Improvements and advances in construction quality assurance for geosynthetics

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ABSTRACT: Geosynthetic materials are powerful materials for geotechnical works: projects can be completed with geosynthetics that would be impossible without them. In the applications of barrier materials, drainage, reinforcement, stabilization and erosion protection use of geosynthetics is the current standard of practice. However, as with all materials, geosynthetics must be properly installed to provide the functionality desired. An improperly installed geosynthetic will likely not provide the desired function and lifespan. A broad set of standards and instructions were developed for the construction quality assurance of geosynthetics and these have been historically effective in providing guidance for installation. In the last few years, new tools and techniques have been developed that advance the process and capabilities of construction quality assurance for geosynthetics. This include: The use of digital systems for tracking and testing geosynthetic deployment, welding, installation and performance data and improved and more rapid management and distribution of quality data. The use of global positioning systems, aerial photography and drones to document geosynthetic deployment and installation. The real time digital tracking of installation machinery and variables. The use of these technologies translates into a higher quality installation with lower potential for poor installation quality issues and more rapid review and engineering approval of construction. Examples of these technologies are presented and demonstrated and potential global best-practice technologies are introduced.

1 INTRODUCTION

While the focus of this paper is geosynthetic material installation, there are several assumptions made that, while self-evident for the experienced user, should be established here. Most important is that geosynthetic materials need to be properly installed to function. Barriers must be free of holes, reinforcements that are directional must have the proper orientation, drainage must flow in the desired direction without clogs and blockages, etc. Construction Quality Control (CQA) is designed around this precept. Further, an established quality principal can be stated as "everyone does better work when someone is looking over his/her shoulder". It is a human tendency to perform better when our work output is monitored and evaluated. Also, many of us are usually more capable that one of us – humans' function more optimally as a group. Thus, Construction Quality Control involves many people in the process and improves overall performance.

As these prior statements are "obvious" also is construction quality control an "obvious" and well-established field. Books, papers, manuscripts and guides have been created on this topic, most geosynthetic material manufacturers publish Installation Quality Control Manuals that address this topic, there is regulatory and technical guidance available in many countries round the world and every reputable geosynthetic installation company has a CQA program. The purpose of this paper is to address and inform the reader on recent changes to the "CQA-world". Our societies have advanced in recent years: the vast majority of people on the earth are connected via smartphones and electronic media. Smartphone and computer "Apps" (applications) for communicating, disseminating information and collecting and sharing data including global positioning system (GPS) location on our planet are commonplace. This paper addresses the use of these functions to improve the process of geosynthetic CQA and offers examples and benefits of their use.

These advances are presented in four general categories:

- Improvements in management, control and monitoring of currently commonly existing/CQA data. (Paper and manual data to digital)
- Advances in capture, control and monitoring of new and additional aspects of CQA data. (Digital to digital – i.e. welding conditions from welder to CQA database)

- Advances in capture, control and management of new and additional aspects improving CQA location performance. (Drone mapping to as-builts, i.e.)
- Summary of the benefits these and other new techniques bring to owners, regulators, insurers and the general population.

2 MANAGEMENT OF EXISITING DATA

In every CQA program there is a great deal of data: in fact, the CQA program could be considered to be the existence and accumulation of data. This data has many forms and uses, Critical data for CQA of a geosynthetics installation includes the following at a minimum: qualification and acceptance of the soils the materials are placed on/within, location and identification of materials deployed, records and testing evaluations of the welding and joining of materials (this includes test welds, continuous testing such as ASTM 5820 Air Channel testing for example and destructive testing), locations and welding records for penetrations and other irregular features of the installation, construction of a diagram/map illustrating the installation (commonly called an "as-built"), weather and meteorological data and other pertinent information. The volume of information for a site run with good quality CQA is significant; a final CQA report can run several hundred pages with scores of charts, maps and tables. Moreover, this data is commonly reviewed on a daily basis. In some instances, approvals are required before advancing to the next step(s) and locations. Further, the geosynthetic installation must be integrated into the overall project progress, meshing with normal site activity, soil installations and movements, traffic restrictions and other important non-geosynthetic related activities.

Management control and daily inspections of this information and the results of quality testing are much more easily, rapidly and efficiently accomplished with digital tracking of the data. The installation operators and CQA inspection staff is equipped with smartphones or tablets and the data is generated, input, recorded, sorted and examined digitally.

A system developed by C3T (Construct 3 Technologies) and utilized by Gen-X of Johannesburg, South Africa which is called Geo-Q is an early leader in the field.

