building programme of the project. To this end, the CMRL Manager was seconded to the CSIR Built Environment Advanced Materials Testing Laboratories. The secondment was aimed at providing a learning experience to the CMRL Manager for a period of three (3) weeks, which included job shadowing the Manager of CSIR Built Environment Advanced Materials Testing Laboratories, who was the Materials Specialist for this project. The secondment was intended to provide the CMRL Manager the insight into the operational and managerial requirements of a testing laboratory, both as a reference laboratory and a research laboratory, and therefore the knowledge and skills needed to implement best laboratory practices at CMRL.

Provided below are the broad areas covered during the secondment. Details, including the overall programme for the secondment were provided in Capacitation of Laboratory Staff: Phase 2 Report[4]. The CMRL Manager observed and participated in certain aspects of laboratory safety, service delivery, for example, sample routing, laboratory testing and standardisation, which included operational procedures and equipment evaluation, discussions on both managerial and technical aspects of a research laboratory, proficiency schemes and required procedures, to have an insight into different testing procedures. Observed testing included the standard granular materials tests, binder testing and asphalt tests, summarised as follows:

- Sample preparation
- Optimum Moisture Content / Maximum Dry Density determinations (OMC/MDD)
- California Bearing Ratio (CBR)
- Atterberg Limits
- Aggregate Crushing Value (ACV)
- Introduced to Tri-axial testing
- Bitumen penetration
- Recovery of binder from asphalt materials
- Softening point of binder
- Ductility of binder
- Bitumen ageing determination
- Viscosity determination
- Dynamic Shear Rheometer (DSR) testing
- Bending Beam Rheometer tests
- Introduction to the preparation of various asphalt mixes
- Various methods of the laboratory compaction of asphalt
- Fatigue testing of asphalt beams
- Hamburg rutting test
- The determination of the dynamic modulus of asphalt mixes

During the period of the secondment, CSIR Built Environment Advanced Materials Testing Laboratories were preparing for the inspection by South African Accreditation System (SANAS). It was an opportune time for CMRL Manager to witness preparation procedures for the accreditation inspection. An opportunity was also provided for him to hold discussions with researchers within the Transport Infrastructure Engineering Competence Area. A discussion on staff appraisal was held with the Project Team Leader. Specific discussions through a prepared Question and Answer process, covered in the Capacitation of Laboratory Staff: Phase 2 Report, were held with the project

[4] M B Mgangira and D Ventura. Capacity Building and Skills Development Programme for the Laboratories of the Local Government Infrastructure and Transportation Research Centre (LoGITReC) in Tanzania. Capacitation of Laboratory Staff: Phase 2. CONTRACT REF NO. AfCAP/TAN/2095A. April 2017

Laboratory Materials Specialist in his capacity as Manager of the CSIR Built Environment Advanced Materials Testing Laboratories and covered the following areas:

- Laboratory organization
- Duties and daily responsibilities
- Staff appraisal
- Working tools, machines and computer programs
- Accreditation requirements (SANAS).

In addition to testing procedures, he was also introduced to laboratory management systems, both manual and electronic and he was acquainted to the Lab Work Management System that was being developed for CMRL. This provided an opportunity for CMRL Manager to have prior knowledge and a better understanding of the system.

2.5 Results of the training sessions

During Phase 1, the observational method of assessment of the participants was used as they performed the different tasks in their respective groups. At the end of the first training block, information was also sought from the participants to determine whether they effectively gained the knowledge and competence needed to perform specific tests. The captured information was useful in the preparation of Phase 2 training as the feedback helped in pointing out the areas where the participants felt they had not gained adequate knowledge. In Phase 2, the evaluation was through assessment of each participant’s ability to demonstrate capability to carry out a specific test method. This was to ensure that each technician is able to independently complete a test procedure.

2.5.1 Sample preparation

Participants were made aware that the sample for laboratory testing must be representative of the field sample and preparation procedure is used to minimize variation and that field material must be reduced to an appropriate size for specific laboratory tests and analysis. The method of preparing material for laboratory test samples, from large field sample is not specifically referenced in the CML Laboratory Testing Manual of 2000. There is reference to reducing the sample size by riffling and quartering to obtain a suitable test sample. However, it would be appropriate to include a chapter on sampling procedures in the manual for all the material types Soils and Gravels, Aggregates, Bituminous Binders, which is currently not the case.

Observations:
The expected outcome of the training as per procedure on sample preparation was that the participants should know how field samples are produced and prepared for a representative sample for laboratory testing particle size analysis and for constants testing (liquid limit and plastic limit). Participants demonstrated awareness that sample preparation is done by quartering and with the use of rifflers. There were no problems observed during the procedure to produce a representative sample.

Outcome:
All the technicians demonstrated a good understanding of the requirements of the sample preparation process and how to produce a representative sample.

2.5.2 Moisture content

During the classroom session the fundamental principle on moisture content of the soil or aggregate, that it is assumed to be the amount of water present in the pore spaces of the particles, was explained to the participants, so that they understand that this moisture is removed by oven-drying and the amount removable is expressed as a percentage of the dry mass. In practice, the presence of moisture has an effect on soil behaviour, for example reduction in shear strength or volume change in fine grained soils. The test was carried out in accordance with CML Tests 1.1 and 2.1.

At the end of the training, the participants were expected to:

- Know the applicable sample preparation for the test method
- Know the minimum soil sample weight requirement for fine-grained, medium-grained and coarse-grained soils;
- Know the drying process of the soil sample
- Be able to calculate Moisture Content of the soil specimen as a percentage of the dry soil mass.

Observations:
There were no problems observed during the determination of Moisture Content.

Outcome:
All the participants satisfactorily demonstrated that they were familiar with the scope of CML Test 1.1, knew minimum specimen size requirements for moisture content determination, balance readability requirements for samples based on desired accuracy and were able to calculate moisture content and how to report it.

2.5.3 Atterberg limits and linear shrinkage

These methods cover the determination of the liquid limit, plastic limit and linear shrinkage. The fundamental principle was provided, explaining that these tests define the state of moisture and its variation in fine grained soils and that these parameters will provide an indication of the expected behaviour of soils, when subjected to a variation in moisture condition. Although the Cone Penetrometer is the preferred method according to CML Laboratory Manual, participants were made aware that there are two methods for determining the liquid limit, use of the Casagrande apparatus and the Cone Penetrometer – One-Point method. The tests were conducted according to CML Tests 1.2, 1.3 and 1.4:

At the end of the training, the participants were expected to:

- Know that there are two methods for determining the liquid limit, but the cone penetrometer method is the preferred method and why.
- Be familiar with the procedure and required testing equipment (cone penetrometer, balance, specimen containers, glass plate, spatula, desiccators).
- Be familiar with the procedure to adjust the cone penetrometer for testing.
- Know the wet preparation method to obtain the material for testing.
- Know the testing procedures for the liquid limit testing using the cone penetrometer.
- Know how to prepare and store the test sample(s).
- Know the testing procedure for testing the plastic limit.

- Know the testing procedure for the linear shrinkage and the difference between the types of moulds used and implication.
- Be able to calculate liquid limit, plastic limit, and plasticity index and report results

Observations:
At the beginning of the training, the areas of concern were; the determination of the Plastic Limit, where the rolling was not done until cracking or shearing was noticed but simply rolled to about 3 mm, also, no measuring rod was available to compare the thickness with. The other major concern was that no timer was used to determine the 5 seconds penetration time. It was merely estimated and thus prone to variations of between 2 and 3 seconds.

It was obvious that more attention should be paid to the Atterberg limit tests. The unsatisfactory performance was rooted in the fact that most of the participants lacked exposure to laboratory testing since leaving tertiary institutions and while Atterberg limit tests are simple, proper mixing and working with sample requires experience. Retraining was therefore done. Training exercise was repeated until the participants performed the testing to the satisfaction of the project Laboratory Materials Specialist.

Outcome:
It was through repetition of the tests that all the participants satisfactorily demonstrated that they were able to carry out the test competently. Participants were able to correctly prepare material for the tests (material passing 0.425mm sieve). The mixing of the soil with water and filling of the penetration cup was also done correctly. A stop watch was used. Rolling was done until cracking or shearing was noticed for the Plastic Limit determination test. The filling of the shrinkage trough was also done properly and at the correct moisture content.

2.5.4 Particle density - small Pyknometer method

Participants were made aware that the small pycnometer test method is used for the determination of the particle density or Specific Gravity for soils consisting of particles finer than 2 mm. Test was conducted according to CML Tests 1.5. Definition of particle density was given as the ratio of soil particle mass and soil particle volume. In practice, knowledge of the particle density and the bulk density can be used to calculate the porosity and voids, which will influence the compaction and consolidation properties of the soil. The results of particle density determination have application in the hydrometer analysis as well as the determination of the zero-air-voids line in soil compaction.

