Improving the quality of laboratory testing in the SADC regions through various educational and onsite training interventions

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Abstract— **This paper looks to outline the laboratory training under taken in Southern African Development Community (SADC) countries and what is required to improve the overall testing facilities and the results produced by them. This will include discussion on various interventions employed in the region including laboratory audits, implementation of proficiency testing schemes in various regions with the goal of developing an ISO 17025 approach to testing in the SADC region. The paper will also expand on typical issues experienced in the region that need to be addressed to ensure more consistently reliable results are produced by these facilities.**

The region attracts a wide variety of contractors, consulting engineers and other civils organizations that each have their own specific approach to how laboratory testing needs to be undertaken including a wide variety of test methods being specified from various countries around the world. This creates problems in the laboratory staff ability to competently undertake the methods specified on a specific contract and often results in some alternatives being introduced in the methods which can have quite alarming effects on the results as produced.

It is the opinion of the author to look at a more standardized approach to testing in the region to reduce the variety of methods currently employed in the region with the main aim of improving the quality of the testing results by maintaining well trained staff who understand the methods and are able to execute them effectively.

Keywords—laboratory testing, proficency testing scheme (PTS), ISO 17025, ISO 17024

I. INTRODUCTION

The SADC region attracts a wide variety of contractors, consulting engineers and other civils organizations from around the world, each having their own specific approach to how laboratory testing needs to be undertaken including the test methods specified which tend to vary from country to country. This is often the case when donor money from international organisations is provided for large contracts for infrastructure development e.g. roads, dams and airports. This variety in testing methods creates problems for the laboratory staff as they need to be able to discern which method is to be used. Their ability to competently undertake the methods specified on a particular contract often resulting in some alternatives being introduced to the methods which can have quite alarming effects on the results as produced. Each test method has its own subtle differences to the method details which need to be followed meticulously if a comparable result is to be obtained. These results are critically important as it ultimately results in decisions on acceptance or rejection of work done. This can have dire consequences to the longevity of the infrastructure developments ability to last throughout its design life if the results are incorrect. If the results show that the work is within the specification when in actual fact it's below the specification, the work should actually be rejected and redone to the minimum specification instead of being accepted and paid for. The opposite goes for work that is rejected that should be accepted.

The test methods used in the laboratories could be any of the following international standards i.e.

- SANS 3001 (South African),
- TMH 1 (South African National Standards),
- AASHTO (American),
- ASTM (American),
- EN (European Union standards),
- BS (British Standards)

or some of the lesser known methods such as NP (National Portuguese standards). It must be noted that the TMH1 document has been superseded by the SANS 3001 series and is no longer in use in SA.

What often occurs is the testers end up doing a combination of the methods which affects the end results and makes it incomparable with other comparative test results from other laboratories should comparative testing be undertaken to determine the correctness of the results as provided.

II. LABORATORY TESTING

Currently within the SADC region numerous testing methods are included in the project specifications largely dependent in which country the Consulting Engineers reside. This makes testing for the laboratory personnel extremely difficult given the subtle changes in each of the methods, dependent on which country they originate from. An example of this would be the CBR which differs between TMH1, SANS 3001 and AASHTO methods both in the steps to be followed as detailed in the methods as well as the apparatus specifications e.g. weight, hammer diameter and height of the drop.

South Africa (SA) has, over the past 10 year or so, gone through a process of converting from the old TMH1 (1986) to

the updated and revised SANS 3001 test methods along with other changes to general laboratory practice including the introduction of ISO 17025 accreditation and participation in the National Laboratory Association – South Africa (NLA-SA) PTS. Participating in a PTS is a requirement for ISO 17025 accreditation. Although SA has been accrediting laboratories for a number of years, the remainder of the SADC region only has one accredited facility. Although accreditation does not mean that the facility will produce zero errors in their results, the facility at the very least has a system in place that will allow them to track such errors and look at a methodology to correct the errors identified so as not to have them repeated. Table I details the number of testing facilities in SA versus the remainder of the SADC region.