The following screenshot indicates the various tabs used for recording data in a typical installation. The materials are received and exist by roll number in the Material Stock Delivery Section. As material is deployed and panels placed it is recorded in the Materials Cutting List and Panel Placement sections. Damaged product is logged. Seaming details are recorded and the results of destructive and non-destructive testing is recorded. Repairs, Patching and Joints (penetrations) also are tracked digitally.

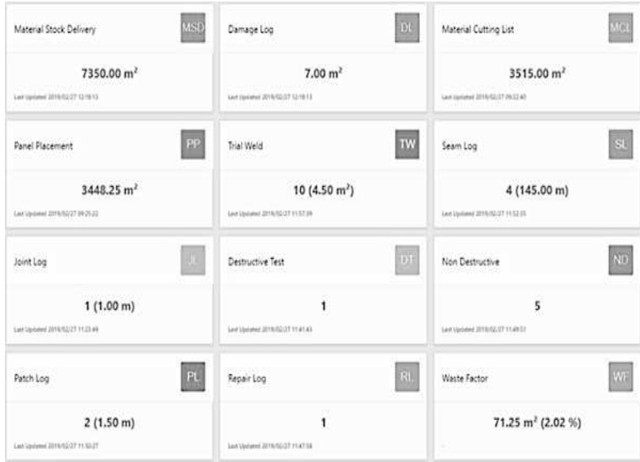


Figure 1. Screenshot of Geo-Q quality tracking contents page

Various levels of oversight can be implemented. The following screenshot illustrates an example of recording of damage to a roll of geosynthetic material. The damaged material is noted and if necessary multiple management approvals/acknowledgements can be initiated. These can be transmitted digitally, within the system, dramatically improving response time and documentation accuracy.

Figure 2: Screenshot of Geo-Q damage log example

The Aquatan AQ-Cloud™ system, Johannesburg, South Africa, is another early leader in this field. A screenshot of that content design is shown below.

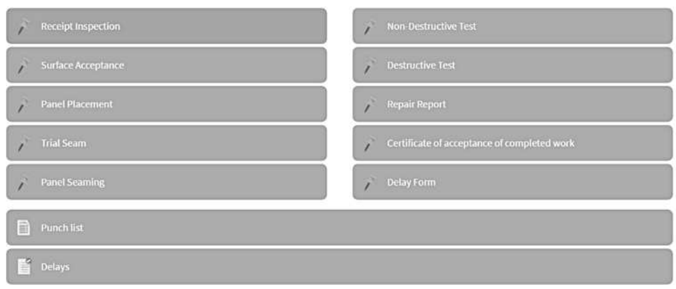


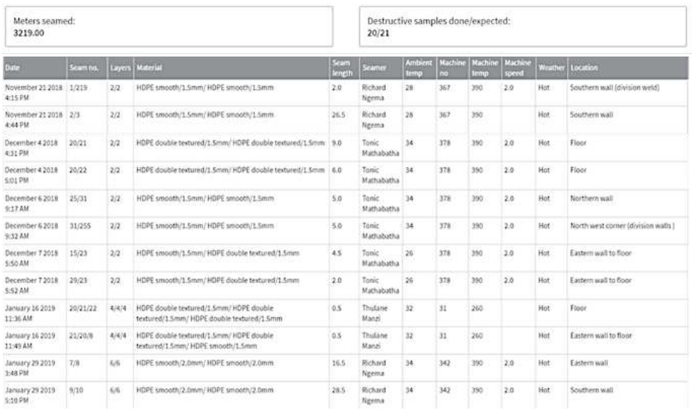
Figure 3. Screenshot of AQ-Cloud quality tracking contents page

Prior to the deployment of materials, the surface needs to be inspected and accepted by the Lining Contractor, the Civil/Earthworks Contractor and Engineer. A picture is taken of the surface area and each party physically signs digitally on the tablet.

As material is deployed, the panel placement form is completed. The operator will select the type of material and the associated roll number from the database. This prevents human errors from slipping in and accidently recording the wrong roll number. The operator will at this point assign a layer number to enable identification of the panels on a multi-liner installation project. The system also automatically keeps track of how much material is used of each roll.

The trial seam needs to be completed and data recorded before the seaming of the deployed panels can commence. The system has built in hold points such as these to prevent the procedures being bypassed which could be detrimental to the quality of the project. The details relating to each and every seam is recorded under the panel seaming records.

