SRW HISTORY ARTICLE SERIES

This article is part of the series of technical articles on the history of segmental retaining walls.

NCMA QUALITY CONTROL / QUALITY ASSURANCE OF SEGMENTAL RETAINING WALL (SRW) UNITS

Quality Control (QC) is a process by which entities review the quality of all factors involved in production (Ref.16). Quality assurance (QA) refers to the engineering activities implemented in a quality system so that requirements for a product or service will be fulfilled (ASQ Definition). It is the systematic measurement, comparison with a standard, monitoring of processes and an associated feedback loop that confers error prevention.

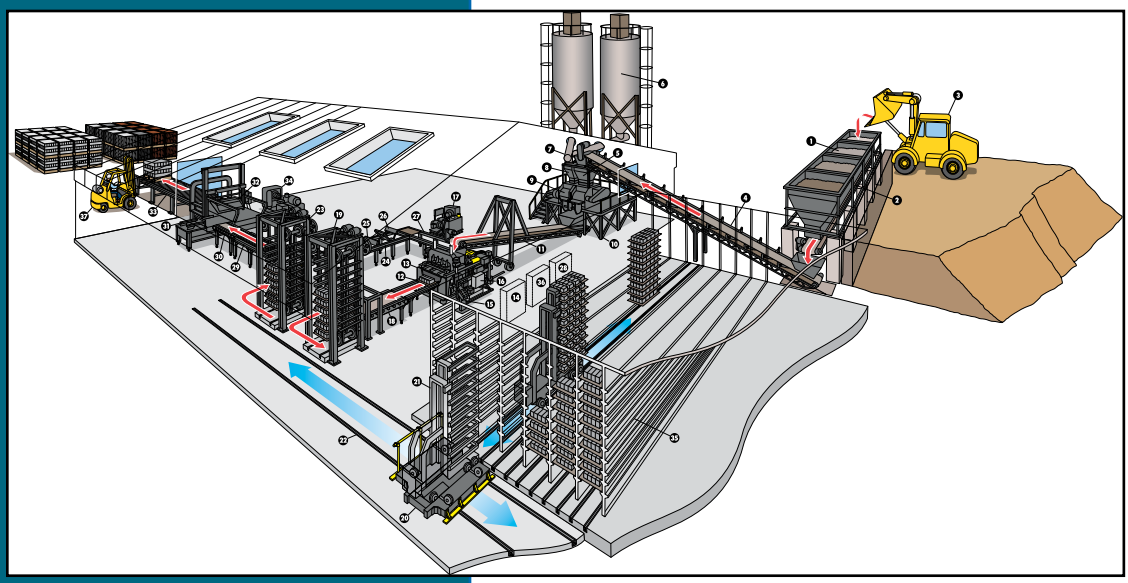

Figure 1. Modern Production Plant (Courtesy of Columbia Machinery)

In the first article of this series (Ref. 15), we talked about production and the growth of an industry that started on a single, manually operated machine making 300 units during a 10 hour day to today's automated systems making thousands of units per day. The early processes maintained quality control by physically touching every process and viewing each step as it was being accomplished. In today's systems, the processes are automated with remote instruments measuring parameters, computers collecting the data and displaying the results to the equipment operators or flagging conditions that do not meet the programmed conditions and sometimes adjusting the processes (see Figure 1).

In this article, we will review what Quality Control measures are taken in a segmental retaining wall unit plant during production and the Quality Assurance steps needed to confirm the product meets the requirements of published ASTM, project specifications, or plant operation manuals.

QUALITY CONTROL: WHAT IS REQUIRED?

The definition for QC involves reviewing all the factors involved in production to make a quality SRW product. To see what factors are required, we must review the published product standards to see what the customer is expecting and what industry has specified will be provided. Every industry relies on consistent production practices to deliver consistent quality products. The best

place to start for SRWs is the NCMA-ICPI Quality Control Manual for Dry-Cast Manufactured Concrete Products Production Plants (Ref. 14). References in the NCMA-ICPI Manual point to all the ASTM standards for zero slump concrete products but for this article we are only focused on segmental retaining wall (SRW) products (ASTM C1372, Ref. 12). ASTM C1372, Specification for Dry-Cast Segmental Retaining Wall Units, was adopted following the ASTM C90 (Ref. 2), Standard Specification for Loadbearing Concrete Masonry Units requirements. ASTM C1372 was created to add specific requirements for SRW products that are not applicable to loadbearing concrete masonry units.

In the Canadian market the Canadian Standards Association (CSA) produces standardized testing procedures similar to ASTM in the U.S.