At the end of the training, participants were expected to:

- Be familiar with the scope of CML Test 1.5
- Be familiar with the test procedure and the required equipment (to include capacity of balance, entrapped air removal, thermometric device, desiccator, the type of water to be used etc.)
- Know that there are two different acceptable methods for performing specific gravity tests (large and small pycnometer methods) and know when to use which method.
- Know the proper specimen size for different types of soil and test method performed.
- Know the procedure for calibration of the Pyknometer.
- Be able to calculate and report the particle density of a soil, given the critical testing

Observations:

At the end of Phase 1, the participants indicated a lower confidence in calibrating the Pyknometer for the determination of the particle density, followed by the ability to prepare samples for hydrometer test. During Phase 2 of the training further explanation of the procedure was given.

Outcome:
Participants demonstrated that they had gained the knowledge needed to perform the tests including being able to calculate and report the particle density of a soil. No actual tests were conducted during Phase 2 of the training, due to lack of equipment. 2 Hydrometers were to be acquired, included on a separate list of equipment to AfCAP.

2.5.5 Particle size distribution Test

The test was conducted according to CML Tests 1.7, 1.8 and 2.3. Participants were made aware of the reference in these tests to the proportions by dry mass of a soil or aggregate distributed over specified particle-size ranges. Participants were made aware that depending on the material particle size, the particle size distribution analysis is done using the wet method, the hydrometer method or the dry method. In practice the particle size distribution or grading is used for soil or aggregate classification and affects the packing and degree of interlock in unbound granular pavement materials and will therefore contribute to the performance of granular basecourse for example.

At the end of the training, the participants were expected to:

- Be familiar with the scope of CML Tests 1.7, 1.8 and 2.3.
- Know the different methods for the determination of particle size distribution test based on the nominal particle size, larger than 75 µm sieve is determined by sieving, and the distribution of particles smaller than 75 µm sieve is determined by a sedimentation process using the hydrometer.
- Be familiar with the test procedure and required equipment for the respective tests.
- Know what sieve(s) to use as the separation sieve.
- Know how to prepare the dispersing agent.
- Know proper sample sizes based upon nominal particle size.
- Be familiar with methods of stirring and the necessary stirring times.
- Be able to calculate mass retained on each sieve as percent retained and the mass of material passing the finest sieve as percent passing.
- Be able to calculate the corrected mass of the material retained on each of the sieves between 20 mm and 75 µm, in the wet sieving method.
- Be able to calculate the true hydrometer reading and the effective depth.
- Be able to determine the equivalent particle diameter from the hydrometer test

Observations:
The participants were expected to know the different methods for the determination of particle size distribution test based on the nominal particle size, thus larger than 75 µm sieve is determined by sieving, and the distribution of particles smaller than 75 µm sieve is determined by a sedimentation process using the hydrometer. To enhance an understanding of the particle size distribution process, sieving was done by hand although sieve shakers are available. Washing of the fines through the 75

µm sieve was done properly, and participants understood it is slow process as the sieve was found to be severely blocked resulting in much longer time taken to wash the sample.

Outcome:
The participants demonstrated confidence in carrying out the particle size distribution test, including how to calculate the corrected mass of the material retained on each of the sieves between 20 mm and 75 µm in the wet sieving method and correctly plot the grading curve.

2.5.6 Compaction Test

Test was performed according to procedure CML Tests 1.9. Participants were made aware that this test is used to determine the relationship between the compacted dry density and soil moisture content. Application in practice is that the test is used to provide a guide for specification during field compaction and that compaction increases the strength of a soil and reduces settlement under working loads.

At the end of the training, the participants were expected to:

- Be familiar with the CML 1.9 test procedures and the required equipment
- Know the required material preparation to get the representative samples and gradation for the test.
- Know the two compactive effort used to compact soils in the laboratory.
- Be familiar with the calibration/verification of the equipment.
- Be able to calculate the bulk density and moisture contents for each specimen.
- Be able to plot the dry densities as ordinates against the moisture content as abscissae obtained from the series of determinations.
- Be able to determine optimum moisture content and maximum dry density from the compaction curve

During the hands-on training, compactions were done according to British Standards heavy effort using a 4.5kg hammer. Participants were made aware that the compactive properties of soils are determined using two magnitudes of campactive effort: the light compaction test using a 2.5 kg rammer (Standard Proctor) and the heavy compaction using a 4.5 kg rammer (Modified Proctor).

Observations:
The participants applied the correct number of blows to the five layers as prescribed. However, it was observed that the last layer protruded from the mould, on average by up to 30mm, whereas the method requires that a maximum of 6mm protrudes from the mould. Participants were made aware of the implications and that is, less energy is applied to the material in the mould. There was no means for measuring the compaction depth of the various layers throughout the compaction process. The operation of the manual compaction hammer was also not consistent. Typically, too much bounce was observed.

It was obvious that the participants required retraining in carrying out the test itself in order to achieve a level of competence that will ensure they can produce reliable results for this test. Retraining was done.

Outcome:
The trimming of the protruding material was done adequately. There were no problems with respect to calculations and plotting of the compaction curve and determination of the optimum moisture content and maximum dry density from the compaction curve.

The participants were able to demonstrate a satisfactory level of mastery on how to compact the sample in the mould. The outcome is that the procedure was carried out satisfactorily.

2.5.7 California Bearing Ratio (CBR)

This method covers the California Bearing Ratio, an indicator test for the strength of material less than 20 mm. The test was carried out according to the procedure CML Tests 1.10, 1.11. The CBR-value is the bearing capacity of the material in comparison to that of a well-graded crushed stone. It is used for assessing the subgrade, subbase and base course materials for pavements.

At the end of the training, participants were expected to:

- Know that this method determines the bearing ratio of pavement subgrades, subbase, and base course materials.
- Know the required material preparation and that maximum particle size is less than 20 mm
- Be familiar with the procedure and required equipment
- Know the compactive effort for the three-point method
- Know the different methods of compaction of soil in the mould, dependent upon the specifier.
- Know the surcharge weights and what they simulate/represent.
- Know the soaking period.
- Know when and how to take the initial and final swell readings.
- Know what the Manual says about the penetrations at 2.5 mm and 5.0 mm.
- Be able to inspect the shape and surface irregularities of the curve and how to make the appropriate corrections.

Observations:
After the participants were able to compact the sample properly, there were no problems in conducting this test. The surcharge weights were put in place and the swell measuring device was mounted onto the mould correctly.

Outcome:
The whole test procedure inclusive of soaking the moulds for required period of four days after which they were penetrated using the CBR compression machine and plotting of the curve for CBR determination was conducted satisfactorily by all the participants.

2.5.8 Preparation of Stabilised samples for UCS, Compaction of Stabilised Material, UCS of Stabilised Materials and Initial Consumption of Lime

Participants were made aware that the listed tests are used either to assess the suitability of the natural gravel materials for stabilisation, preparation and compaction of stabilised samples, or determination of the unconfined compressive strength of the stabilised material. Stabilisation is done when properties of materials of inadequate quality need to be improved to meet strength requirements for use in selected, subbase or base layers. In practice, stabilised material will provide the required structural capacity and importation of material for construction is limited or entirely avoided. The tests were carried out according to CML Tests: 1.19, 1.20, 1.21 and 1.22.

At the end of the training, participants were expected to:

- Be familiar with the scope, test procedures and required equipment for the specific tests.
- Know the quantity of air-dried material passing the 20 mm sieve required for the preparation and making of stabilized samples for the Unconfined Compressive Strength (UCS) according to CML Test 1.19.
- Be able to calculate the mass of air-dried material required for each lot of raw material for making specimens.
- Be able to calculate the quantities of three different stabiliser content required for the three lots of raw material for making specimens.
- Be able to calculate quantity of water to be admixed with material for specimens.
- Be able to calculate percentage of stabiliser by volume.
- Be able to calculate the bulk density and moisture contents for each specimen of stabilised material according to CML Test 1.20.
- Know the required period and condition for curing specimens according to CML Test 1.21
- Know the required load/stress and rate of application to fail the specimen for the determination of the UCS according to CML Test 1.21.
- Be able to calculate the UCS for the specimens.
- Know how to determine the minimum amount of lime required to achieve permanent gain in strength, the ICL of the material being treated, according to CML Test 1.22.
- Know how to determine the suitability of the lime to be used for ICL test
- Be familiar with the method of calibration and use of the pH meter

Observations:
No problems were observed in the preparation of stabilised material, using cement.

Outcome
Participants easily demonstrated confidence in the preparation of stabilised samples and UCS testing procedure.

2.5.9 Flakiness Index, Average Least Dimension and Elongation Index

These tests are used to determine the particle shape of aggregates. Shape particles are defined as angular, rounded, elongated and flaky. Participants were made aware that shape characteristics play a role in the performance of pavement materials. In practice, flaky and elongated particles are considered undesirable for base course construction as they are more likely to break under loading, while angular particles increase the interlocking capacity and therefore shear strength, unlike rounded particles. However, rounded particles increase workability in concrete work. The average least dimension (ALD) is used in the determination of the required basic spray rate of bitumen to hold the chipping for surface dressing in place. The tests were conducted according to CML Test 2.4 and 2.5.