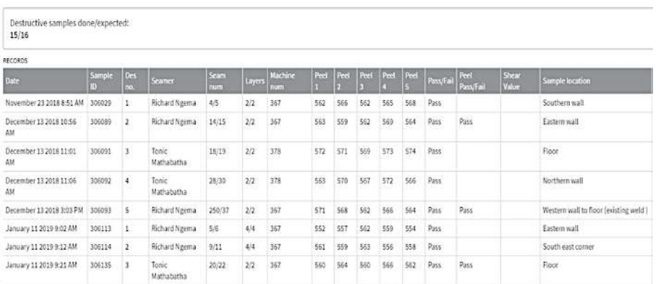
A principal benefit that results from the digitization of records is the ability to track the performance of staff and operators over multiple projects and installations. An example from the Q-Cloud system is illustrated in figures 4 and 5.


Meters seamed:
3219.00

Destructive samples done/expected:
20/21

Date	Seam no.	Layers	Material	Seam length	Seamer	Ambient temp	Machine no	Machine temp	Machine speed	Weather	Location
November 21 2018 4:15 PM	1/219	2/2	HDPE smooth/1.5mm/ HDPE smooth/1.5mm	2.0	Richard Ngema	28	367	390	2.0	Hot	Southern wall (division weld)
November 21 2018 4:44 PM	2/3	2/2	HDPE smooth/1.5mm/ HDPE smooth/1.5mm	26.5	Richard Ngema	28	367	390		Hot	Southern wall
December 4 2018 4:31 PM	20/21	2/2	HDPE double textured/1.5mm/ HDPE double textured/1.5mm	9.0	Tonic Mathabatha	34	378	390	2.0	Hot	Floor
December 4 2018 5:01 PM	20/22	2/2	HDPE double textured/1.5mm/ HDPE double textured/1.5mm	6.0	Tonic Mathabatha	34	378	390	2.0	Hot	Floor
December 6 2018 9:17 AM	25/31	2/2	HDPE smooth/1.5mm/ HDPE smooth/1.5mm	5.0	Tonic Mathabatha	34	378	390	2.0	Hot	Northern wall
December 6 2018 9:32 AM	31/255	2/2	HDPE smooth/1.5mm/ HDPE smooth/1.5mm	5.0	Tonic Mathabatha	34	378	390	2.0	Hot	North west corner (division walls)
December 7 2018 5:50 AM	15/23	2/2	HDPE smooth/1.5mm/ HDPE double textured/1.5mm	4.5	Tonic Mathabatha	26	378	390	2.0	Hot	Eastern wall to floor
December 7 2018 5:52 AM	29/23	2/2	HDPE smooth/1.5mm/ HDPE double textured/1.5mm	2.0	Tonic Mathabatha	26	378	390	2.0	Hot	Eastern wall to floor
January 16 2019 11:36 AM	20/21/22	4/4/4	HDPE double textured/1.5mm/ HDPE double textured/1.5mm/ HDPE double textured/1.5mm	0.5	Thulane Manzi	32	31	260		Hot	Floor
January 16 2019 11:49 AM	21/20/8	4/4/4	HDPE double textured/1.5mm/ HDPE double textured/1.5mm/ HDPE smooth/1.5mm	0.5	Thulane Manzi	32	31	260		Hot	Eastern wall to floor
January 29 2019 3:48 PM	7/8	6/6	HDPE smooth/2.0mm/ HDPE smooth/2.0mm	16.5	Richard Ngema	34	342	390	2.0	Hot	Eastern wall
January 29 2019 5:10 PM	9/10	6/6	HDPE smooth/2.0mm/ HDPE smooth/2.0mm	28.5	Richard Ngema	34	342	390	2.0	Hot	Southern wall

Figure 4. Screenshot of AQ-Cloud panel seaming records page


Destructive samples done/expected:
15/16

RECORDS

Date	Sample ID	Des no.	Seamer	Seam num	Layers	Machine num	Peel 1	Peel 2	Peel 3	Peel 4	Peel 5	Pass/Fail	Peel Pass/Fail	Shear Value	Sample location
November 23 2018 8:51 AM	306029	1	Richard Ngema	4/5	2/2	367	562	566	562	565	568	Pass			Southern wall
December 13 2018 10:56 AM	306089	2	Richard Ngema	14/15	2/2	367	563	559	562	569	564	Pass	Pass		Eastern wall
December 13 2018 11:01 AM	306091	3	Tonic Mathabatha	18/19	2/2	378	572	571	569	573	574	Pass			Floor
December 13 2018 11:06 AM	306092	4	Tonic Mathabatha	28/30	2/2	378	563	570	567	572	566	Pass			Northern wall
December 13 2018 3:03 PM	306093	5	Richard Ngema	250/37	2/2	367	571	568	562	566	564	Pass	Pass		Western wall to floor (existing weld)
January 11 2019 9:02 AM	306113	1	Richard Ngema	5/6	4/4	367	552	557	562	559	554	Pass			Eastern wall
January 11 2019 9:12 AM	306114	2	Richard Ngema	9/11	4/4	367	561	559	563	556	558	Pass			South east corner
January 11 2019 9:21 AM	306135	3	Tonic Mathabatha	20/22	2/2	367	560	564	560	566	562	Pass	Pass		Floor