TABLE I. ACCREDITED CIVIL TESTING FACILITIES IN SA & REMAINING SADC COUNTRIES

#	**ISO 17025 Accredited SADC Civil Engineering Testing Laboratories**	
	Country	***Facility No***
1	South Africa	52
2	Rest of SADC countries	1

[a.] Source: http://home.sanas.co.za/?page_id=38

[b.] Information as at 3rd May 2018

Added to this, and also a requirement of ISO 17025 accreditation, is the calibration of testing equipment traceable back to National or International standards. Although SA has numerous accredited calibration facilities, most of the SADC countries have at very best limited providers and at worst none. Although this is good for accredited SA calibration providers, the cost of providing this service across borders is very expensive, especially when calibrated artefacts and equipment needs to be transported between the countries to undertake onsite calibration. Table II details the number of calibration facilities in SA versus the remainder of the SADC region.

TABLE II. ACCREDITED CALIBRATION FACILITIES IN SA & REMAINING SADC COUNTRIES

#	**ISO 17025 Accredited SADC Calibration Laboratories**	
	Country	***Facility No***
1	South Africa	207
2	Rest of SADC countries	20

[c.] Source: http://home.sanas.co.za/?page_id=38

[d.] Information as at 3rd May 2018

Only 6 other countries in the SADC region have calibration facilities besides South Africa. Thirteen of these facilities are the standards body for that country with only 1 private organization capable of providing a calibration service. As can be seen from the data in Table II, the rest of the SADC region has only 10 % of the calibration capability that SA has.

Table III details the applicable calibration services mostly required in civils laboratories between SA providers and the remainder of SADC region.

TABLE III. CALIBRATION FACILITIES FOR SPECIFIC ACTIVITIES

#	**Calibration activities**		
	Calibration Activity	***South Africa***	***Rest of SADC***
1	Mass	35	7
2	Dimension	21	4
3	Temperature	31	4
4	Force	17	-
5	Pressure	15	2
6	Time	13	-
7	Volume	9	3
8	Rate of force	-	-

[e.] Source: http://home.sanas.co.za/?page_id=38

[f.] Information as at 3rd May 2018

No facilities exist outside of South Africa for the calibration of force and time. In total, only 6 other countries in the region have calibration capabilities leaving 7 with no calibration capabilities within their own borders. This scenario obviously adds to the cost of undertaking any traceability within their own countries. This gives rise to a possibility of a whole new job market in these countries in the field of metrology that currently does not exist plus much scope to improve and increase the numbers employed in the countries.

The final additional requirement for the ISO 17025 accreditation is the deeming of staff members (testers) competent to undertake the various methods. The more methods one is involved in performing regularly, the more extensive the competency deeming process becomes with the associated costs. SA has recently revised its methodology away from a qualification-based approach and is now endeavoring to undertake this process using ISO 17024 to certify the testers competent to undertake the testing regularly undertaken in their facilities. The development of the requirements for the deeming competent is well advanced, and the actual framework required is planned to be in place and functioning by the end of 2018. This will be undertaken by the NLA-SA who will manage the process and look at becoming a certified provider of ISO 17024.

SANRAL has been the main driver of this program due to their concern over testing results and the final approval/rejection of material being seen as a critical management tool in ensuring that the infrastructure built by contractors provides them with an acceptable design life for the capital expenditure and the growth and development of the country through the quality based road network system. SANRAL has managed to achieve this through the inclusion in their tender requirement that laboratories that tender on their contracts must be ISO 17025 accredited. A similar model is envisaged for the SADC countries where such a tender requirement pushes the laboratories who wish to tender on the larger contracts put out by the roads agencies and other large government tenders have to go the route of becoming ISO 17025 accredited. The Association of Southern African National Road Agencies (ASANRA) would be best suited to

assist in this process given that SANRAL sits on the same committee and can provide guidance on the processes to follow. The Southern African expertise is there based on experience over many decades in the region. Imposing European or American standards does not always work on the African continent. Take for example the CBR test method and design method. SA still makes use of it even though it's no longer used in the USA where it was developed for determining behavior for clayey type soils and just look what we've adapted it to work on. As per new SANS methods it tests up to a 37.5 mm fraction which plays havoc with the test results depending on the representivity of the whole laboratory sample but also the individual layers as they are put into the mould to make up the sample.

It has been a long road to get to this point in SA where this has been achieved but the benefits are far reaching to all parties involved as well as the benefits of the road users.