At the end of the training, participants were expected to:

- Know how to reduce the sample to produce the required material proportion for Flakiness Index (FI) and Elongation Index (EI) testing.
- Know how to perform the grading analysis on representative sample of the chipping to determine the ALD.
- Be able to gauge each fraction using the gauge thickness for FI and length gauge for EI.
- Know how to select the gauge appropriate to size-fraction under test.
- Be able to calculate the Flakiness Index.
- Be able to determine the median size.
- Be able to determine the ALD from the Nomo graph
- Be able to calculate Elongation Index.

Observations:
There were no problems observed in carrying out these tests.

Outcome:
The participants satisfactorily demonstrated ability to use the slot gauge and an understanding on how to calculate the Flakiness Index (FI) and the Elongation index (EI), based on using the gauge thickness for FI and length for EI to gauge each material fraction.

2.5.10 Aggregate Crushing Value (ACV), Ten percent Fines Value (TFV), Aggregate Impact Value (AIV), Los Angeles Abrasion (LAA), and Soundness of Aggregates (SSS)

Participants were made aware of the use of these tests to determine the resistance of aggregates to crushing, sudden shock or impact as well as their hardness and soundness when subjected to weathering. In practice, good shape characteristics are required for aggregates to resist crushing under traffic loading and these tests are used to quantify the quality of the aggregates. Testing was conducted according to CML Test 2.6, 2.7, 2.8, 2.9 and 2.10.

At the end of the training, participants were expected to:

- Be familiar with the test procedures and the required equipment for the specific aggregate strength tests
- Know the required material preparation to get the representative samples and gradation for the tests
- Know the required force and rate of application for the determination of the Aggregate Crushing Value.
- Be familiar with the preferred optional testing method of combining the TFV test and the ACV test.
- Know the required force and rate of application to produce the required penetration for the specific type of aggregate in the determination of TFV.
- Know the size of the sieve through which material should pass through to determine the TFV.

- Know the procedures for the Aggregate Impact Value (AIV) test under both dry and soaked condition.
- Be familiar with the requirements for the minimum mass of test portions required to obtain mass of material to determine the AIV.
- Know the speed at which the Los Angeles testing machine should rotate and the number of revolutions required for the test.
- Know the requirements for the minimum mass for the different size fractions to obtain the mass of material to determine the soundness of aggregates (SSS)
- Know the solution required for immersion of test samples for the determination of the soundness of aggregates.
- Be able to determine and report the ACV, TFV AIV and SSS.

Observations:
There were no problems observed on how the tests were conducted. Emphasis on AIV test was on the requirements for the minimum mass of test portions required to obtain mass of material to determine the AIV.

Outcome
Participants were able to demonstrate satisfactorily the procedures for the determination of the required parameters as well as required calculations when using the newly acquired cube press.

2.6 Impact of capacity building and skills development

The support of this project by AfCAP has enabled LoGITReC to achieve its capacity building and skills development objectives. CMRL is now staffed with laboratory personnel who can conduct, with confidence, the laboratory tests according to CML Laboratory Manual 2000. It is acknowledged that technician competencies are usually acquired and built through laboratory experiences over time.

The training programme demonstrated its effectiveness in approach. Irrespective of academic qualification background, it has been able to provide the training environment that allowed all participants to be able to achieve the required level of competence for the specific test methods that constituted the content of the current training programme.

The participants demonstrated progression in capability to carry out specific laboratory tests, from the basic level they were at in September 2016, when the training started, to a more advanced level of competence by the end of the project implementation.

There is already evidence, reflecting the quality of the capacity building and skills development programme under this project. Since March 2017, CMRL has already conducted twenty-four testing projects for clients working on Government projects. Contractors and consultants working on Government projects are expected to use CMRL. In spite of this requirement, the fact that there are repeat clients, seeking the services of CMRL, is an indication of the confidence they have in the quality of delivery of services including results being produced by the laboratory. A project list is provided in Appendix A.

CMRL Manager was acquainted to the operational and managerial requirements to operate a typical laboratory, both as a reference laboratory and a research laboratory. The secondment work scenario included observation of advanced testing, discussions on both managerial and technical aspects of a research laboratory, such as testing methods, laboratory systems, including proficiency schemes and required procedures as well as witnessing preparation procedures for SANAS inspection. He now has an understanding of the operational management system to ensure quality control of laboratory processes for LoGITReC-CMRL.

The impact of the training programme goes beyond LoGITReC. A total of nine participants attended the training programme. Three of the participants were from the city councils of Arusha, Mbeya and Mwanza. They will be involved in the establishment of laboratories in their respective municipalities. The laboratories will therefore be headed by skilled people with a good understanding of the fundamental principles of the laboratory tests according to CML Laboratory Manual 2000 and how to conduct the tests. This is an additional achievement of the capacity building and skills development programme specifically and the project in general.

With the acquired skills, LoGITReC personnel will also be in a position to contribute on other AfCAP projects, for example the project on "Long Term Pavement Performance Monitoring of Existing Trial Sections and Implementation of Regional Guidelines for Establishing and Monitoring Trial Sections in Tanzania".

3 LoGITReC-CMRL facility

3.1 Organisation of the facility

A good facility should provide adequate and environmentally friendly working space for personnel and equipment location. The organisation of the laboratory work space should in general be clearly demarcated for the different laboratory activities: Sample reception area; sample storage facility; sample preparation area; sample testing areas; and waste disposal areas. Currently, the layout is an open floor working area arrangement for the different laboratory activities. There is a proposed revised layout, presented in the **Capacity Building and Skills Development Action Plan[5],** which provided for demarcated working areas. However, it was partially implemented leading to the current layout.

3.2 Working area

Sample preparation is currently performed within the laboratory, the same space area where the technicians have their desks, see Figure 2. The current sample preparation area is shown in Figure 3, photo taken from the opposite side to that shown in Figure 2. Sample compaction also takes place in the same area. The working of the bulk samples with spades and the breaking up of soil clods in the confined space of the laboratory, as shown in Figure 3, generates a lot of dust and noise – this practice is considered both a safety and health hazard to staff and detrimental to sensitive equipment such as computers, scales, and hydraulic presses.

Area where compaction takes place should be sound-proofed. The current working area arrangement calls for provision to be made to compact moulds outside. This will reduce noise inside the laboratory and also dustiness. The laboratory staff should be in a fully enclosed room.

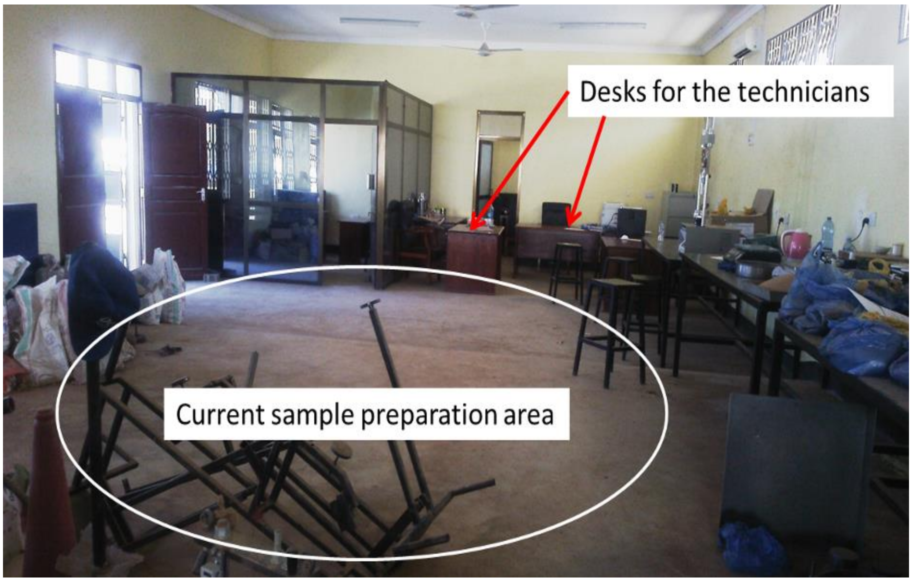

Figure 2: Current working space arrangements

[5] BMJA Verhaeghe, 2015. Technical Assistance to Tanzania Local Government Infrastructure and Transportation Research Centre (Interim Phase): Capacity Building and Skills Development Action Plan. CONTRACT REF NO. AFCAP/TAN/2046A. December 2015.

Figure 3: Sample drying on the laboratory floor

To mitigate the problem, the open space immediately outside the laboratory next to the undercover area, should be used for what it was meant for, sample drying, currently done inside the laboratory as shown in Figure 3 above. The area as shown in Figure 4, is being used as a solid waste collection area by the municipal council, containing, old desks and chairs, discarded computers and printers, etc., including, a vehicle and very heavy old machinery that would require heavy machinery for removal. Once this area is cleared, it will free up valuable Laboratory space, currently being used for sample preparation and can then be used for housing equipment in the future.