Figure 5. Screenshot of AQ-Cloud destructive test record page

In this illustration the seams/welding is being tracked, the operator is identified, machine setup conditions are recorded, and a general location is identified, further the CQA results of that specific weld are recorded. Thus, a company can review and track the performance of a seamer/welder, a particular piece of equipment and other variables. This allows the non-subjective identification of the "better" welder, identifies individuals who may need additional training or instruction, identifies machines that are performing better or worse than others and generally supply data to fit the well-established quality management maxim – "if you can't measure it, you can't control or improve it".

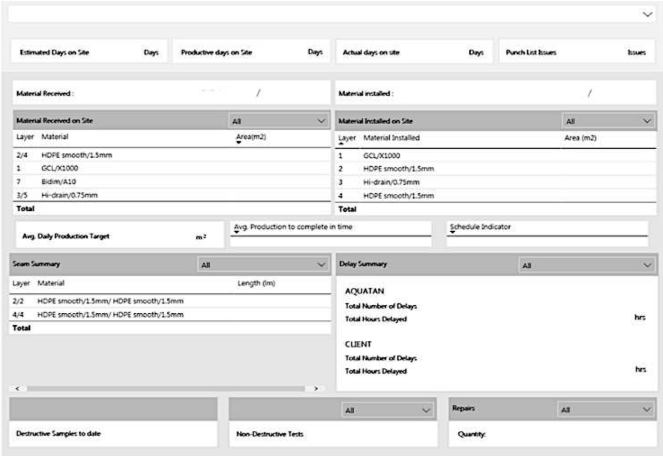


Figure 6. Management dashboard for the Q-Cloud system

On a project specific basis, the management dashboard illustrated in figure 6 provides a format for overall project management: materials inventory, construction progress and CQA results and other information.

3 CAPTURE AND CONTROL OF NEW DATA

An additional improvement is the ability to capture and record data that is currently not available via standard CQA methodologies. The principal example in the regard is the capability to record, monitor and review data on the operation of welding equipment. Welding is recognized as a critical component of the installation. In previous examples we saw the recording of data and the connection of welding information (operator and conditions) with related CQA testing (both destructive and non-destructive methods can be applied). Welding equipment manufacturers have improved the capability of the welding machines to be monitored. Multiple variables such as temperature (both set points and real time measurements, welding rate (movement distance per unit time) and pressure.

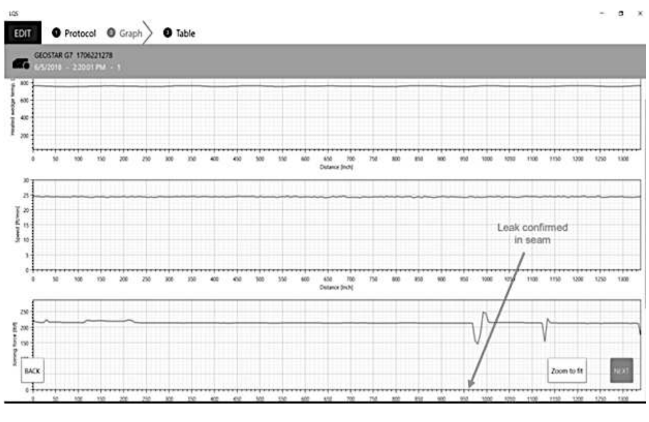


Figure 7. Screenshot of MyLeister / Geostar™ welding record page

Figure 7 illustrates the output of this type of measurement. In the illustration, taken from the Bullock paper, welding machine setpoint data can be tracked and upsets are readily visible. The "X" axis on the graphs represents location: distance from the beginning of that particular weld. This data is uploaded digitally and also can be monitored by the welding operator using a digital interface. This feature can be additionally developed to include GPS location and recording to allow for the exact placement of the welding machine upset and the area of concern for weld integrity. Several benefits include the ability of management to review and identify these areas of concern, CQA staff to use this data to improve the effectiveness of destructive sample testing and early identification of operator or machine errors.