Another problem exists where staff that are deemed competent in a particular laboratory leave the employment of the laboratory for various reasons. This leaves a gap in the knowledge and experience in the facility which may place their results in doubt. Currently very little if any documented proof exists in laboratories outside of SA regarding the training and deeming competent of their staff members. In most cases new staff members are trained by the existing staff members who themselves have had little or no formal training as well as not following the correct procedural steps in the methods themselves. This leads to further variations in the methods being built in as each person is taught through word of mouth and demonstrations as against using an actual official printed test method.

All of these additional aspects required to be undertaken by the laboratories will assist in growing new industries with business investment and employment opportunities in the countries in the form of calibration laboratories, PTS and the training of testers. This would possibly be best coordinated by the various NLA's currently being established in the SADC countries. As the PTS provision is a paid for service, it'll also assist in providing a source of income for the newly formed NLA's to assist in establishing them in the various countries and provide for some cash flow. Another option would be the drive the process through ASANRA as mentioned earlier in this paper.

It is a huge step to introduce these measures into the current laboratory facilities but a necessary one to ensure that the correct decisions are made regarding construction work that is undertaken in the various countries to ensure the money spent on infrastructure development for the roads industry is money well spent. The cost of failures and the resultant legal costs to fight such decisions in a legal system, given the costs of replacing material and legal representation, can run into millions of Rands. In such cases the final outcome is largely based on a particular figure/values as determined by a laboratory. The legal decision maker normally does not have an engineering background and therefore will make a legal decision based on the technicalities as presented or some legal loophole and not necessarily that results in a correct engineering decision. So what happens? One party wins and one loses and then does it mean that the road will last for its design period? Most likely not. So at the end of the day, does such a decision benefit the end users or the clients for whom the road was built or not? Invariably not.

Unfortunately, going the legal route does not always mean that the correct civil engineering decision is made relating to the correct specification being applied but often results in a decision based on some technical loophole to allow additional costs to be paid over for the reworking of the section in question. Such results do not benefit the client or the contractor whoever ends up carrying the costs of such a ruling. The legal battles are normally won or lost based on a value (test result) provided by a testing facility which invariably can be questioned from a legal point of view.

III. Introduction of PTS in laboratories

The benefits of a proficiency testing scheme (PTS) are that the laboratories in the country are evaluated against one another to determine their ability to obtain results that are within the specification of the material supplied as well as their proximity to the consensus mean of the sample circulated in that round.

One of the problems that face the civils industry is that there are no reference materials with a true value that one can test against and evaluate the accuracy of the results as submitted by the participants. As a result, a consensus mean is used as the most accurate value for the material used in a particular PTS round. What needs to be assumed in such a scenario is that the material is sufficiently consistent to produce acceptable results and that the facilities participating are carrying out the methods exactly as laid out in the method. Particular care is required in the preparation of the samples for such a PTS especially if it is for a large PTS round with many participants. Civils materials are known to be quite variable so ensuring that each sample is as constant as the next one is critical to a good set of results. Although various measures can be put in place to ensure the material is as constant as possible there is no way to confirm that all the laboratories are conducting the methods in exactly the same manner as one would like them to be. Certain checks and balances can be put in place to confirm aspects of the method are being followed but it's not a full check on the entire methods procedure. Unfortunately, in some cases it is plainly obvious that the methods are not being followed correctly and as consistently as would be expected which does place some doubt on some of the laboratories abilities to produce acceptable and believable results.

The SA PTS has been running since 2011 and is now running quite smoothly with over 70 participants partaking in 10 rounds per year. Most of the common laboratory tests are included in these rounds for each of the 5 material types used in civils contracts. Mozambique is currently busy with a pilot project to implement a national PTS through their Roads Agency Administração Nacional de Estradas (ANE) and is funded by Research for Community Access Partnership (ReCAP). It is envisaged that the other countries will follow

suite once the Mozambican project is completed by the end of 2018.

The process of setting up such a scheme needs to be a long term project which will need to be adapted over time to extract the full benefit for each country. It took SA 4 years to get the system up and running and this is still undergoing further improvements and automation 6 year down the road. The training of a group of individuals that will run the PTS is also a process on its own given the amount of statistical analysis required as the participants in the scheme grows country for country.