Figure 4: Open space next to Laboratory used as dumping yard

3.3 Sample storage

Sample storage is within the laboratory, space that could be available for equipment as it was established during installation of newly acquired equipment. A key measure that must be implemented is the use of the undercover area, shown in Figure 5, which is being used for storage of motorcycles, bicycles and planks and is also being used as a resting area for staff. The area is supposed to be used for sample storage. The area is adequately suited to be fitted with large shelves that can accommodate at least 50 kg samples. Shelf partitions of roughly 500 x 1000 mm in size can be fitted once the area has been cleared. This will free up the space inside the laboratory that is used for sample storage and at times for used for waste materials, see Figure 6, which is then routinely cleared.

Figure 5: Available covered area used for bicycle and motorcycle storage

Figure 6: Waste material stored within the Laboratory

3.4 Sample soaking

Currently the soaking tank is outside the Laboratory as shown in Figure 7. The temperature of water in a soaking tank should not vary greatly during curing of samples for example. Soaking tank should be at 22 to 25 ^{0}C. Under the outside climatic conditions and depending on the time of the year, it probably gets very hot in summer – samples most likely cure at different temperature rates, potentially ranging from 15 to greater than 35 degrees Celsius in a day.

Figure 7: Sample soaking tank located outside the Laboratory

During the visit in April 2017, it was noted that the soaking tank was not suitable as it was too deep. A recommendation was made that a rack be installed to reduce the total depth of water. A maximum water depth of 250 mm is adequate for soaking CBR moulds and curing of concrete cubes, for example. This has since been implemented. However, a key implementation measure regarding the soaking tank is that it should be located inside the laboratory where temperature variation is less likely and the room should be air conditioned

3.5 Summary

It is vital that staff working environment is safe and free from health hazards. The working of the bulk samples with spades and the breaking up of soil clods in the confined space of the laboratory generates a lot of dust and noise. The provision of office accommodation away from storage and sample preparation areas as well as sound proofing introduced between the current compaction area and the space used for offices should mitigate these problems. Furthermore, it is recommended that storage and sample preparation should be done outside the laboratory. In the meantime, laboratory personnel should wear masks, in order to reduce respiratory exposure to dust, as the health of the staff will be affected in the long term.

Available space around the Laboratory is not being used for laboratory purposes as presented above. It is recommended that final solution be found to clear the area around the Laboratory and more than adequate space will be available for sample storage and preparation. Otherwise the working space will soon be limited and staff will not be working in a safe place. The above issues should be addressed as they will impact on the operations of the laboratory.

Whilst space constraints have been highlighted, CMRL has adequate space for the required laboratory operations and office accommodation. What is required is effective use of the available space and to use the designated areas to serve laboratory purposes as recommended in this report.

4 Laboratory Work Management System

4.1 Development

The project terms of reference required that a framework for a laboratory management system be developed for CMRL. This has been achieved and Software called "LoGITReC Lab Work Management System" has been developed for CMRL. It is intended to effectively and efficiently process laboratory material records "LoGITReC Lab Work Management System" is an electronic job and materials management system for the administration of incoming work and the samples related to the work. The progress of jobs through the laboratory will be tracked using the system. The framework in form of a flow chart is provided, which helps in decision making process from sample acceptance scheduling, sample preparation, testing and recording of results, storage; and procedures for (internal and external) calibration of laboratory equipment; maintenance of the work space and laboratory equipment; and storage and filing of completed work documents.

4.2 Functionality

The Lab Work Management System is simple, but will enable CMRL to meet the requirements for sustaining good practices in laboratory information management, one of the requirement expected for an accredited laboratory. It will allow for the required inputs to capture and store required data for managing the laboratory operations and further processing and application, when required. Name of users, Institutions, technicians, and requestors may be added/edited as and when required. Full details have been provided in the Operational Laboratory Systems Report. Figure 8 and Figure 9 show the interfaces after entering details of work request and details of samples, respectively.

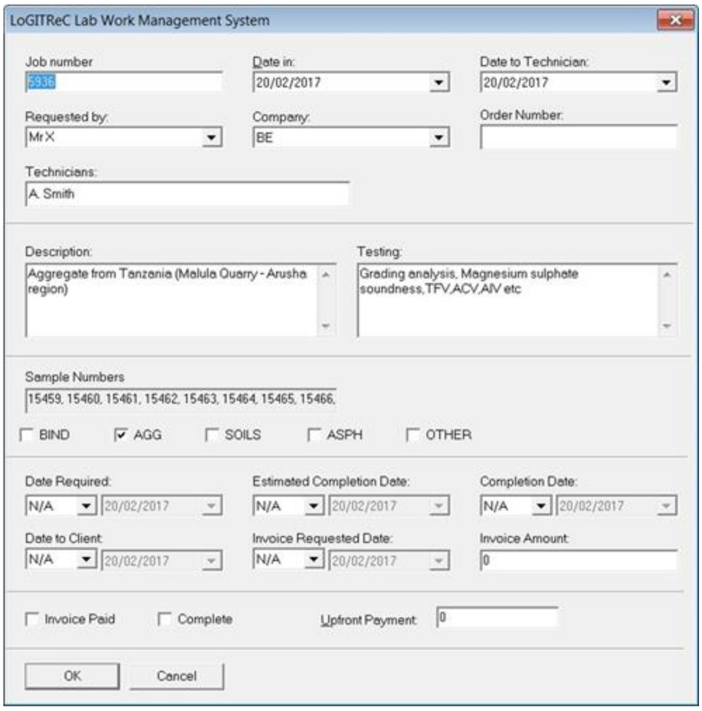

Figure 8: Interface after entering details of work request

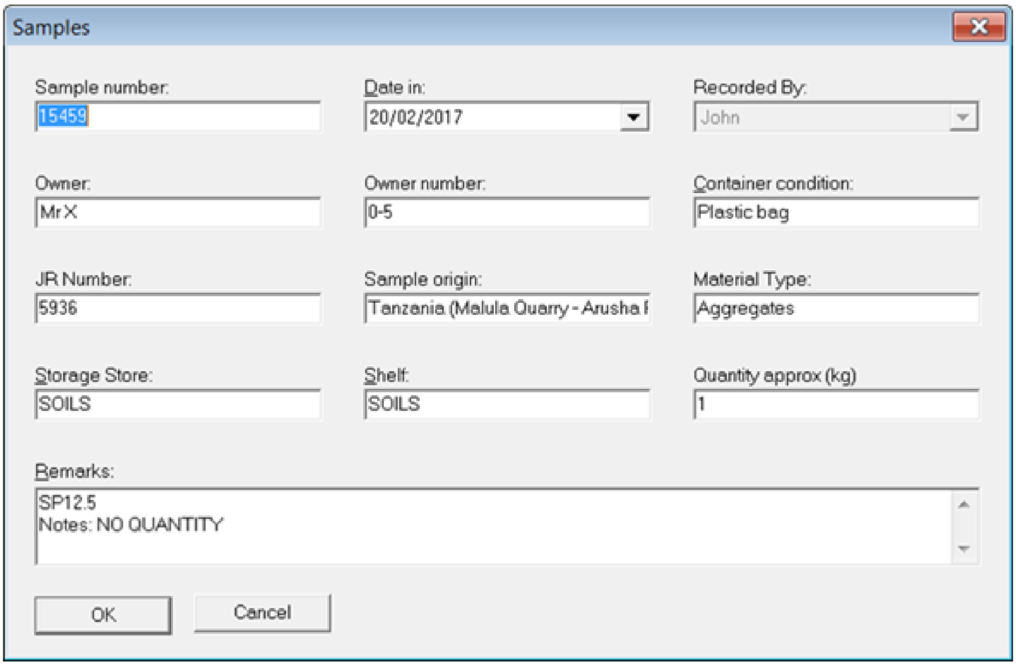

Figure 9: Interface after entering details of samples

Currently the system is only accessible to CMRL personnel due to the fact that CMRL is physically situated in a separate building from the PO-RALG Headquarters and is not connected to the main server. An institutional problem has yet to be resolved. The ultimate goal is to provide access to "LoGITReC Lab Work Management System" to all Regional Materials Laboratories (RML), according to the structure of the recently established TARURA.

The functionality of prototype software was tested at the CSIR, before being installed at CMRL. The software was installed on the CMRL Manager's computer in April 2017 and following trial and training of the technicians it was installed on a second computer. A statement of satisfaction was submitted to the service provider indicating that "LoGITReC Lab Work Management System" is being used and no problems have been encountered.

4.3 Benefits of LoGITReC Lab Work Management System

The Lab Work Management System has been developed for the collection of data regarding laboratory operations making it easy to collect and manage the data. All the details pertaining to the job, e.g. owner, technicians doing the testing, date received, date completed, etc. are entered and stored in the program. The system will ensure that all data about laboratory operational procedures is recorded and kept in a centralised database. The system will enable the technicians to check, search and update sample status.

The practice of collecting and storing sample data systematically will now be embedded at CMRL and other laboratories within TARURA and TANROADS-CML, which is an essential process for sustaining good practices in laboratory information management. It will improve data security; terminate data being recorded on paper forms. The management of the data is complimentary to standardised procedures and provides the means for sound operational and management procedures in the laboratory, this is provided for in Procedure LoGITReC-LAB-3.