IMPLEMENTING A PROGRAM FOR QUALITY CONTROL/ QUALITY ASSURANCE FOR SEGMENTAL RETAINING

Wall Units

Requirements for compression strength, absorption, dimensional consistency, and durability of products produced on high speed block machines have been increased with the introduction of Segmental Retaining Wall units. Although the same basic equipment that has been used to produce billions of Concrete Masonry Units used in the construction of buildings and other structures all over the world, stronger more consistent unit than what has typically been produced were needed. The following section describes what Quality Control Measures and Quality Assurance Programs have been implemented in plants to accommodate these elevated standards. Engineers, Contractors and Inspectors should ask for the processes put in place at the plant that will be delivering the units to the project to ensure that these higher standards are met.

Segmental Retaining Wall units have evolved to the point that they now are controlled by an ASTM specifically developed for the SRW industry. ASTM C1372 and C1262 (Ref. 11) provide a baseline for minimum standards for units produced for this industry and necessary testing. Guidelines for the strength and absorptions requirements are included in Table 1; designers can always specify higher values than the minimum recommended depending on their project specific needs.

Table 1: Strength and Absorption Requirements for SRWs (ASTM C1372)

Strength and Absorption Requirements		
Minimum Required Net Average Compressive Strength, psi (MPa)		
Average of 3 units 3000 (20.7)		Individual Unit 2500 (17.2)
Maximum Water Absorption Requirements Weight Classification Oven-Dry Density of Concrete Lb/ft^3 (kg/m^3)		
Light Weight Less than 105 (1682) 18 (288)	Medium Weight 105 (1682) to less than 125 (2002) 15 (240)	Normal Weight 125 (2002) or more 13 (208)

At the time of delivery, SRW units must conform to at least the properties shown on Table 1.

Segmental retaining wall units may be used in aggressive freezing and thawing environments. When units are used in applications where freezing and thawing under saturated conditions can occur. To address the exposure NCMA has published some recommended changes to the SRW product properties in the article Durability of SRWs (Ref. 15), ASTM C1372 includes three different methods of satisfying freeze-thaw durability requirements:

1. Proven field performance,
2. Five specimens shall have less than 1% weight loss after 100 cycles in water using ASTM C1262, or
3. Four of five specimens shall have less than 1.5% weight loss after 150 cycles in water using ASTM C1262.

In order to achieve products that consistently meet the minimum standards or better if necessary, some of the items that are considered in developing a proper Quality Control Plan are presented here.

QUALITY CONTROL PROGRAM

Each manufacturing plant is encouraged to develop a written quality control plan covering all aspects of the production process that must be followed during all phases of production. The Quality Control Plan must accurately represent the plant's practices and procedures to attain consistent quality products. Quality Control Plans should be plant specific and there should be one person at each plant that is responsible for maintaining records to ensure that the details of their specific plan are met. Examples of issues that may be included in the QC Plan are as follows:

SAMPLE PLANT SPECIFIC QUALITY CONTROL PLAN

- Formal review of the specifications as outlined in defined ASTM requirements, or other unique product specifications on project by project basis. This provides the benchmark for the required product characteristics.
- Raw Materials: all materials used need be traceable to their origin and have documentation that the necessary standards are met. Most SRW mixes consist of:
  - Cementitious Materials: mill certificates need to be retained. Depending on the cementitious material used it must conform with ASTM C150 (Ref.), C595 (Ref. 6), C1157 (Ref. 10), C618 (Ref. 7) or C989 (Ref.8) specifications:
  - Fine Grained Aggregates: documentation of compliance testing for ASTM C33 (Ref. 1) for normal weight aggregates or ASTM C331 (Ref. 5) for lightweight aggregates from supplier and gradation (ASTM D6913, Ref. 13) from supplier must be retained.
  - Course Grained Aggregates: documentation of compliance testing for ASTM C33 for normal weight aggregates or ASTM C331 for lightweight aggregates from supplier and gradation (ASTM D6913) from supplier must be retained.
  - Admixtures or Additives: documentation of compliance testing for air-entraining agents, coloring pigments, integral water repellents, finely ground silica, and other constituents established as suitable for use in segmental retaining wall units should be kept. Any additive used should not be detrimental to the durability of the segmental retaining wall units or any material used in segmental retaining wall construction.
  - Water: reports obtained from municipal suppliers or test reported conducted on well water, as applicable.
- Batching Equipment shall provide consistent batching processes to preset tolerances for each measurement. A routine validation and verification process should be identified in the written plan (see Figure 3).
- Production Equipment shall be maintained to allow production units to meet the product standards specified by the customer or designer (See example equipment on Figure 4).

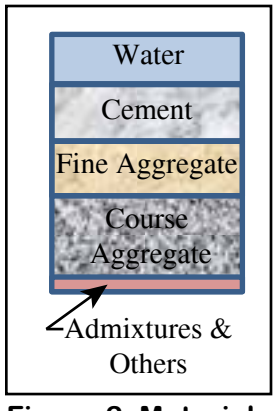

Figure 2. Materials used to produce SRWs

Figure 3. Batching Controls

Figure 4. Production Machine. This machine can produce a number of different products.