Numerous training opportunities are identified during such an exercise both internally within testing facilities as well as national requirements that need to be addressed. These would include revisions to test procedures to reduce variability of the results as well as methods that are by their very nature reflect highly variable results. It will also identify methods that are particularly difficult to conduct and where additional care is required in preparing and testing of specific materials.

Additional benefit of running a PTS include

- One is able to get a more realistic value for the range of results one can expect from a particular test method.
- The results over time can be used to determine a National uncertainty value for various materials and test methods.
- Laboratories get a better feel for how reliable their results are based on the proximity of their results to the consensus mean.
- Corrective actions can be checked against the following rounds results to see how effective the corrective action one in resolving the problems as identified.
- Trending between rounds and different staff members can be evaluated to determine a laboratories ability to perform the test methods consistently within an acceptable range of results.
- Can also be used to assess different testers ability within the same laboratory and to back up competency assessments.

IV. Introduction of Reference Laboratories in each country

The introduction of a reference laboratory in each country will assist in having a facility that can be used as a reference against which to check results produced in that country especially for approval of payments for work done. It is also proposed that the reference facility will be used to manage and conduct that countries national PTS which will be further used to confirm the countries laboratories ability to test and produce acceptable results. In the case of a dispute this reference laboratory will be the go-to facility to determine if the results produced by a particular facility are within an acceptable range or not.

In SA SANRAL are again leading the charge in this regard with the reference laboratory already in the design phase. It is planned to be up and running into 2020 and will then take over the preparation of all the samples for the NLA-SA National PTS. This approach is to limit the variability of the prepared samples used for the PTS and to build up a solid knowledge base and expertise on the best practice in sample preparation.

It is further proposed that the reference laboratories undertake a PTS between themselves to ensure that their results all fall within an acceptable range and then to manage the PTS within their own country based on their performance within the regional reference laboratory PTS rounds. For this to be effective there will need to be consensus on which methods are to be used in the SADC region as it does not make sense to partake in a PTS for SANS 3001 methods and then undertake ASTM or AASHTO methods within your country as these methods will not have been evaluated through a PTS.

V. CONCLUSIONS

The laboratory methods used in the SADC regions urgently need to be standardised to ensure accurate results which can be used to evaluate the quality of the material used and whether it conforms to the required quality as specified in the contract documentation. This will ensure confidence in the laboratory results and for the international donors a sense that the money has been well spent and the infrastructure will last for an acceptable period of time. This would be best undertaken through ASANRA with assistance from the region NLA's in each country.

The introduction of a regional and national PTS will assist in ensuring that the laboratories in each of the SADC countries are testing to a specific standard and that the results are representative of the materials tested. The introduction of such a scheme also changes the laboratories perspective on what is required to produce a result that is acceptable and ensures a more professional approach to the practice of laboratory testing.

Much is still required to be undertaken to train up the testers on the methods they use and to introduce the PTS in each country. The additional requirement for a regional PTS to evaluate the ability of each of the countries reference laboratories also needs to be set up to so that the individual national PTS's can be undertaken from these transferred capabilities. The training required for the introduction of a PTS is quite an intensive process as it's a very different way of managing the laboratories ability to undertake testing and in particular assisting with the analysis and evaluation of the results.

It is also proposed that, with these systems in place, the next step of getting laboratories accredited to ISO 17025 in the SADC region will be far easier. As the PTS will already have been established and, in participating in such a scheme, a better awareness is developed about what is required to produce results to an acceptable level of quality.

The introduction of these proposals will lead to an increase in the cost of providing laboratory testing services, but would

be justifiable given the better accuracy of results produced attributable to the laboratory management system in place. There would be less disputes related to material failure with the related material and legal costs of getting private consultants in to identify the problem when such disputes occur. This, in itself, is normally a very high additional cost to one or more of the parties involved. Improved decision making on approval of materials as used in contracts can drastically reduce risks and associated life expectancy. Increased confidence that work conforms to the specifications will easily off-set the additional cost of the improved testing facilities.

This is by no means a simple quick fix nor a cheap option to implement but rather a long-term approach that needs to be incrementally introduced to grow and develop the critically import function of laboratory testing and the related activities in the SADC region into a professional body whose results can to be trusted.