The Lab Work Management System is simple, but allows for the required inputs to capture and store required data for managing the laboratory operations and further processing and application, when required. One of the essential requirements of ISO 17025 is the proper keeping of records. Thus the practice of collecting and storing data systematically is essential for CMRL to fully function as a road material testing laboratory, as well as a reference and research laboratory. It will enable CMRL to meet the requirements for sustaining good practices in laboratory information management, fulfilling the requirement expected for an accredited laboratory.

The framework in a form of a flow chart is provided, which helps in decision making process from sample acceptance scheduling, sample preparation, testing and recording of results, storage; and procedures for (internal and external) calibration of laboratory equipment; maintenance of the work space and laboratory equipment; and storage and filing of completed work documents. It also provides the linkage to the general operational protocols/procedures, presented in Section 5.

4.4 Impact

The first indicator of project achievement is the number of testing projects already undertaken by CMRL. The fully functional operational management system for LoGITReC, which is aimed at strengthening the operational procedures for CMRL is the second indicator of the project achievement. Not only will the system be used by LoGITReC. Other laboratories within TARURA will have access to it, once it is uploaded on the server. The uptake of the system, within all TARURA laboratories and rollout within TANROADS-CML will impact on how these laboratories manage and keep their records. It will have a national impact as each Regional Materials Laboratory will implement good practice in the collection and storage of laboratory data, systematically and electronically.

5 Quality assurance documentation

5.1 Introduction

An essential element of a quality system for a laboratory is the management of documents and records. An established operational and management system should therefore be in place for a laboratory such as CMRL to function efficiently and effectively as a reference and research laboratory. The management system specifies procedure on how the laboratory will deal with all operations pertaining to the efficient and effective running of the facility.

The everyday management of the laboratory is regulated through the general operational protocols/procedures. The standardised procedures provide step-by-step instructions and are necessary to ensure consistency in procedures within a laboratory. Aspects that should be covered in standardised procedure include: sample acceptance protocols; test data recording and storage; schedules and procedures for (internal and external) calibration of laboratory equipment; maintenance of the work space and laboratory equipment; and storage and filing of completed work documents. These documents, presented in Table 4 below, have been prepared for the purpose of ensuring that CMRL has a quality assurance and quality control scheme in place.

5.2 Laboratory standard operational procedure documents

The procedures for adoption by CMRL are relevant as they are similar to those being used by the CSIR's Advanced Materials Laboratory and have gone through revisions over the years to meet accreditation standard requirements. The relevance of each included procedure was discussed with CMRL Manager while on secondment at the CSIR. The operational procedures form the building foundation for laboratory quality management of CMRL and can be updated accordingly. The documents provide criteria and recommendations in line with requirements for a facility that must comply with ISO 17025[6]. The following are technical requirements of ISO 17025:

- **Technical Records**: This covers a record of all raw data, observations, calculations and, request available / completed, records are permanent, corrections legible and authorised, calculations check and that data on computer is protected;
- **Personnel:** There should be proof of competence, appropriate method of determination of competence;
- **Test Methods and Method Validation**: Test method description, controlled copy of Test Method should readily be available;
- **Assurance of Validity of Results**: Method and proof of Inter-laboratory testing with accredited laboratory;
- **Equipment and Measurement Traceability**: This will include maintenance, completed records, description of equipment used in testing, equipment used in verification of testing equipment, equipment used in verification of verifying equipment;
- **Accommodation and Storage**: To cover accommodation and environmental conditions, monitoring of controlled areas, effective segregation of tests, adequate storage areas;

[6] ISO/IEC 17025:2005. General requirements for the competence of testing and calibration laboratories

- **Purchasing Services and Supplies**: Supplies verified prior to use to meet quality criteria as required for the methods;
- **Sampling and Handling of Test Items**: Should uniquely be identified, ensure that there can be no confusion;
- **Reporting of Results**: All relevant information is reported.

The standard procedures/protocols are provided in the Operational Laboratory Systems Report and have been prepared in a designated folder at CMRL. Table 3 below presents a summary list of the standard procedures provided, related to the above requirements. Each document contains the following:

- Title – description of procedure;
- Purpose, which includes information about the procedure;
- When, frequency of procedure or linkage to another procedure
- Responsibility, designated specific person/in what capacity should be assigned, for implementing;
- Scope, detailed information for the procedure;
- Supporting instructions and forms;
- Name and signatures of approving officials, capacity and dates of approval.

Apart from “Safe working procedures” all these procedures are requirements of ISO 17025. More procedures can be written, however, these were considered the most essential at the time and in line with the Laboratory requirements and capabilities. ISO 17025 has just been updated, there is now a 2017 version.

Table 4: List of Laboratory Operational Standard Procedures

Standard Procedure description	Reference	SANS 17025 Clause
Job Description	LoGITReC-LAB-1	Section 5.2.4
Guidance for Calibration, Verification and intermediate checks	LoGITReC-LAB-2	Section 5.5
Identification and Record Keeping of Equipment	LoGITReC-LAB-3	Section 4.3, 5.5.5
Incoming Samples Administration	LoGITReC-LAB-4	Section 5.8
Review of Requests, Tenders and Contracts	LoGITReC-LAB-5	Section 4.4
Testing of Certified and In-house Reference Samples	LoGITREC-LAB-6	Section 5.6.3.2
Competency Assessment: Declaring Personnel Competent to carry out the various test methods	LoGITReC-LAB-7	Section 5.2.3
Safe working procedures in the workplace	LoGITReC-LAB-8	Good Lab. Practice
Proficiency Testing	LoGITReC-LAB-9	Section 5.4.5.2

5.3 Proficiency testing scheme

This requires that a systematic process is in place to conduct inter-calibration study, in which participant performance against pre-established criteria by means of inter-laboratory comparisons is evaluated. It is a means by which laboratories can prove their technical competence and the level of operation of their management system. The standards ISO 17025 and ISO 15189[7] require that laboratories seek confirmation for confidence in their results and organize quality control procedures for monitoring the validity of performed tests. A laboratory should prove its test/calibration competence, either via proficiency testing or any other source available to the laboratory, to issue results covered by accreditation, according to ISO 17025.

The standards ISO 17025 and ISO 15189, have identified key responsibilities of laboratories participating in a proficiency testing scheme, they include:

- Documentation
- Frequency of participation
- Statistical evaluation of the results
- Corrective actions

Thus an accredited laboratory should take part in proficiency testing on a regular basis and define its frequency of participation. The participation in proficiency testing is therefore supposed to be documented in the quality manual or in other documents pertaining to the management system of the laboratory. This has been provided for in the case of CMRL, under reference Procedure LoGITReC-LAB-9.

5.4 Summary

A management system specifying procedure on how CMRL will deal with all operations pertaining to the efficient and effective running of the facility has been established. The requirements for a Proficiency Testing scheme and the participation in proficiency testing, is covered under reference Procedure LoGITReC-LAB-9. However, for CMRL to implement this, it will only be realistically achieved if a national body exists that can coordinate such an activity. Discussions held during the execution of the project revealed proficiency testing was not yet a standard practice in Tanzania.

With quality assurance documentation in place, CMRL has now a system in place which meets the criteria for recognition as provider of quality service and has processes in place to ensure validity of results and their accuracy, fulfilling some of the requirements for ISO 17025. Currently civil engineering laboratories in Tanzania are registered with the Engineering Registration Board of Tanzania and not accredited to ISO 17025. TANROADS-CML plans to acquire ISO 17025 accreditation and it is an ongoing project. Expectedly, CMRL is to aim for this accreditation.

The achievement of the project in this regard is that, it has provided the foundation and confidence that CMRL should be able to sustain high quality services long term, as sound operational and management procedures have been implemented.

The impact of this project with respect to laboratory quality management systems is that it has set in motion the efforts to implement an inter-calibration study programme that will be implemented across civil engineering laboratories in Tanzania. As previously stated, no similar study has ever been conducted for civil engineering laboratories in the country. TANROADS-CML has agreed that this is a priority for country's laboratories. The coordination of such an activity has yet to be agreed upon.

[7] ISO 15189:2007: Quality Manual and Procedures

There is, however, a proposal for change in the organisation structure of TANROADS, and the planning and implementation of an inter-calibration study programme can only take place thereafter.

6 Equipment

6.1 Introduction

The purpose of CMRL is to provide laboratory and field testing in support of the research agenda of LoGITReC and at nominal charges to provide services to other government departments, road authorities and the private sector. As part of its functions, it will be expected to test, calibrate and verify precision instruments, gauges, scientific apparatus and other laboratory and field measurement equipment to ensure compliance. To this end, additional equipment was to be acquired under the current project, to fully equip CMRL in line with these testing functions.

The need to acquire additional equipment was identified in the Capacity Building and Skills Development Plan, and PO-RALG was to purchase the additional equipment that could not be funded by AfCAP. During the course of the project, discussions were held between LoGITReC team and project team on establishing a revised priority equipment list. A priority list was first drawn by the project Laboratory Management Specialist in December 2016 and subsequently revised, to provide additional list to that LoGITReC had submitted for procurement.