4 ADVANCES IN LOCATION AND IDENTIFCATION (GPS AND "AS-BUILTS")

The data capture and operations described above are significant improvements to CQA operations. A further advancement is linking this data to verifiable, easily relocated locations: this is being done with GPS (Global Positioning Systems): the digital capture of data at specific GPS locations is a powerful tool.

GPS is familiar to most people as the systems that power directional guidance in automobiles. While powerful, those systems of single point GPS positioning lack sufficient accuracy for critical CQA operations. An automobile is commonly positioned with an accuracy of approximately 10 meters. This is wider than the width of most geosynthetic products and thus improvements are necessary to improve the accuracy to appoint where specific rolls/panels and welds can be confidently located. This is best done using a GPS base unit that is installed on or immediately adjacent to the project site and can produce GPS accuracy to approximately one meter.

The photos below illustrate a process used by COMANCO of Plant City, FL to prepare visual inspection of sites and create a real-time as-built record that accurately identifies all pertinent locations within the installation for CQA activity and future location/inspection.

Figure 8. Photos (3) of drone overflight preparation courtesy of COMANCO

In the example illustrated in this section, a camera equipped drone is used for daily overflights of the project installation. Large (1 meter by 1 meter) location markings, as indicated in Figure 7, are created and identified by GPS location. The drone overflight records the status of the installation at that point and reconciles the visual markings with GPS positioning.

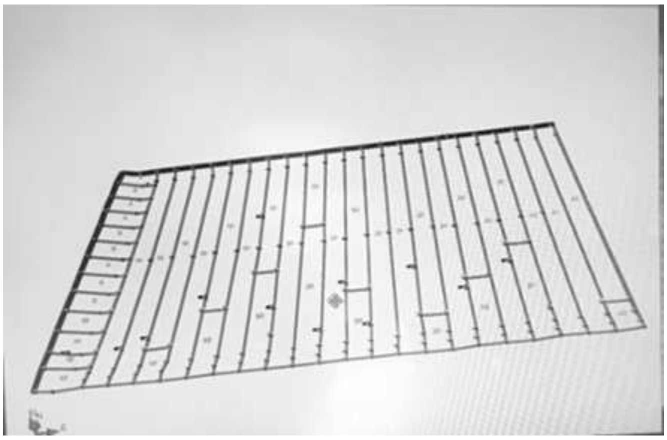


Figure 9. Screenshot of as-built preparation courtesy of COMANCO

The results of the overflights are used to generate the as-built drawing as illustrated in figure 9. Roll numbers and panel deployments are integrated into the document. Further, during construction, any upsets or particular circumstances are labeled with a GPS location.

Figure 10. Photo of GPS location of a "T" joint, courtesy of COMANCO

In the photo above, Figure 10, a material roll end/beginning and the resulting "T" joint is marked with a GPS location. This protocol can also be used for the locations of destructive samples, repairs, penetrations and any other special circumstances. By using this methodology, the digital as-built (constructed for each layer of geosynthetic) becomes a very powerful document for both CQA and potentially for identification and correction of future issues. Current best practice for leak-free barrier sites, for example, uses a electronic leak location survey which is also coordinated through GPS location. Overlay of a leak location survey result with a digital as-built, both accurate to a meter or less, would be a very powerful tool for performance evaluation and leak location identification and repair.

5 BENEFITS TO OWNERS AND THE GENERAL PUBLIC

The advances above offer multiple benefits to owners, project participants and the general public. The broadest of these is the improved assurance that the installation and performance of the site and construction will be as designed and intended. Reliability, organization, record-keeping and inspection are clearly facilitated by these methods and protocols. Clearly, use of these techniques and equipment is an indicator of geosynthetic installation professionals, who are expert in their fields. A requirement for the use of some or all of these techniques is a simple way to improve the quality of the installation.

Longer term, there is also great benefit for the users of these systems. The ability to access performance across multiple projects easily will allow evaluation of materials, staff performance and equipment over a statistically more significant period. This can be used to optimize training content and frequency, identify and optimize machine performance and maintenance schedules and provide a multitude of other benefits.

Overall, the use of these techniques in CQA will produce faster, more durable, more reliable and efficient installations that allow the benefits supplied by geosynthetic materials to be fully realized.

6 CONCLUSIONS

The author has presented new and powerful techniques for construction quality control that are currently being utilized by progressive and capable installation companies. Clearly, these systems and protocols will continue to improve and evolve. It is not the authors intention to single out a “best-practice” as this point, however the use of digital CQA is clearly beneficial and the addition of this requirement into engineers designs and installation requirements is appropriate and beneficial to the engineers, site owner and all people involved and effected by a project.

7 ACKNOWLEDGMENTS

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