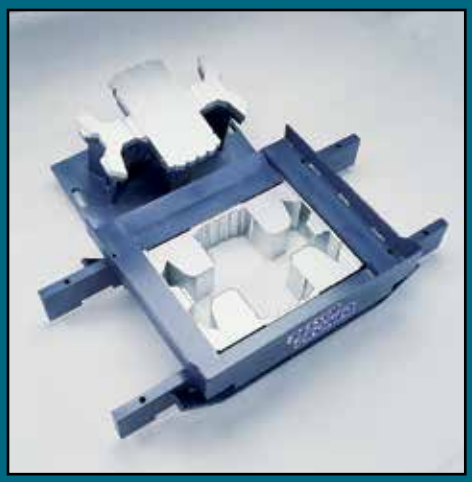

Figure 5. SRW Mold (Courtesy of Besser)

Figure 6. Manual Height Consistency Check During Production

Figure 7. Product Placed in Kilns for Curing

- Mold Inspection Document shall provide a complete review of the mold and requires documentation of check points and out of compliance conditions which require rework before product may be run. A new mold is shown in Figure 5.
- Mix Designs for each product must be documented and changes must be approved and documented by the Quality Control Manager.
- Batching sequence and mix cycle times and processes shall be defined to achieve a consistent mix. Changes to the written guidelines must be approved and documented by the Quality Control Manager.
- Concrete Products Machine settings should be defined to achieve a consistent density and height to meet the final standards of the unit being produced. Changes to the written guidelines should be approved and documented by the Quality Control Manager. A production machine is shown in Figure 5 and in Figure 6 a technician is checking height consistency during production.
- Product curing shall conform to a predetermined protocol for preset time, time and temperature for curing and soak time. Variations from this protocol must be approved and documented by the Quality Control Manager. Figure 7 shows a type of curing chamber.
- Cubing and packaging shall be determined for each type of product with proper identification marking and applicable lot number shall be attached to each cube. Lot number identification shall allow tracking to details on mix design, settings for mixing, machine settings, unit height measurements and weights of units as well as date of production and number of units produced for this lot number.
- A Product Compliance sheet will summarize starting point for mix design, settings for mixing, machine settings, unit height measurements, unit weights, any changes made during the production run, and any issues encountered.
- A Production Control Log will be maintained to allow access to the written reports for each production run.
- A Corrective Action report will be maintained to document corrective actions for any out of specification condition that is tied to the Lot number of the process modification.

This example highlights many of the Quality Control Points that are used to ensure the product is being produced to meet the specification requirements. The system described allows for traceability of the details of the production process for any given production lot run. Each plant supplying SRW units may have their own unique Quality Control Plan and therefore some plants may produce more consistent units than others. The designer and customer should be empowered to ask for the details of the Quality Control Plan from their local producer.

Quality Control provides a path to ensure that the detailed methods and processes utilized during the production of the SRW units provides a consistent output. The next step of ensuring that the specifications are indeed met centers around a Quality Assurance Program.

QUALITY ASSURANCE PROGRAM

In a comparable manner to the Plant specific Quality Control Program, each Plant should have a Quality Assurance Program that meets the needs of their customers and assures that the product is in compliance with the applicable

specification. The QA Program will differ by company and it is important for the designer and customer to understand the differences. More QC and QA will yield better, more consistent products but will also increase the cost of the product. Better more consistent product, although potentially more expensive, may yield a lower overall project costs as a result of fewer challenges during construction and/or lower life cycle costs of the project.

In order to verify that specifications are met we will present some of the items that are considered in developing a proper Quality Assurance Plan. Quality Assurance Plans, like Quality Control plans should have one person at each plant that is responsible for maintaining records to ensure that the details of their specific plan are met.

Examples of issues that may be included in the QA Plan are as follows:

- Specifications are identified and documented for a given product or project. This should be in agreement with those used in the QC Plan but verified again during the first step of the QA Plan.
- Written objectives for frequency of testing and if testing is to be done internally or sent to a third party testing laboratory.
- For in house testing laboratories, a written log with test equipment validations shall be maintained.
- For third party laboratories, a written verification from them is necessary on their accreditation (ASTM C1093 establishes the minimum requirement to accredit a concrete masonry laboratory).
- Written protocol for distribution of test results.
- Formal review process to ensure that specifications required are achieved.
- Test report copies need to be included in the Quality Assurance Manual and attached to the specific Lot number in the Quality Control Log.