6.2 Required additional equipment

6.2.1 Status of priority additional equipment

Following the CMRL Manager's secondment at the CSIR and during the last hands-on training session in Dodoma, conducted in April 2017, further discussions were held between CMRL Manager and the project Laboratory Management Specialist. An assessment of equipment requirements for CMRL was again conducted, taking into account the immediate and medium-to long-term testing requirements. Table 5, shows the status of the procurement of additional equipment. The equipment procurement was the responsibility of the CMRL Manager.

Table 5: Status of additional required equipment

Equipment	April 2017	September 2017
Personal protective equipment (long overdue).	**Very urgent** Laboratory staff being provided limited safety	**Not acquired,**
First Aid Kit; Fire extinguishers	**Urgent,** safety requirement	**Not acquired**
Rifflers, with openings of 37.5, 25 and 10 mm. This is necessary for sample preparation and obtaining representative samples for testing	**Urgent**	Acquired = 2No. 1 - 45mm and 1 - 30mm slot width
Scale of approximately 25 kg capacity (15kg may also be used, but the higher capacity is preferable), readable to 1 gram	**Urgent**	Acquired a Dual range 60/150kg cap. X 2/5 g resolution, digital balance**.** *The 25kg scale readable to 1g is still urgently needed*
Scale of approximately 1000 g capacity, readable to 0.01g for determining weight of Atterberg Limits	**Urgent** Current scale not sensitive enough	**Not acquired**

moisture content tins.		
Moisture content tins; 1kg – compactions, 50g – Atterberg Limits	Important	Acquired Moisture Content tins 18g = 16No, and 24g = 24No.
BS Linear shrinkage troughs – part of plasticity determination	**Urgent**	Acquired = 10No.
Concrete cube press	**Urgent** Should also be used for ACV, Ten percent fines, ACV and UCS	**Acquired**
Moulds for UCS	Urgent	**Not acquired**
Auto compactor for granular materials	Urgent	**Not acquired**
Apparatus to determine ARD/BRD and water absorption	Necessary	**Not acquired**
Durability Mill Index apparatus	Necessary	**Not acquired**
Vacuum pump – density determinations	Necessary	Acquired 1No
Triaxial testing equipment	Necessary	Acquired not installed, due to inadequate space
Large tarpaulin for drying samples	Necessary	**Not acquired**
Toolkit: screwdrivers, pliers, spanners	Necessary	**Not acquired**
Measuring tapes/rulers (5m min), long steel rule (1m), chisels and hammers, 3m straight edge	Necessary	Currently acquired; 30m long fibreglass tapes = 2No, 2m long steel tape = 2No, 2m long straight edge = 2No, metric graduated wedges = 4No
Additional medium sized oven	Necessary	Acquired

While the personal protective equipment, First Aid kit and fire extinguishers are expected to be delivered soon, the personal protective equipment has been outstanding for more than eight months. Fire extinguishers are required in the laboratory to be able to extinguish small fires and the First Aid kits are required as they can be used immediately following minor laboratory injuries. These items are essential for the protection of laboratory personnel and should therefore have received special attention.

The fact that the acquisition of critical equipment for the safety of the laboratory staff should take so long, is obvious that there is a need to address constraints in the procurement processes, as this is more likely to jeopardise the safety of personnel and efficiency of operating the laboratory in the long term.

6.2.2 Installation and testing of newly acquired equipment

The newly acquired items comprised small laboratory items, a new cube press and the tri-axial apparatus. The small items required no installation or training for their use. On the other hand, the triaxial apparatus is a complex system and requires that the supplier or their agents assemble and commission to ensure full functionality of the whole system.

Contact has been made with Controls who supplied the equipment regarding installation of tri-axial equipment. They will as suppliers test the individual components of the equipment to ensure functionality after the apparatus has been fixed in place. On advice by Controls, a visit was made to

GST Lab in Dodoma by CMRL Manager, where similar equipment was supplied and installed by Controls. It was during this visit that it was noted that sufficient and uninterrupted space is required to install the equipment, currently not available without making changes to the current laboratory arrangements. Approval is pending for Controls to come and assess the space proposed for locating the triaxial machine and commission.

6.2.2.1 Cube press

Cube press – general description

This is an automatic cube press supplied by Controls and has a load capacity of 2000 kN (Figure 10). It can be used to crush concrete cubes, paving blocks, ACV, 10% FACT and UCS tests (Figure 10). The loading rate for testing can be manually set to perform tests according to specifications. The set loading rate is computer controlled and during the crushing tests, the machine stops the loading once failure of the specimen occurs. The maximum load attained and the calculated stress values are displayed on a screen.

For ACV and 10% FACT the press has to be manually stopped once the required load is attained (e.g. 400kN for ACV test) as there is no specimen failure for these tests. Otherwise the machine will simply continue loading until it reaches its maximum capacity. The operator therefore has to attentively observe the load readings on the screen provided so as to stop the loading at the correct point.

Details on the training in the use of the equipment and required reference table for setting the machine for the different tests has been provided to CMRL and is presented in the Equipment Status Report.

Figure 10: Newly acquired automated press

6.3 Equipment serviceability

The project required that all available equipment be properly installed and calibrated. The Laboratory Management Specialist demonstrated to the technicians on how they should become accustomed to the management of laboratory equipment. The importance of proper management of laboratory equipment, inclusive of maintenance and calibration requirements was covered during the hands-on training. It should also be noted that this is a requirement for a facility that must comply with ISO 17025[8] and especially for a research laboratory.

6.3.1 Equipment verification

Each piece of equipment in the Laboratory was checked for functionality. Where deficiencies were found, corrective measures were either implemented or recommended and where external services were required - for example, there was equipment during the April 2017 inspection, with Tanzanian Bureau of Standards (TBS) calibration stickers indicating re-calibration should have taken place some six months earlier (October 2016). This was brought to the attention of CMRL Manager to arrange for the calibration exercise. Table 6 shows the verification status of the available equipment at CMRL as at April 2017.

Table 6: Verification of Equipment

Equipment	Condition	Action Taken/Recommendations
	Atterberg Limits	
LL penetrometer	Assembly overweight by 150g	Removed weights to required 80g
	Good - new	
Cone condition	Good	
Shrinkage troughs	Good - new	Buy BS troughs currently using ASTM type
Palette knives	Good - new	
Moisture tins	Good	Too few in quantity, more needed
Balance-large platform	Not suitable for the test	Buy smaller scale (2000g, small platform)
	Compaction	
Old hammer	Poor – underweight by approx. 180 g. Due to wear. Face of hammer rounded.	Stop using hammer
New hammers	Good – complying to specs	Use new hammer from then on.
Moulds	Good – new, comply to specs	Do not use old moulds
Trimming device	OK – straight, minimal wear	
Gauge for swell	Good - new	Do not use old ones lying around

8 ISO/IEC 17025:2005. General requirements for the competence of testing and calibration laboratories

Equipment	Condition	Action Taken/Recommendations
CBR		
Press general	Good - new	
Load speed	OK	
Load reading	Could not determine accuracy	TBS to check
Plunger Face	Good	
Perforated base plates	Blocked	Unblock and clean regularly
Sieving		
Sieves condition	Good - new sieves	
Sieve 0,075mm	Almost totally blocked	Sieve cleaned. New one used
Scale (6000g)	Calibration out (6g in 2000)	Must be calibrated
Impact Value		
Aggregate Impact Value Apparatus	Good - new	
In situ density		
Sand replacement app.	Good - new	
In situ strength		
Dynamic Cone Pen (DCP)	Good - new	
Oven		
Door seals	New	
Temp	Could not verify	Need thermometers. TBS verified OK
General operation	Good condition - new	
Sample heating		
Hotplates	Good condition - new	
Aggregate shape factors		
Flakiness gauge	Good – new, slots correct size	Slots correct size
Elongation gauge	Good - new	Distance between posts - correct

Following the equipment verification and recommendations to arrange for equipment calibration, TBS was contacted and calibration of equipment was completed on 18 September 2017 and calibrated equipment is shown in Table 7.

Table 7: List of equipment calibrated by TBS as of 18 September 2017.

S/No	EQUIPMENT	QTY
1	Compression Machine	1
2	Digital balance	2
3	Hotplate	2
4	Digital liquid limit penetrometer	1
5	Compaction / Schmidt hammer	3
6	Swell reading gauge (dial gauge)	9
7	Stopwatch	1
8	Thermometer	4

As a guide, recommendations are given in Table 8 for the verification and/or calibration of equipment typically used in road materials testing laboratories. Guidance for Calibration, Verification and intermediate checks has also been provided as reference Procedure LoGITReC-LAB-2 in the Laboratory Operational Systems Report.