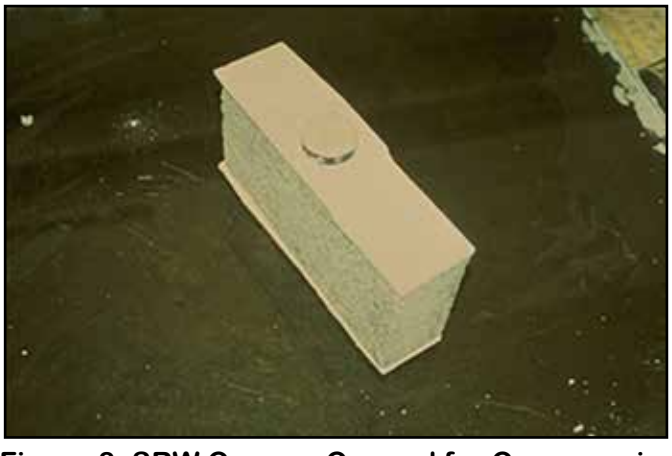

Figure 8. SRW Coupon Capped for Compressive Strength Testing

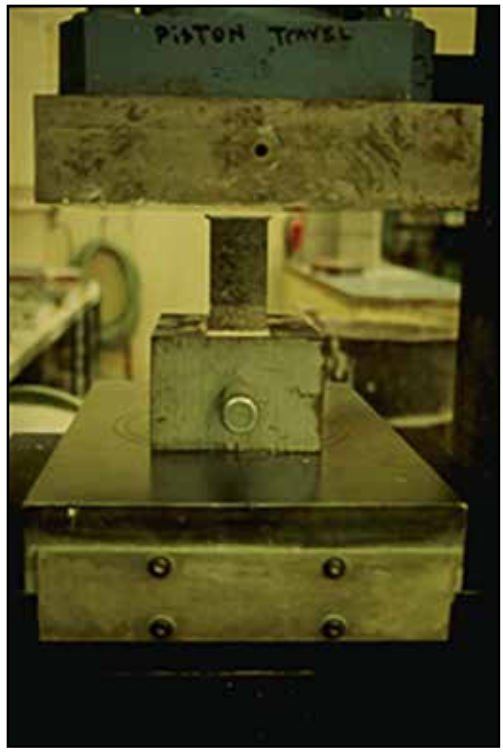

Figure 8. SRW Coupon Capped for Compressive Strength Testing

- Formal Written Corrective Action Process must be included for any results that do not meet required outcomes.
- Formal Communication protocol must be established to report results to Production, Sales, and Management personnel regularly.

These issues outlined here may be included in a Quality Assurance Program. The verification of compliance to required specifications should be included in the submittal process for any project.

PLANT CERTIFICATION

Plant certification programs are established to provide designers with the added assurance that a manufacturing facility has in place an independently monitored QC program. The plant certification procedures provided for many industries serve the public and private markets. The National Concrete Masonry Association and the Interlocking Concrete Pavement Institute have developed a Certification Process where a plant is evaluated by an independent, third-party auditor who will review the quality control program implemented to verify that the facility's quality control program meets the requirements of the NCMA-ICPI Manual. Based on the results of the independent audit NCMA and ICPI will issue a certificate, valid for one year, certifying the plant for participating in the program.

REFERENCES

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4. ASTM C150-15, *Specification for Portland Cement*, ASTM, 2015.
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6. ASTM C595-15, *Specification for Blended Hydraulic Cements*, ASTM, 2015.
7. ASTM C618-15, *Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete*, ASTM, 2015.
8. ASTM C989-14, *Specification for Slag Cement for Use in Concrete and Mortars*, ASTM, 2015.
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14. "NCMA-ICPI Quality Control Manual for Dry-Cast Manufactured Concrete Products Production Plants", National Concrete Masonry Association, 2015.
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The NCMA-ICPI Manual presents an overview (or template) of what is required for a Quality Control plan for a manufacturing facility. The objective of a Quality Control program is to review each step during the manufacturing process. A big part of the QC program is the Quality Assurance procedures used to verify the raw materials used (cement, aggregates, water and admixtures) meet the recommended standards before they are incorporated into the SRW production line.

SUMMARY

Quality Control is an ongoing process requiring good Quality Assurance of the raw materials received for production prior to SRW production, consist evaluation during the production, and good Quality Assurance of the finished products. It also requires a dedicated and trained staff that reviews each step of the production process. The function of the Quality Manager is to do QA based on the in-plant and outside laboratory testing results and if operations don't meet the QA standards, makes changes to bring production back into the QC plan laid out for the plant.

The NCMA-ICPI Manual was created to give designers an added assurance that the certified manufacturing facility has in place an independently monitored QC program. The certification manual is an excellent reference and guide for developing a Quality Control Manual for each production facility.

This article is part of a series on the history of segmental retaining walls developed under a grant from the NCMA Education and Research Foundation. The ninth article, Quality Control / Quality Assurance of Segmental Retaining Wall (SRW) Units, and all articles in the series are posted on the NCMA website (www.ncma.org).