Table 8: Equipment Checking/Calibration Frequency

EQUIPMENT	Check/Calibration Frequency	
	Check	Calibrate
Balances, Scales and weights	Weekly	24 months
Test thermometers	When used	24 months
Analytical balances	When used	24 months
Weights		36 months
Timers		24 months
Ovens	When used	24 months
Penetrometer: Dial, timer		12 months
Penetrometer cones	When used	
Moisture tins	When used	
Compression or loading devices	3 months	24 months
Mechanical compactor	weekly	
Moulds		12 months
Manual hammer	weekly	
CBR Penetration Apparatus		12 months

EQUIPMENT	Check/Calibration Frequency	
	Check	Calibrate
Sieves	When used	
L. A. machine / Texas ball mill		24 months
Steel balls (L.A. apparatus)		24 months
Aggregate Impact Value apparatus	When used	12 months
Sand replacement apparatus	When used	12 months
Vacuum systems		24 months
Atterberg Limit device	When used	6 months
Flakiness/Elongation gauges		6 months
pH meter		12 months
pH probes	When used	
Water/oil baths	When used	12 months
Penetrometer needles	When used	
Ring and ball device		12 months
Brookfield viscometer		24 months
Viscometers (other)		36 months
Ductility apparatus		24 months
TFO & RTFO oven shelf/carriage		24 months
Load cells		24 months
Tri-axial apparatus	When used	24 months

6.3.2 Summary

Guidance is provided for the proper calibration, verification and checks to ensure functionality of equipment, inclusive of maintenance and calibration requirements. The benefit of the project is that it has not only developed required highly trained personnel, but has assisted in ensuring that the appropriate equipment is procured, verified and installed. This will enable CMRL function properly and provide laboratory and field testing in support of the research agenda of LoGITReC as well as provide services to other government departments, road authorities and the private sector.

However, the threat to quality provision of services is the procurement system if no improvements are implemented in the processes. Excessive delays were experienced in the acquisition of laboratory equipment, including essential safety equipment. This is more likely to affect the efficiency of operating the laboratory in future.

7 Conclusions and recommendations

7.1 Project achievements

7.1.1 Capacity building

The capacitation of CMRL staff was designed and planned to be implemented through three main capacity building activities, namely: (i) training at TANROADS-CML in Dar es Salaam, (ii) Hands-on training at the LoGITReC testing laboratory in Dodoma and (iii) secondment of the CMRL Manager to an ISO 17025 accredited research laboratory.

7.1.2 Laboratory skills development

A total of six CMRL staff and three additional technicians from the city councils of Arusha, Mbeya and Mwanza participated in the training programme, which involved laboratory testing according to the CML Laboratory Testing Manual (2000) of Tanzania. First part of the training was prepared by TANROADS-CML senior staff with intimate knowledge of testing procedures detailed in the CML Laboratory Testing Manual (2000). The capacity building programme at TANROADS-CML was aimed at enhancing knowledge of testing procedures in all areas of the materials laboratory and to strengthen required competencies of the participants. The hands-on training programme of the technicians, as a capacity building process, was aimed at creating the environment for the individual technician to demonstrate their capability to conduct materials testing. In addition it was required of them to show how familiar they are with the principles and procedures of reference test methods in accordance with CML Laboratory Testing Manual (2000).

The project has addressed the need for laboratory capacity building which, included staff from the city councils of Arusha, Mbeya and Mwanza, provided CMRL with quality assurance procedures, developed laboratory management systems, inclusive of safety procedures, strengthened laboratory management towards accreditation and instituted equipment calibration procedures.

All the participants on the training programme successfully demonstrated competence in conducting tests in accordance with CML Laboratory Testing Manual (2000). The project has achieved the objective of laboratory skills development and has provided additional highly and appropriately trained technicians for the country.

However, further training and re-training is advisable. Experience has shown that technicians often go back to their old ways (old habits) if the training is not repeated (reinforced). Also, as new equipment becomes available for other tests training on these should be done. It's also important that more technicians from the regional laboratories are trained. Recommendation for additional training is therefore provided in Section 7.3 below.

7.1.3 CMRL Manager's secondment

The secondment of CMRL Manager to an ISO 17025 accredited research laboratory was intended to provide the CMRL Manager the insight into the operational and managerial requirements of a testing laboratory, both as a reference laboratory and a research laboratory, and therefore the knowledge and skills needed to implement best laboratory practices at CMRL. The project has achieved this objective. The CMRL Manager has demonstrated leadership skills in the way he managed the equipment procurement process and implementation of recommendations for equipment calibration made by the project Laboratory Management Specialist The delay in procurement of additional equipment was due to processes out of his control. Procurement procedures for goods and services are guided by Public Procurement Act and its regulations, and as such the CMRL has no influence on the processes other than to follow up on the requisitions. The CMRL Manager is capable of managing CMRL and is also capable of providing mentorship to Regional Materials Laboratories in liaison with the Regional Coordinators according to TARURA's organisational structure for Regional Coordinators.

7.1.4 Operational systems for CMRL

CMRL is to function as a research laboratory and provide services as testing and calibration laboratory. The performance criteria of a laboratory are based on quality of service provided, operational efficiency and quality of results. Such type of laboratories have to fulfil the general requirements for the competence of testing and calibration laboratories according to ISO 17025, the standard for which most laboratories must hold accreditation to be deemed technically competent.

This project has contributed in setting up systems for CMRL that will assist in meeting two main requirements according to ISO 17025, namely Management Requirements, which are primarily related to the operation and effectiveness of the quality management system within the laboratory and the Technical Requirements, which focuses on factors that determine the correctness and reliability of the tests and calibrations performed in the laboratory.

The LoGITReC Lab Work Management System has been installed. This will ensure effective and efficient processing of laboratory material records and permanent storage of data for future reference. Documents have been prepared that provide information on procedures, to ensure that a quality assurance and quality control scheme is in place at CMRL. This has included suitable statistical methods for treatment of the results in order to determine precision, repeatability, variance and identification of outliers. Maintenance of quality assurance and quality control scheme will be dependent on CMRL being accredited.

7.1.5 Procurement of additional laboratory equipment

For CMRL to function as a research laboratory and provide services as testing and calibration laboratory requires that the equipment is well maintained and calibrated.

The project support has assisted in ensuring that the appropriate equipment is procured. The equipment has been installed and verified for functionality. However, the triaxial apparatus will be installed once adequate space has been created. This will include freeing up space around the laboratory, currently being used for storage of discarded equipment and furniture.

Guidance is provided for the proper calibration, verification and checks to ensure functionality of equipment and enable CMRL function properly. CMRL is already providing laboratory and field testing to other government departments and the private sector. It has the equipment to support the research agenda of LOGITReC and TARURA in general, but additional equipment will be required as the laboratory expands and capacity is built in the areas of laboratory expertise.

7.2 Project impact

7.2.1 Capacity building

The capacity building programme has provided a group of well trained technicians capable of delivering laboratory services more effectively and efficiently and therefore ensure quality control of results. Laboratory services play a crucial role in the implementation of research efforts and the support will enable CMRL to play a crucial role in road research agenda of LoGITReC.

7.2.2 Information management

The installation of LoGITReC Lab Work Management System has resulted in improvement in the way the information on samples from receipt to producing test results has been traditionally handled within the laboratory. This has led to better information management within the laboratory and is to be expanded to other laboratories under TARURA.

7.2.3 Laboratory quality assurance

The project has increased awareness of the importance of laboratory quality management systems, which includes the requirement for a national proficiency testing programme. As a result, it has influenced the motivation to launch a proficiency testing programme that will be implemented across civil engineering laboratories in Tanzania.

7.3 Recommendations

7.3.1 Additional capacity building

Next phase training programme should be provided as follows:

- *Soils and Gravels*: Triaxial testing; pH value; hydrometer, Initial consumption of stabiliser (lime/cement) (**Immediate**).
- *Aggregates*: Relative Density and Water Absorption; Los Angeles Abrasion (**Immediate)**.
- *Asphalt and Bituminous Materials*: Density of Binders; Thin Film Oven Test (TFOT); Penetration; Ductility; Softening Point; Brookfield Viscosity; Production of hot bituminous mixtures and all the testing associated with hot mix asphalt, as listed in CML Laboratory Testing Manual 2000. (M**edium term**)
- *Geotechnical investigation*: The project team is aware that CMRL has on several occasions been requested to conduct investigations for bridge design. Training is therefore required. **(Immediately)**

7.3.2 Additional equipment

In order to carry out the additional tests, particularly those related to asphalt and bituminous materials, and fulfil its research objectives and services to be provided, additional equipment will be required. It is for this reason that additional training in asphalt and bituminous materials is indicated as medium term. In the list of equipment provided in Appendix C, equipment for bitumen testing is rated the highest.

7.3.3 Space utilisation

Available space around the Laboratory is being used as storage for old desks and chairs, discarded computers and printers etc. It is recommended that the space urgently be cleared so that it can be used for laboratory activities such as sample storage and preparation. Adequate space is available for CMRL to function properly.

7.3.4 Accreditation of CMRL

Accreditation of CMRL: It is recommended that the Laboratory implement ISO 17025 to ensure that the quality of the work carried out is of a high international standards and credible as well that the management and administration is well organized and laboratory operations are effective in order to achieve the objectives and goals of CMRL. Implementing ISO 17025 is a task that requires months of preparation and training (possibly a year), after which the laboratory facilities and personnel have to be evaluated by an accreditation body.

It is advisable that a specific budget allocation is set aside to ensure the accreditation process is realised, particularly that CMRL will be responsible for implementing quality assurance and function as research laboratory. The fact is that accreditation is a costly process, especially in terms of time for preparation (putting procedures in place) and training of staff to follow the prescribed systems.

LoGITReC is to initiate talks with the accreditation body responsible for providing accreditation services in the SADC region, the Southern African Development Community Accreditation Services (SADCAS)

7.3.5 Proficiency/inter-calibration study programme

It is recommended that CMRL plays a key role in the planning and implementation of a proficiency testing programme for civil engineering laboratories in Tanzania. CMRL should liaise with TANROADS-CML under the auspices of the Engineers Registration Board, which is the body responsible for the registration of civil engineering laboratories in Tanzania. This will however, require that the distribution of samples for each particular test, for example CBR test, for the proficiency testing to all the participating laboratories be done one specific laboratory. It is advisable that the interpretation and statistical analysis of the results be done by an independent body such Engineers Registration Board. An institution with experience in laboratory testing and proficiency testing programmes for accreditation purposes should provide guidance the inception of the proficiency testing scheme.

7.3.6 Procurement processes

It is recommended that the factors constraining existing procurement processes be established and measures taken to minimise the delays in the acquisition of required equipment and supplies for the laboratory.

7.3.7 Institutional arrangements

With the move of LoGITReC to TARURA, it has been assumed that CMRL will be under the Quality Control and Research Unit. Understandably it is a transitional period, but there is a need for finalisation.

7.3.8 Collaboration and visibility

It is recommended that CMRL expands and enhances the cooperation with research laboratories in sub-Saharan Africa and internationally in relation to road research.

APPENDIX A

List of Works carried out after Installation of LoGITReC Worklist System in 2017

S/No	Date	Client	Contract Name	Tests Carried Out
1	17/03/2017	District Executive Director	Chamwino District Council roads	Grad; AL; LS; OMC/MDD; CBR;
2	21/04/2017	Ravji Construction Ltd	Chigongwe - Chipanga road in Bahi District Council	Field Density (Sand replacement)
3	08/05/2017	Millenium Master Builders & NCS Construction Group	Kisasa - 300 Houses Roads	Field Density (Sand replacement)
4	03/06/2017	ABALT Company Ltd	Routine maintenance along Mzakwe - Lamaiti road & Spot improvement of Msisi - Tinai road	Field Density (Sand replacement)
5	05/06/2017	Ravji Construction Ltd	Construction of Lot II 8.6Km and box culvert along Chigongwe - Chipanga road at Bahi District Council	Field Density (Sand replacement)
6	05/06/2017	MEDES Company Ltd	Upgrading of Bahi Town roads from Gravel to Tarmac road at Bahi District Council	Field Density (Sand replacement)
7	06/06/2017	Ravji Construction Ltd	Construction of Lot II 8.6Km and box culvert along Chigongwe - Chipanga road at Bahi DC	Field Density (Sand replacement)
8	09/06/2017	COMFIX & Engineering Ltd	construction works to extend Box culvert from Twin to Tetra and its protection along Mbande - Mkoka District road at Kongwa District Council (Banyibanyi Borrow Pit)	Grad; AL; LS; OMC/MDD; CBR;
9	10/07/2017	MEDES Company Ltd	Upgrading of Swaswa - Meriwa road	Proctor for MDD & CBR Test
10	10/07/2017	Ravji Construction Ltd	Construction of Lot II 8.6 Km and Box culvert along Chigongwe - Chipanga road at Bahi	Field Density (Sand replacement)

S/No	Date	Client	Contract Name	Tests Carried Out
			District Council	
11	01/08/2017	Millenium Master Builders & NCS Construction Group	Upgrading of roads along 300 Houses to Bituminius standars in Dodoma Municipal Council	Bitumen Spray rate test
12	02/08/2017	Ravji Construction Ltd	Borrow Pit investigation for Chipanga Borrow Pit	Grad; AL; LS; OMC/MDD; CBR;
13	11/08/2017	Ravji Construction Ltd	Construction of Lot II 8.6Km and box culvert along Chigongwe - Chipanga at Bahi District Council	Concrete cube crushing
14	11/08/2017	NCS Construction Group	Periodic & Routine maintenance of Kongwa Township roads,Routine maintenance of Kongwa - Mlanga and Mbande - Machenje road at Kongwa District Council	OMC/MDD and Field Density (Sand replacement)
15	11/08/2017	HEMATECH Investment Ltd	Construction of Lot II Three culvert along Mahoma Makulu - Mahomanyika - Nzuguni road section in Dodoma Municipal Council	OMC/MDD and Field Density (Sand replacement)
16	11/08/2017	Ravji Construction Ltd	Construction of Lot II 8.6 Km and Box culvert along Chigongwe - Chipanga road at Bahi District Council	Concrete cube crushing
17	12/08/2017	Ravji Construction Ltd	Construction of Lot II 8.6 Km and Box culvert along Chigongwe - Chipanga road at Bahi District Council	Concrete cube crushing
18	30/08/2017	Ravji Construction Ltd	Construction of Lot II 8.6Km and box culvert along Chigongwe - Chipanga at Bahi District Council	Concrete cube crushing
19	30/08/2017	AJA Building	Construction of Proposed Shops & Residential Building in Dodoma Municipality	Concrete cube crushing

S/No	Date	Client	Contract Name	Tests Carried Out
20	12/09/2017	Zuzu Ward Executive Officer	Construction of Laboratory at Zuzu Secondary School	Block crushing
21	12/09/2017	Ravji Construction Ltd	Construction of Lot II 8.6 Km and Box culvert along Chigongwe - Chipanga road at Bahi District Council	OMC/MDD and Field Density (Sand replacement)
22	13/09/2017	JOSAM & Company Ltd	Nzuguni Borrow pit Investigation	Grad; AL; LS; OMC/MDD; CBR;
23	13/09/2017	Maginga Business Holding Company Ltd	Twanga-Sunya & Namelok – Sunya Borrow pit Investigation	Grad; AL; LS; OMC/MDD; CBR;
24	21/09/2017	TARURA – DODOMA MUNICIPAL	Upgrading of Town roads	Grad; AL; LS; OMC/MDD; CBR;

APPENDIX B:

Recommended list of Equipment for CMRL

S/No.	NAME OF EQUIPMENT / ITEM	QTY	Priority: 1 = high
1	Binocular and petrographic microscopes	2	3
2	Expansion index test device (swell) of soils	2	2
3	Shear test device	2	2
4	Permeameter	2	1
5	Oedometer test device	2	2
6	Equipment for Characterization of filler for asphalt mixtures (Rigden voids)	2	3
7	X-ray diffractometer	1	3
8	Accelerated carbonation and ICS tests equipment	1	2
9	Soil sampling equipment, including drilling equipment for geotechnical investigations (e.g. soil profiling of foundations)	1	1
10	Light Falling Weight Deflectometer	2	1
11	Plate loading test equipment or a suitable alternative	2	2
12	Equipment for Spot characterization of skid resistance and macrotexture (British Pendulum Tester and sand patch)	1	1
13	Profiling equipment (Brink and Bruin)	1	1
14	Falling Weight Deflectometer (FWD)	2	2

S/No.	NAME OF EQUIPMENT / ITEM	QTY	Priority: 1 = high
15	Seismic Refraction tests equipment	1	3
16	Equipment for continuous measurement of skid resistance	1	2
17	Los Angeles Testing machine - complete	1	1
18	Standardized pycnometers for bituminous binders	2	1
19	Cleveland open cup apparatus	2	2
20	Bitumen Sample containers (TFOT - pans), diameter 140mm, height 9.5mm	5	1
21	ASTM 13C thermometer, 155°C – 170°C or similar	2	1
22	Container of glass or metal, approx. 0.25 litre	5	1
23	Rings and steel balls (3.5g)	2	1
24	Ring holder for 2 rings	4	1
25	ASTM 15C (or similar) Low softening point thermometer, having a range from -2 to +80°C	2	1
26	ASTM 16C or 16F (or similar) High softening point thermometer, having a range from 30°C to 300°C Forceps	2	1
27	Standardized brass moulds	2	
28	Testing machine for pulling the bituminous test specimens apart	1	
29	Brookfield Thermosel high temperature unit	1	1
30	Spindles for Brookfield Thermosel Viscometer	1	1
31	Thermosel system including thermal container, temperature controller, sample chamber and extraction tool	1	1
32	Pestle and Mortar	2	1
33	Saw for cutting core samples	2	1
34	Marshall test apparatus with a load and deflection measuring device	1	1

S/No.	NAME OF EQUIPMENT / ITEM	QTY	Priority: 1 = high
35	Automatic or manual mixing equipment for asphalt mix specimen	1	1
36	An indirectly tensile loading frame	1	1
37	Binder Extraction apparatus (include solvent fume extractor and masks for safety consideration)	1	2
38	Centrifuge with approx. 3500 rotations per minute	1	1
39	Centrifuge cylinders	1	1